WATER QUALITY ASSESSMENT IN POLAND

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WATER RESOURCES AND WATER DEMANDS

In area, Poland is 312,520 km^2 and is 82.8% the size of Japan (Fig.1). The total water surface covers 5000 km^2 or 1.6% of the total area of the country. Poland has about 9300 lakes covering an area of 3200 km^2. For example, the Masurian Lakes District has 1063 lakes with the largest ones having areas about 11,000 hectares. Lakes and artificial reservoirs have a capacity of 33 km^3, and a large number of ponds hold additional 1 km^3. The two most important rivers in the country are: the Odra river, which has the area of the basin (Gozdowice station) of 110,000 km^2, and the Vistula river with the area of basin of 194,000 km^2 (Tczew station). The water balance during a normal annual cycle in the country is presented below(1). The average annual amount of rainfall is 597 mm, equivalent to 186.6 km^3 of water per year over the whole country. Since tributaries from outside of Poland yield annually additional 5.2 km^3 of water, therefore a total ammount of water is 191.8 km^3. The underground water resources have been estimated as 33 km^3 of water per year, for an area of 272,520 km^2, since the remaining 13% of the total area is waterless. The annual dynamic underground water resources have been evaluated as 9.2 km^3. However, rivers and streams discharge only about 58.6 km^3 of water into the Baltic Sea in a mean low-flow year, and about 34 km^3 in a mean dry-weather year. Obviously only a portion of this volume is available. About 10 km^3 is necessary as a minimum flow to maintain biological life and for sanitary reasons. Therefore, the available flow is only 24 km^3 of water. Poland belongs to the group of the European countries most deficient in water resources. The country ranks as 22nd in Europe. The average annual water resources in Poland estimated on the basis of atmospheric falls and a number of population amount to 1800 m^3 per inhabitant, comparing with 2800 m^3 per inhabitant for Europe and

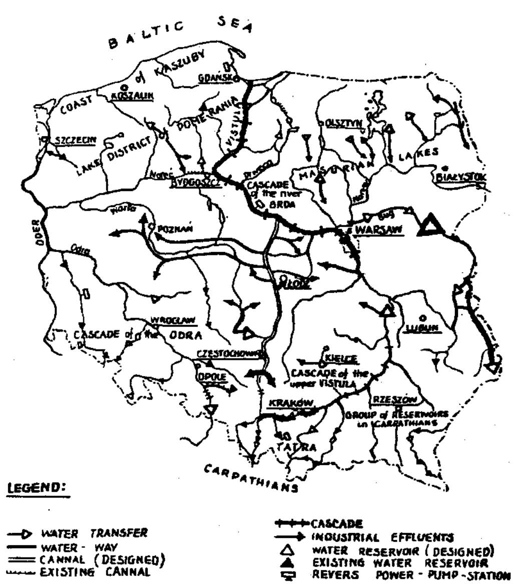

Fig.1. Basic concepts of water resources management in Poland (1).

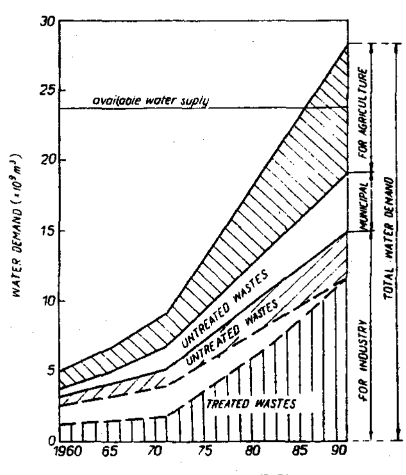

Fig.2. Water demand and wastewater discharge in Poland (3).

3000 m^3 per inhabitant for Japan. The annual water demands for Poland in 1990 are anticipated in the amount of about 28 km^3 (13 km^3 in 1976), with about 5 km^3 for municipal supply (2 km^3 in 1976) and 9 km^3 for agriculture, comparing with 4 km^3 in 1976 (2). Most water for agriculture is taken during the summer months. Water demands and wastewater discharges are shown in Fig.2. The available water volume compares unfavourably with the water demand anticipated in the year of 1990.

LEGISLATION AND ADMINISTRATIVE ASPECTS

Poland has sixty years old history of legislation for water pollution control. The Water Quality Act has been issued in 1922 and revised in 1962. Presently, the basis for legal action in the field of water protection against pollution in the country is a new version of the Water Law Act issued by the Polish parliament in 1974. On the basis of the Water Law, in 1975 the Council of Ministers announced regulations concerning classification of waters and determination of effluent standards, as well as financial penalties for the effluent discharges which do not meet the requirements specified in the regulations. These regulations are set-up for BOD, COD, ether extracts, PCB, various metals, pesticides, etc. The following classes of surface water quality were established: Class I waters are those used in municipal and food processing supply purposes and for salmon fish growth. Class II waters are intended for use as recreational waters, including swimming, and for growth of fish other than salmoidae. The lowest class of waters — Class III — allows only for their use as industrial water supplies and for irrigation purposes. Water quality standards are tailored to meet the appropriate use of the surface waters. Permissible concentrations of selected constituents for the different classes are shown in Table 1, as an example. In addition, the following provisions are laid down by the Water Law: industrial plants and other operations, which discharge wastewaters to water or to land are obliged to construct, maintain and utilize wastewater treatment facilities; and without simultaneous operation of wastewater treatment systems, no industrial plant or any other plant from which wastewater is discharged should be started up. To maintain a wastewater discharge it is required to obtain a permit. In order to promote administrative measures for overall conservation of the environment a Ministry of Administration, Local Economy and Environment Protection was established with environmental offices on a voivodship (prefecture) level. However, the field of water resources management is presently under Ministry of Agriculture.

Table 1. Examples of permissible concentrations of some pollutants in surface freshwaters according to the Polish Water Law

Parameter	Unit	Water class		
		I	II	III
DO	mg O_2/dm^3	6	5	4
BOD_5	mg O_2/dm^3	4	8	12
COD	mg O_2/dm^3	40	60	100
Saprobic index		oligo to betamezo	betamezo to alfamezo	– alfamezo
Chlorides	mg Cl/dm^3	250	300	400
Sulphates	mg SO_4/dm^3	150	250	250
Hardness	mval/dm^3	7	11	14
Dissolved solids	mg/dm^3	500	1000	1200
Suspended solids	mg/dm^3	20	30	50
Temperature	°C	22	26	26
$N-NH_4$	mg NNH_4/dm^3	1.0	3.0	6.0
$N-NO_3$	mg NNO_3/dm^3	1.5	7.0	15
N– organic	mg Norg/dm^3	1.0	2.0	10
Total iron	mg Fe/dm^3	1.0	1.5	2.0
Manganese	mg Mn/dm^3	0.1	0.3	0.8
Phosphates	mg PO_4/dm^3	0.2	0.5	1.0
Cyanides	mg CN/dm^3	0.01	0.02	0.05
Phenols	mg/dm^3	0.005	0.02	0.05
Lead	mg Pb/dm^3	0.1	0.1	0.1
Mercury	mg Hg/dm^3	0.001	0.005	0.01
Copper	mg Cu/dm^3	0.01	0.1	0.2
Zinc	mg Zn/dm^3	0.01	0.1	0.2
Cadmium	mg Cd/dm^3	0.005	0.03	0.1
Chromium	mg Cr/dm^3	0.05	0.1	0.1
Total heavy metals	mg/dm^3	1.0	1.0	1.0

WATER QUALITY SURVEILLANCE SYSTEM

The water quality surveillance system is composed of conventional and automatic monitoring stations. The conventional monitoring with manual sampling at the voivodship (prefecture) level was established in 1957. At the present, the country is covered by a network of about 2500 conventional stations and established cross-sections located along 30,000 km of streams. The sampling frequency depends on the purpose for which data are recorded, and it ranges from a minimum of once-in-two-months up to daily sampling at some points. The sampling of water is performed simultaneously with the rate of flow measurements. For the continuous monitoring of the Odra and Vistula the automatic water quality monitoring stations (AWQMS) have been installed at important cross-sections, connected mostly with water intakes. The AWQMS are either in lab buildings or on barges. The automatic network, one of the first in Europe, has been operating since 1968. It was organized under the auspices of the WHO, and initially was based on imported monitoring equipment. Presently, domestic automatic monitors (Aquamers) are being used. These monitors are capable of measurement and teletransmission of such parameters as: water temperature, pH, conductivity, dissolved oxygen (DO), chlorides, turbidity, water level and meteorological data. The additional parameters will be added after suitable sensors are developed. However, it should be stressed that the scarcity of automatically measurable parameters limits the efficient application of AWQMS. The development of automatic measuring devices for other important parameters such as heavy metals, organo-chlorine compounds, oxidized nitrogen, soluble organic content and others is greatly needed. At the present, the automatic stations are also used for manual bioassay tests and fish tests. The monitoring network in the country has been summarized at an international conference on automatic monitoring in Europe held in Krakow, Poland(4). The future surveillance development programme calls for monitoring of the coastal drainage basins, in addition to the Odra and Vistula drainage basins. These stations will be structured in hierarchic order. Two types of automatic monitoring stations ate being presently integrated into the monitoring network, namely the water intake stations and the pollution load stations. The details of this system are given elsewhere (5).

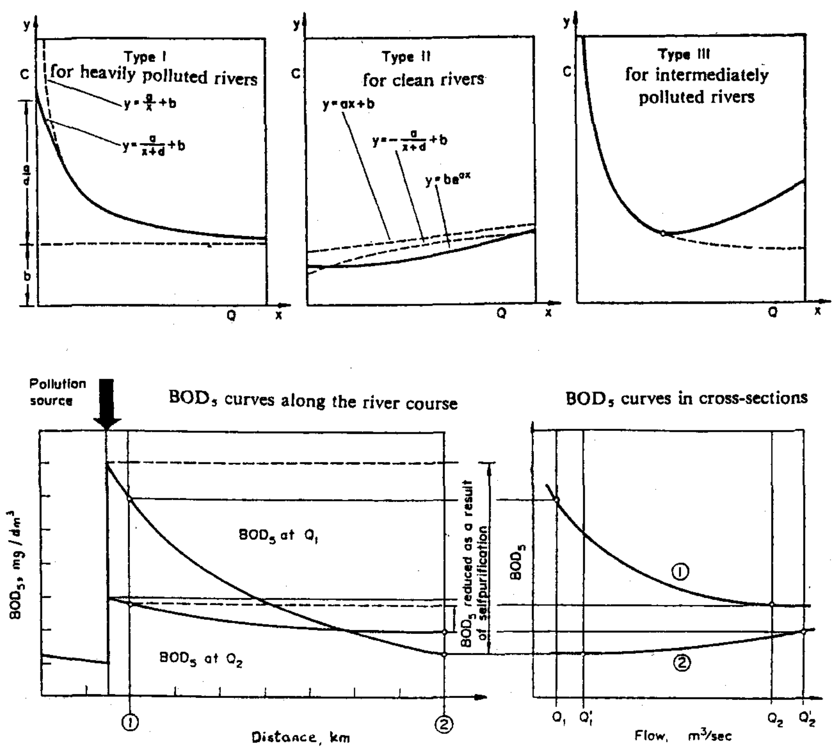

Fig.3. Relationship between concentration of pollutants and rate of flow (7).

DATA ANALYSIS AND MATHEMATICAL SIMULATION

The river monitoring network provides a large number of observed data. These data are analyzed by a statistical method based on the assumption that at a given cross-section some correlation exists between the pollutant concentration and rate of flow (6). Three basic types of curves representing this correlation are applied (Fig.3). The shape of the curve depends on many factors, such as: the degree of water pollution, the type of pollutant, hydrological and hydrotechnical characteristics of the river, its self-purification capacity, the distance between monitoring stations and others. Figure 4 shows as an example, these correlations between biochemical oxygen demand (BOD), permanganate value (PV), dissolved oxygen (DO) and phenols for the Odra river, at one of the monitoring stations, including temperature influence. These relationships have been derived from about 300 observations in a year, in the temperature ranging from 0.1°C to 27°C. Inorganic compounds, such as chlorides and sulphates, are usually described by correlations defined by curves I and II, and the effect of temperature is not included. From these relationships between streamflow and concentrations of water quality constituents the so-called indicative concentrations (IC) for a design flow are established. As the design stream flow at each site the mean low streamflow (MLQ) has been selected, based on the assumption that higher streamflows will result in higher DO concentrations and better water quality. In other countries, a similar approach has been taken, for example in the United States the design flow is the minimum average 7-day consecutive flow expected once every 10 years. However, it is an extremely low streamflow often being exceeded more than 99% of time. The IC values are plotted along the river for various water quality constituents. Final interpretation is based on such hydrochemical profiles (Fig.5), and the overall river classification is performed after all measured water quality constituents are compared with the standards. A compendium of hydrochemical profiles for major rivers and streams the so-called Water Atlas (9) is prepared every second year.

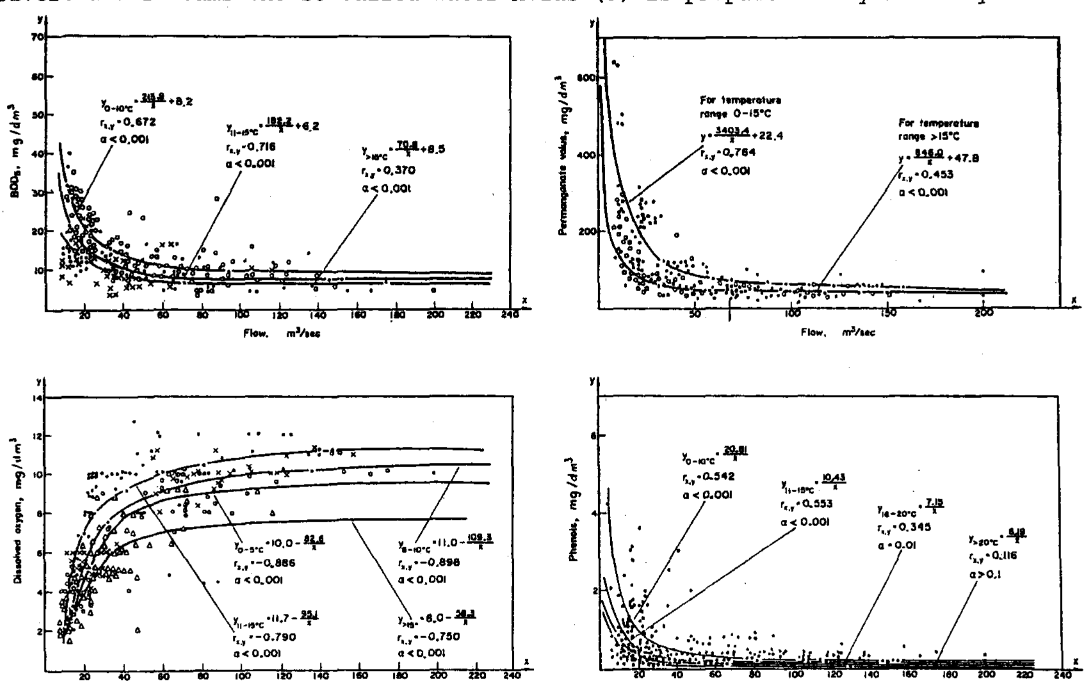

Fig.4. Relationship between BOD, PV, DO, phenols and flow for the Odra river at Chalupki station, including water temperature effect (7).

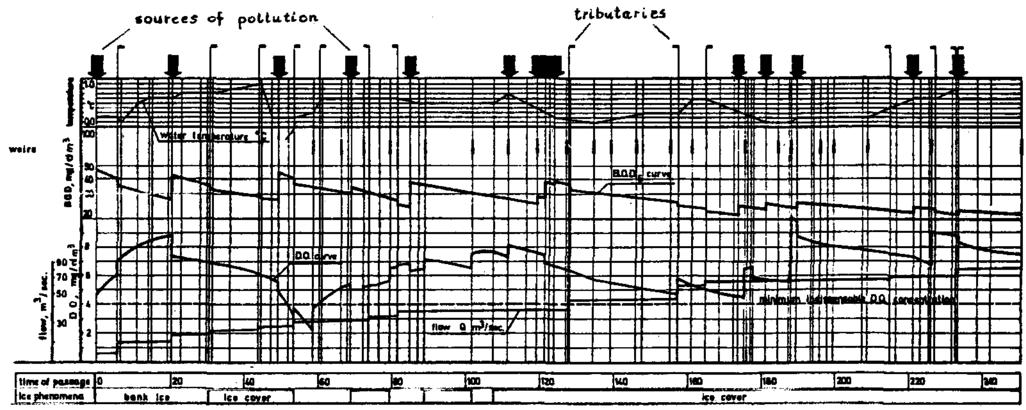

Fig.5. Example of hydrochemical profile for the Odra river — winter period (8).

The above method has been serving as a basis for the determination of investment policies in the construction of treatment plants and for the prediction of water quality. Recently, however, mathematical modeling of river systems has become an integral part of water resources planning and water quality management. These models can be used to aid water quality surveillance and to predict future water quantity-quality conditions. Various computerized models have been applied for water quality simulations in the Odra and Vistula rivers. As an example, a Streeter-Phelps type model and QUAL-I model were used to evalutate concentrations of BOD in Vistula river reaches (Fig.6). It is stressed, however, that these models are considered only as tools in assisting management decision-making process.

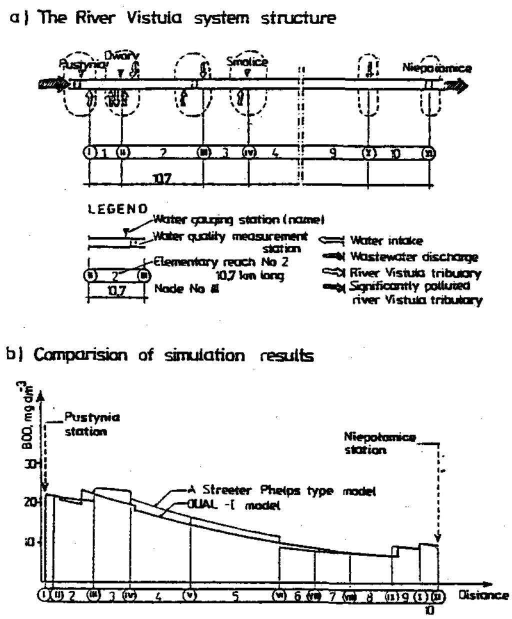

Fig.6. Comparison between BOD simulation results obtained by application of a simple Streeter-Phelps type model and QUAL-I to a section of the Vistula river (10).

WATER QUALITY MANAGEMENT AND INTERNATIONAL ACTIVITIES

Intensive urban transformation processes, growth of population, intensification of agriculture and development of industry resulted in deterioration of surface water resources, despite legal, technical and financial measures for water pollution control. About 80% of the wastewaters comes from 600 cities and 2800 industries, with chemical machinery, mining, power, food and paper production industries being as the main polluters. Recently only 60% of all wastewaters are treated. Recognizeng that water is the resource without no nation can survive, the Governmental Programme on Water Resources Development(PR-7) has been carried out since 1975, concentrating on solving problems of water shortage in the country. The main coordinator for this programme is the Institute of Meteorology and Water Management. Within this programme R & D activities in the field of water quality management are coordinated by the Research Institute for Environmental Development. The problem of water pollution control has become one of the most important problems of the country, since the larger part of industry is situated in the southern parts of Poland. In addition, the main rivers, the Vistula and Odra, are used for municipal and industrial supply, agricultural irrigation, cooling purposes for power plants, and navigation, but also receive discharges of wastewaters of various degree of treatment and run-offs. The numerous users make contradictory demands on waters, and water resources management must protect many desirable uses. Present water pollution control policies are based on the concept of regional management and systems approach. Systems analysis is an extremely useful tool for analysing river systems and for providing informations on the effect of any particular policy. The principal water quality problems in Poland relate to the effects of dams and other water structures (resulting from the phenomena associated with impounded water), the effects of power plants (since the discharge of heat from cooling operation, eutrophication, and the influence of non-point souces such as agriculture and urban stormwaters. However, a regulatory program for the non-point sources have not been adopted yet. Present water quality improvement program include: improvement of treatment methods and implementation of advanced treatment processes, recovery and water reuse in industry, encouraging the production of biodegradable detergents and pesticides, the use of dry technologies, etc. Also, in order to improve the oxygen conditions in some Vistula river stretches artificial aeration installations such as turbine aeration or application of pure oxygen are provided. Research and implementation activities in water quality management are connected with international cooperation. Protection of the Baltic Sea was agreed upon in the 1974 Helsinki Convention, and Poland is taking steps into the implementation of this convention provisions. A number of the international development and demonstration projects, sponsered by the United Nations, has been realized. One of them is the Comprehensive Environment Programme (POL/CEP) realized under auspices of the UNDP in the Upper Silesia region and is aimed at the solution to problems of air, water and soil pollution in this heavily industrialized and polluted region of Poland. Also, a joint M.Skłodowska-Curie Fund (MSCF) was established by the Government of the United States of America and the Government of Poland to sponsor joint research projects on environmental problems and water quality management.

REFERENCES

1. Przybylski, H.E. and Gromski, L.B. (1967). Some problems of designing and planning sewage purification plants. *Water Poll. Control, 66*, 33-44.
2. Blaszczyk, P. and Nowakowska-blaszczyk, A. (1977). The relationships between water management and physical planning in Poland for urbanized areas. *Proc. of the Amsterdam Symposium on Effects of Urbanization and Industrialization on the Hydrological Regime and on Water Quality*,IAHS-AISH Pub. No. 123.
3. Oleszkiewicz, J.A. and Oleszkiewicz, A. (1978). Water pollution control in Poland. *Env. Protection Engineering, 4*, 1, 27-48.
4. Krenkel, P.A., Ed. (1971). Proceedings of special conference on automatic water quality monitoring in Europe, Krakow, 1971. *Vanderbilt Univ. Press.*
5. Oleszkiewicz, J.A. and Sadomska-skorupska, W. (1980). Control of waste water discharges and plant performance and procedures for establishing effluent permits. *Proc. of the Seminar on Methods for the Control of Sewage Treatment Plants (Helsinki Convention)*, Lübeck.
6. Manczak, H. (1973). Statistical method for estimation of water quality monitoring data and hydro-chemical profiles of rivers. *United Nations Econ. Soc. Council, CES/SEM.6/ENV./SEM.1.*
7. Manczak, H. and Florczyk, H. (1971). Interpretation of results from the studies of pollution of surface flowing waters. Water Research, 5, 575-584.
8. Manczak, H. (1969). The course of self-purification process of canalized highly polluted rivers. *Proc. of the Fourth Int'al Conf., held in Prague 1969, Advances in Water Pollution Research /Ed. S.H. Jenkins/*, Pergamon Press, Oxford.
9. Jarmolinska, K., et al. (1980). Atlas of water quality of Polish rivers. *Research Institute for environmental Development*, Wroclaw (in Polish).
10. Adamczyk, Z., et al. (1978). A simple mathematical model of quantitative and qualitative process occuring in the stream channel for water distribution control. *Proc. of the Baden Symposium on Modelling of Water Quality of the Hydrological Cycle*, IAHS-AISH Pub. No. 125.