UNDP/HUN/86/007 • Terminal Report • WHO/HUN/CWS/002

PROTECTION OF BANK – FILTERED DRINKING WATER RESOURCES

HUNGARY

PROJECT FINDINGS AND RECOMMENDATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

WORLD HEALTH ORGANIZATION
Regional Office for Europe
COPENHAGEN, 1992

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Report prepared for
the Government of Hungary
by
the World Health Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

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The World Health Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice and facilities.

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1. INTRODUCTION

1.1 Project background

The water supply systems of Hungary provide drinking water for 9.2 million inhabitants of 2070 towns and villages, over 90% of the population therefore receives a piped water supply. This compares favourably with most of the developed countries.

About 88% of the total volume supplied comes from groundwater sources and, of this, about half is derived from bank-filtered water resources. Moreover, it has been estimated that there is an additional four million cubic metres per day in resources remaining to be developed along the River Danube. Thus, bank-filtered water is potentially the country's most important resource.

In Budapest, for example, to provide drinking water for more than two million inhabitants, 90% of the total daily supply (on average 945 000 m^3/d) is derived from bank-wells, the main location of which is the Island of Szentendre. Here, the permeability of the gravel terraces of the River Danube and their particle composition permit the inexpensive production of good quality water.

The protection of bank-filtered drinking water resources against pollution is the common task of outstanding importance of the water management and environment protection sectors in Hungary. Since the recharge of bank-filtered water resources is derived mostly from surface waters, protection activities should eventually be extended also to the rivers and their immediate catchments.

An unfavourable aspect for water management in Hungary is that approximately 95% of the surface water resources originate from abroad. This condition creates a continuous potential risk for water users principally from the point of view of quality, but also of quantity. In particular, the safety of drinking water intakes is endangered, because the river systems entering Hungary are often subjected to accidental water pollution incidents. For example, in 1989, the total number of such accidental water pollution events was 213 all over the country, of which 27 arose in upstream foreign countries. The polluted water travelled down the rivers to Hungary. Budapest Waterworks has a surface water intake on River Danube upstream from the Capital with a capacity of 200 000 m^3/day and its operation had to be closed down for a period of time in several cases during the last ten years because of water quality deterioration caused by accidental pollution events.

A significant number of the accidental river pollution cases was caused by oil-spills from different sources during the last ten years. The Danube-Maine-Rhine waterway, after being put into operation, may be exposed to an increase in oil pollution, which may also affect the Hungarian stretch of the River Danube, where the safety of bank-filtered drinking water resources is outstandingly important from point of view of public supply.

To prevent water supply problems arising from the short-, and medium-term quality deterioration of resources caused by pollution incidents, it is vital to develop methods for monitoring the quality of the resources as well as methods for the monitoring and prediction of serious pollution events to protect water users. Emergency treatment technologies are also needed by the waterworks to treat the water for periods when the quality of the raw water has temporarily deteriorated.

In the field of the protection of drinking water resources, the objectives of the National Water Authority (OVH) coincided with those of the Specialist Organisations of the United Nations and, especially, the endeavours of the "International Drinking Water Supply and Sanitation Decade" programme of the World Health Organization. To develop methods for the protection of bank-filtered drinking water resources, a comprehensive research programme was formulated. The Hungarian Government requested UNDP to provide assistance for its implementation and the Project was commenced in 1987.

1.2 Outline of official arrangements

The Project Document "Protection of Bank-filtered Drinking Water Resources" HUN/86/007 was signed by the Government, UNDP and by WHO-EURO as the executing agency in December 1986.

The National Water Authority (OVH) was responsible for the supervision of the project as the Government Implementing Agency. Due to organisational changes in the state administration, OVH was merged with the Ministry for Environment Protection and Water Management (KVM) and from 1990, the Government Implementing Agency was the Ministry for Transport, Telecommunication and Water Management (KHVM).

The Project activities started in March 1987 and the planned completion was 31 December 1990. As agreed in the Project Document, the Government contribution amounted to 11 million Hungarian Forints and UNDP contributed US $ 170 000. Annual Project (budget) revisions were made according to the expenditure of UNDP-funds on the different budget-lines. Following the recommendations of the "Tripartite Monitoring Review Meeting" held in November 1988, the Project was extended into 1991 by revision "D", and the UNDP contribution was increased to US $ 191 000. The Government contribution was simultaneously increased to 14 million Hungarian Forints. Revisions "E" and "F" of the Project budget were prepared to update the annualised expenditure estimates for the current years.

1.3 Objectives of the Project

The overall objective of the Project was to investigate and develop methods of practical application for the reliable utilisation and protection of bank-filtered water resources.

The immediate objectives were:

- to establish methods of practical application to increase the safety of public water supplies based on bank-filtered water resources;
- to study the short and long-term effects of contaminated groundwater inflow;
- to study water and sediments in polluted rivers;
- to elaborate methods for emergency treatment and for early warning systems, and
- to develop methods for the rehabilitation of already polluted drinking water resources.

Other important features of the Project were to provide training for local personnel through study-tours, and to provide special analytical instrumentation and computer facilities supporting them to meet all the requirements of the project.

The list of Project personnel is contained in Appendix 1. The training provided up to the end of 1991 is summarised in Appendix 2. Equipment (instruments) supplied is listed in Appendix 3.

1.4 Implementation

The Government Implementing Institution was the Water Resources Research Centre (VITUKI) in Budapest, where the Project Secretariat was established, headed by the National Project Director. VITUKI was the institution responsible for the management and also partly for the implementation of the Project activities in co-operation with organizations closely involved in public water supply and resource protection, such as the Waterworks of Budapest, the Danube Regional Waterworks, the Public Health Institute and the District Authorities (Water, Environmental Protection) along the Danube stretch studied. Their names are given in Appendix 4.

The directing and decision-making body of the Project was the "Co-ordinating Council". Regular meetings of the Council were held , generally once a year. The results of the Project activities were the subject of "Tripartite Monitoring Reviews" in November 1988 and November 1990. The main research results incorporated in the Field Documents were evaluated and discussed by a scientific jury in December 1991, and also in December 1991 by Professor D. H. Newsome, a WHO-consultant.

Since environmental protection is one of the global priorities stressed by UNDP, it is interesting to note that the results attained in this Project could also be used in other countries with similar conditions.

2. PROJECT RESULTS AND CONCLUSIONS

The research work and field studies were performed according to a mutually agreed detailed work plan which divided the Project activities into four main themes as follows:

(1) An assessment of polluting impacts on bank-filtered drinking water resources.

(2) Investigations into development of methods to provide early warning water quality monitoring system.

(3) Investigations into development of methods to provide emergency technologies for drinking water treatment.

(4) Studies on the rehabilitation of polluted bank-filtered water resources.

Accordingly, the results of the Project activities were included in four "Field Documents". Their abstracts are attached at Appendix 5.

The field studies were carried out in two pilot zones. The northern part of the Island of Szentendre was selected as Pilot Zone No.1. This Island forms the biggest bank-filtered drinking water resource under full utilization in Hungary, being the main source of supply for the Hungarian capital, Budapest. Due to its importance, very reliable protection has to be given to this resource, particularly against accidental water pollution incidents.

Pilot Zone No.2, the area of the Southern Waterworks of Vác located on the left bank Danube section at the town of Vác. This bank-filtered water resource was affected by gross groundwater pollution of industrial origin in 1981 and was not in operation even at the beginning of the Project.

Both pilot zones had well established monitoring networks and significant background information was available. The circumstances were thus ideal from the point of view of the implementation of the Project activities.

2.1 Assessment of polluting impacts on bank-filtered drinking water resources

More than 60% of the total water production of the Waterworks of Budapest is provided by the bank-filtered drinking water facilities of the Island of Szentendre. Along a 36 km long riverside there are 17 plants in operation with an average total yield of about 690 000 m^3/day. In spite of the good quality of water abstracted from the wells, indications of possible future problems can be observed in this area. During the last decade, the yield has been decreasing at a rate of 2% per year. The quality of abstracted water has been slowly but steadily decreasing as well. It was also observed that contamination of the river bed material has been increasing during the past decade, and this tendency will have to be faced in the future too. Accidental river pollution events also represent a potential risk for the bank-filtered water resources because of the recharge of polluted river water. To develop methods for the protection of these water resources, the processes of water quality changes in the filter media were first of all studied.

2.1.1 Objective and activities

The objective was to carry out field investigations and model studies aimed at the exploration of the processes and causes of water quality changes in the bank-filtered drinking water resource in Pilot Zone 1.

The activities implemented were:

- an extended field investigation programme focussed on the representative sampling section of the (Pilot Zone, Waterworks Tahi II - Kisoroszi), to provide adequate data for comprehensive water quality evaluation and for modelling activities;

- laboratory column-filter experiments;

- development of a method (model-system) to assess and predict quality changes in the bank-filtered water esources induced by various potential changes in the conditions of the river and the filter media.

Numerical modelling techniques were applied in order to achieve:

- the calibration of hydraulic and transport parameters on the basis of measured data in the Pilot Zone;
- the calculation of the transportation of various assumed pollutants from the Danube to the water of the wells;
- the assessment of the quality changes of the water of the production wells;
- the development of short-term forecasting of water quality changes caused by accidental pollution events of the River Danube;
- the analysis of possible water quality control strategies.

2.1.2 Field investigations and laboratory experiments

The extended field measurement programme was carried out between 1988-1990 and explored the hydraulic and water quality conditions of the study-area. Sampling was concentrated mainly on the selected representative cross-section of the Pilot Zone. Sampling points were established on both Danube branches (water and bottom sediment), the observation wells and the producing wells. The sampling frequency was generally quarterly. During the field investigation programme, hydro-geological, hydraulic, hydrological, aquatic chemical, hydro-biological and microbiological data were collected and evaluated. The results of the water quality studies showed characteristic quality changes in the filter-media: the chemical oxygen demand (COD) concentration gradually decreased from the river towards the middle of the island reflecting the decomposition of organic pollutants, while nitrate was the reverse, increasing towards the mid-island, where nitrate from agricultural sources also made a contribution. The concentration distribution of organic (chlorinated hydrocarbons, pesticides) and inorganic (mercury, cadmium, lead) micro-pollutants was not significant; measured values were less than those of the drinking water standards. (See Appendix 6 of Report No. 44).

Hydro-biological studies on phyto-, and zooplankton species showed that benthic organisms were not found in the water of the wells. However pico-, and nano-algae were detected in a density, which was less by 1-2 order of magnitude than it was found in river water. Daphnia toxicity tests gave negative results for the Danube and filtered well-waters.

Microbiological studies to meet public health requirements indicated that the River Danube had significant faecal coliform pollution, but the numbers of coliforms in the filter media were much less. Samples of the producing wells did not contain bacteria representing faecal pollution at all. Thus, the high efficiency of bacteria-removal during bank-filtration was proved. Coli-phages used as an indicator of virus-pollution were also measured. The results of these tests were negative in each case, verifying that these micro-organisms were not able to pass through the filter-media. (See Appendix 6 of Report No. 22).

The Hewlett-Packard gas chromatograph Fast Transfer Infra-red (FTIR) detector instrument-system provided by the UNDP for the Project was put into operation in 1989 to identify the Danube's volatile organic micro-pollutants in both longitudinal and cross-sectional profiles. In addition to aliphatic acids, (which are important from the view point of oxygen consumption), two main types of compounds were detected: Pthalate-acid-esters (mostly dibutyl- and dioctyl-pthalates) and Actinit-PK, belonging to the family of triazines. These substances originate from the plastic manufacturing industry and from large scale farming (pesticides). They are chemically quite stable which means that their continuing leaching into the groundwater will have to be faced. The results of investigations carried out with the infra-red detector GC/FTIR proved the usefulness of the instrument in identifying unknown micro-pollutants. Comparing the analytical results of water samples taken simultaneously from the two arms of Danube indicated that the occurrence of critical micro-pollutants is more frequent in the Vác arm of Danube than in the Szentendre arm. (See Appendix 6 of Report No.31).

Water quality studies carried out in the Island of Szentendre concluded that, during the life of the Project, there was no accidental river pollution event on the Danube which would have affected the quality of the drinking water production wells.

One of the most important events revealed by the field studies was the outstanding tritium wave that travelled past the study site in the Danube in August 1990. High frequency sampling was carried out in the Danube and in the radial well selected for the investigations (taking samples from the well's radial pipes of the landward as well as the channel-side) in order to determine the time profile of tritium concentration accurately. By comparing the tritium profile of Danube water to that of the radial well at the channel-side, the time of reaching the well could be determined, together with the hydraulic parameters needed for modelling.

Data obtained during the field studies enabled the calibration of the numerical model and an assessment of the environmental impact to be carried out.

Laboratory column-filter experiments were carried out to provide information about those physical and chemical parameters for the modelling of quality changes in the filter media that could not be determined during the field investigations. In extremely low flow periods, core samples from the dry channel bed were taken and analysed in laboratory column experiments in order to determine the pollutant-removal efficiency of the bottom layer, using suspensions of various organic and inorganic micro-pollutants and other contaminants. This provided additional information to calibrate the parameters of the numerical transport model. Results of the column-filter studies provided valuable and practical additional data which could be used as inputs for the modelling activity.

2.1.3. Model-system to assess and predict water quality changes in the filtration zone.

The effects of hydraulic and thermo-physical conditions on the time of travel to the bank-filtered wells from the River Danube were investigated in a sensitivity study. The time of Danube water reaching the bank-wells was determined as a function of the water levels of Danube and the temperature gradient in the filter zone. It is interesting to note that more than 50% of the wells are characterised by times of travel significantly less than one day. These wells belong to the "highly endangered" category especially when pollution incidents in the Danube last more than one day, and when dangerous substances are involved in these events.

The hydro-geological model developed was designed to consider two layers. The first layer was the silty bottom deposit that separates Danube water from the water-bearing aquifer. The mass transport in this layer is dominated by vertical and transverse advective flows. The second layer, below the first, is the sandy-gravel layer that forms the bulk of the Island. Lateral seepage and transport were simulated in this layer. Advective mixing due to exfiltration across the channel bed, and the singular mixing at the production wells were considered in the model runs.

The modelled area (3.3 km x 4.0 km) between the Danube arms was overlaid by a 50 m x 50 m grid. The boundary conditions for modelling the depressions caused by the wells were sufficiently well defined on the basis of measurement data. For the transport model, however, this was not possible and boundary conditions could be considered only by rough estimation. Nevertheless, the error thus introduced seemed not to be not significant for the processes in the main section and the operation of most of the wells. In simulating the water quality, steady state river flow and groundwater flow were assumed.

The most important transport parameters of the area were the dynamic porosity of the bottom sediment and the gravel layer, and the transverse and longitudinal dispersivity of the gravel layer. Since there were not sufficient measurement data of the bottom sediment available, the value of the dynamic porosity was estimated. The dynamic porosity of the gravel layer was sufficiently well determined by fitting the model to observed data of the tritium load wave of August 1990. It was detected both in the stream and in the radial well.

During the period of the studies, there was no similar environmental pollution event on the land and in the river that would have permitted the study of the processes of pollution in the bank-filtered water resources on the basis of actual measured data. Thus, there was no opportunity for the direct determination of the transport parameters that affect the propagation of pollutants in the bank-filtered system. Because of this, the following analytical and research methods were developed and applied:

- The dispersion coefficients of the filter zone were determined on the basis of tracer (tritium) studies.

- The numerical transport model was calibrated with measurement data from the production and observation wells.

- The numerical model for seepage hydraulics and pollutant transport was calibrated against field and laboratory (column-filter) measurement data, and data gained during waterworks operations. The model was used for assessing the impacts of various assumed permanent and accidental pollution events of the parent river.

The quality effects of simulated accidental water pollution incidents on River Danube were analysed, taking into consideration three different types of dangerous pollutants: chromium, chloroform and atrazin (conservative, easily adsorbable, and rapidly decomposing micro-pollutants). The estimated concentrations entering the bank-filtered water resource as input recharge were predicted by the DUNAWARN model-system developed for the Danube early warning monitoring system (see Chapter 3). The results of the simulations concluded that concentrations in the well waters detrimental to human health would not result from accidental pollution events in the Danube when the duration of the event did not exceed 3 days, 1 day and 5 hours for chromium, chloroform and atrazin respectively. Groundwater polluted by chromium would remain for a decade, because of the storage available in the channel bed. Simulation results indicated that smaller concentration peaks would show up in the well water with a time-lag of the order of a year. The conclusion that can be drawn is that the quality of bank-filtered drinking

water resources is most endangered by long-lasting (month or year-long) continuing pollution of the Danube (see Annex 6 of Report No.53).

The research results indicated - in accordance with the relevant international experiences - that bank-filtered drinking water resources are most vulnerable to toxic conservative substances that move along with the water, non-adsorbing radioactive substances of longer half-lives, certain organic micro-pollutants, oil derivatives and also by small micro-organisms.

Given the current average water quality conditions in the Danube, under normal operation the bank-filtered production wells supply water of a quality which meets the present drinking water standards. With the exception of accidental pollution events bank-filtration is, therefore, a safe and efficient way of producing drinking water. During accidental pollution events the level of danger to the bank-filtered water resource depends on the duration of the accidental event, the time of travel, the type of the pollutant and on the management's operational strategy for abstraction from the production wells.

The model-studies on Pilot Zone 1 provided new general knowledge for making decisions on the operation of waterworks and on the design of hydro-geological protection areas. This knowledge can help to formulate the optimum preventive measures that can be taken against accidental or long-term water pollution. The model-system can also be utilised for assisting in the rehabilitation of already contaminated water resources and for selecting the appropriate emergency drinking water technologies when a pollution accident has occurred.

2.2 Early warning water quality monitoring system for the River Danube

The River Danube and other surface waters are regularly endangered by deteriorations in water quality caused by accidental pollution events. There is a growing need expressed by water users, and especially waterworks having direct water intakes from rivers, to establish regional warning systems for providing early information about quality problems in order that measures to ameliorate the problems can be taken. The existing observation system needs appropriate methods to fulfil these requirements. There is no practical experience of early warning monitoring systems in Hungary, but Project assistance contributed to a great extent in the collection and evaluation of foreign experience and results in this field. This will form a basis for further development in Hungary.

2.2.1 Objective and activities

The objective was to develop methods for the establishment of an early warning water quality monitoring system to predict the effects on quality of accidental pollution events that might occur along the Danube reach upstream of the Pilot Zones. This would

provide timely information for the downstream water users (first of all for waterworks) on the expected temporal and spatial quality changes, thereby increasing the protection and safety of potable supplies.

The main activities of implementation were:

- the evaluation of accidental pollution events and the compilation of an inventory of polluting sources;

- the application of model systems for the simulation and prediction of the transport and mixing of pollutants in the river;

- the elaboration of the principles and the formulation of a proposal for the establishment and operation of the Danube early warning water quality monitoring system.

2.2.2 Review on accidental water pollutions

The past records of accidental water pollution cases were evaluated, covering the period of 1978-1987. The evaluation was carried out at a national level and also for the Danube catchment involved in the Project (i.e. the direct Hungarian catchment belonging to the river sections between Rajka and Budapest). The number of accidental water pollution events was steadily increasing during this ten year period at a rate of 3.2% per year, the same as the national average. In the Project area, which is the territory of the District Water Authorities of Győr and Budapest, this rate was, however, as high as 5.4% per year.

The distribution of the type and kind of observed accidental water pollution events showed that mineral oil and its products were responsible for most (51% - 73%) of the pollution events in each of the years.

Accidental water pollution events endangered drinking water resources, resulting in restrictions on, or even the shut- down of water intakes in 26 cases during the ten year period. There were also temporary closures of intakes on five occasions for longer periods than two days. Events of special interest were related to an increased rate of primary production (algal blooms), that had paralysed the operation of the Surface Water Intake Works of the Budapest Waterworks on four occasions. (See Annex 6 of Report No. 9).

The conclusion was drawn that the database on accidental water pollution events because of the few, if any, number of water quality measurements taken of the individual pollution event was at present inadequate to serve practical purposes.

2.2.3. Inventory of polluting sources

Based on the three years data collection, an inventory of polluting sources was prepared, consisting of 80 dischargers whose discharges were greater than 100 m^3/day. The wastewater dischargers are all situated in the Hungarian catchment area of the Danube upstream of Budapest to Rajka. These characteristic data of the treatment facilities and effluent quality of these municipal industrial and agricultural discharges are included in the inventory (see Annex 6 of Report No. 32). Preliminary information was also available on significant polluting sources on the Slovakian catchment area draining to the river.

Important background information was developed in the form of "serious pollution events", in which possible pollution effects of technological failures or accidents in industrial plants, and also of road and navigation accidents were estimated. (See Annex 6 of Report No. 43). Risk assessment of an assumed industrial accidental water pollution event was also carried out. (See Annex 6 of Report No. 15).

2.2.4. Model-system to simulate and predict mixing and of pollutants in the Danube.

A model-system was constructed to act as a basic tool for warning purposes and consisted of two main elements:

- A hydro-dynamic model (based on the numerical solution of the Bernoulli equation, taking the effects of the uneven flow velocity distribution of natural channels into account with the dispersion factor of kinetic energy), which can be used for the determination of the times of travel corresponding to various rates of flow. This model also calculates the hydraulic characteristics needed for the application of the mixing model.

- A mixing model (based on a reach-by-reach application of an approximate analytical solution of the two-dimensional dispersion equation) that can be used for the assessment of longitudinal and cross-sectional distribution of polluting materials.

The one-dimensional hydraulic model was used for the prediction of the times of travel of water and pollutants in the Danube corresponding to the following flows observed at the Pozsony/Bratislava gauging station:

900 m^3/s (low flow-range)
1600 m^3/s
2000 m^3/2 (mean flow-range)
3000 m^3/2
10000 m^3/s (high flow-range)

The hydraulic model was applied - based on the available data series - for a much longer river stretch (Rajka-Dunaföldvár) than that of the project area between Rajka and Budapest.

The computer software "DUNAWARN" based on the hydro-dynamic and mixing model-system developed for the Danube stretch between Rajka and Dunaföldvár for warning purposes, can be applied for the assessment of the impact of various pollution effects on the river such as the longitudinal and cross-sectional distribution of the concentrations of pollutants, characteristics of the plume, the time of travel can be simulated and predicted with different hydraulic conditions and pollution discharges. (See Annex 6 of Report No. 21).

One of the practical applications of the "DUNAWARN" model-system was the simulation of three assumed accidental pollution events viz:

- a road accident
  (a tanker carrying chloroform overturned and spilled its load on the river bank)

- a rail accident
  (a tank-wagon carrying pesticides became derailed and spilled its load into the river)

- an accidental pollution incident on a tributary of the Danube
  (an accidental spill of mercury on the River Vág was carried into the Danube)

The results of these calculations were considered also as inputs to the other model-system, developed for the assessment of quality changes of the filtration zone of the bank-filtered drinking resource of the Island of Szentendre.

Practical applications of the "DUNAWARN" model-system led to the conclusions, that the time of travel could be assessed satisfactorily and the dispersion and mixing of pollutants were well described. The novelty of the software was, however, the ability of the model to handle in bifurcations of the river around an island. For completeness, post project period in-situ measurements will be needed to determine the dispersion coefficients of characteristic stretches of the Danube.

2.2.5. Method for the establisthment of the Danube early water quality monitoring system

The principles of the early warning water quality monitoring system were developed (see Annex 6 of Report No. 27) based upon the results of studies on the existing observation network, the state and utility of the existing two automated water quality monitoring stations (at Rajka and Szob - both currently out of operation) and the review of bio-monitoring possibilities. An important contribution was given to these activities through the experience of the study-tours of the Project's training programme, for example, visit to the well organised warning system in operation on the River Rhine. The requirements of the interested authorities and waterworks were also taken into account. The strategy developed for the establishment and operation of the Danube early warning monitoring system consisted of three main elements:

- the water quality observation and monitoring network, covering approximately a 200 km long stretch of the River Danube;

- the "DUNAWARN" model-system to simulate and predict quality changes caused by permanent or accidental pollution;

- the information sub-system to distribute observed data and warning signals.

The observation network was recommended to consist of twelve stations along the River, of which four would provide continuous water quality measurements and observations. It was proposed that two automated monitoring stations (at Rajka and Szob) should be established which would utilise the existing buildings of the former stations. It was further proposed that these should be equipped with bio-monitoring facilities (e.g. fish-test monitors) and oil detectors in addition to automatic samplers and the instrumentation for measuring traditional water quality determinands. Two waterworks will participate in the continuous quality measurements by providing data acquired during treatment processes. Temporary measurements and observations will be provided by eight other stations in accordance with the plan of operation. Well-equipped field and mobile laboratories and motor-boats were also recommended as important parts of the observation system. The staff of the industrial plants, the personnel of fire-brigades, police and border- guards could be also involved in the observation of severe pollution cases occurring in the hydro-geological protection zones.

The DUNAWARN model-system is to be located on high-speed (33 Mhz) computers of the field sub-centres (Győr and Budapest) of the early warning system similar to those of the National Water Quality Laboratory at VITUKI, and the Central Alert Services of the Ministries KHVM and KTM.

The flow of information (observed data, outputs of model runs, warning signals) between the stations of the observation network, and the field sub-centres, the water users, and also the Central Alert Services was planned to be provided by the information-subsystem. The local flow of information will be integrated into the two separate field sub-centres which maintain higher level contacts and make decisions on the level of alarm-stages and generate warnings if and when necessary. It is also planned that telecommunications will use the telefax-network and a personal intercom-network. (See Annex 6 of Report No. 54).

Studies on the available knowledge gained from monitoring water quality in the basin of the Danube which is shared by eight different countries, concluded that no regional early warning monitoring systems exist at present in the whole region, only those for intake protection schemes are in operation. In future however, the number of accidental water pollution cases may increase, as a consequence of the opening of the Danube-Main-Rhine shipping canal and its expectedly high traffic. Thus, the need for the establishment of early warning systems to protect water users against pollution effects will also be stengthened in the near future.

2.3 Emergency technologies for drinking water treatment

Because of the good water quality of the bank-filtered drinking-water resources in Hungary, no special water treatment methods applied by the waterworks have been installed at these resources. Some of the waterworks had to apply technologies for removing iron and manganese. This, however, was not due to poor water quality of the recharge from the river, but to the oxidation-reduction conditions prevailing in the channel bed, in the filter zone and to the inappropriate siting of the production wells. Most of the waterworks, therefore, are not equipped with the necessary treatment techniques for supplying water of drinking water quality during periods of accidental pollution events. Even more vulnerable are surface water intakes which do not have the benefit of bank-filtration.

These circumstances necessitated the study of control strategies that could, in the case of accidental pollution events lasting for a few days, assure the supply of safe drinking water to the population served by the water distribution network.

2.3.1. Objective and activities

The objective was to develop emergency drinking water treatment technologies for waterworks, which are applicable for periods of temporary water quality deterioration, based primarily on the existing treatment facilities and consisting of complex multi-function treatment procedures.

Activities of the research work were:

- the indentification of potential contaminants;
- the treatment technologies for the removal of potential contaminants;
- the design of multi-function treatment technologies.

For the purpose of this study, the term emergency water treatment technology means technologies applied to bank-filtered waters for removing contaminants (mostly micro-pollutants) that occur temporarily in water. Thus, iron and manganese removal are not included in these technologies, but the removal of nitrate or ammonium-ion are considered emergency technologies, as these contaminants show up not continuously, but temporarily from time to time.

2.3.2. Identification of potential contaminants

The groups in which contaminants likely to occur were determined and divided into inorganic and organic micro-pollutants. The most important inorganic pollutants were grouped into two categories: nitrogenous inorganic substances (ammonium, nitrite, nitrate, etc.) and toxic heavy metals (mercury, cadmium, nickel, lead, copper, zinc, chromium). Of the inorganic pollutants, ammonium-ions get into the water of the wells mainly from the river, while nitrate and nitrite-ions infiltrate from the background zone. Compounds belonging to the second group of inorganic micro pollutants (toxic heavy metal compounds), might originate from either the river or the background zone.

Of the organic pollutants that can reach the water of bank-filtered wells, mineral oil and derivatives, phenols and phenol derivatives, detergents, PAH compounds, chlorinated hydrocarbons (PCB, THM), organic metal complexes, complex forming organic substances, humus, lignin and dissolved excreta are the most common.

In carrying out laboratory and pilot experiments, the basic assumption was that the selected contaminants, or groups of contaminants, would reach the water of bank-filtered wells in concentrations higher than that allowed by the drinking water standards.

2.3.3. Treatment technologies for the removal of potential contaminants

The basic idea of selecting and elaborating emergency treatment technologies was that technologies based on physico-chemical, or chemical processes should be used exclusively, since the technologies would have to be operative within a few days of notification of the accidental pollution. This speed cannot be reliably matched by biological technologies.

Another factor that affects the character of a feasible solution at a given waterworks is whether it has technological units available for certain water treatment technologies or not. Depending on hydro-geological conditions many Hungarian waterworks, based on bank-filtered water resources, have to apply iron and manganese removal technologies. In such waterworks the possibility of applying emergency technologies is different from those where no technology except disinfection is applied. The size of a waterworks also determines the practical solutions for the removal of given polluting substances.

For removing ammonium ions, break-point chlorination was suggested. Activated carbon adsorption was proposed as a means of removing the chloramines thus generated. Selective ion-exchange was recommended for removing nitrate-ions, or granulated activated carbon might be also applied - to a limited extent - for the removal of nitrate-ions.

The traditional methods of solid-liquid phase separation (coagulation, flocculation, sand filtration) seem to be suitable for removing most of the toxic heavy metals. In the case of certain heavy metals (e.g. cadmium and nickel) these procedures are of limited

efficiency only, when the pH is close to neutral. The above method can be efficiently applied for the removal of toxic heavy metal ions in the pH range of 9.0-10.0. For the removal of chromium, in the form of Chromium/VI/ compounds, a solid-liquid phase separation technology was elaborated, with a redox process forming the first stage. This would be followed by conventional solid-liquid phase separation methods for removing chromium compounds from the water.

Adsorption methods are recommended for the removal of organic pollutants. The overwhelming majority of organic substances that are likely to occur as accidental pollutants in the Hungarian Danube can be efficiently removed by activated carbon. For removing volatile organic substances, intensive aeration of the water provides a good and inexpensive solution.

On the basis of laboratory and pilot-scale experiments, it was concluded that appropriately selected water treatment technologies could be used for decreasing the concentrations of the contaminants investigated to levels allowed by the respective drinking water standards. Applying the various water treatment technologies in an appropriate sequence, or grouping such technologies, multi-function technology systems can be formed, and recommended for application. These systems can remove far more polluting substances than would be possible by applying the various technologies, either individually, or not in the most appropriate sequence. (See 2.3.4 below).

2.3.4. Methods of multi-function treatment technologies

Multi-function technologies have been elaborated to the end that an existing technological unit could be utilised (with certain modifications and temporary extensions) for the removal of the most likely components of groups of polluting substances.

The main processes for removing pollutants, expected to occur during accidental pollution events, are as follows:

- aeration (removal of volatile substances)
- solid-liquid phase separation (removal of solids, or, by precipitation, solidified substances)
- absorption (removal of most of the organic, and some of the inorganic constituents).

The technology of solid-liquid phase separation relies on single-, or multi- layer filters contained in a pressure vessel while adsorption is provided by a container filled with granulated activated carbon. In the case of the simultaneous occurrence of a combination of contaminants, the above mentioned two containers can be used in sequence.

Alternatives to these multi-function emergency treatment technological units were proposed for waterworks with capacities of 1000 m^3/d and 20000 m^3/d for different

groups of pollutants to be removed. Cost estimations of the capital and operating (including maintenance) costs were made.

The simulated accidental river pollution incidents (discussed also in chapter 2.1 and 2.2) were also analysed from the point of view of pollutant-removal by emergency drinking water treatment technologies. It was found that the modelled maximum concentrations of chloroform and atrazin in Danube water entering the filtration zone (0.47 mg/l and 1.0 mg/l, resp.) would result in only trace concentrations in the water of the wells. The same result was achieved for Chromium/VI/ compounds. In the case of assuming very high concentrations of the above pollutants in river water, which would result in concentrations much higher in the production wells than allowed by the drinking water standards, the alternative of the multi-function treatment method developed was recommended.

Taking the general quality conditions of Hungarian surface waters also into consideration (having rivers that recharge bank-filtered water resources in mind) as well as the technologies being (or not being) applied at the waterworks, the proposals of the Project were focussed not only on water treatment technologies, but also on other, possibly more efficient, means of solving the accidental pollution problems.

The emergency treatment techniques proposed would, normally, be used only infrequently. They would not, therefore, be very cost-effective. If, however, the units were utilised to treat the normal run of water quality in the Danube and the water so treated were to be recharged in the background zone of Szentendre Island, a sufficiently large reserve might be accumulated that the passage of a slug of pollution might not adversely affect the yield of the production wells. Indeed, the hydraulic gradient might be such that very little pollution would be able to enter the filter zone on the river channel side of the well. Moreover, by making use of the emergency water treatment units in this way, their cost-effectiveness would be greatly enhanced.

2.4. Rehabilitation of contaminated bank-filtered water resources

One of the most important units of the Danube Regional Waterworks - the Southern Waterworks at Vác - has a capacity of 20,000 m^3/d. One year after the expansion of the abstraction facilities on the left bank of the Danube, the works had to be closed down because of the infiltration of excessive organic pollution of industrial origin. This contaminated resource was selected to be Pilot Zone 2 of the Project so that the local waterworks, DmRV, could be assisted in their efforts to rehabilitate the resource and thus enable the supply to be resumed.

2.4.1 Objective and activities

The objective of the studies was to contribute to the elaboration of methods for the rehabilitation of the contaminated bank-filtered water resource of Pilot Zone 2, by methodological and scientific/technical assistance.

The technical planning of field activities to be carried out by the local waterworks aimed at re-starting supplies (the rehabilitation) from the polluted drinking water resource of the Southerm Vác area was not started during the Project, due mostly to the lack of financial resources. All available funds were spent in providing a potable supply to the forty thousand inhabitants of the country-town of Vác following the pollution event. This was achieved by the construction of a pipeline under the Danube to obtain a supply from Szentendre Island where the abstraction plants of the Waterworks of Budapest were operating. The Tripartite Review Meetings on project activities considered these limiting factors and, as a result, most of the Project's planned manpower and financial resources of Theme 4 were transferred to Themes 1 and 2 of the programme (see Annex 6 of Report No. 46). Due to all these circumstances, the activities of Theme 4 of the Project were principally focussed on the overall evaluation of the quality of the water resource in question and on the formulation of further research work needed to prepare a plan for a later rehabilitation programme.

Activities implemented were:

- a review and synthesis of the information available on the Pilot Zone and the preparation of a base line survey of the state of the contaminated water resource;
- gas-chromatography fingerprint studies;
- studies on preventive strategies.

2.4.2. Baseline survey of the state of the contaminated water resource

One of the important activities of the Project was the review and synthesis of existing studies on the contaminated drinking water resource. This resulted in the "Baseline Survey", which was prepared on the basis of available data, analytical results, and other information. The survey drew an overall picture of the present state of the drinking water resource of the Southern Waterworks of Vác and described the steps taken for making preparations for the potential rehabilitation of this resource in the future. (See Annex 6 of Report No. 51).

The study gave a summary of the main technical parameters of the Waterworks that was shut down in 1981, described the circumstances of the pollution incident that contaminated the water resource and presented the results of research work that had been carried out during the past decade with the purpose of identifying and quantifying the source and extent of pollution.

Although the case study presented certain potentially utilisable technical measures for the rehabilitation of the drinking water resource, the final conclusion was that no decisions on the rehabilitation techniques (drinking water treatment, and/or technical protection) could be made until sufficient knowledge of the type and quantity of organic micro-pollutants that polluted the water resource were made available, and the necessary toxicological investigations had been made. The significance of this study was that it was the only summary review of all the relevant explorations, investigations, research results, etc.

2.4.3. Gas-chromatographic fingerprint studies

In accordance with the proposal of the WHO consultant, gas-chromatographic fingerprint studies were carried out in 1989 to reveal the changes of the level of pollution in the drinking water resource. Pumping of several month's duration of the abandoned radial well and pipe wells was started in February 1989, discharging the abstracted water into the Danube, thus re-establishing the former operational hydraulic conditions and creating conditions that allowed the survey of the state of the water quality to be undertaken.

On the basis of the gas chromatographic analysis of forty water samples taken from the production wells, the observation wells and the Danube, from the public health point of view, the water resource was still heavily polluted by the leachate of the landfill site of the pharmaceutical factory. The pollutant plume, moving westward underground, reached the Danube and the bank-filtered groundwater resource. The polluting effect was most marked in the water of the radial well, but several contaminants were also contained in the water of other wells. The quality and the biological effect of the contaminating substances were revealed by mass-spectrometric analysis. The results of the investigations indicated that the drinking water resource remained dangerous and could not be used for drinking water supply purposes. (See Annex 6 of Report No. 30).

Some of the extracts of the water samples taken within the framework of this project study were forwarded to a university laboratory where the main unkown organic micro-pollutants were identified by gas- chromatography/mass-spectrometry (GC-MS) analysis. Many of the identified substances were unambigously of industrial origin.

2.4.4. Studies on preventive strategies

In addition to identifying the extent of the danger and evaluating potential remedial and control measures, water quality modelling techniques can make a significant contribution to the planning of rehabilitation strategies of heavily polluted groundwater resources. Of the polluted groundwater resources in Hungary, those of the Southern Water works at Vác are among the most outstanding. This resource is being contaminated mainly by the leachate from the pharmaceutical waste in the off-river background zone and also from polluted recharge of the river. Mathematical modelling methods could be used first

to establish the ratio of the recharge from the background zone to that from the Danube at continuous steady water abstraction levels and at various natural hydrological conditions, making use of the detailed hydrological, hydro-geological and water quality measurement data. If the results of such a study indicate that the quality of the abstracted water is not going to improve, even after long-lasting pumping operations of contaminated water to waste, then water quality modelling should, perhaps, be extended to involve the processes of in situ self-clarification in the aquifer (the processes of decomposition and adsorption).

The results of the laboratory column-filter experiments, that had been successfully applied during the Project activities should be used since, due to the complex nature of contaminating substances and to their frequently unknown composition, theoretical approaches to the description of these transformation processes do not seem to be feasible. On the basis of the results of the research activities and laboratory investigations, decisions could be made on the timing of the restoration of the supply from the resource, taking into account the capital cost of the necessary active protection methods (e.g. a barrier well series and/or special water treatment processes) including their operational and maintenance costs (see Annex 6 of Report No. 42).

The research results gained with the modelling of the processes of water quality changes in the filter zone of the bank-filtered water resource along the banks of the Island of Szentendre could be efficiently utilised in further investigations into the planning of the rehabilitation of this potential drinking water resource.

The standards and guidelines regulating the utilisation and protection of groundwater resources have been significantly updated and expanded in recent years. This involved, in each case, the strengthening of the criteria. Within the framework of Project activities, the new regulations were evaluated in the light of the experience gained with the contaminated water resources at Vác. This was developed in accordance with the regulations in place at the time of construction but, with the benefit of having collected water quality data and other information during the past decade, it is now apparent that the siting of the abstraction wells was unfortunate.

The first step in the rehabilitation process must be to establish the boundary of the background zone under stable conditions with no pumping taking place so that the "rest water level" (i.e. stable ground water level has been established) and groundwater contours can be mapped. The direction of the flow of groundwater to the well can then be determined when pumping is re-started.

Project results contributed significantly to the development of methods for designating the protection zones of drinking water resources. The new Technical Guideline MI-10-432-88 recommends, in case of bank- filtered water resources, the elaboration and use of water quality transport models that can describe initial pollution levels, the mixing of waters of different pollution levels, the dispersion and adsorption of contaminants and the time variation of concentrations. The scientific background for such modelling efforts was provided by the numerical transport model of the seepage zone that was developed for Pilot Zone 1. This model could be utilised also for the purpose of the preparation and planning of the rehabilitation of potential drinking water resources.

2.5 Training

The training programme of the Project provided possibilities for 45 Hungarian scientists and technical experts to participate in study-tours, workshops and symposia. They involved travel to different European countries to exchange experiences and to study the applied research, planning and management methods in each of them. Details of the study-tours are given in Appendix 2.

3. RECOMMENDATIONS

Bank-filtered water resources are the most important drinking water resources in Hungary, due to their good quality, productivity and their general cost-effectiveness. The protection of these resources is, therefore, of high priority.

It is recommended, that:

- the methods developed by the Project to increase the safety of supply and the protection of drinking water resources (the hydro-geological and transport models of the filtration zone of the Island of Szentendre, the Danube early warning water quality monitoring system and the emergency drinking water treatment methods) should be implemented in practice at the waterworks and by the authorities concerned;

- nationwide dissemination of the results of the Project should be considered, based on the practical experiences of their implementation;

- hydro-geological protection zones of the bank-filtered water resources should be extended to the river itself, whose water ensures the recharge of these resources.

Evaluation of the data on accidental river pollution incidents (originating both in upstream countries and within Hungary) during the past decade showed that water users - especially waterworks operating along River Danube and other rivers in the country - were endangered and restricted several times every year because of the temporary quality deterioration of the surface water resources.

It is recommended, that:

- an early warning water quality monitoring system should be established for the Danube reach involved in the Project (between Rajka river km 1848, and Budapest at surface water abstraction plant of the Waterworks of Budapest river km 1659) to protect all water users, but especially all water works, by providing them with warnings in due time about pollution incidents;

- two automatic water quality monitoring stations to be equipped also with bio-monitoring facilities should be installed at Rajka and Szob, utilizing the existing buildings;

- high-speed computers (33 MhZ) should be provided for the sites where the DUNAWARN software is planned to be located, to ensure its fast and effective operation;

- professional training and continuing further education of the staff members (observers, analysts, computer operators, etc.) to be employed for working in the monitoring/early warning network, should be programmed;

- further research work and utilisation of foreign experience should be carried out on bio-monitoring methods to be applied in Hungary.

The hydro-geological and water quality transport model-system developed for the filtration zone of the selected area of the Island of Szentendre predicts the effects of pollution both in the parent river and in the landward background zone. This model can be used for aiding the design and selection of technical control measures against polluting effects. They will also be beneficial for operational management in its decision-making. The application of this numerical model in Pilot Zone 1 resulted in improved management ideas.

It is recommended, that:

- an optimal operations schedule of the bank-filtered wells should be elaborated for accidental pollution incidents, in order to minimise the risks. This should be done with due concern to the duration of the pollution event and to the time of travel to the wells;

- the establishment of a second line of wells on Szentendre Island, parallel to the existing ones, but situated further (50-100m) from the river should be considered, because most of the existing production wells are too close to the river channel. The travel time of contaminated water to reach the wells from the river is less than one day for 54% of the existing wells;

- the existing wells on Szentendre Island should be used as "barrier wells" in the case of accidental river pollution events to protect the new production wells established further from the river bank;

- the results of preliminary hydro-dynamic modelling indicate that, in the Island of Szentendre a recharge of about 15 million m^3 could be stored, provided that the quantitative and qualitative impact of this recharge are evaluated first and found to be acceptable. In the river reach investigated, the impact assessment of the planned developments in river canalisation, river training and channel re-shaping should take into account the need for the protection of bank-filtered drinking water resources;

- the further refinement and development of the model system should be continued to increase the accuracy of results, with special regard to the determination of dispersion parameters, the composition and sorption properties of the channel bed sediments (being most important from the hydro-geochemical point of view) and the effects of unsteady flows.

The protection of the drinking water resources of the Island of Szentendre should be solved in such a way to ensure (in addition to the safety of drinking water production) the employment and well-being of the inhabitants, the maintenance of agricultural and forestry activities, and recreational land uses.

It is recommended, that:

- the contamination of the production wells from the off-river background zones should be intensively investigated to determine its effects on the quality of the water produced by the bank-wells. Possible means of preventing this type of pollution should also be investigated.

The application of emergency drinking water technology could assist waterworks to maintain supply during the period of temporary deterioration of water resources caused by accidental pollution. Most waterworks have not the capability at present to apply emergency treatment technology.

It is recommended, that:

- waterworks should be made to install the necessary equipment to put into operation temporary emergency technologies when needed, especially in cases where they utilize surface water sources (rivers) because they are especially vulnerable to accidental pollution incidents;

- applicable emergency technologies should be considered to remove organic and inorganic micropollutants for small and medium-size waterworks;

- in the case of favourable hydro-geo-chemical conditions, the small and medium size waterworks should be made independent of the parent river for a few days with groundwater re-charge in the landward background zone and with the establishment of new production wells that draw on these resources;

- in the case of shorter (1-2 days) accidental pollution events, an appropriate solution can be provided by establishing sufficiently large clean water storage capacity at the waterworks. The present situation, when the clean water storage capacity of the waterworks is only 15-25% of the daily quantity supplied is inadequate.Investment in this field would prove useful, not only in the case of accidental pollution events, but also at low river flows, when bank-filtered production wells operate with capacities much below their average.

Public and professional interests are increasingly focussed on the methods of rehabilitation of contaminated drinking water resources. Due to external constraints, the Project activity's contribution was reduced only to extending the knowledge of water quality conditions and developing modelling tools for future studies on rehabilitation methods.

It is recommended, that:

- research and development work into the rehabilitation of contaminated groundwater resources should be continued in order to develop methods of protecting drinking water resources. The Southern Waterworks of Vác seems to remain the most appropriate Pilot Zone for such research work in the future;

- efforts should be made to develop rapid and reliable methods for human-toxicological investigations for the determination of public health effects of specific pollutants in water;

- the protection areas of the waterworks should be determined and planned with due regard to the presently effective stricter quality requirements and the likely quality of potential recharge from the off-river background zone.

Waterworks along the Hungarian stretch of the River Danube were often endangered by transboundary water pollution incidents. The implementation of project's results could increase the safety of drinking water supply in this region by applying the method of the early warning water quality monitoring system in practice. For international utilization of the results, first of all this method could be suggested for consideration, as a contribution to the international endeavours concerning the formulation of the regional environmental protection programmes for the Danube River Basin.

APPENDIX 1.

PROJECT STAFF

Name	Function	Dates
International consultants		
Prof. D. H. Newsome	Workplan and pilot zones	05. May-02. June 1987
(United Kingdom)	Field studies and review	08-18. Nov. 1988
	Model studies and review	28. Oct.-02. Nov. 1990
	Final evaluation	01-06. Dec. 1991
	Editing of Final Report	07-15. apr. 1992
A. J. Montiel (France)	Emergency treatment	16-22. Oct. 1988
O. Espinoza	Tripartite Review	16. Nov. 1988
(WHO-EURO)		16. Nov. 1990
B. Piazza-Georgi (UNDP)	Tripartite Review	16. Nov. 1990
National staff		
Dr. Gy. Pintér	Project Director[1]	1986-1992
Dr. F. László	Chief Scientist[1]	1989-1992
Dr. A. Homonnay	Chief Scientist	1987-1988
P. Liebe	Scientific leader of bank-filtration studies	1988-1990
Dr. J. Déry	Leader of Topic 1. (Bank-filtration studies)	1990-1991
L. Pinkola	Chemistry HP-IRD	1988-1990
Mrs. K. Zotter-László	Chemistry	1987-1989
Dr. P. Gulyás	Hydrobiology	1987-1990
Dr. M. Borsányi	Bacteriology	1987-1989
Dr. M. Kádár	Bacteriology	1987-1991
B. Ferenc	Hydrogeology	1988-1989
Dr. G. Horváth	Field studies (Pilot Zone 1)	1987-1991
Mrs. Á. Laczkó	Field monitoring	1987-1991
Dr. F. Székely	Groundwater modelling	1990-1991
H. Phan Tra	Groundwater modelling	1990-1991
Dr. F. László	Micro-pollutants, Transport modelling	1987-1992
Dr. B. Hock	Leader of Topic 2. (Early warning monitoring)	1987-1991
Dr. L. Horváth	Polluting sources	1987-1991
Dr. P. Varga	Polluting sources	1987-1991
Mrs. K. Debreczeni	Accidental pollution	1987-1990
B. Csányi	Biomonitoring	1989-1991
J. Józsa	Hydraulic modelling	1989-1990
A. Darázs	Transport modelling	1988-1991
P. Farkas	Software development	1990-1991
M. Pannonhalmi	Information-system	1987-1991
Dr. I. Licskó	Leader of Topic 3. (Emergency technologies)	1988-1991
Dr. Gy. Pintér	Leader of Topic 4. (Rehabilitation)	1989-1991
Dr. A. Homonnay	Leader of Topic 4.	1987-1988
F. Vincze	Field studies (Pilot Zone 2)	1987-1991
Mrs. K. M. Zimonyi	Baseline survey	1987-1991
Dr. Z. Kárpáti	GC-fingerprint studies	1989
Mrs. M. Vehofsits	Project secretary[1]	1987-1989
Mrs. L. Pusztai	Project secretary[1]	1990-1992
National Supervisory Board		
E. Almássy	President of Project Coordinating Council	1989-1992
Dr. L. Balásházy	Technical supervisor	1989-1992
G. Aujeszky	Scientific adviser	1990-1992

Another 32 staff members were also involved in the implementation of the Project tasks on part-time basis.

[1] Full time

APPENDIX 2.

TRAINING PROGRAMME

Number of study tours	Number of participants	Field of study study	Country	Duration in week	Beginning date
1. LIST OF STUDY-TOURS					
1	1	Analytical methods	France	2	Nov. 1987
1	1	Rehabilitation	Italy	1	Febr. 1987
1	2	Groundwater models	FRG-Neth.	2	Sept. 1987
2	3	Pollution control	FRG-Neth. FRG-Switzerl.	1	Nov. 1987
1	1	W.qual.monitoring	U.K.	1	Nov. 1987
1	1	Microbiology	Neth.	1	Nov. 1987
1	2	Water supply systems	Austria	1	Dec. 1987
1	2	Water resources protection	USA Canada	1,5	Apr. 1988
1	1	Math.modelling	Italy	1	Aug. 1988
3	4	Early warn.monitoring	U.K.	1	Sept. 1988 Oct. 1988
1	2	Hydrobiology	Austria	1	Sept. 1988
1	3	Gr.water monitoring and modelling	FRG-Neth., Neth.-U.K.	1,5	Oct. 1988
1	1	Microbiology	U.K.-Neth.	2	Oct. 1988
1	3	Pollution controland rehabilitation	FRG	1	Nov. 1988
1	2	Water treatment technologies	USA	2	May 1989
2	3	Gr.water modelling	FRG-France	1,5	Sept. 1989
1	1	Bacteriology	Finland	2	Oct. 1989
1	3	W.qual.monitoring	U.K.	1	Oct. 1989
1	1	Emergency treatment	FRG	2	Oct. 1989
1	1	Math.modelling	Austria	1	Nov. 1989
1	1	Microbiology	Denmark	1	Apr. 1990
1	2	Early warn.monitoring	FRG-Neth.	1,5	July 1990
1	2	Gr.water management, pollution control	France	1	July 1990
2	4	Gr.water modelling	Netherland Denmark	1	Sept. 1990 Dec. 1990
1	1	Hydrobiology	Austria	1	Sept. 1990
1	2	Treatment technologies, Protection zones	USA	1	Sept. 1990
2	4	Pollution control, Warning systems	U.K. FRG	1	Oct. 1990
1	1	Hydrogeological modelling	FRG-Neth.	1	July 1991
2. GROUP TRAINING					
1	4	WHO/UNDP Training course in Warsaw	Poland	5	May 1989
3. PARTICIPATION IN SYMPOSIA					
16	16	Participation in various scientific symposia and workshops related to the project areas.	Austria, Belgium, Italy, FRG, UK, etc.	3-6 days	1987-1991

MAJOR ITEMS OF EQUIPMENT PROVIDED BY UNDP

			Approx. Cost US$	Use/site
Analytical instruments for the determination of volatile organic micropollutants in waters				
1 set	Gas chromatograph/FTIR detector instrument-system Hewlett-Packard Mod.5965A with various accessories Serial Nos:		65 000,-	VITUKI (IWPC)
	Gas chromatograph	2436G01918		
	Infrared detector	2724A00051		
	Winchester drive	2623A08496		
	Computer	2751A22603		
	Memory-extension of the system:			
	Fixed disk drive (152 MB)	2922E10034	6 956,-	VITUKI (IWPC)
Computer-system:				
1 set	AT 486-33 MHz computer system with HP Laser Jet II. printer, 211 MB HHD tower case, 101 keyboard, VGA Colour monitor 14". Notebook FBU 386 SX-16 MHZ computer 40 MB FDD.		7 540,-	VITUKI (IWPC)

LIST OF NATIONAL INSTITUTIONS PARTICIPATING IN THE IMPLEMENTATION OF THE PROJECT

KHVM	Közlekedési, Hírközlési és Vízügyi Minisztérium,Budapest (Ministry for Transport, Telecommunication and Water Management), since 1990.
KVM	Környezetvédelmi és Vízügyi Minisztérium, Budapest. (Ministry for Environment Protection and Water Management), 1988-1989
OVH	Országos Vízügyi Hivatal, Budapest (National Water Authority) 1986-1987
VITUKI	Vízgazdálkodási Tudományos Kutatóközpont, Budapest (Water Resources Research Centre) Intézetei (Institutes of VITUKI): Hidrológiai Intézet (Institute for Hydrology) Hidraulikai Intézet (Institute for Hydraulics) Vízminőségvédelmi Intézet (Institute for Water Pollution Control, IWPC)
Fővárosi Vízművek	(Waterworks of Budapest)
DmRV	Duna menti Regionális Vízművek, Vác (Danube Regional Waterworks)
OKI	Országos Közegészségügyi Intézet, Budapest (National Public Health Institute)
ÉDKÖVIZIG	Észak-dunántúli Környezetvédelmi és Vízügyi Igazgatóság, Győr (North-transdanubian Environment Protection and Water Authority)
ÉDKF	Észak-dunántúli Környezetvédelmi Felügyelőség, Győr (North-transdanubian Environmental Inspectorate)
KDVKÖVIZIG	Közép-Duna-völgyi Környezetvédelmi és Vízügyi Igazgatóság, Budapest (Central Danube Valley Environmental Protection and Water Authority)

VITUKI Innosystem Kft/Ltd.

WHO. Protection of Bank-filtered Drinking Water Resources Project, Hungary. Assessment of polluting impacts on bank-filtered drinking water resources, based on the work of Dr. J. Déry, Dr. F. László et al, Budapest 1991. 133 pages, 113 figures, 7 tables, 1 annex. HUN/86/007. Field Document I.

ABSTRACT

The Government of Hungary, assisted by the United Nations Development Programme and the World Health Organization of the United Nations, began a research project to increase the safety of drinking water supply based on bank-filtered water resources and to develop practical methods to protect these drinking water resources. Special field studies were carried out on two pilot areas. The Project activities lasted from March 1987 to December 1991. The implementing institute of the project was the VITUKI in co-operation with organizations and Waterworks interested in public supply and resource protection.

The specific field investigations, experiments and model studies covered in this Field Document were designed to explore and simulate the processes affecting the changes of water quality within the filter media at Szentendre Island, which is the most important bank-filtered drinking water resource of the Waterworks of Budapest. The Northern part of the Island was chosen as Pilot Zone 1 of the Project.

The three years field investigation programme, carried out in order to provide data for modelling seepage and pollutant transport processes included hydro-geological, hydro-biological, aquatic chemical, hydrological and microbiological studies and measurements. The pollutant removal efficiency of bank-filtration for various organic and inorganic components, micro-organisms were revealed. Organic micro-pollutants in Danube water and bank-filtered water were identified by using the GC-FTIR analytical instrument-system, provided by UNDP for the Project. To supplement field studies laboratory model investigations were carried out to determine adsorption and degradation parameters of pollutants liable to be retarded and/or decayed during the bank-filtration process.

A numerical model-system was developed to simulate the behaviour of the water resource and the transport of pollutants. The most important transport parameters of the area were the dynamic porosity of the bottom sediment and gravel layer as well as the transverse and longitudinal dispersivity of the gravel layer. The model was calibrated with measurement data of a tritium load wave in the Danube. The numerical transport model is a practical tool to assess the effects of an accidental, or a long lasting pollution incident along the river on the quality of the bank-filtered water resources and thus on the quality of water abstracted from the production wells. Provided that sufficient warning (see Field Document II.) is given, the practical application of the model-system could assist to develop management strategy to ameliorate the effects of the pollution incident.

The results and conclusions were summarized and recommendations were given for the utilization of the experience gained.

Field Documents of the Project were written in Hungarian with extended English summaries.

WHO. Protection of Bank-filtered Drinking Water Resources Project, Hungary. Early warning water quality monitoring system, based on the work of Dr. B. Hock et al., Budapest 1991. 106 pages, 28 figures, 14 tables, 4 annexes. HUN/86/007. Field Document II.

ABSTRACT

The Government of Hungary, assisted by the United Nations Development Programme and the World Health Organization of the United Nations, began a research project to increase the safety of drinking water supply based on bank-filtered water resources and to develop practical methods to protect these drinking water resources. Special field studies were carried out on two pilot areas. The Project activities lasted from March 1987 to December 1991. The implementing institute of the project was the VITUKI in co-operation with organizations and Waterworks interested in public supply and resource protection.

The Project activities covered in this Field Document were designed to develop an early warning water quality monitoring system to predict the effects of accidental water pollution events for the water users (and especially for Waterworks) along the River Danube.

Accidental water pollution events from the year 1979 were evaluated with special regard to pollutant changes in time and consequences. An inventory of polluting sources was developed for the direct catchment area of the River upstream from Budapest. Characteristics of the river quality entering Hungary were evaluated. State of the existing monitoring stations was reviewed.

The basic principles of a Danube early warning water quality monitoring system were developed taking into account foreign experiences and needs of the interested waterworks. The role of automatic water quality monitoring stations in a warning system were studied with special regard to possibilities of bio-monitoring.

A model-system was developed to describe and predict the transport and mixing of pollutants in the Danube. The time of travel of pollutants at different flow-rates and specific hydraulic characteristics were determined by the hydraulic sub-model, while the longitudinal and transverse distribution of pollutants and also the width of the plume were assessed by the mixing sub-model. Steady and unsteady pollution cases can be dealt with, as well as bifurcations around islands. Practical applications of the model-system are illustrated by examples.

A detailed proposal was made to establish an early warning water quality monitoring system for the selected Danube-stretch, including an observation network, information system and a system for issuing warnings.

The results and conclusions were summarized and recommendations were given for the utilization of the experience gained.

Field Documents of the project were written in Hungarian with extended English summaries.

WHO. Protection of Bank-filtered Drinking Water Resources Project, Hungary. Emergency technologies of drinking water treatment, based on the work of Dr. I. Licskó, Budapest 1991. 98 pages, 29 figures, 14 tables HUN/86/007. Field Document III.

ABSTRACT

The Government of Hungary, assisted by the United Nations Development Programme and the World Health Organization of the United Nations, began a research project to increase the safety of drinking water supply based on bank-filtered water resources and to develop practical methods to protect these drinking water resources. Special field studies were carried out on two pilot areas. The Project activities lasted from March 1987 to December 1991. The implementing institute of the project was the VITUKI in co-operation with organizations and waterworks interested in public supply and resource protection.

The activities covered in this Field Document were designed to develop methods for emergency technologies of drinking water treatment for periods of temporarily deteriorated water quality conditions of bank-filtered resources. As a first step the main groups of the potential organic and inorganic pollutants were identified. Then the accidental pollutions over the past years were reviewed with a view to selecting the components to be studied for removal at the laboratory and in pilot facilities. The components liable to cause accidental pollution arriving at the well from the river and from the background area were also identified.

The optimal methods and conditions of removing the individual components selected were determined first in the laboratory. The most effective sequence of the unit operations to be applied for treating raw waters containing several pollutants was determined next by laboratory experiments. The data obtained served as the basis of the pilot trials, the results of which were used in compiling the proposals for the development of multi-function water treatment technologies. These multi-function technologies were checked by means of laboratory models. Cost analyses were also made for waterworks of different capacities treating bank-filtered waters containing particular combinations of polluting components. The results of these analyses were also taken into account in elaborating the proposals for waterworks of different size drawing on bank-filtered waters. Also, the methods developed, as well as the alternative sources of supply such as groundwater recharging were taken into consideration and attention was called to the importance of increasing the storage capacity of treated water.

The results and conclusions were summarized and recommendations were given for the utilization of the experience gained.

Field Documents of the project were written in Hungarian with extended English summaries.

WHO. Protection of Bank-filtered Drinking Water Resources Project, Hungary. Rehabilitation of polluted ban-filtered drinking water resources, based on the work of Dr. Gy. Pintér et al. Budapest 1991. 61 pages, 19 figures, 1 tables, 3 annexes. HUN/86/007. Field Document IV.

ABSTRACT

The Government of Hungary, assisted by the United Nations Development Programme and the World Health Organization of the United Nations, began a research project to increase the safety of drinking water supply based on bank-filtered water resources and to develop practical methods to protect these drinking water resources. Special field studies were carried out on two pilot areas. The Project activities lasted from March 1987 to December 1991. The implementing institute of the project was the VITUKI in co-operation with organizations and waterworks interested in public supply and resource protection.

The specific activities covered in this Field Document were designed to assist the local waterworks DmRV in the elaboration of methods for the rehabilitation of the contaminated bank-filtered drinking water resource of Pilot Zone 2, by participating in special field investigations and providing methodological-scientific support for the field activities.

The Southern Waterworks of Vác were closed down in 1981 due to the pollution effect of an industrial waste disposal site in the background zone. They were still not in operation at the beginning of the Project. Following a five months' intensive pumping period of the former production wells to restore the operational hydraulic conditions, samples were taken for gas-chromatographic (GC) fingerprint studies. These results indicated that the water resource remained dangerous and unusable for drinking water supply, organic micro-pollutants still were detectable in the wells. Many of the contaminants unambigously originated from the industrial waste disposal site. Evaluation of the existing standards and quidelines regulating the utilisation and protection of subsurface drinking water resources showed, that the exploratory work and protecting zoning made at the time of the establishment of the Waterworks could not have met the present significantly stricter requirements.

A baseline survey of the state of the contaminated water resource was prepared on the basis of all available data, analytical results and other information, which highlighted the still missing knowledge on pollution transport characteristics in the area of the water resource. For this purpose the hydro-geological and transport modelling of the Pilot Zone 1 (see in Field Document I.) provided utilizable methods which could be applied to the necessary further works on rehabilitation, as well as the results summarized in Field Document III. (Emergency treatment technologies) on possible drinking water treatment alternatives.

The results and conclusions were summarized and recommendations were given for utilization of the experience gained.

Field Documents of the project were written in Hungarian with extended English summaries.

APPENDIX 6.

LIST OF IMPORTANT TECHNICAL REPORTS PREPARED DURING THE PROJECT ACTIVITY

By the end of 1991 there were 57 different reports and technical documents prepared, mainly in Hungarian. The most important of these are as follows:

No.	Title of report	Note
9.	Analysis of accidental pollution events. Background study for Project Topic 2. (Early warning monitoring system). VITUKI, Budapest, Dec. 1987	Research Report In Hungarian
10.	The Vác-South Water Resource. Summary report. DmRV, Vác, Dec. 1987	Summary Report In Hungarian
15.	Risk assessment and management of accidental water pollution events. Case study. VITUKI, Budapest, Oct. 1988	Research Report In Hungarian
16.	Evaluation of the present state of the water quality monitoring stations along the River Danube in Hungary. VITUKI, Budapest, Oct. 1988	Draft Report In Hungarian
20.	Emergency technologies for drinking water treatment. VITUKI, Budapest, Nov. 1988	Draft Report In Hungarian
21.	Application of a model-system to describe the transport and mixing processes of pollutants in the River Danube. VITUKI, Budapest, Nov. 1988	Draft Report In Hungarian
22.	Progress report on microbiological studies on Pilot Zone 1. OKI, Budapest, Dec. 1988	Interim Progress Report in Hungarian
23.	Annual report of the Waterworks of Budapest on project activities. Fővárosi Vízművek Budapest, Dec. 1988	Interim Progress Report in Hungarian
27.	Principles of the early warning water quality monitoring system. VITUKI, Budapest, June 1989	Research Report In Hungarian
30.	GC-fingerprint studies related to the rehabilitation of Vác-South Water Resource DmRV, OKI, Budapest, Sept. 1989	Research Report In Hungarian
31.	Determination of volatile organic micro-pollutants. (Application of the GC/FTIR detector.) VITUKI, Budapest, Sept. 1989	Research Report In Hungarian
32.	Inventory of polluting sources in the Danube Region 1988. VITUKI, KDVKÖVIZIG, ÉDKÖVIZIG, Budapest, Nov. 1989	Final Report In Hungarian
42.	Field experiments and model studies on Pilot Zones. Revised Mid-term report. VITUKI, Budapest, June 1990	Research Report In Hungarian
43.	Assessment of the pollution load characteristics of potential accidental discharges along the Danube. ÉDKÖVIZIG, KDVKÖVIZIG, Győr, Oct. 1990	Interim Draft Report In Hungarian
44.	Water quality data-basis. Field studies in 1989-1990 VITUKI, OKI, Budapest, Oct. 1990	Interim Report In Hungarian
46.	Brief progress reports for the Tripartite Monitoring Review. VITUKI, Budapest, Nov. 1990	Progress Report In English
51.	Baseline survey of the state of Vác-South water resource. DmRV. Vác, June 1991	Final Report In Hungarian
53.	Assessment of polluting impacts on bank-filtered drinking water resources. Field Document I. VITUKI, Budapest, Dec. 1991	Terminal Report In Hungarian with English summary
54.	Early warning monitoring system. Field Document II. VITUKI, Budapest, Dec. 1991	Terminal Report In Hungarian with English summary
55.	Emergency treatment technologies. Field Document III. VITUKI, Budapest Dec. 1991	Terminal Report In Hungarian with English summary
56.	Rehabilitation of polluted bank-filtered Water Resources. Field Document IV. VITUKI, Budapest, Dec. 1991	Terminal Report In Hungarian with English summary
57.	Protection of bank-filtered drinking water resources. Summary terminal report HUN/86/007 Project. VITUKI, Budapest, Dec. 1991	Terminal Report In Hungarian