River Bankwell Filtration for Potable Water Supply

1981-1990

Report on a Working Group

WORLD HEALTH ORGANIZATION
REGIONAL OFFICE FOR EUROPE
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RIVER BANKWELL FILTRATION FOR POTABLE WATER SUPPLY

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ANNEX I

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As improved analytical techniques increase information about pollutants present in river bankwell-filtered water, acceleration of research into health aspects and treatment options available for removal should be encouraged. The systematic coordination and interchange of such information should be encouraged to avoid duplication of effort.

(v) Gather information on the influence of off-river contribution to river bankwell filtration, under varying hydrological conditions, that could provide essential data and guidance on the potential changes in potable water quality. Such knowledge, coupled with reliable data on means of influencing the effect of off-river contributions, would provide for safer control over potable water quality via river bankwell filtration.

(vi) Close the gaps in present knowledge concerning effective methods for rehabilitation of damaged polluted river bankwell filtering systems and wells. There is an urgent need for a comprehensive scientific investigation into the most proficient manner of rehabilitation.

f. In special isolated situations, it has been possible to rehabilitate a polluted river filtration system. However, in the great majority of cases, rehabilitation has proved to be an extremely difficult, if not impossible, task.

This had led to well abandonment, with all its implications, and to the establishment of a new well system, with all the costs involved. Therefore, the economic and practical advantages of safeguarding the integrity of existing filtration systems by introducing and operating an effective river quality management system were stressed. The serious consequences of continuous river water quality deterioration on the ecological system and safe potable water production cannot be too strongly emphasized.

g. Abstraction of water from a river source via bankwell filtration could provide a vital additional potable water resource, especially in those less developed countries which are not at present exploiting the technique and where the hydrogeological conditions are favourable.

WHO should investigate the advantages of exploiting this technique, to provide a potential solution to providing potable water in such less developed countries.

Investigation of the influence of various physical parameters such as the nature of granular media, porosity and permeability of aquifers on the transmission times of infiltration, infiltration velocities on produced water quality, and travel times on the quality of the abstracted water - especially when treating source water contaminated with various industrial pollutants under both aerobic and anaerobic conditions.

To obtain water of suitable quality, an attempt should be made to provide data on the optimum physical characteristics of filtration strata related to transmission times between river source and well.

(ii) Encourage microbiological investigations to ascertain the optimum microbial flora necessary within a bankwell filtration zone to ensure effective degradation of the river water contaminants and the ways and means of maintaining such flora and encouraging its proliferation. The beneficial role played by aerobic and anaerobic conditions could be investigated with the objective of controlling the problem of solubility of manganese and iron.

(iii) Investigate the most suitable warning system in the event of river pollution incidents which could endanger the integrity and operation of the river bankwell filtration process and provide advice to water abstractors. An essential component in designing such a warning system is the need to provide abstractors with an adequate time gap to enable them to take effective evasive action to safeguard the integrity of the wells and future drinking water supplies. There is also a need for establishing an inter-country monitoring system to effectively assess transboundary river water quality; necessary considerations include the optimum locations for such stations, operational procedures, significant components to monitor, data processing and evaluation. It is also necessary to ascertain the most proficient manner of operating an effective evasive action plan upon receiving a warning of a pollution incident in a river system.

(iv) Collect and collate information concerning the effects of various river pollutants on potable water quality from riparian countries operating river bankwell filtration systems. Such information could provide the fundamental evidence to enable decisions to be taken on the imminence of additional water treatment processes necessary to safeguard potable water integrity in the event of continued deteriorating river water qualify from specific pollutants.

14. Conclusions and Recommendations

a. Major river systems, especially those of an international character, which are used as a source of drinking water supply whether by direct abstraction or bankwell-filtration, should be protected from pollution originating either from municipal or industrial discharges, or from injudicious use of pesticides and fertilizers which could damage the ecosystem and jeopardize the integrity of the drinking water produced.

b. River pollution control strategies are therefore vitally important in the preservation of this critical water source. Where rivers transpose national boundaries, a system of international water pollution control strategies, such as is practised by the Rhine Commission to control pollution in the Rhine River Basin, should be initiated for effective control of river water quality. This approach necessitates close international collaboration, and such collaboration involving WHO/EURO and the European riparian countries should be promoted.

c. As practised at present, pollution control does not appear to be fully effective. Evidence indicates that the pollution level in some important major international and national rivers used for bankwell-filtered water supply is such as to endanger the quality of drinking water produced by this technique.

It is important to supply drinking water which is protected from the risk of infection from water-borne diseases and the long-term hazards associated with many of the inorganic and organic micropollutants now contaminating surface water resources.

d. Water resource protection contributes significantly to the success of the International Drinking Water Supply and Sanitation Decade within the WHO European Region. An improvement in river water quality will be a major step in reaching this highly important goal, and every effort should be made to ensure such protection.

Such collaborative effort would be a major step in ensuring the continuing success of river bankwell-filtered water technology as a means of providing a safe, satisfactory and economical drinking water supply for a large proportion of the European population without the necessity of introducing additional, very expensive water treatment processes.

It was felt that failure to achieve this strategy would endanger the protection of river bankwell-filtered water supply as a long-term objective and have a most damaging effect on the safety of future drinking water supplies obtained via river bankwell filtration.

e. The vital importance the following short-term objectives which would contribute beneficially to the achievement of the long-term goal was stressed:

(i) Improve the understanding of river bankwell filtration processes. Such understanding must include a knowledge of the efficiency of the various encountered strata in the filtering capacity between river and pumping well.

Factors affecting bankwell filtration system operation, based on Romanian experience, include: (i) degree of river bed clogging (ii) modification to permeability of the gravel sand strata (iii) the landward contribution to water extracted, and (iv) variations in parent river water quality.

Sometimes after an initial clogging and associated reduction in flow, a steady state is reached and no further reduction in capacity results. Romania has also introduced artificial river bankwell replacement which has been successful in increasing the capacity and improving the filtering performance characteristics.

13. Economic aspects

Drinking water supply systems developed in individual countries differ according to conditions and circumstances, but efforts should always be directed towards an economically optimal solution. In this regard, both investment costs and operating expenses should be considered.

The operating cost of the various alternatives for potable water production is largely dependent on such factors as the type of water source utilized, river surface water intake, reservoir impoundment, shallow wells, deep wells, and river bankwell filtration. For puposes of comparison, operating costs should normally be divided into two categories: production costs and distribution/delivery costs. In deciding production costs, available resources and the required treatment technology to ensure the required ultimate water quality can be compared. Distribution costs relate to the distance, relative elevation and terrain between the source and the centre of consumption.

In cases where the water-carrying strata are relatively shallow, the use of short collection mains, especially when radial well systems are used, is usually economically advantageous both from the point of view of initial investment and operation costs.

The operating costs of using water from confined or unconfined aquifers are generally higher due to the need for greater lifting heads and frequently larger connecting mains between well points. The extra operating costs are the result of greater energy requirements for pumping and such costs as increased well and pump maintenance.

The operating costs for abstracting surface water sources are higher but variable, depending upon the degree of water treatment and the number of chemical agents required to achieve the required standard of potable water quality. However, this difference will probably lessen in the future as more and more bankwell-filtered water is found to be of unacceptable quality and hence requiring additional post-extraction treatment.

Treatment costs for the removal of iron from all types of raw water source are the same, or of the same order of magnitude, while degasification costs for bankwell-filtered water, in general, tend to be less than in the case of water from confined aquifers.

Surface water, especially river water, generally requires the highest degree of treatment and hence is the most expensive to treat, depending upon the levels of pollution. Higher operating costs are due to increased treatment and chemical demands and more sophisticated treatment, i.e. carbon filtration and regeneration, more power and more highly skilled manpower.

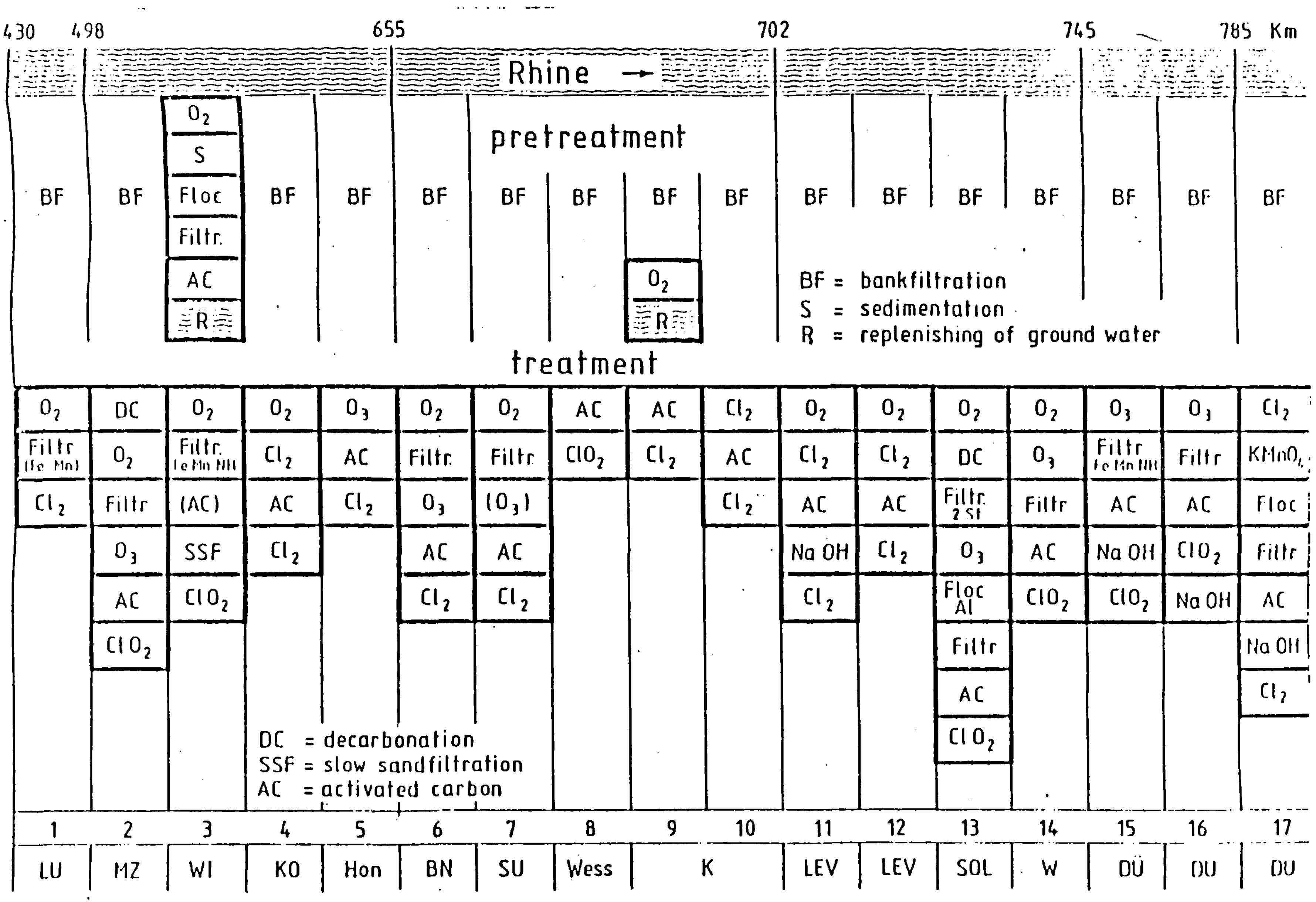
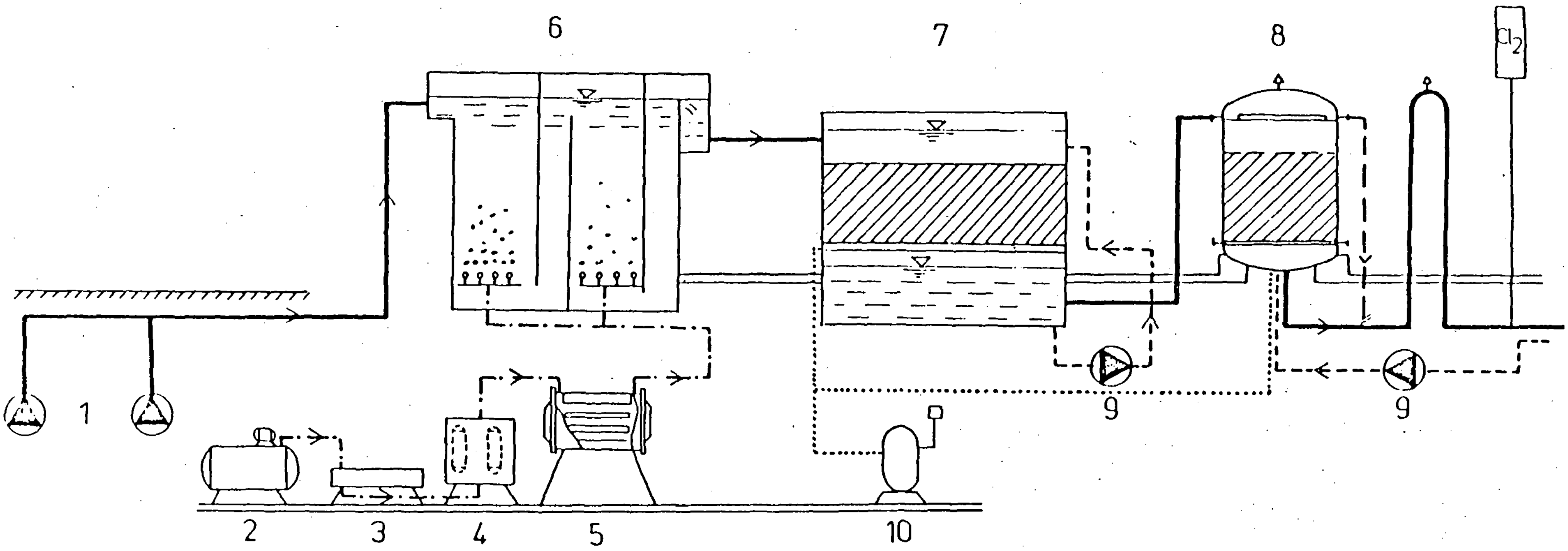


Fig. 9 Cities along the River Rhine



——— WATER FLOW
—·—·— OZONE GENERATION AND DOSAGE
------ FLUSHING WATER
·········· FLUSHING AIR
— — — DRAINAGE

1 Wells (outside of the plant)
2 Compressor and air tank
3 Air cooler
4 Air drier
5 Ozone generator

6 Tank for ozonisation
7 Sand filter
8 Activated carbon adsorber
9 Flushing water pump
10 Flushing air diffusor

Fig. 8 Iron, manganese and organic matter removal from bank-filtered waters by ozone-oxidation, filtration and activated carbon absorption

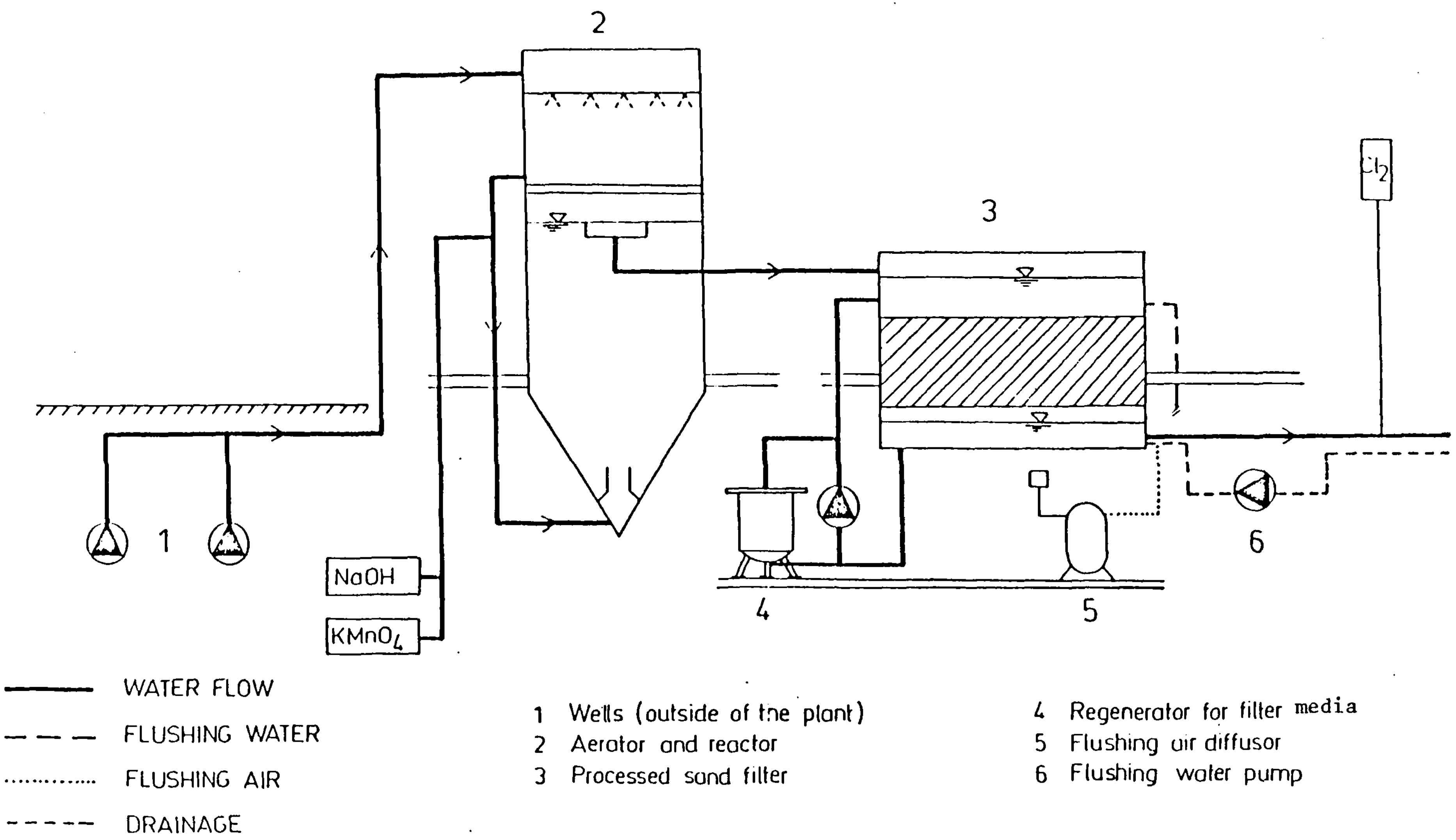


Fig. 7 Iron, manganese and ammonia removal from bank-filtered waters by aeration, chemical treatment and filtration

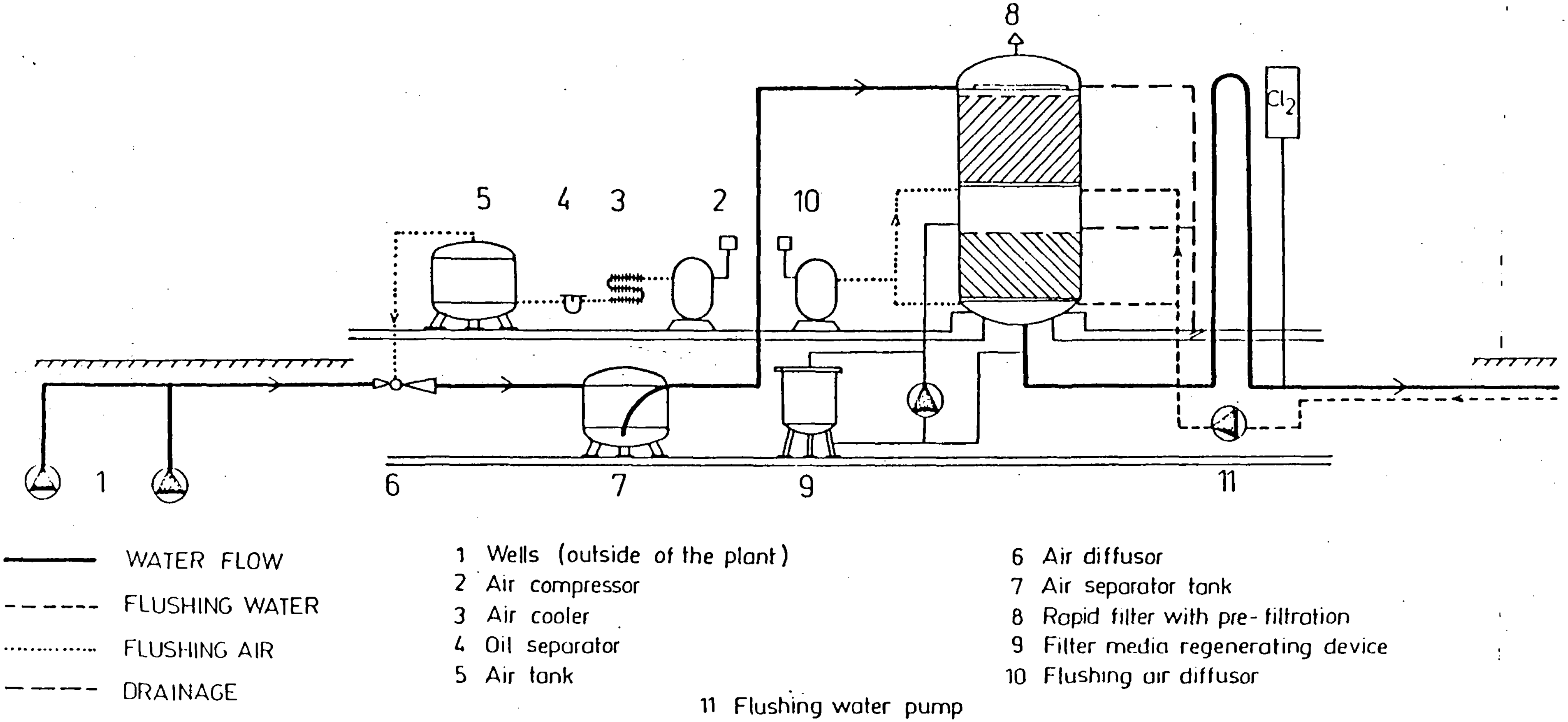
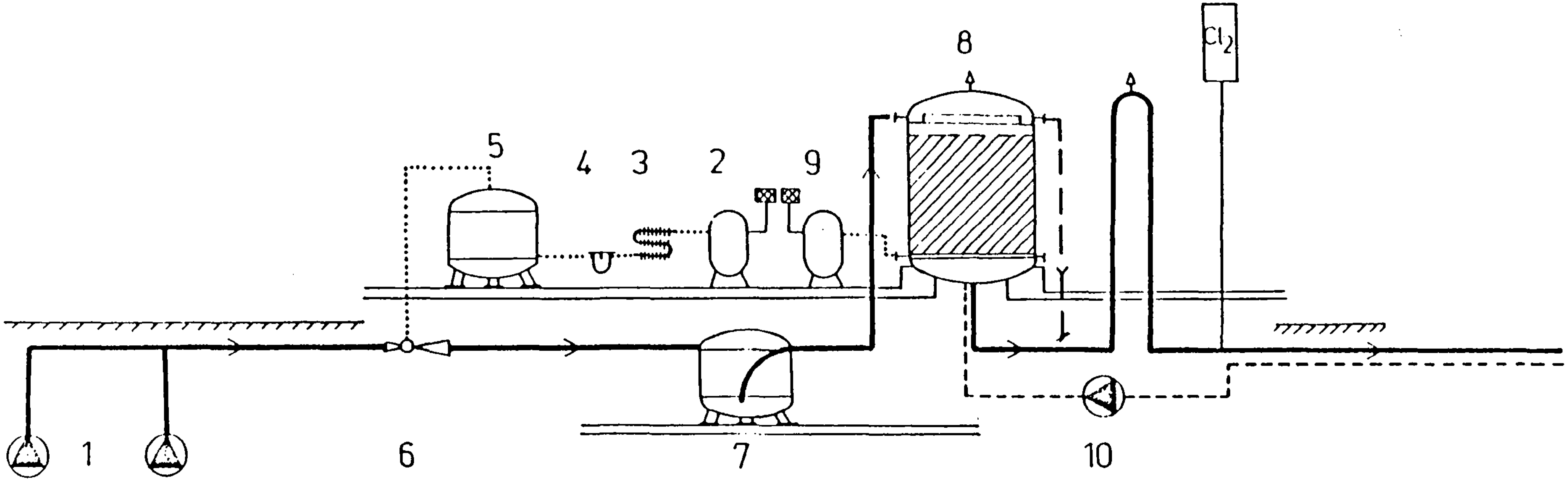


Fig. 6 Iron and manganese removal from bank-filtered waters by closed aeration and closed filtration with preliminary filtration



——— WATER FLOW
------ FLUSHING WATER
.... FLUSHING AIR
— — — DRAINAGE

1 Wells (outside of the plant)
2 Air compressor
3 Air cooler
4 Oil separation
5 Pressure tank

6 Air diffusor
7 Air separation
8 Closed rapid filter
9 Flushing air diffusor
10 Flushing air pump

Fig. 5 Iron removal from bank-filtered waters by closed aeration and filtration

An annual decrease in production capacity of 2 per cent was recorded due to this accumulated deposit. The presence of both metals associated with organic debris resulted in a biologically active mass in which iron bacteria played a prominent role. This state of affairs has resulted in the introduction of regular pipeline cleaning.

Similarly, a well cleaning and clearing procedure is employed, involving the use of compressed air to the pipe well and using high pressure (100 atm.) water back-flushing technique which flushes the wells. This procedure also removes plant roots which enter the pipes and well systems.

In addition to this process, the continuing deterioration in the quality of river water for treatment over recent years has necessitated the introduction of post-extraction treatment in Hungary. Figures 5 to 8 are typical of the schemes which have been introduced in Hungary to safeguard its drinking water quality.

In an endeavour to increase water production over a period of 20 years recharge basins and natural recharge have been practised with varying degrees of success.

Compared with mean production capacity under summer temperatures of 20°C, a 30 to 40 per cent decrease in volume can be experienced when ambient temperature is about 0°C, especially if it coincides with periods of low river water level. These conditions also frequently correspond with the highest levels of pollution in the river, especially pollutants such as ammonia, manganese and iron.

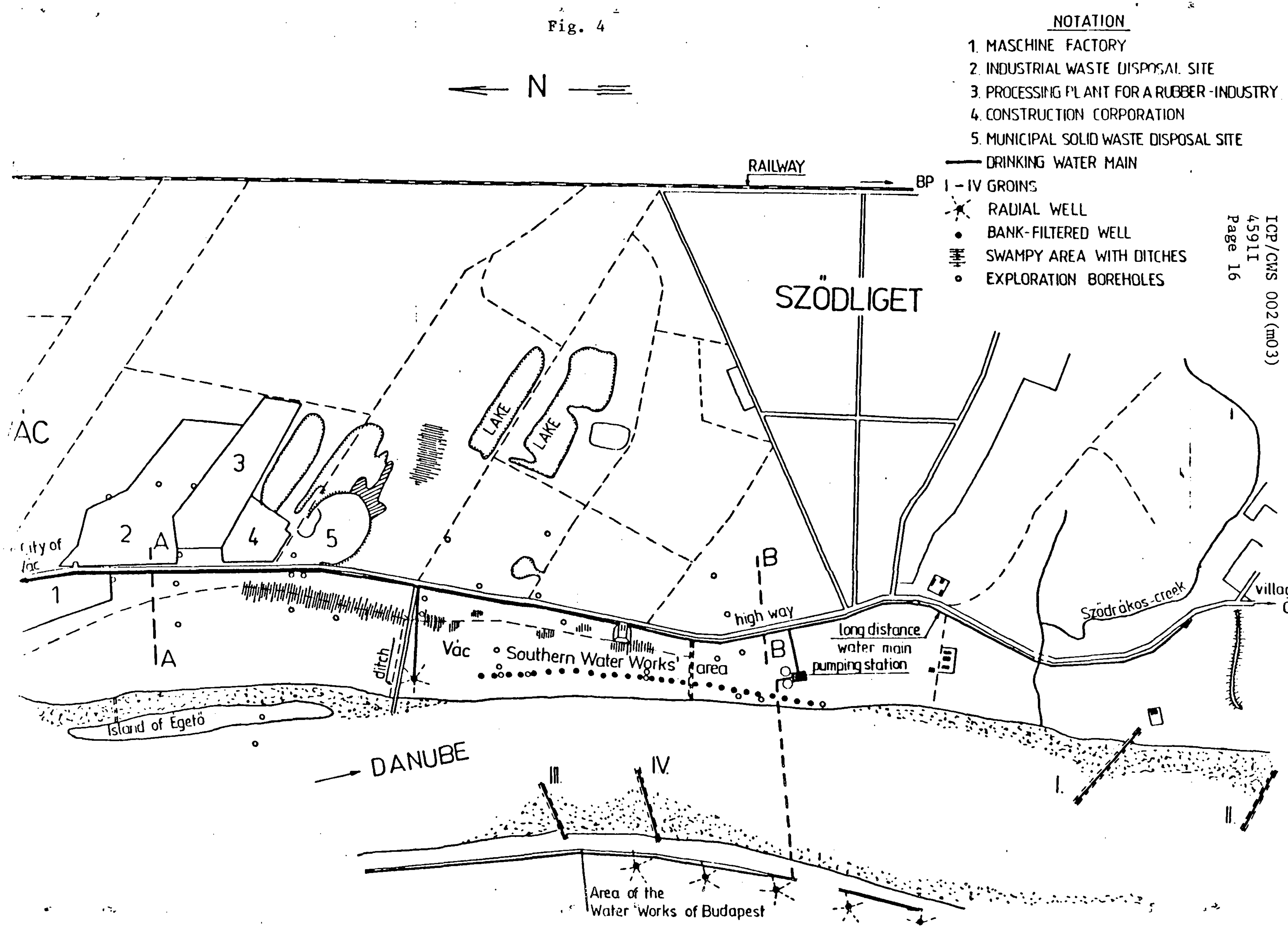
Flood water causes considerable difficulties in river bankwell operation because of the possibility of direct intrusion of untreated river water into the extraction structure. However, even when this intrusion does not occur, the distance and the travel time of the water to the extraction points appear to be considerably reduced. In such cases, particular attention has to be paid to the integrity of the disinfection systems to remove harmful bacteria from the drinking water.

In the Federal Republic of Germany, post-extraction treatment is usually practised, particularly in the vertical wells along the banks of the Rhine where the main extraction systems are located. This imposition requires more operational effort and higher operating skills to surmount the increased difficulties. Although the treatment applied obviously varies from situation to situation depending on the quality of the extracted water, the most common treatment applied is oxygenation followed by activated carbon filtration to remove organic micropollutants. Figure 9 shows examples of the post-extraction treatment applied at the main water supply works along the Rhine.

Post-extraction treatment has also been introduced at the works in Vienna. At the Lobau water treatment plant, the bankwell-filtered water has to be treated for iron and manganese removal, present because of the low dissolved oxygen levels in the river water, prior to disinfection.

Due to the deterioration of the bankwell-filtered water at the Donauinsel Nord Waterworks, it was also considered advisable in 1981 to introduce pre-aeration, flocculation, oxygenation, and activated carbon filtration followed by disinfection to ensure a safe potable supply and safeguard against the presence of organo-micropollutants.

Fig. 4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NOTATION
1. MASCHINE FACTORY
2. INDUSTRIAL WASTE DISPOSAL SITE
3. PROCESSING PLANT FOR A RUBBER-INDUSTRY
4. CONSTRUCTION CORPORATION
5. MUNICIPAL SOLID WASTE DISPOSAL SITE
DRINKING WATER MAIN
I – IV GROINS
RADIAL WELL
BANK-FILTERED WELL
SWAMPY AREA WITH DITCHES
EXPLORATION BOREHOLES
RAILWAY
BP
SZÖDLIGET
VAC
City of Vác
1
2
3
4
5
A
A
B
B
LAKE
LAKE
ditch
Vác
Southern Water Works' area
high way
long distance water main
pumping station
Szödrákos-creek
village Gö
Island of Egetö
DANUBE
I.
II.
III.
IV.
Area of the Water Works of Budapest

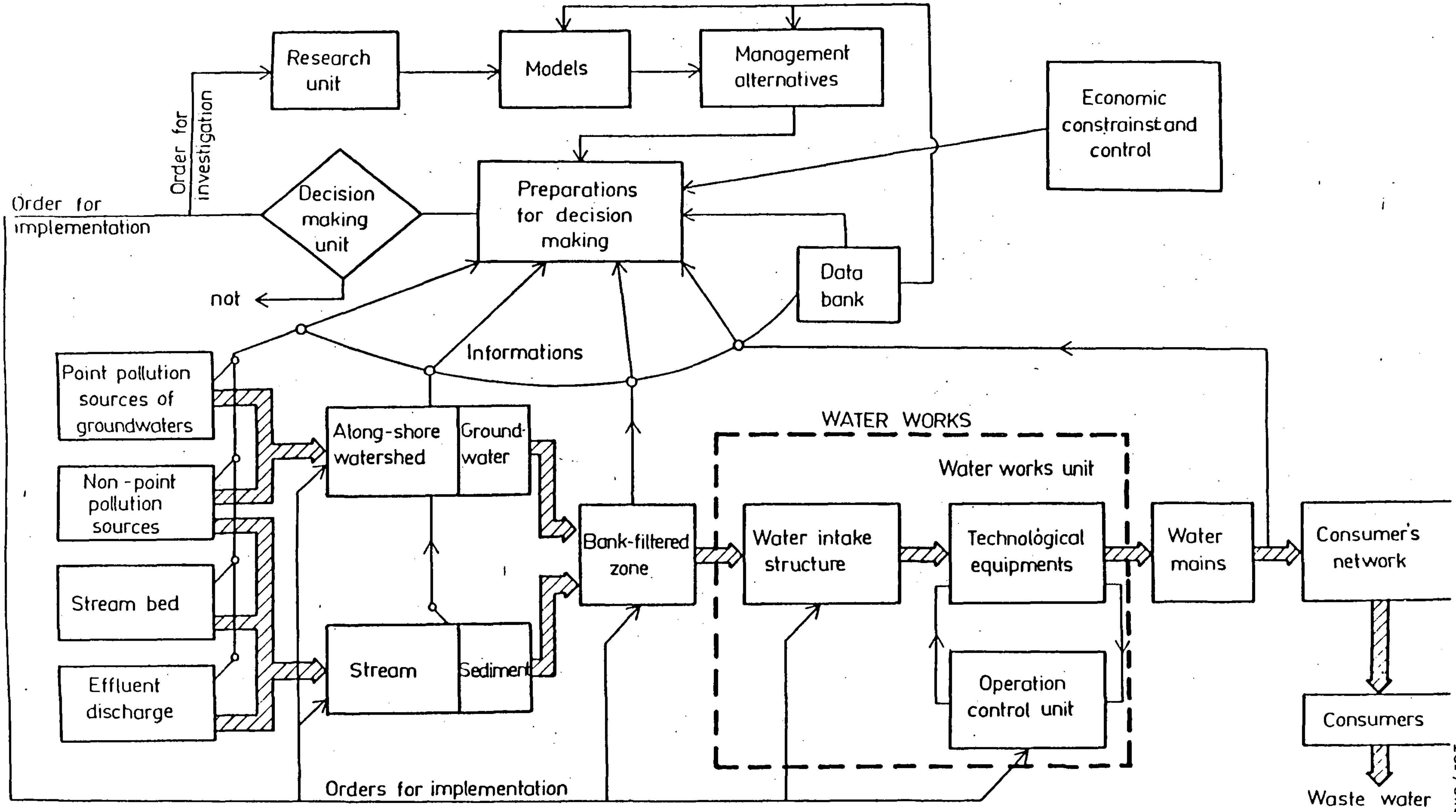


Fig. 3 Water quality management flow-chart for drinking water production from bank-filtered wells

producing the required quantity of water at a quality which permits direct delivery for public service. They often require post-extraction treatments, some of which may need to be relatively complex in character and expensive to operate.

An example of barrage construction in the Austrian stretch of the Danube serves to demonstrate some of the changes which can be expected and the problems that can result. At the water extraction site of Goldwarth, sited upstream of the power station of Ottensheim-Wilhering, the water level in the Danube has subsequently been raised by an average of 9 metres above the original level due to river regulation work. This has resulted in reduced flow velocities and an increase in deposit of organic matter on the river bed, causing blanketing and subsequent reduced capacity of the bankwell filtration plant.

Similar conditions have been recorded where subsequent raising of water levels has led to reduced flow rates in the area of both Vienna and Hainburg. The barrage weir constructed at Hainburg has been shown to affect the groundwater in the area of Lobau while the weir constructed near Vienna effects the water supply system at Nussdorf.

At the water works of Ybbs and at the water supply facilities at Goldwarth supplying the town of Linz, the reduced oxygen levels in the river water, resulting from an increase in organic matter in the river sediments, have necessitated the introduction of post-extraction treatment to produce a drinking water of acceptable quality.

11. Water Quality Control Strategies

Today increasingly complex water quality management systems are necessary for the effective protection of river bankwell filtration water. One such system as practised is illustrated in Figure 3.

Figure 4 deals with an existing river bankwell filtration system which may be typical and illustrates three elements or boundary conditions: the bankwell-filter aquifer, the parent river, and the landward groundwater.

12. Operational Considerations

The operational problems associated with river bankwell filtration systems may be highlighted by examining the experience gained in operating the Budapest water supply system. This is the largest water works in Hungary, totalling 745 wells of different types (pipe wells, radial wells and shafts) and all of differing age. The wells are located along the Danube in a parallel zone 500 metres wide with depths in the range of 10 to 25 metres. The oldest wells have been in operation for more than one hundred years. The total capacity of this bankwell system is of the order of 10 million cubic metres per day at average water level and summer water temperature. It is also the largest river bankwell filtration system in Europe.

Until 1983, no treatment of the bankwell-filtered water was necessary other than disinfection via chlorination for health protection. However, the gradual deterioration of the Danube River water quality resulted in the presence of both manganese and iron in the drinking water. This has resulted in metal deposition in the pipework and discoloured drinking water, necessitating flushing of the water mains at two two-yearly intervals to remove accumulated deposits and other adhering materials. The organic content of the deposits proved on examination to be as high as 12% which in itself is very demanding on chlorine content and leads to water quality deterioration.

wells. Rainwater also leaches the halogenated and volatile organic contaminants, into the contaminated groundwater.

An often serious pollution source from the landward area arises from the agricultural use of treated and untreated sewage and sludges as fertilizers. This practice, plus the application of artificial fertilizers over and above crop needs, or applied at the wrong season of the year, adds to the potential hazard of groundwater pollution.

Perhaps, however, a far more serious threat is posed by the disposal of industrial solid wastes, machinery and cutting oils, etc., in landfill sites. Leachates from such sites, especially those sited in ill-chosen locations, may result in a complex mixture of toxic non-biodegradable chemicals entering groundwater sources and frequently entering bankwells and other water abstraction points for potable supply.

Along the Danube, the contribution of pollution originating from the landward areas has been traced in several studies and in some cases has been found to be significant. For example, prior to 1977, no wells in a system of 23 examined along the Hungarian stretch of the Danube had nitrate concentrations of higher than 40 mg NO_3/l. In 1977, 3 wells were found with concentrations exceeding this value, and by 1980, the number had risen to 8.

The rapid increase in nitrate concentration in water extracted via bankwell filtration systems can only be attributed to groundwater contamination originating from the landward side. This pollution is clearly attributable essentially to increased use of fertilizers by the above-mentioned practices by agriculture. Exacerbation of the problem is caused by the unsatisfactory disposition of pit latrines for disposal of faecal matter in villages having no systematized sewerage.

10. Effects of River Regulation

Construction of river barrages and other regulatory structures after the siting of bankwell filters may significantly alter the hydraulic conditions in a river and may have an effect upon the groundwater level. These changes can affect considerable stretches of the river, seasonal flow, etc., depending upon the river profile and the gradient at the point of regulation. Reduced flow rates may lead to increased deposits of the smaller-grained, silt-like material, causing in the most extreme cases blinding of the river bed. Reduced flow rates or increase in water depth may cause a reduction in dissolved oxygen content of the river water, leading to subsequent water quality changes, solubility of iron and manganese, and a reduction of sulfates and nitrates, leading to problems of taste and odour, etc. in the finished water.

An increase in navigation, which may be expected as a result of improved river regulations, can also lead to an increase in the likelihood of marine accidents resulting in increased oil contamination of the river water.

Any situation which reduces the flow from the river to the extraction wells will tend to increase the proportion of flow from the landward area resulting in a potential increase in concentration of the pollutants of agricultural, urban and industrial origin within that area.

These changes in the natural flow conditions in a river caused by the construction of barrages of the river regulating systems often result in existing river bankwell filtration systems being rendered incapable of

The intractable pollutants of river water are the most difficult to remove by bankwell filtration and, therefore, potentially the most dangerous. These micropollutants include the range of halogenated hydrocarbons operating within the filter system, resulting in taste and odour problems in the final water.

The effect of heavy metals on the final bankwell-filtered water depends largely upon their form of occurrence which in turn influences the degree of mobility within the filtration zone. Many other factors, some of a physical nature, also have a great influence on the subsequent fate of metallic contaminants in the river water. Bankwell filtration systems have proved to be highly efficient in the removal of bacteria and, thus, for improving the general microbiological quality of the final product. Usually, however, this efficiency is to a large degree dependent upon the retention or travel time of the water within the filtration zone and its nature, and overpumping to increase extraction rates can seriously interfere with this efficiency.

Knowledge of the fate of viruses within bankwell filtration systems is rather limited, and generally an estimation of their presence is based on the behaviour of bacteriophages possessing similar characteristics. Available data, however, tend to indicate that river water viruses are more likely to pass river bankwell filtration during low river flow conditions and also during the winter periods when the capacity of river self-purification is at its lowest.

Microbiological evidence over a period of years on bankwell filtration systems has indicated that, because of reduced parent river water quality and/or increased extraction rates there is a microbiological deterioration in finished water quality. Consequently, there is an increasing requirement to introduce effective disinfection of the extracted water to ensure its hygienic quality to protect the health of the consumer. Tests recently performed in Hungary clearly demonstrate the present-day hazards facing operators of bankwell filtration plants: when treating polluted river water, they were able to confirm the presence of constituents which possessed mutagenic properties in the bankwell-filtered water.

Frequently along the course of the Danube, particularly downstream from Budapest, water quality deterioration in bankwell filtration systems occurs due to upsilting of the river bed, resulting in anaerobic conditions. Under such conditions, manganese, iron and ammonia concentrations in the extracted water increase. To overcome the presence of such constituents, post-treatment such as ozonization and filtration has to be applied to the bankwell-produced supply.

9. Effects of Groundwater Quality Adjacent to and Landward of the Extraction System

Practices of both industry and agriculture located inland of the bankwell extraction structures can pose a threat to the quality of water extracted. Groundwater flowing towards the wells, from the landward side, may contribute pollution arising from the disposal of industrial wastes, fertilizers and pesticides.

Over recent years it is claimed that rainwater pH has decreased over large areas of Europe, and the reduction in pH increases the propensity for leaching of heavy metals from the soil, leading to deterioration of the quality of groundwater which may reach the bankwell filter. It is also claimed that the increased sulfate content of such rainwater increases the rate of transfer of nitrates to groundwater and hence to the extraction

A large proportion of industry and of population within the Federal Republic of Germany is located along the valley of the River Rhine. To overcome the threat to river water quality from industrial discharges and to bankwell filtration efficiency, a programme of construction of waste-water treatment facilities has been implemented in recent years.

This implementation has resulted in the reduction of dissolved organic carbon (DOC) levels in the middle Rhine from 6.0 ug/l to 2.5 ug/l during the 1970 to 1980 period. The threat to bankwell systems still exists, however, due to the uncertainty of the compounds responsible for the DOC levels.

Increased pollution over recent years, measured in the Hungarian stretch of the Danube has had the effect of decreasing the capacities of the bankwell systems due to physical clogging of the interstices. Adherence of micropollutants, including heavy metals, to the filtration media, and development of anaerobic conditions within the filtering layers resulting from increased loading by organic biodegradable material, together with the presence in the river water of chemical complexing agents, lead to remobilization of the heavy metals previously adsorbed. Increased incidence of carcinogenic polycyclic aromatic hydrocarbons, together with the annual 4.5% increase in the nitrate content of Danube river water at Budapest over the past 25 years, is a further illustration of the problems facing water authorities practising bankwell filtration as an economic process for producing potable supply. In addition, ammonia, once present only during winter months when oxidation rates were reduced by low river water temperatures, is now present continuously, with annual average concentration approximating 1 mg/l. Phosphorous, the other major nutrient, has also steadily increased its concentration as phosphate on an annual average basis of about 4%.

Microbiological quality of the river has also deteriorated noticeably in recent years.

These changes in water quality clearly overtax the capacity of bankwell filtration to achieve the desired quality of potable water which hitherto has been a feature of the system.

Experience in the USSR has demonstrated the efficiency of bankwell filters in improving water quality by, for example, removing suspended and colloidal river water particles and significantly reducing bacteria and phytoplankton. Unfortunately, this efficiency, as a means of water treatment, can no longer be relied upon as an effective treatment of polluted river water and this leads to increasing concern over monitoring the parent river water quality to ensure that the treated water is suitable for potable supply.

In Yugoslavia, the Raney wells have been subjected to increasing concentrations of organic material, nitrites and nitrates which, together with the resulting depletion in dissolved oxygen, has resulted in a general increase in the concentration of iron and manganese.

8. Filtration Process

Generally, the longer the travel time between the river bank and the filtered water extraction point, the more effective is the system as a means of improving the original river water quality. However, in an endeavour to achieve greater volume throughput, there is a tendency to reduce retention time. Between these two extremes a compromise is usually achieved.

7. Water Quality Problems

The physical, chemical and microbiological quality of water extracted by means of river bankwell filtration is dependent on several factors, including:

(a) The quality of the water in the parent river;

(b) the characteristics of the filtration media, e.g.; practical size and distribution, permeability, width, depth;

(c) flow velocity through the aquifer from the river to the point of extraction;

(d) time of flow (retention time) within the aquifer;

(e) the quality of the natural groundwater adjacent to the extraction point on the landward side.

The quality of bankwell-filtered water will depend primarily upon the quality of the water in the parent river. Pollution capable of detrimentally affecting the microflora of the filtration media will obviously lead to a deterioration in extracted water quality. The present trend of increased pollution in many rivers, especially from synthetic organic chemicals, is especially worrying to those abstractors dependent upon this technique as a means of producing the bulk of their drinking water supply. For example, in Austria the River Danube contains a significant amount of waste originating from pulp and paper production. In all countries a common problem of well silting is experienced. All countries are extremely concerned at the actual and potential problems of endangered drinking water supplies due to the increasing load of toxic substances entering major rivers the waters of which are abstracted for potable supply by this technique. Organic pollutants create taste and odour problems in the potable supply which necessitate that consideration be given to the construction of a post-bankwell filter treatment plant comprising aeration, coagulation and flocculation, filtration, ozonation, activated carbon absorption and disinfection. Consequently, what is a relatively simple economical method for the production of potable water will become a far more costly process both in chemicals and technical expertise to operate such a plant.

The need to introduce additional sophisticated treatment after river bankwell filtration, where once considered unnecessary, will depend entirely upon the discipline exercised by riparian countries in relation to the discharge of wastes and effluents to water courses.

Again, in Czechoslovakia, evidence is available indicating a range of organic chemicals present in water extracted via bankwell filtration, including chlorinated aliphatic and aromatic hydrocarbons, chlorinated phenols, cresols, ethers, alkadienes, triazinic herbicides, polysaccharides, higher alcohols and organic acids. Pollutants of this nature, with the potential for gaining access to a potable supply, may pose serious health problems to the consumer and, thus, a monitoring system to ensure their presence must be instituted. Clearly additional attention and monitoring of constituents in bankwell-filtered water are required, with particular attention being paid to organic micropollutants.

appraisal whether the flow direction is from the landward area towards the extraction point or vice versa, bearing in mind that during the design of a system, all of these conditions are continuously changing. The flow pattern in an aquifer is dependent on the above-mentioned head and water level conditions, hydraulic conductivity and permeability parameters etc.

Consequently, no two river bankwell filtration systems are exactly alike and the variable parameters both between systems and at different times within the same system can significantly influence the flow pattern.

A particularly unstable water regime situation is observed when the main groundwater flow direction is parallel to the river since there will be a quickly changing alternating flow towards or from the river, influenced by the slightest change in relative water levels.

Computerized, analytical and numerical models can be used for the analysis of the flow and discharge under differing bankwell filter conditions and the assumption of constant transmissivity, independent of head conditions, will not be valid in many cases. Usually, however, with suitably chosen models, the flow pattern and the time of travel corresponding to various sites can be described, which can prove extremely useful when pollutants may pose a threat to the water quality. Some models of this kind have been developed and are in operation in several European countries.

Differing criteria and procedures exist for the design, operation and monitoring of river bankwell filtration systems largely because their operation is insufficiently understood and because each system is characteristically different. For the same reason, criteria for establishing protection zones, under conditions of changing flow pattern, are extremely difficult to set.

To-date, protection strategy is based upon practical operational experience with a knowledge of the pollutants existing and experienced in the parent river. Thorough knowledge of the travel times of the river water to the extraction point may be used successfully as a tool in plant operation to prevent, over relatively short periods, river water pollutants from reaching the extraction point.

Such operational flexibility may be facilitated by providing sequentially sited individual wells, with short travel times between them and with limited overlapping in their travel time. In this way either cessation of pumping or return of the pumped water to the river has been shown to prevent short-term pollution from entering the potable supply. It is also an advantage for such operations to be successful if the capacities of bankwell filtration system are slightly overdimensioned, thus enabling a minimum water supply to be maintained while another well or gallery is out of operation.

In addition to the above basic design approach to keep polluted water from being extracted for potable supply, the normal strategies and procedures practised in the protection of groundwater aquifers should always apply, i.e., establishment of protection zones, design of waste disposal systems and land-use planning.

disinfection as a protection measure for public health. In 1980, France, the Federal Republic of Germany and Switzerland published a report ("Seine-Normandie Basin Agency") which, after studying aspects of bankwell filtration processes, made a series of recommendations relating chiefly to their design, taking into consideration a range of influencing parameters. It is claimed that post-treatment will be required for a certain number of locations operating bankwell filters.

Netherlands

During 1982 an estimated 55 million m^3 of drinking water was produced via bankwell filtration of river water, representing 5% of the country's needs, and in the future it is anticipated that production by this means will rise to 75 million m^3 annually. The towns of Gouda and Dordrecht, in particular, obtain a large proportion of their potable water needs via bankwell filtration. Generally, however, bankwell filtration of river water, in the strict sense, is not practised in the Netherlands as well fields are situated, on average, at some distance from direct river infiltration. However, as river-induced recharge does occur - in addition to groundwater withdrawal perhaps - they differ only in the magnitude of river input from conventional river bankwell filters.

6. Planning and Construction Aspects

Aquifers of a relatively uniform character can be exploited by means of simple vertical wells or galleries located at a suitable distance from, and parallel to, the river bank. In the case of more varying aquifer conditions, radial well systems may be more appropriate.

It is essential at the stage of preliminary planning of a river bankwell filtration system that the physical and hydrogeological characteristics of the land area adjacent to the river are investigated in detail. During these studies, information of the steady/natural infiltration rate and of the degree of purification achieved at design extraction rates is determined. The interpretation of the results of these preliminary investigations are of primary importance for planning and design.

Conditions corresponding to full operating conditions have generally to be assessed theoretically because it is difficult, if not impossible, to reproduce them on an experimental basis. Results from existing systems under similar hydrogeological conditions may be of assistance in making such assessments.

For the planning of the utilization of bankwell-filtered water resources, knowledge of the relationships between water levels in the river and head conditions within the aquifer is essential, with special attention being paid to the periodically and usually seasonal fluctuations in the river levels. The variation of water level in the river and its effect upon the groundwater levels should also be determined.

Abnormal situations, such as when the relationship of the water level of the river and that of the aquifer lose connexion and a third flow-field across the river bed towards the aquifer exerts an influence, should receive examination.

Comparison of head conditions within the aquifer adjacent to the river bank, the underlying formations, and the off-river formations will enable

Czechoslovakia

In Czechoslovakia, bankwell-filtered water constitutes an important proportion of drinking water supplies and the city of Bratislava is dependent upon water so derived from the Danube.

Romania

An increasing number of drinking water supplies in Romania depend upon water obtained via bankwells located along the banks of the Danube. Bankwell filtration is important in supplying both Craiova and Galati with drinking water. At another location on the banks of the Jiul River, a bankwell filtration capacity of 700 litres per second is in operation.

Yugoslavia

Both Belgrade and Zagreb rely heavily upon bankwell-filtered water for potable supply, the former obtaining 95% of its total needs via this system. Zagreb obtains a potable water of excellent quality from the relatively unpolluted waters of the river Sava. Novi Sad also obtains water via an extensive radial bankwell filtration system operating along the banks of the Danube. In the province of Voivodina, where more than 10% of Yugoslavia's population live, 15% of all water requirements are satisfied by bankwell filtration supplies.

USSR

In many settlements in the Republic of the Ukraine, the Baltic Republics, Uzbekistan, Kazaklistan and the Transcarpathians, bankwell filtration is claimed to be an economical source of potable water supply and there is much experience in operating such systems. The Rhine River and its tributaries are also utilized as a source of drinking water via bankwell filtration, and it is estimated that some 29%, of a total abstraction of 935 million m^3, is via bankwell-filtered techniques.

Federal Republic of Germany

Of the country's 4100 million m^3 drinking water needs, approximately 7% is obtained by bankwell filtration processes. Although the Rhine River frequently carries a heavy load of dissolved organic carbon and the absorbable organic carbon and organochlorine compounds reach values of 60 ug/l, it is claimed that bankwell filtration reduces these values by approximately 60%. The fear is expressed, however, that increasing pollution via unidentified synthetic organic compounds in the river water will seriously damage the bankwell filtration microflora and thus endanger the production of potable supplies.

France

Drinking water derived via alluvial deposits in France represents about 50% of the total drinking water demand, and it is claimed that a significant amount of this is derived via bankwell filtration. The chief river systems on which bankwell filtration is practiced are the Rhône, Garonne, Seine, Loire and their tributaries. A special attraction regarding this method of producing potable water is, it is claimed, that to-date it has required only

Investigations of the hydraulic connexion between the aquifer and the landward areas are necessary for an assessment of the situation at a chosen location to be identified. Some aquifers are confined by vertical impermeable formations, while in other cases, the alluvial deposits are connected to older aquifer formations. In some cases, transient sections exist while in other cases there is a clearly distinguishable confining boundary as is the case when the alluvial deposits are interrupted by karstic outcrops along the river.

When rivers influence the groundwater regime of their surroundings it may be considered, for practical purposes and under normal conditions, that the zone of the active water exchange between the river and its surroundings is confined to a certain strip along the river. Consequently, the surface water quality will affect mainly this zone and the groundwater quality will thus be influenced by the water quality in the parent river. A transition zone also exists where both river and landward area groundwater influence the bankwell water quality. Thus, the ratio of river and groundwater removed via a bankwell filter varies with location and depends largely on local hydrogeological conditions. See Figure 2.

A river bankwell filter system may be expected to modify the natural hydraulic conditions to a greater or lesser degree. Alternating flow directions depend upon the relative levels of the river and groundwater.

Drawdown of the water table around the extraction point will result in increasing flow velocities which are influenced not only by river water level but also on the landward area by the structure and physical characteristics of the aquifer media.

In general, the further the wells are located from the river, the lower will be the extraction rate. To compensate, the degree of treatment provided by such located wells will frequently increase the quality of water produced. A compromise must therefore be made between the required quantity of water and the quality.

5. The Importance of River Bankwell Filtration for Water Supply in Europe

Within Europe, bankwell-filtered water constitutes and important source of water for potable and other supply purposes. This is particularly so along the two main international rivers, the Danube and the Rhine, and their catchment areas.

Hungary

Europe's largest bankwell abstraction scheme (one million m^3/day) supplies drinking water to Budapest, and Hungary, in general, derives 45% (7-5 million m^3/day) of its drinking water from bankwell filters located along the 660 km stretch of the Danube within the country's national boundaries.

Austria

Bankwell filtration of river water has been practiced for more than 40 years to supply Vienna with about one fifth of its drinking water requirements. The waterworks at Nussdorf, in fact, obtain all its drinking water for supply via bankwell filtration. The city of Linz also obtains its drinking water from bankwell-filtered Danube water.

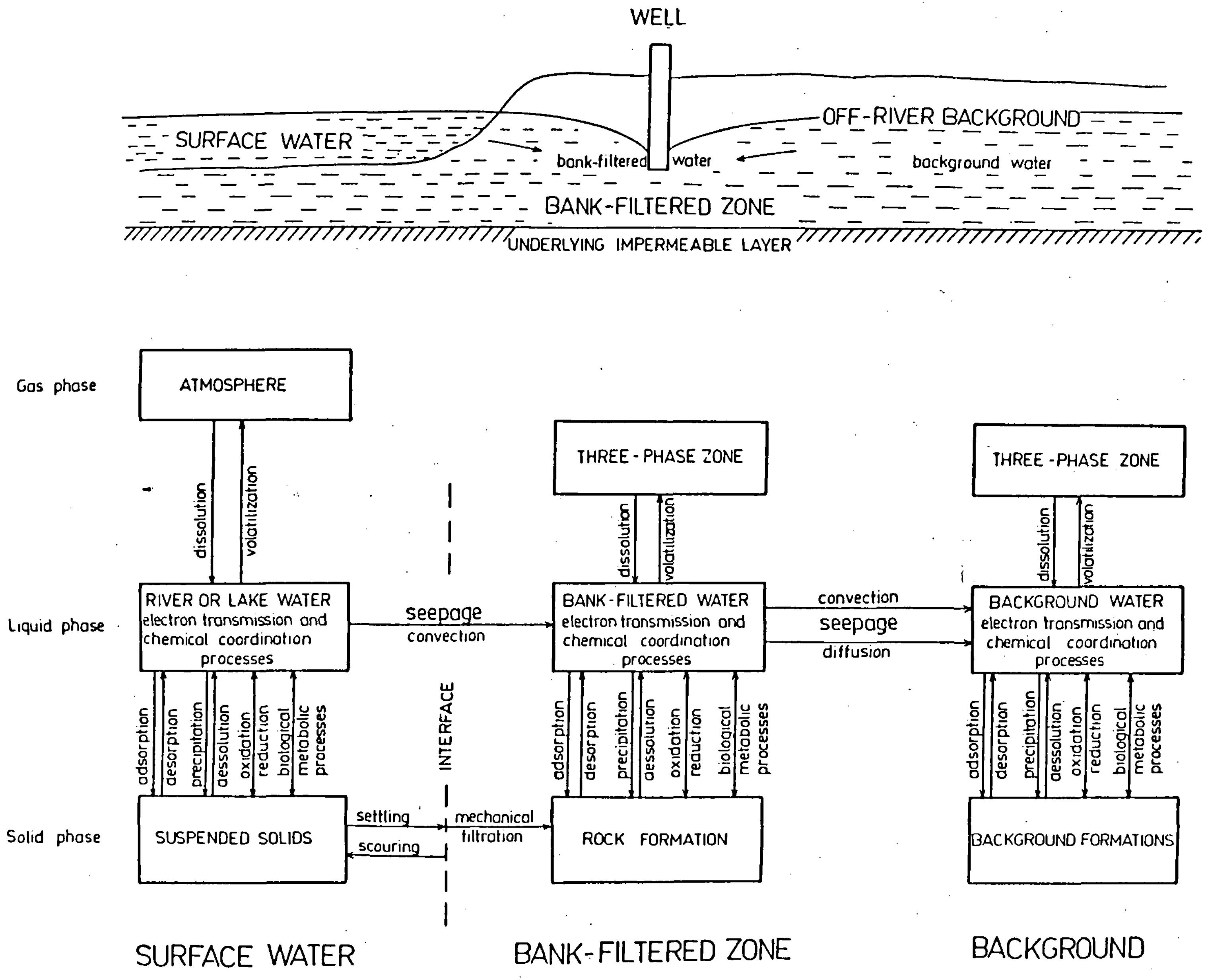
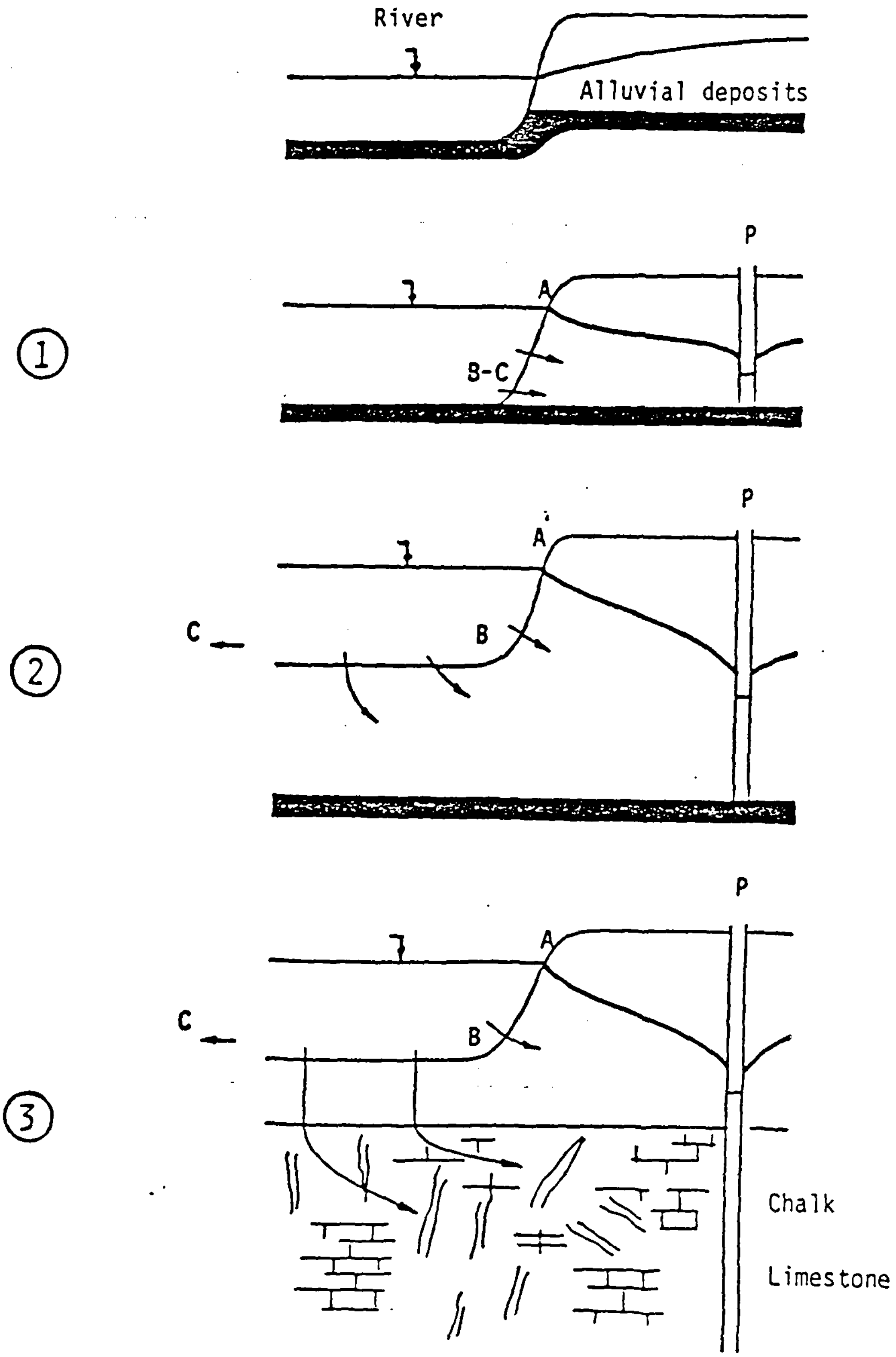


Fig. 2 Water quality model for water production from bank filtered wells

Fig 1

MAIN TYPES OF "ALLUVIUM COMPLEXES" WITH REGARD TO THE RELATIVE POSITIONS OF RIVER BOTTOM AND IMPERMEABLE BASEMENT



Impermeable basement
ABC Infiltrating area

Water resources are finite. Areas already exist where water resource limitations have been identified as curtailing either industrial development or improvement in service levels. The ever-expanding demands from the population, agriculture and industry necessitate the development of a protection strategy to ensure that provision is adequate for future needs. National strategy requires that these needs be satisfied in the most efficient and economic manner without the necessity of resorting to highly sophisticated treatment techniques which are not only expensive to operate but which require highly skilled operators who are not always readily available.

Defective or badly designed sanitation and waste disposal systems, oil spills, excessive fertilizer application to land, pesticide and herbicide application and the release of other chemical substances to enter the aquatic environment endanger raw water sources.

4. Current Situation

River bankwell filtration systems utilize the naturally occurring permeable subsurface formation to provide physical and chemical treatment via a direct hydraulic communication with a water course to provide filtering capacity to improve the quality of the water extracted for potable supply. A typical river bankwell extraction system is shown in Figure 1.

The alluvial gravel and sand formations and terraces situated along river beds can, when an appropriately allocated well or gallery system is constructed and operated, be considered essential in producing bankwell-filtered water.

The flow is never totally from the river since the water table drawdown due to pumping will induce flow from the landward side of the wells. The proportion of drainage to the wells from the landward side will also vary often with the distance of the wells from the river bank, the relative surface levels of the river and groundwater, and the characteristics of the aquifer. However, "river bankwell filtration" infers movement of surface water from the river to the wells and is the significant part of the bankwell flow.

Extraction points along a river are situated in the alluvial deposits, the depth of such formations generally being between 8 and 30 m. In extreme cases, they may extend to several hundred metres. Some formations are found only in a narrow strip along the river, while in other cases, alluvial deposits may extend over a large proportion of a river basin.

Thickness, continuity and permeability of the upper covering layer vary considerably. The aquifers generally consist of gravel and rough sand of mixed particle size distribution whose permeability enables relatively free flow while providing the desired filtration efficiency.

The forms of the hydraulic connexion between the water-yielding formation and the river differs in some cases. In others, the river bed extends into the lower impermeable confining layer and does not fully penetrate the aquifer. When the river bed is cut in the impermeable or semi-permeable layers, only an indirect communication with the alluvial aquifer is possible.

On behalf of Dr L.A. Kaprio, Regional Director of the WHO Regional Office for Europe, Dr G. Watters, Regional Officer for International Water Decade, thanked the Government of Hungary for having agreed to host the meeting, and in particular thanked Mr Varga and Dr Stelczer for their welcoming words on behalf of the National Water Authority and VITUKI.

3. Background

The period 1981 to 1990 has been designated the International Drinking Water Supply and Sanitation Decade. The goals of the Decade are adequate and safe water and appropriate sanitation for all by 1990. Within the framework of United Nations support to Member States in their efforts to attain these goals, WHO has been given special responsibilities providing the basis on which the "Strategy for WHO's Participation in the International Drinking Water Supply and Sanitation Decade" (EHE/82.29) has been developed.

The European Region of WHO faces many problems associated with the provision of "adequate and safe" water which differ from those experienced in other parts of the world where levels of development, both economic and industrial, are less. In these latter countries, much of the Decade emphasis will obviously be concentrated on providing supplies to the, as yet, under-served, most of whom are located in the rural areas and urban undeveloped regions.

In most of Europe, the problem of providing services to the population was, to a large extent, overcome before the start of the Decade, at least in the urban areas of the more industrialized countries. The Regional Office undertook an assessment of what were the European Region priorities for the Decade and what activities were required to ensure that by 1990 not only had the Decade goals been attained, but also that the levels of service already attained were maintained.

As a result of this work, the 31st Session of the WHO Regional Committee for Europe in Berlin in 1981 adopted Resolution RC31/R9 in which special emphasis was given to, among others, (i) the establishment of national drinking water quality (ii) the improvement of water source protection, and (iii) the identification and promotion of appropriate technology.

These three elements of the Regional Strategy are closely related and interdependent; the quantity of drinking water, to a large extent, depends on the quality of the raw water source and the technology available to economically upgrade such supply to a potable standard. The higher the quality of the raw water supply, the less sophisticated the treatment needed to produce economically a potable water of the required standard to protect health.

In the light of the above, source protection must be considered as the initial and fundamental stage of treatment and an important element of any successful Decade strategy for the European Region. Source protection, in the form of pollution control strategies, is not only important for the present but will become even more important as water demands increase and pollution threatens to become more serious. Therefore, the Regional Office has established as one of its prime targets the study of adequate protection strategy and internationally acceptable guidelines for safeguarding surface and groundwater sources from pollution. Particular emphasis is given to protection from both microbiological and chemical pollution with reference also to practice for protecting transboundary streams and lakes.

1. Introduction

The Working Group on River Bankwell Filtration was convened at the Research Centre for Water Resources Development/VITUKI/, Budapest, from 20 to 24 February 1984.

The meeting was attended by 18 temporary advisers from 10 Danube and Rhine riparian countries and 7 observers from Hungary.

The purpose of the meeting was to consider the approaches and technology of river bankwell filtration in Europe in terms of human health, ecological and economical aspects, and the increasing threat from pollution, as well as to evaluate the use of river resources for drinking water supplies. In this regard, the different aspects of planning, design, construction and operation of river bankwell filtration systems, with emphasis on the importance of water quality in the parent river, were reviewed. The meeting also identified areas for future activities and international cooperation in relation to river bankwell filtration, bearing in mind that many of the problems associated with the technique are shared by countries, particularly those with large rivers.

2. Opening Address

Dr K. Stelczer, Deputy Director General of the Research Centre for Water Resources Development (VITUKI), welcomed the participants in the absence of Dr G. Kovac, Director General, and expressed the satisfaction of the Institute in being able to host the meeting. VITUKI had been involved over several years with questions related to the safe operation of river bankwell filtration systems and the health measures necessary for the protection of the population served. In addition, VITUKI is the WHO Collaborating Centre for Water Source Protection. It was, therefore, particularly appropriate that the Institute act as host for this meeting.

On behalf of the Government of Hungary, the Vice-President of the National Water Authority, Mr M. Varga, opened the session by emphasizing the importance of river bankwell filtration as a water source for drinking supply in Hungary. His country derives 45% of its supply by means of this technique along the banks of the Danube and its tributaries, producing a total of 400 million cubic metres of potable water per year.

He noted that European countries, particularly the riparian states of both the Danube and the Rhine, have a long and wide experience of river bankwell filtration system operation. In all cases, water extracted via bankside wells constitutes an important source of potable water.

He felt that this meeting provided an opportunity for expertise from the different countries to exchange experience with the objective of providing a clearer understanding of the design and operational aspects of such systems and an identification of gaps in present knowledge requiring action for the future.

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