Internationales Symposium / *Internationales Symposium*

KÜNSTLICHE GRUNDWASSERANREICHERUNG

Artificial Groundwater Recharge

Forschungsergebnisse und praktische Erfahrungen
Research Results and Practical Applications

14.–18. Mai 1979
Dortmund
Bundesrepublik Deutschland

Kurzfassungen
Summaries

Internationales Symposium / *Internationales Symposium*

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Artificial Groundwater Recharge

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Research Results and Practical Applications

Veranstaltet von der
Fachsektion Hydrogeologie der Deutschen Geologischen Gesellschaft
Convened by the
Hydrogeological Section of the German Geological Society
zusammen mit dem
Nationalkomitee der Bundesrepublik Deutschland für das Internationale Hydrologische Programm der UNESCO
and the
National Committee of the Federal Republic of Germany for the International Hydrological Programme of the UNESCO

Unter Mitwirkung von / *in cooperation with*

IAHS	International Association of Hydrological Sciences
IRC-WHO	International Reference Centre for Community Water Supply der WHO
KIWA	Keuringsinstitut voor Waterleidingsartikelen, Niederlande
ÖVGW	Österreichische Vereinigung für das Gas- u. Wasserfach
ÖWWV	Österreichischer Wasserwirtschaftsverband
SGH	Schweizerische Gruppe der Hydrogeologen der SGG und Nationales Komitee Schweiz IAH
SVGW	Schweizerischer Verein von Gas- und Wasserfachmännern
UNESCO	United Nations Educational, Scientific and Cultural Organization
WRC	Water Research Centre, England
BMI	Fachausschuß "Wasserversorgung und Uferfiltrat" des Bundesministeriums des Innern
DVGW	Deutscher Verein des Gas- und Wasserfaches
DVWK	Deutscher Verband für Wasser- und Kulturbauwesen
Fachgruppe Wasserchemie	in der Gesellschaft Deutscher Chemiker
IAH	Sektion Bundesrepublik Deutschland der International Association of Hydrogeologists

Dortmund
1979

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

The symposium was sponsored by the following institutions and companies:

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FH - DGG
Hydrological Section of the German Geological Association

It is the task of the FH-DGG to enhance the cooperation and the information exchange between experts of different disciplines who are working in the research and use of groundwater. Hydrogeologists and hydrologists as well as water economists, chemists, physicists, microbiologists, soil scientists and hygienists are members of the FH.

Regular meetings, excursions and publications concerning different scientific or applied fields of hydrogelogy help to approach the aims of the FH-DGG.
(five meetings, arranged in Krefeld, Würzburg, Essen, Berlin and Kassel; Hydrologische Beiträge 1 - 5, german translation of the legend to the International Hydrogeol. map 1 : 1 500 000).

The FH-DGG arranged the following working groups:

Groundwater (together with DVWK)
" - exploration
" - exploitation
" - hydraulics and -modelling
" - biology
" - chemistry
" - measuring equipment
Education and information.

The FH-DGG has been founded 10 years ago and has 400 personal and corporative members now.

IHP - UNESCO

The National Committee of the Federal Republic of Germany for the International Hydrological Programme of UNESCO

As a member of UNESCO, the Federal Republic of Germany participates actively in the International Hydrological Programme. At the beginning of IHP, the National Committee, which formulated and now handles the Federal German contribution, was instituted under the leadership of the Ministry of Foreign Affairs. Current business is handled by an IHP Secretariat seated at the Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde). For dealing with topical hydrological problems, the National Committee established a number of IHP working groups. Within the framework of IHP, it participates in the regional co-operation of the Rhine countries, the Baltic Sea countries and the Danube countries. For research work, the National Committee has special IHP funds at its disposal.

International Hydrological Programme of UNESCO

UNESCO's International Hydrological Programme (IHP) represents an interdisciplinary approach to the safeguarding of man's most precious renewable resource - water.

The main objective of IHP is to develop a scientific and technological basis for the rational management of water resources, both as regards quantity and quality. With world demand for water expected to double within thirty years, a rational, problem-oriented approach is essential. Since a wide range of water problems is common to all countries and since rivers, aquifers and catchment basins do not stop at national boundaries, only an international approach can offer any hope of success.

Realization of the significance of hydrology for the development of water resources increased gradually in the period following the Second World War. In 1950 UNESCO launched a programme of research on the world's arid zones, in which hydrology played an important role. This was followed in 1965 by the launching of the International Hydrological Decade. But gaps were noted, particularly in the application of scientific advances to the solution of practical problems. Economic and social development tends to aggravate difficulties arising from natural fluctuations in the hydrological regime, and man's impact on water resources increases with the spread of urbanization and industrial pollution.

UNESCO therefore decided to launch the International Programme with the aim of finding solutions to the specific problems of countries in different geographical conditions and at different levels of technological and economic development. The International Hydrological Programme is being carried out in successive phases of a six-year duration. The first of these phases, 1975 to 1980, consists of eigth main scientific projects. The IHP forms an integral part of the efforts made by the United Nations system as a whole to promote a rational policy for the development and management of world water resources. At the United Nations Water Conference, held in Argentina in 1977, the IHP was recognized as one of the principal agents through which these aims could be achieved.

IAHS

International Association of Hydrological Science

The International Association of Hydrological Science (IAHS) was founded in 1922, and their main task is scientific hydrology.

The acitivities include e.g. the convenience of international symposia and the publication of the IAHS-Bulletin. For the performance of their aims the IAHS arranged the six following international commissions:

International Commission for Surface Water (ICSW)
International Commission for Subsurface Water (ICSSW)
International Commission for Snow and Ice (ICSI)
International Commission for Erosion and Sedimentation (ICES)
International Commission for Water Quality (ICWQ)
International Commission for Water Resources Systems (ICWRS)

INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY AND SANITATION

Established in 1968 at the Netherlands' Institute for Water Supply in Voorburg, (The Hague), the WHO International Reference Centre for Community Water Supply (IRC) is based on an agreement between the World Health Organization and the Netherlands Government. In close contact with WHO, the IRC operates as the nexus of a worldwide network of regional and national collaborating institutions, both in developing and industrialized countries.

The objective of the IRC is to develop activities, aiming at the implementation and improvement of water supply and sanitation systems, by means of international cooperation. Special attention is given to the solution of structural and fundamental problems in this sector, mainly by promoting the exchange and transfer of technical and scientific knowledge and experiences.

next time, bit more content.

KIWA

Keuringsinstituut voor waterleidingsartikelen N.V.

KIWA - the Netherlands waterworks' testing and research institute carries out research into and judges the quality of materials used in waterworks and in other sectors of architecture and hydraulic engineering. KIWA gives advice in certain fields of drinking water supply, carries out fundamental research on aspects of the collection, purification and distribution of water and co-ordinates for the waterworks, other activities within the scope of the institute's articles of association.

KIWA is owned by the waterworks, by VEWIN
(the Netherlands Waterworks Association) and VWN
(the Netherlands Waterworks Engineers Association).

ÖVGW

Österreichische Vereinigung für das Gas- und Wasserfach

The Österreichische Vereinigung für das Gas- und Wasserfach is a voluntary organisation of

- persons taking active part in gas or water industries
- enterprises of gas and water, appliance manufactures or distributors
- homogeneous organisations and institutions of scientific, technological and economical type on a non-profit base.

ÖWWV

The Austrian Water Resources Association

The Austrian Water Resources Association is providing a national forum unifying scientists, engineers and administrators interested in all aspects of water resources. Exchange of experience and information on a national and international level.

National Committee of the

International Commission on Large Dams (ICOLD)
International Water Supply Association (IWSA)
International Association on Water Pollution Research (IAWPR)
International Water Resources Association (IWRA)

Organization of

conferences, seminars, workshops, courses, study tours, lectures etc.

Committee, information, documentation

Elaboration of guide lines, reports, information, documentation center.

Publications

Wasserwirtschaftliche Mitteilungen - WWM
Schriftenreihe des Österreichischen Wasserwirtschaftsverbandes
Regeln des Österreichischen Wasserwirtschaftsverbandes
Mitteilungsblatt für den Klärfacharbeiter
Schriftenreihe "Die Talsperren Österreichs" (co-publisher)
Österreichische Wasserwirtschaft (co-publisher)

SGH - SGG / IAH - Schweiz

Swiss Group of the Hydrogeologists
National Committee Switzerland IAH

The group of the hydrogeologists (SGH) is a working group of the Swiss Geological Society (SGS), representing Switzerland in the International Association of hydrogeologists as a so-called "National Committee".

The group units specialists of each discipline who devote with approved scientific methods to the research, the exploration, the utilization and the protection of groundwater.

SAGWE (svgw)

Swiss Association of Gas and Water Engineers

The Swiss Association of Gas and Water Engineers (SAGWA) - founded in 1873 - aims at the advancement of the gas and water branch from a scientific, technical and economical viewpoint and expecially encourages the exchange of experience. The members consists of gas and water suppliances, plant managers, engineers, federal, cantonal and communal authorities and other enterprises who are interested in gas and water supply. The Association especially cares for the professional guidance of its members. As they are interested in a perfect drinking water supply, the Association contributes actively to the protection of waters. The SAGWE continously publishes new directives and cooperates with other institutions at the elaboration of their rules and directives. The Association also stands for an active cooperation with the Authorities an legal institutions and will be aware if the interests of gas and water users when new laws are passed. Besides, the SAGWE organises courses and meetings to promote the further professional development.

UNESCO

United Nations Educational, Scientific and Cultural Organisation

UNESCO is one of the fourteen bodies of the United Nations system. The aim is the worldwide exchange of knowledge and the development of the fields education, natural and technical sciences, culture, social sciences, communication, information e.a. It has 142 Member States.

WRC

Water Research Centre

The Water Research Centre is an internationally known organisation and one of the largest institutes of its kind in the world. Funds are provided by over 300 members in the United Kingdom and overseas including water authorities, industrial concerns, consultants and university departments, and also from contract work and a grant from the department of the environment. The WRC research programme includes work on water resources, treatment, distribution and supply, treatment of sewage and industrial wastes, water pollution studies and water quality and health effects.

BMI - Working Group on Water Supply and Bank Filtration

The Working Group on "Water Supply and Bank Filtration" was founded by the Ministry of Interior of the Federal Republic of Germany (BMI), to advise the Ministry of Interior in all questions concerning bank filtration and artificial recharge of ground water. Moreover the working group is employed with the coordination and control of research work on this fields financed by the BMI and on the development of proposals for further research programs.

DVGW

German Technical and Scientific Association on Gas and Water

- Founded in 1859
- Members: Experts, gas and water supply companies, industries, institutes etc.,
- publishes the DVGW-standards - technical standards in the field of gas and water supply
- sponsors research and development,
- and organizes congresses and seminars (in close cooperation with state authorities and relevant organizations at home and abroad).

GAWL (DVWK)

German Association for Water Resources and Land Improvement

The "German Association for Water Resources and Land Improvement" (GAWL) unites as its members professional and interested, institutes, associations, government boards and private companies and also the federal government and federal state ministries which are concerned with water. The association is organized in regional subdivisions and in professional sections with numerous working groups.

The GAWL promotes water and land resources development with due consideration of the environment by applied science and technical publications, by formulation of technical rules and standards, by organizing seminares, symposia and congresses and by suggesting, supporting and executing research in this field all of it with due emphasis on international cooperation.

FW - GdCh

Water-chemistry division in the German Chemical Society

Since 1926, the water-chemistry division of the German Chemical Society unites chemists, biologists, microbiologists, geologists, engineers, process engineers and water works, boards, companies and institutes as well. Members of the water-chemistry group deal with surface and subsurface water as groundwater, springwater, mineralwater and seawater; water protection, water treatment and using as drinking-water, table water, service water, boiler feed water, medical water and swimming pool water; cleaning of waste water, treatment and deposition of sludge, return of treated waste water into the hydrological cycle, and actions for recycling water and material within industrial plants.

IAH

International Association of Hydrogeologists

The International Association of Hydrogeologists (IAH) is a scientific organisation based on individual membership for hydrogeologists and engineers working mainly in the field of underground water, its ongin, movement and chemistry, its exploration and use included.
The IAH with members in more than 70 countries is belonging to the International Union of Geological Sciences (IUGS).
About 130 German members are organised in the National Committee of the Federal Republic of Germany (IAH-BRD).

IfW

Institute for Water Research, Dortmund

Since the establishment of their Hydrological Division in 1948 the Municipal Water Works of Dortmund (Dortmunder Stadtwerke AG) have promoted research work mainly on slow sand filtration and artificial groundwater recharge.
In 1969 was founded the Institute for Water Research, Dortmund (IfW) as a daughter-company of the Dortmunder Stadtwerke AG. The IfW is employed chiefly with the carrying out of research programms financed by public funds. The greatest part of the work concerns with the behaviour of harmful substances during infiltration and underground passage.
IfW is running a computer literature collection mainly on ground water use and quality and a data bank of substances harmful to water (DABAWAS), both of them in service to all which are envolved with problems on this fields.

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KÜNSTLICHE GRUNDWASSERANREICHERUNG
DORTMUND, 14. – 18. MAI 1979

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5620 Velbert 11

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4354 Datteln

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6368 Bad Vilbel 1

Water Research Centre - WRC
Medmenham Laboratory
P.O.Box 16, Henley Road
Medmenham Marlow
GB - Buckinhamshire SL7 2HD

Wissenschaftlich - Technische Werkstätten GmbH
WTW
Postfach 59
812o Weilheim

Verzeichnis der Diskussionsleiter / List of Chairmen

Montag - 14. Mai 1979

11,00 - 13,00 Uhr	Dr. Rene Viktor Blau Wasser- und Energiewirtschaft des Kantons Bern Rathausplatz 1, CH-3011 Bern
14,30 - 16,00 Uhr	Hendrik Colenbrander Bureau Committee for Hydrological P.O. Box 297, NL-The Hague
16,30 - 18,00 Uhr	Dr. Wolfgang Merkel Deutscher Verein des Gas- und Wasserfaches e.V. Frankfurter Allee 27, D-6032 Eschborn

Dienstag - 15. Mai 1979

9,00 - 11,00 Uhr	Prof. Dr. H.R. Langguth Lehrgebiet für Hydrogeologie RWTH Aachen Templergraben 55, D-5100 Aachen
11,30 - 13,00 Uhr	Prof. Dr. Gedaliah Shelef 62 Hapalmach St., Haifa, Israel
14,30 - 16,00 Uhr	Erich Bieske, Ingenieurbüro Wilhelmshöhe 12, D-5204 Lohmar 21
16,30 - 18,00 Uhr	G. Dassonville Societe Lyonnaise des Eaux 45 Rue Cortambert, F-75769 Paris Cedex 16

Mittwoch - 16. Mai 1979

9,00 - 11,00 Uhr	Dr. Gerhart Siebert Landesanstalt für Wasser und Abfall NW Steinstraße 137, 4150 Krefeld
11,30 - 13,00 Uhr	Dr. Udluft Institut für Wasserchemie Marchioninistraße 17, D-8000 München 70
14,30 - 16,30 Uhr	Prof. Dr. Gerhard Einsele Geologisches Institut der Universität Sigwartstraße 10, D-7400 Tübingen

Donnerstag - 17. Mai 1979

9,00 - 11,00 Uhr	Prof. Dr. Norbert Wolters Institut für Wasserversorgung TH Darmstadt Petersenstraße 13, D-6100 Darmstadt
11,30 - 13,00 Uhr	Dr. Paul Koppe Ruhrverband Kronprinzenstraße 37, D-4300 Essen
14,30 - 16,00 Uhr	Kenneth Edworthy Water Research Centre, Medmenham Laboratory P.O. Box 16, Henley Road, GB-Medmenham, Marlow Bucks.
16,30 - 18,00 Uhr	Prof. Leenhart Huismann Technische Hochschule Stevinweg 1, NL-2600 GA Delft

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

THE HISTORICAL DEVELOPMENT AND PRESENT STAND OF ARTIFICIAL GROUNDWATER RECHARGE IN THE FEDERAL REPUBLIC OF GERMANY

AUTHOR(S)
W.H. FRANK (Dortmund)

The development of artificial groundwater recharge in Germany was always closely related to the use of bank filtration on the one hand and to the application of slow sand filters on the other. The different trends in the technical development of surface water processing since the mid-1900's can be seen in the use of bank filtration and slow sand filtration. Artificial groundwater recharge using sand-filled infiltration tanks can be considered a combination of these two methods.

Central water supplies in Germany were first extended on a broad basis around 1850. It was in the wake of severe epidemics, however, which broke out in several major cities at the turn of the century that raised the issue of drinking water quality and how it could be better guaranteed by exploiting true groundwater, bank-filtered water and artificially recharged groundwater instead of directly extracted surface water.
The first artificial groundwater recharge unit started operation in Chemnitz in 1875. It was composed of a sand-filled infiltration canal and a periodically flooded field. It was only in 1900, however, after the publication of experiments by the Swedish scientist Richert that artificial groundwater recharge using infiltration tanks made a real breakthrough.

The waterworks in the industrial region of Rhine-Westphalia which transported bank filtered water in the Ruhr River valley at the time did not meet the hygenic standards and the demand at the turn of the century. This situation was clearly improved by the introduction of artificial groundwater recharge.

The first recharge tanks in the Ruhr area were built in Essen-Steele in 1902. The favourable hydrogeology of the Ruhr River valley allows for the infiltration and recycling of relatively large amounts of water within a small area.
In other river valleys in the F.R.G. the method of underground passage of surface water is still used.
The effectivity of slow sand filtration and underground passage in clearing water of persistent pollutants varies greatly. Yet in comparison to other processing methods, underground passage does generally have considerable advantages which justify its continued use even under today's raw water conditions. In accordance with the river water quality, underground passage is increasingly being combined with other processing methods before and after treatment.

Considerable research is presently being carried out in the F.R.G. in the field of artificial groundwater recharge. An important expansion of its practical applications is to be expected in the future not only as regards drinking water but all aspects of water distribution and supply.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Artificial ground water recharge in the Netherlands

AUTHOR(S)

J. Van Puffelen (Gravenhage)

For almost forty years surface-water had been infiltrated in the dune area near the Dutch coast at the North Sea. Since 1955 this had been carried out on a large scale at different places in the dunes of North- and South-Holland by infiltration of pretreated Rhine water in behalf of the drinking-water supply of Amsterdam, The Hague, Leiden and North-Holland. Since 1976 also river Meuse water is used for The Hague. The present infiltration capacity is 175 million m3/year. The purpose of this infiltration is to combine the advantage of ground water as a source for drinking-water supply with the disadvantage of the only available source, namely heavy polluted surface water. The functions of this artificial ground water recharge are:

1. storage for time of quality and quantity problems with the river Rhine or Meuse;
2. flattening of quality peaks and the temperature of the surface water;
3. quality improvement of the water and
4. preservation of nature areas and ground water levels.

During almost twenty-five years of practice with artificial recharge the sequence of importance of these four functions has been changed several times. The following aspects will be discussed more in detail:

1. historical significance and future;
2. methods of infiltration and storage in the aquifers;
3. flattening of quality peaks and temperature;
4. chemical and physical quality changes and accumulation of substances;
5. bacteriological and virological quality changes;
6. influence of pre- and post-treatment;
7. reliability and comparability as a treatment step;
8. interaction with other interests in the dune areas.

Besides the dune area there are plans and studies to infiltrate water in other areas like the Veluwe in the eastern part of the Netherlands. This infiltration will take place under aerobic conditions, while the ground water from the dunes is anaerobic. Comparisons will be made between storage of water in the dunes and storage in open reservoirs like the Biesbosch reservoirs of Rotterdam.
In future more attention will be paid to deep-well infiltration and to a more complete pretreatment of the surface water. Extensive research on these points is done bij the Waterworks and by the KIWA, the Dutch Waterworks testing and research-institute.

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TITLE

Artificial groundwater recharge in the USSR

AUTHOR(S)

G.V. Bogomolow

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

The situation of artificial groundwater recharge in Switzerland

AUTHOR(S)

E. Trueb (Zürich)

Switzerland is the reservoir of Europe. It offers excluding the evapotranspiration a water quantity of 50 Mia m^3/a. In view of that the water requirements of the public water works amount to sum 1,2 Mia m^3/a only. Still it occurs at times that we find bottlenecks of the water supply in the great urban areas especially in the regions around Basle, Geneva and Zurich. Responsible for that is the divergency of the local reserve capacity and need of water.

The great importance which the groundwater has for the satisfaction of need in Switzerland becomes obvious in consideration of it's share in supply of needs reaching 84 % of the total.

In 1911 the water board of Basle made already use of the artificial recharge. Today we have 12 plants running. Specially in connection with the peak prosperity setting in after World War II the assignment of artificial recharge was increased to satisfy the quickly growing needs. The tables I and IA give a survey of the main datas of these plants.

Following set of problems has special topicality in Switzerland:

- the artificial recharge as emergency measure
- the underground storage of drinking water
- the increase in sufficiency of spreading basins
  - . through raised flooding
  - . through clearing of sludge in the flooded phase
- the optimal use of gravel filters

Above problems will be given particulary interest in the complete paper.

Table 1, Plants for artificial recharge in Switzerland after [1] and [3]

		Aarberg, BKW	Aesch	WV Basel	Chaux-de-Fonds	Genève	Hardwasser AG
		Aarberg - Gimmiz		Lange Erlen	Gorge de l'Areuse	Genève - Vessy	Muttenz
Year of completion		1971	1976	1920	1958	1979	1956
Raw water source		Aare	Birs	Rhine	Areuse	Arve	Rhine
Raw water amount	m3/s	0,2	0,5	1,4	-	0,6	2,0
Cubage	Mio m3/a	1,5	7,7	40,0	0,4	12,0	20,0
Yield	Mio m3/a	-	-	21,0	-	-	18,2
(Financial) outlay	Mio Fr.	2,13	6,5	14,5	0,206	15,5	28,3
Operation and maintenance charges	Rp/m3	12,7	7,8	13,0	3,0	7,5	22,5
Raw water treatment		Gravelfilters	Settling basins Gravelfilters	Rapid sand filters	Filter	Coagulation Rapid sand filters	Flocculation Rap.sand filt
Method of direct recharge		Slow sand filters	Slow sand filt. Injecting wells	Afforested basins	Sprinklers	Drain pipes	Ditches and Ponds
average unsaturated zone	m	4,0	7,0	5,0	5,0	8,0 - 12,0	18,0
average flooding	m	0,2	1,6	0,2 - 1,0	-	-	Ditches: 0,8 Ponds: 3,0
average percolation rate	m3/m2·d	~2,5	~3,7	1,0 - 2,0	-	10 m3/m·d	Ponds: 6,0
Maintenance		Peeler	-	Drainage	-	-	D: Skiving P: Gravel was:
Interval of maintenance		-	-	14 days	-	-	16 months

Table 1 A, Plants for artificial recharge in Switzerland after [1] and [3]

		Metallwerke Dornach	WV St Gallen	Verzasca	WV Winterthur	WV Winterthur	WV Zurich
		Aesch	Breitfeld	Tenero	Oberwinterthur	Grüzefeld	Hardhof
Year of completion		1957	1976	1965	1964	1965	1979/80
Raw water source		Birs	Lake Gübsen	Verzasca	Eulach	Ground water out of the Töss valley	Bank infiltration of the river Limmat
Raw water amount	m3/a	0,020 ... 0,067	0,2		0,033	0,127	0,926
Cubage	Mio m3/a	0,5	-	3,0	0,5	0,3 ... 0,8	15,0
Yield	Mio m3/a	-	-	-	-	according to demand	-
(Financial) outlay	Mio Fr.	0,16	-	-	0,6	0,12	18,0
Operation and maintenance charges	Rp/m3	3,6	-	-	11,0	6,9 - 8,3	~ 7,0
Raw water treatment		Settling basins	none	none	Gravelfilter	-	-
Method of direct recharge		Slow sand filters	Slow sand filt. in operation only if necessary	Basins in the riverbed	Slow sand filters	Injecting well ø 1000 mm	Slow sand filt. with activated carbon
average unsaturated zone	m	6,0	10,0	2,0	6,0 - 16,0	6,0 - 16,0	3,0 - 4,0
average flooding	m	2,0	-	2,0	0,8 ... 1,2	6,0	3,0
average percolation rate	m3/m2·d	1,5 ... 8,5	-	3,0	2,0	127 ℓ/s	6,0
Maintenance		Skiving	-	-	Suction pump	-	-
Interval of maintenance		2 years	-	> 3 years	3 months	-	-

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

ARTIFICIAL GROUNDWATER RECHARGE OF TREATED EFFLUENTS AS PART OF ISRAEL'S NATIONAL WASTEWATER RECLAMATION SCHEME

AUTHOR(S) G. SHELEF (Haifa)

The Israeli scheme of wastewater reclamation on a country-wide scale stems from the severe water shortage, where over 95 percent of the conventional surface and groundwater resources are already in full utilization. Israel will require an additional 360 million cubic meters (MCM) of water per year, within 20 years, to satisfy the growing municipal and industrial demand. This amount assumes a standstill, or even a 5 percent reduction, in the water supply for agricultural irrigation estimated now at 1170 MCM per year. The Master Plan of Water Resources Development for the year 2000, assumes that 310 MCM per year of the utilized water resources will be reclaimed municipal wastewaters that will be directed for agricultural irrigation, thus substituting fresh water, which in turn will be diverted to municipal and industrial uses. At present about 40 MCM per year of municipal and domestic wastewater are being reclaimed for agricultural irrigation.

Groundwater recharge of municipal wastewater effluents is the most advantageous method for such reclamation schemes, due to the following factors:

(a) it enhances the quality of the effluent through filtration, sorption and retention;

(b) it provides seasonal and sometimes annual storage without evaporation losses, and

(c) it assists in the prevention of seawater intrusion into coastal aquifers. The seasonal storage advantage is of insurmountable importance due to the fact that the irrigation season in Israel extends for only six months a year and in the case of cotton, for example, which is the principal cash crop in Israel, the irrigation period extends only to 80 days in mid-summer (Figure 1).

The enhancement of water quality through groundwater recharge is also of high importance since the trend is to provide reclaimed wastewater with the least restrictions as far as the irrigation of agricultural crops are concerned. For example, "Class D" in the Israeli Effluent Reuse Standards, where irrigation of raw edible crops is permitted, specifies BOD levels of less than 10 mg/l and coliform counts of less than 2.2 per 100 ml and requires sand filtration of the polished effluent as a mandatory treatment before irrigation. Such filtration is naturally provided by groundwater recharge by percolation through sand or by storage in sandy aquifers.

The paper discusses two treatment projects, the Dan Region (Greater Tel-Aviv) and the City of Ashdod; both projects are aimed at groundwater recharge of municipal wastewater. The Dan Region wastewater treatment and reclamation scheme will be the largest in Israel serving a design population of over 1.5 million inhabitants and much of the research concerning groundwater recharge of wastewater has been focused around this scheme since 1961. Stage I of this project has already been in operation since 1976, serving a population of about 250,000 (15 MCM per year). A series of recirculating ponds with an area of 110 hectares serves as the basic treatment, while clarification by high lime-magnesium and ammonia stripping in polishing ponds prepare the effluent for recharge by spreading on sand-dune basins followed by infiltration into the sandy aquifer.

The paper describes the enhancement of the quality of the water in each step which finally brings it to nearly drinking water quality. Stage II of the Dan Region Project, (where pilot plant studies have been concluded and preliminary construction has already been commenced) with design flow of 100 MCM per year, will be based on a nitrification-denitrification activated sludge process producing high quality effluent (<10 mg/l BOD, <15 mg/l suspended solids and <10 mg/l total nitrogen) to be directly recharged into the sandy aquifer.

The City of Ashdod is considering using accelerated (high rate) algal ponds for the basic treatment followed by alum flocculation and flotation. This treatment has been developed through a joint Israeli-German research project commenced in 1973. The process produces high quality effluent and a proteinaceous algal by-product that can be used for animal (fish and poultry) feed.

The effluent will be used in mid-summer months directly for irrigation while in the other seasons it will be recharged to the sandy aquifer through sand-dune spreading basins. The quality changes in each step of the process are given in Figure 2. The practically complete removal of nitrogen accomplished in the Dan Region Scheme required to protect wells located at the fringe of the aquifer which produce water for drinking purposes, is not mandatory for the Ashdod scheme where the aquifer will store water for irrigation purposes only.

Figure(s)

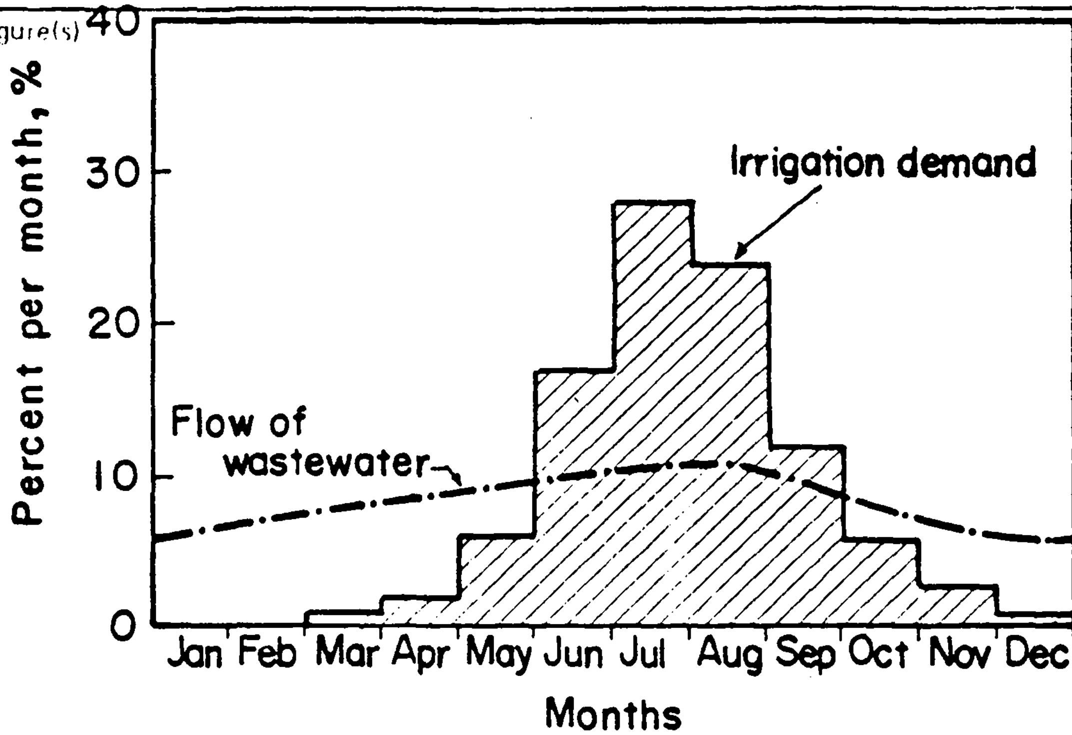


Figure 1. Typical Monthly Distribution of Municipal Wastewater Flow and of Water Demand for Agricultural Irrigation in Israel.

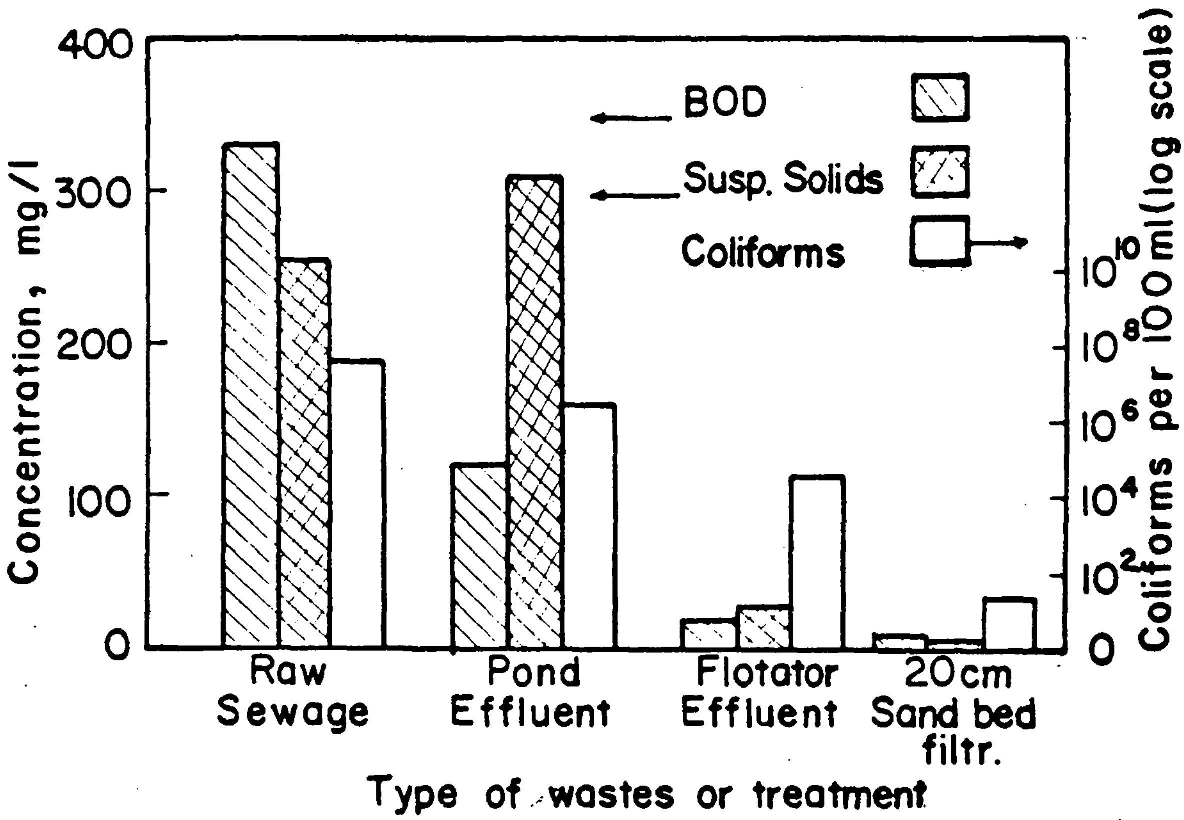


Figure 2. Enhancement of Effluent Quality in Various Treatment Steps of the Accelerated (High Rate) Algal Ponds.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Twenty-five years of groundwater recharge in Barcelona (Spain)

AUTHOR(S)
E. Custodio, J. Isamat, J. Miralles (Barcelona)

Abstract:
The almost 3.5 million inhabitants of the Barcelona's Metropolitan Area live near a coastal area facing the Mediterranean Sea in Catalonia in Northeastern Spain. Water resources are short since only small and irregular inolors exist. Water transportation from other neighbouring basins is yet fully exploited. Since the area supports half of the spanish industry and important agricultural areas, water has become an important issue, both in quantity and quality.

Groundwater artificial recharge was started in 1953 in the Besós area with a special well, surrounded by a crown of 16 small diametre tube-wells, in order to accomplish an intense back-washing of the coarse sand and gravels that form the water table aquifer. The cleaning-up to unclog the well is done by pumping the well and water injection through the tube wells, once a day for 15 minuts. Recharge water comes from an uncovered canal. The well is still operating and an identical second one exists now.

Since 1969 twelve normal tube-wells in the Llobregat area recharge river-treated water, in order to store in the coarse sand and gravel confined aquifer the excess city distribution water that exists in some periods. In periods when no enough river water is available the injected water is abstracted by means of other wells of the same injection wells. Clearing-up is done by pumping every two to three weeks of continuous injection for ten to twenty minutes Initial well capacity is

restored.

In both examples the well clean-up pumps discharge is 3 to 4 times the injection rate and the operation is done before clogging is serious in order to avoid irreversible extractions.

A pilot recharge well is beeing tested in the Besós area, near the sea, in a sea water encroached confined aquifer of coarse sand and gravel. Treated sewage water is injected. Raw water is mainly of domestic origin, but some industrial effluents are incorporated. The recharge is feasible if a certain dose of chlorine is maintained in the injected water, and cleaning is done daily.

Other recharge aspects include the river-bed ploughing and the damming of some small water cources. Two examples are presented.

The presentation is done in a schematical form.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Infiltration practice in Poland

AUTHOR(S)

A.L. Kowal (Wroclaw)

In Poland, infiltration is conventionally practiced for groundwater enrichment. Water supply for household purposes, as well as for the needs of the food industry, involves both groundwater (which is often being enriched by artificial infiltratic and surface water resources. The latter, however, should compl with the requirements of First Class Quality Waters, and also when they are used for infiltration.

Natural infiltration is often practiced in Poland, as for example in a Ranney-type well which has been errected in a river bed, and now yields infiltration waters of a composition similar to that of the groundwater.

Artificial infiltration is usually applied without pretreatment. In one case, however, coagulation and sedimentation are employed prior to the infiltration process. The infiltration units that are nowadays designed in Poland, will involve sedimentation and periodical coagulation processes.

The effectiveness of infiltration depends on many process parameters, such as the composition of both the infiltrated and the groundwaters, the physical-chemical composition of the soil in the infiltration area, the infiltration method and collection techniques.

Infiltration may also be considered as a technological procedure involving biochemical and physical-chemical processes. Biochemical processes occur in the infiltration basin and in the soil layer under the basin down to a depth of 1.5 m. Physical-chemical processes develop both in the basin and in the ground. Those occurring in the ground are in the most part sorption, ion-exchange and minerals dissolution phenomena, while those taking place in the infiltration basin are mixing and equalization of the water composition.

It is generally accepted that the infiltration time approaches 30 days, but in the engineering practice the infiltration time varies from 4 to 30 days, and the residence time of water in the infiltration basins ranges between 1-2 and 7 days. The infiltration velocity falls in the range 0.1-1.0 m/d, and depend on the head loss in the bottom sediments and on the granular composition of the soil and the ground.

The composition and temperature of the infiltrated water are the two basic parameters of infiltration index.

The $\pm$ 5 K difference between infiltration-water and groundwater temperatures is an indication of either a long time of surface-water passage in the ground or a low ratio of surface water to ground water.

Field investigations in the water-bearing areas of Wrocław, Kraków and Poznań show that the infiltration of highly polluted surface waters does not yield complete removals of refractory substances, heavy metals, ammonia nitrogen and colour matter. In that particular case, infiltration in the ground should be considered in terms of the theory of sorption. The overloading of the sorption bed brings about a displacement of the sorption front as far as to the wells. The mineral bottom sediments in the infiltration basins have an essential part in the sorption process, as they can be a buffer to some readily sorbable compounds which periodically occur in the water. At a permanent occurrence of those compounds the effect of bottom sediments is negligible.

Since the infiltration capacity is limited and, therefore, unable to sufficiently remove micropollutants, the surface water applied to the enrichment of water intakes for municipal purposes should meet the requirements of first-class quality.

Comparative studies for the effectiveness of slow sand filtration and long-time infiltration in nitrogen compounds removal were carried out with the following results:

(1) slow-sand filtration yielded a balance of nitrogen content both in inflow and outflow, and an oxidation of nitrogen compounds,

(2) infiltration resulted in a considerable loss of nitrogen which was not attributable to the dilution effect.

8

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Experiments with artificial groundwater recharge in Rumania

AUTHOR(S)

V. Harnaj (Bucarest)

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITEL

WATER QUALITY MANAGEMENT IN ARTIFICIAL RECHARGE OF FLOODWATER IN ISRAEL

AUTOR (EN) D. Katz (Haifa)

About 95% of the conventional water resources in Israel are exploited. To cover the increasing demands of agriculture, industry and domestic supply, development of new sources will be based on further floodwater utilisation and wastewater reuse, before large desalination will be started. The yearly average of the total flow of winter creeks, draining to the Mediterranean Sea, is about 130 mil cu m of which about a half can be conserved and used. The precipitations in this western drainage area of the country drop from 800 - 1000 mm/Y in the northern part, to 200 - 300 mm/Y in the southern part of the coastal strip. Intensive evaporation, together with overexploitation of groundwater in the coastal zone, require evaporation-free storage of the low salt content winter floodwaters to be used in the practically dry summer periodsmonths of high water demand. The first step in this direction, the Shiqma project, in the south, between Ashqelon and Gaza, was commisioned in 1958-1960, to conserve episodic waters of the winter stream Shiqma by impoundment, followed by artificial recharge of the regional aquifer. The work comprises of: 1) a 2.8 mil cu m reservoir, located about 1.3 km from the sea, for floodwater impoundment and suspended solids settling before release to spreading grounds; 2) a pumping and conveyance system to transport the water after sedimentation (with a turbidity of about 50-300 J.U.) at a pumping rate of 250,000 cu m/day, to the higher situated spreading grounds; 3) spreading grounds with a capacity of about 0.8 mil cu m, situated between dunes, for infiltration of sedimented floodwater into the aquifer. The water pumped during summer months is of drinking quality.

In 1966 another plant, the Nahaley Menashe work, in the center of the coastal strip, was started to harvest the water of four periodical winter creeks. The work comprises of: 1) diversion structures for each stream; 2) a 12-km channel to convey the diverted water; 3) a 2.5 mil cu m surface reservoir in the dune region where sedimentation occurs and the coliform count drops from an input figure of 10^4/100 ml to 10^2/100 ml; 4) a 2-km gravity earth channel and 5) spreading grounds in the Caesarea dunes which covers an area of 50 ha, receives up to 1.3 mil cu m and serves for infiltration into the local pleistocene aquifer from which the water is pumped, during the dry summer period, by 15 wells drilled in the vicinity of the spreading grounds. Sedimentation, percolation through a $\sim$5 m sand layer, retention time in the underground and mixing with the aquifer water improve the water quality

	from	to
Cl^-, mg/l	60 - 80	30 - 50
NO_3, mg/l	∿ 20	10 - 20
ABS, mg/l	∿ 0.2	0.02 - 0.04
El. Cond.	∿ 600	400 - 500
$KMnO_4$ Demand mg/l O_2	3.3	1 - 2
Coliform counts/100 ml	∿ 10^2	≤ 2.2
	before discharge	in the pumped water

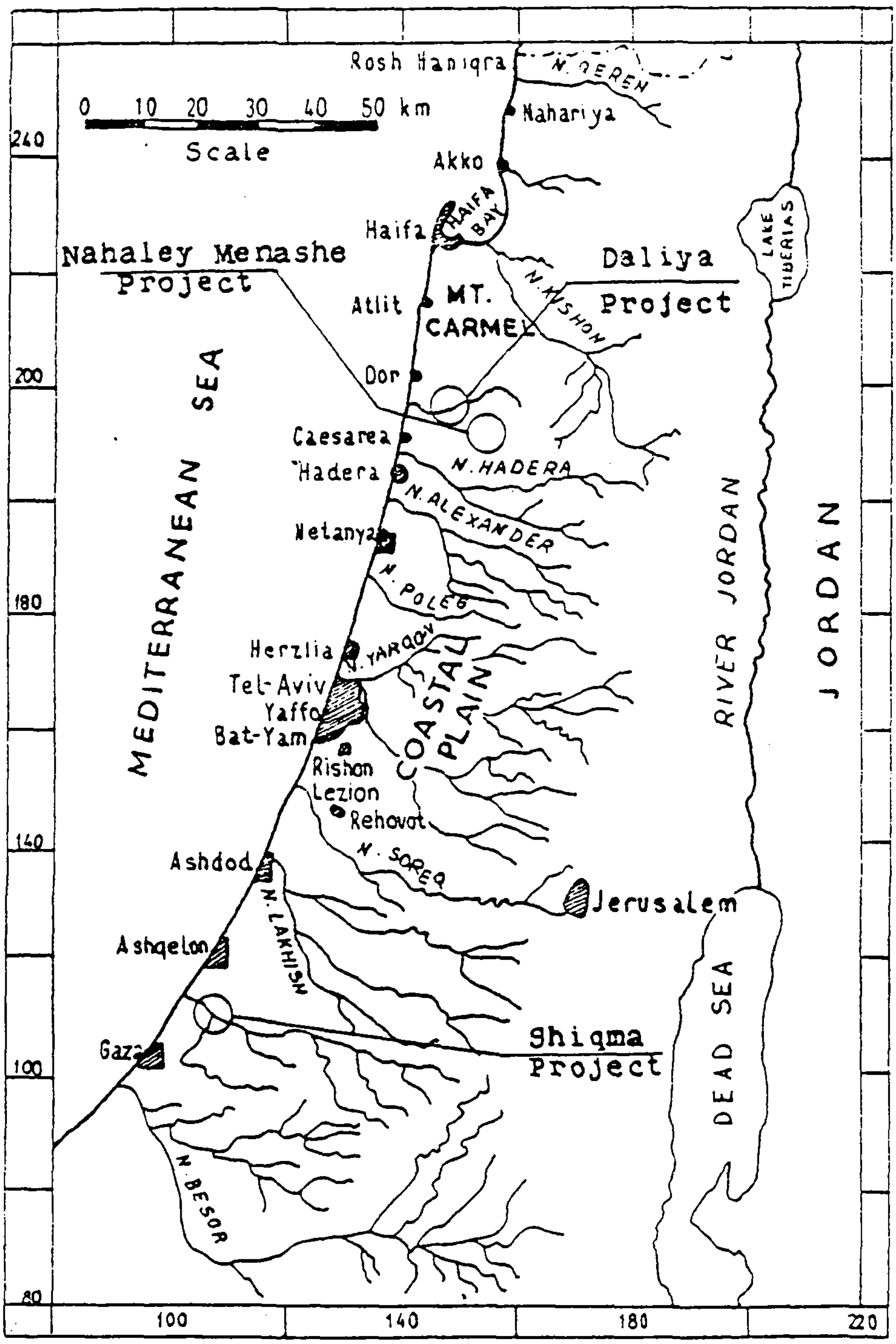
By such a way, drinking quality is reached, using a recharge scheme which replaces conventional treatment.

A third facility, the Daliya project, is not operated at present due to environmental problems. The natural conditions of the region enable conservation of the periodical flow of the creek, polluted by industrial and domestic sewage, by direct recharge, via wells, into a Turonian-Cenomanian aquifer. This direct recharge, lacking natural filtration, together with the short retention time in the underground, possible connection with neighbouring aquifers and the aim to yield drinking water in the summer, require handling of quality problems without compromises. Thus, the water must reach drinking quality or at least very close to it before recharge. To obtain such a quality a "non-discharge" wastewater management policy has to be applied. Background quality of a non-polluted tributary in the Daliya stream network showed a bacteriological load of about 4.10^2/100 ml coliforms. It can be predicted that this quality will be obtained in the polluted tributaries by avoiding wastewater discharge. This background-polluted water, with low organic load and a 5-10 J.U. turbidity will be treated before recharge. Treatment experiments demonstrate that by a dual-media-contact-filtration (sand 0.9 - 1.1 mm, anthracite 2.7 - 4.3 mm, 10 - 15 mg/l alum) with a filtration rate 16 m/h, a water with turbidity of 0.1 - 0.2 J.U., suitable for recharge after chlorination, can be obtained. To realize the non-discharge policy, the industrial and domestic wastes can be diverted to the southern neighbouring catchment area of the Nahaley Menashe recharge plant where they can be impounded, biologically treated and used for irrigation. Alternatively, the effluents can be fully treated to such a degree that discharge into the stream network will not affect recharge quality. Managing by such a way the water quality of the two catchment areas with different recharge schemes make possible conservation of Daliya stream water by direct recharge, after a relatively simple and modest dual-media-contact-filtration. The watershed of the less pretentious Nahaley Menashe recharge work will receive therefore the generated wastes using them without impairment of the quality of its catchment waters.

Abbildung(en)

Anlagen zur Anreicherung von Flusswasser in Israel

Artificial recharge of floodwater in Israel



INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE National and international legal regulations for the application of groundwater recharge

AUTHOR(S)
M. Bauer (Bonn)

The Federal Government has issued the "Act on the Regulation of Matters Relating to Water" (Federal Water Act) on 27 April 1957 in line with its competence following art. 75 Nr. 4 of the basic law for the Federal Republic of Germany. The Federal Water Act is a fundamental law. These basic regulations are not only directives to be filled up by laws of the Länder but in the majority direct currently rules.

According § 3 of the Federal Water Act three different legal aspects are to consider for the technical going on artificial groundwater recharge:

- the withdrawal and diversion of water from surface waters,
- the discharge of matter (water) into underground water and
- the withdrawal, bringing or drawing-off to the surface, or the diversion of underground water.

According § 2 of the Federal Water Act these several water uses need a permit or a licence issued by the water authorities. A permit or a licence may be granted subject to the imposition of conditions. Conditions may als be imposed in order to prevent or make good any effects which are detrimental to other persons.

As regards the quality of the water to be withdrawn from surface waters, care should be taken to ensure that this water is treated in such a manner that the drinking water to be supplied later will meet the requirements laid down in the Ordinance on Drinking Water of 31 January 1975.

Moreover the following regulations of the Federal Water Act are specially significant:

- § 19 Water protection areas,
- § 34 Preservation of the purity of Groundwater,
- § 36 a Change ban to safeguard planning,
- § 36 b Exploitation plans and
- §§ 38 to 41 Penalties and fines.

Likely internationally binding regulations are the Directives of the European Communities, which are addressed to the Member States and must be transformed into national law. In this context there will be discussed:

- Council Directive on the protection of inland waters against pollution caused by certain dangerous substances from 4 May 1976,
- Council Directive concerning the quality required of surface water for drinkingwater supply from 16 June 1975,
- proposal for a Council Directive relating to the quality of water for human consumption and
- proposal for a Council Directive on the protection of groundwater against pollution caused by certain dangerous substances.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Regional planning, groundwater protection and artificial groundwater recharge

AUTHOR(S)

H.P. Lühr, W. Möller (Berlin)

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Bank recharge to an esker aquifer in Sweden

AUTHOR(S)

G. Gustafson (Falun)

Esker aquifers play a major roll for water supply in central Sweden. The eskers are ridge-formed glaciofluvial deposits of coarse sand and gravel. In their most typical form they are of subaqueous origin and partly covered by silt and clay. The coarse sand and gravel give the eskers a high permeability and since their path normally follows the low parts of the terrain they can under advantageous conditions drain vast areas.

In many cases the eskers are surrounded bei surface water. In this case a pumpage from the esker will cause induced recharge, bank recharge, of surface water to the esker sediments. By pumping tests it is possible to predict the magnitude of the recharge and the recharge area involved. The aquifers will act as unidimensional leaky systems, and the drawdown will be governed by the channel conductivity and the leakage coefficient between the aquifer and the surface water.

Since the recharge takes place through relatively finegrained sediments the chemical character of the surface water is changed. The total hardness is increased and the colour and turbidity is radically lowered. The organic content of the bank sediments normally causes oxygen free conditions and dissolution of manganese and iron. In extreme cases the temperature changes of the surface water show up in the pumpage well and will affect the drawdown because of viscosity changes.

As an example of bank recharge the watersupply of the town of Kristinehamn, Värmland County, Sweden, can be given. There a continous pumpage from an esker that forms an island in a lake has been going on since 1971. During this period water levels and water quality heve been continously checked and all the above stated features of the aquifer can be shown.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Research into the conjunctive use of surface and groundwater, with artificial recharge in Sussex, England.

AUTHOR(S)

R.Bibby, S.L.Brown and J.Davis, (Medmenham)

The groundwater resources of the Folkestone Beds aquifer of the Lower Greensand succession (Cretaceous) at Hardham, Sussex have been developed in conjunction with surface water abstraction from the River Rother since 1964. The aquifer and river are hydraulically connected. When the aquifer is at full storage it contains approximately 164×10^6 m^3. Average natural recharge to the aquifer is approximately 14×10^3 m^3/d. The mean daily flow of the River Rother is 435×10^3 m^3/d; the standard deviation of $\pm$ 370×10^3 m^3/d gives an indication of the great variation in flow rate.

A progressive increase in groundwater abstraction rate up to 1974 caused a steady decline in water levels throughout the basin. As early as 1968 a series of artificial recharge experiments were initiated to determine the effects of recharging untreated river water through lagoons. These experiments were finally concluded in 1974. However the experimental programme has since been extended to consider the possibilities for both lagoon and borehole recharge of primary and secondary treated river water respectively. The aim of these experiments is to determine the effectiveness of the various recharge techniques and to derive and compare capital and operating costs; information which is not yet available.

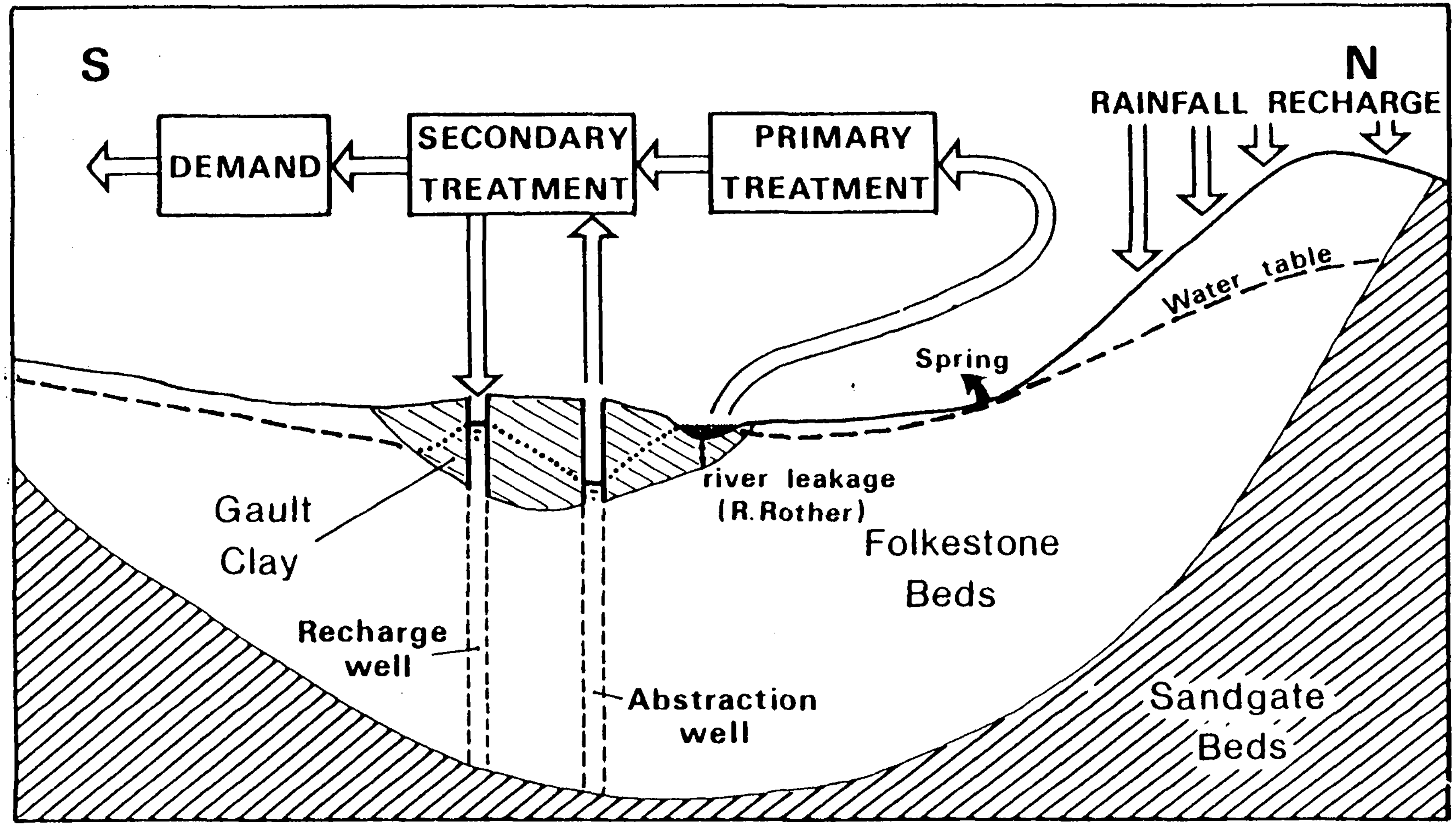
In order to evaluate the potential of the Hardham resource as part of a regional water supply scheme, rather than solely as a local supply source, two mathematical models were developed.

A lumped-parameter simulation model of the river/aquifer system was developed to optimise the design at different demand levels of treatment plant capacities and artificial recharge requirements, and to determine the overall operating policies. This optimisation model uses daily historical river flow data.

A finite difference groundwater model was also developed as an aid to understanding the aquifer system, and to check the feasibility of designs and policies arrived at by the optimisation model. (The latter model has only a simplistic representation of the aquifer).

The model was calibrated using historical data on water levels at twenty-two observation and abstraction wells for the period 1964-77, although many of the records were incomplete. Further information on aquifer properties and water levels was required for several areas of the basin previously undeveloped. This resulted in a number of observation boreholes being drilled to penetrate the aquifer fully; core and cutting samples from these boreholes were studied in detail by lithological logging, grain-size analysis and using thin-sections. Samples were also measured for porosity, specific yield and permeability in order to obtain a fuller understanding of variations in aquifer parameters over the area.

The optimisation model results have shown that the resource is capable of meeting a maximum demand of approximately 200×10^3 m^3/d. The feasibility of the optimum designs and operating policies, determined at two demand levels of 80 and 150×10^3 m^3/d have been tested on the groundwater model over the 1972-76 drought period. This has shown that the aquifer is capable of meeting these demands even with a relatively restricted distribution of wells, thus minimising pipeline costs.



Schematic of the Hardham resource area

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE Artificial recharge for resource storage by the Thames Water Authority in the Lee Valley, London, England

AUTHOR(S) R.J. Flavin, R.J.E. Hawnt (Hertfordshire)

The Lee is a tributary catchment of the River Thames basin, the water resources of which are managed by the Thames Water Authority (T.W.A.). The River Lee is an important source of London's water supply providing about 15% of the total resources via several large surface storage reservoirs in the Lower Lee Valley; the area referred to, and the geology described below, is shown in the diagram.

London is situated on the axis of a major syncline in Cretaceous and Eocene deposits. The Chalk and overlying Lower London Tertiary Basal Sands are generally confined by the London Clay in the area north of the Thames. Facilitated by a highly developed fissure system in the Chalk, groundwater has been abstracted from the combined Chalk/Basal Sands aquifer system via deep wells in the London area, for more than 250 years, and the original artesian groundwater level has been lowered to up to 50 metres below ground level in recent times, leaving the Basal Sands and parts of the Chalk extensively dewatered. Today groundwater still provides about 15% of London's water supply.

Within the dewatered area the Water Resources Board (W.R.B.) defined four areas as suitable for Artificial Recharge for resource storage and of these, the Lee Valley appeared most favourable with an estimated potential storage for 175,000 Ml. This extra storage is equivalent to five times the existing surface reservoir storage available in the same area.

Experimental work was initiated in 1971 by the W.R.B. at two specially equipped well sites for the study of the local effects on water level and groundwater quality. This and other research work by the W.R.B.'s successors, the Water Research Centre and Central Water Planning Unit, assisted T.W.A. in implementing a pilot scheme designed to utilise some of the aquifer storage in the Lee Valley and allow an assessment of the effects of artificial recharge on the aquifer system.

The scheme operates with six public water supply wells with adit systems, and seven purpose drilled boreholes sited along the valley, close to an existing water supply main providing the source of recharge water. Construction of the new boreholes began in 1976 and pumping tests provided yield/drawdown data for the design of recharge and abstraction facilities. During test pumping borehole yields of 2 - 7.5 Ml/day were obtained, with transmissivity values ranging from 25 - 1,300 m^2/day and storage coefficients from 1.4 - 6.5 x 10^{-4}. This data, together with that provided by an extensive groundwater level and quality monitoring network assisted the Water Research Centre in the development and calibration of a numerical model of the aquifer, intended for use in simulation of recharge/abstraction operations for management purposes.

Operational Recharge commenced in December 1977 continuing for five months, in which time 5,800 Ml was recharged and the observed change in regional piezometric levels is shown in the diagram. Groundwater quality monitoring indicated that at some sites dilution and/or displacement of Basal Sands groundwater with recharge water has occurred, with resultant decreases in dissolved solids, particularly in calcium, magnesium and sulphate concentrations. Elsewhere increases in these parameters were observed providing some evidence of chemical leaching from the sands. No significant changes in quality were observed in the Chalk.

The scheme's abstraction facility was subsequently tested in September 1978 when 2,900 Ml was abstracted over two months, allowing a comparison of recharge and abstraction performances and an appraisal of the effects on groundwater quality. Abstraction revealed only minor changes in groundwater quality and at most sites a slight improvement in water quality was observed as the duration of the abstraction period increased.

The pilot schemes maximum recharge capability is estimated at 75 Ml/day whilst the safe yield after recharge is predicted to be about 80 Ml/day, representing an increase of about 18% in the drought yield now available to the T.W.A. from all sources within the Lee Valley. Operational rules for assessing the best use of the scheme as a resource, have been formulated and are being examined in conjunction with a numerical model of the entire T.W.A. resource system.

The capital cost of all works associated with the pilot scheme compare favourably with any surface reservoir alternative and an extension of the scheme is being considered.

THAMES WATER AUTHORITY - LEA DIVISION

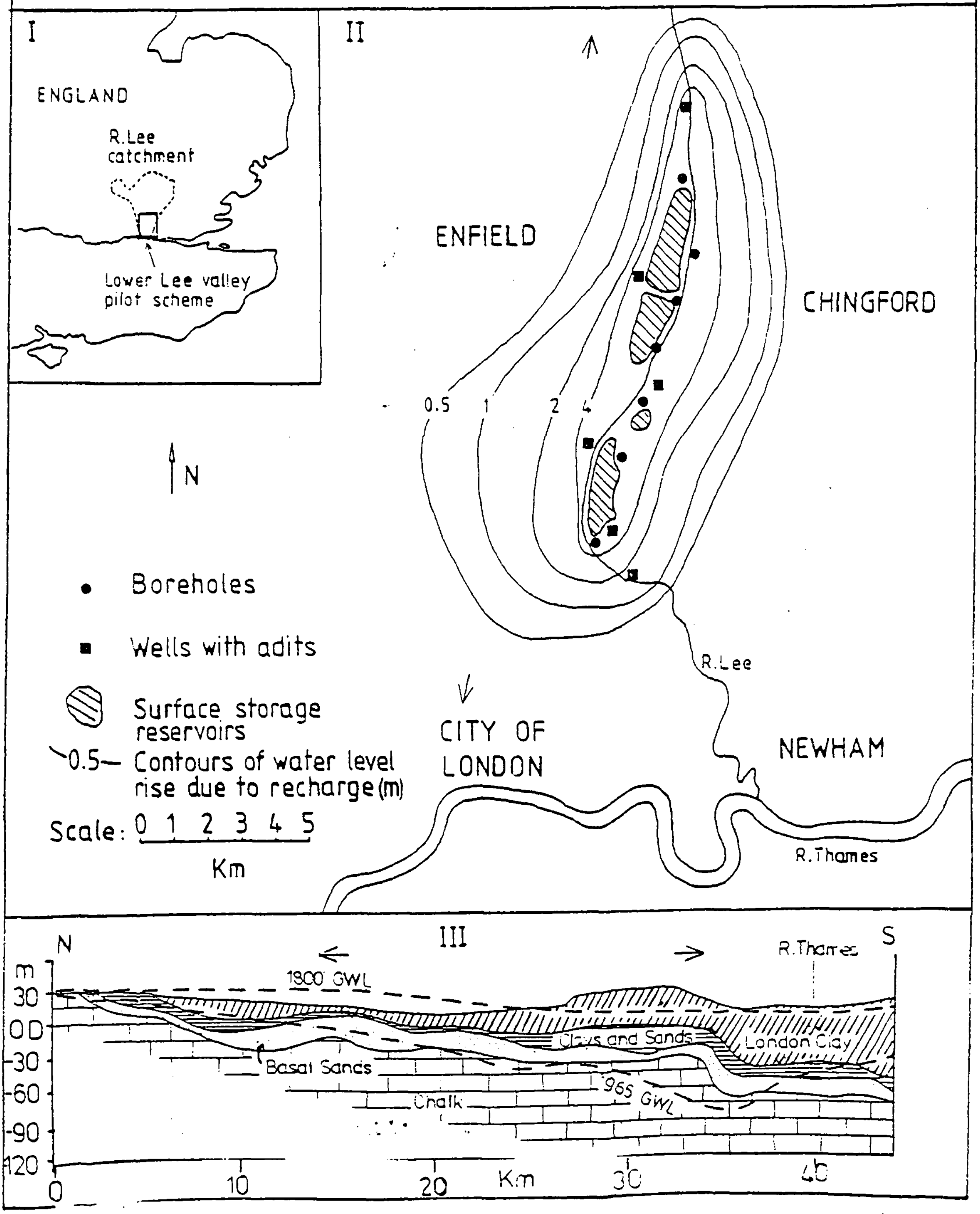
14 3

Lee Valley Artificial Groundwater Recharge Pilot Scheme

I Regional location map

II Map showing wells, boreholes and reservoirs with superimposed contours of the rise in piezometric groundwater levels after recharge. December 1977 to April 1978.

III Geological section, showing the decline of groundwater levels since 1800.



INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

THE ROLE OF THE CAPE FLATS AQUIFER IN THE STORAGE AND ABSTRACTION OF RECLAIMED EFFLUENTS

AUTHOR(S)

G. Tredoux, W.R. Ross, A. Gerber (Bellville)

The City of Cape Town and surrounding areas are at present solely dependent on surface waters which are impounded up to 100 km away. These sources will be inadequate to meet the projected demand at the end of the century due to rapid urban development in this area. The conjunctive exploitation of groundwater from the coastal aquifer of the Cape Flats and reclaimed secondary sewage effluents could play an important role in augmenting the limited supply for general use.

Extensive geohydrological surveys of the Cape Flats aquifer have been carried out during the last ten years in order to define the aquifer with respect to factors such as water quality, the depth, transmissivity and effective porosity of the sand beds and the components of a water balance for the areas. The results proved that the aquifer was geohydrologically suitable for artificial recharge and abstraction operations. The accumulated data are being incorporated into a mathematical model, which will simulate the hydraulic response of the aquifer, to develop feasible exploitation strategies.

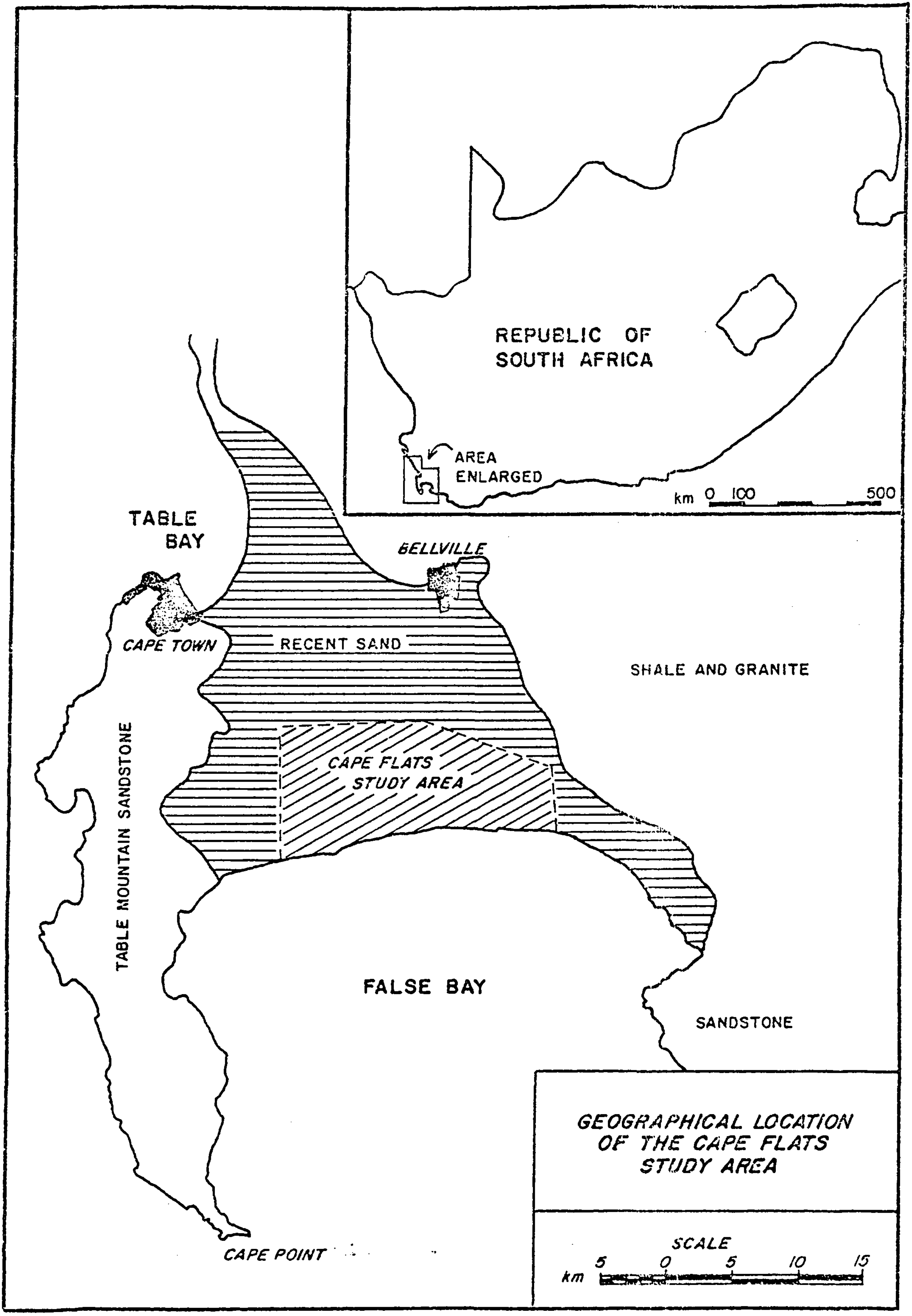
The first stages of a 4,5 Mℓ per day water reclamation plant have been commissioned to supply clarified secondary effluent for pilot artificial recharge studies in a selected area of the Cape Flats aquifer. The research facilities have been flexibly designed to enable various modes of purification and artificial recharge sequences to be studies, including the infiltration of partially reclaimed water followed by abstraction of the groundwater blend. This approach holds several potential advantages, such as being able to buffer seasonal fluctuations in the supply and demand of water and to overcome public prejudice to the

2/ consumption ...

consumption of directly reclaimed water.

The experimental recharge site consists of open infiltration ponds at varying levels above the local groundwater table and an artificial recharge borehole, due provision having been made for a network of observation points to monitor water levels and quality changes.

This paper discusses the geohydrological surveys leading to the construction of reclamation and artificial recharge facilities to be used in developing criteria for exploiting the aquifer as a water resource. Results of the initial reclamation and infiltration experiments are described with special emphasis on the chemical and microbiological quality changes taking place during transmission through the sand strata and maintenance of the infiltration surface.



GEOGRAPHICAL LOCATION
OF THE CAPE FLATS
STUDY AREA

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Experiences with artificial groundwater recharge at Djahrom, Southern Iran

AUTHOR(S)

F. Gholamali

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Artificial groundwater recharge at Varamin and Garmsar (Iran) - Results of infiltration experiments

AUTHOR(S)
J. Bize (Paris)

The Teheran Water Board plans to install two irrigation areas at Varamin and at Garmsar (covering 50.000 ha and 20.000 ha, respectively, in the final stage) which are situated some several tens of kilometers east of Teheran.
Both these areas are situated on the alluvial plains of the rivers Jajerud and Ablerud, which flow from the Elbourz mountain range. The alluvions of these plains are highly permeable in their upper reaches and the transmissivity through them can be as much as 16.000 m^2/d. One hundred liters/s can be pumped from them resulting in a lowering of the water table by only 0,60 m. The groundwater table is found at a depth of 80 - 100 m. In winter when small amounts or no irrigation water is needed, the waters of the Jajerud and Ablerud flow unexploited to the desert downstream from the farming area. It has been planned to store this water in natural underground reservoirs in order to supplement the ground water resources during the irrigation period.
More than 100 million m^3 of water for Varamin and 30 million m^3 for Garmsar will be the result of the artificial groundwater recharge in the next few years.

<u>Experimental:</u>
Infiltration tests are carried out for about 3 months during the spring flood in 1975. Two types of infiltration devices were tried out at each site:

- A unit of type A which is an elaborate construction consisting of two sedimentation basins of 3.000 m^2 and 6 infiltration basins of 1.225 m^2 having a maximum depth of 2 m. A construction of this type is designed to meet the demands which certainly have to be expected each year including the so-called "dry years".

- A type B unit of much simpler construction which consists of a series of small basins which can be dug out by bulldozers. They are separated from each other by small dams of 0,75 m in width. In this device, the basins which succeed each other in a downstream direction primarily serve as recharge basins and then change to act as sedimentation basins.

Results:

For the construction of type A the total filter capacity was 1,5 x 10^6 m^3 (1.000 m^3/h) in Varamin and 4 x 10^5 m^3 (580 m^3/h) in Garmsar. The sedimentation effect was excellent. A looding rate of 6 to 8 m/d (according to HAZEN) allowed the sediment concentration to fall from 2.000 mg/l to 100 - 300 mg/l at Varamin and from 3.000 - 6.000 mg/l to 400 - 600 mg/l at Garmsar. Due to this sedimentation the filtration rates dropped from 4 m to 2 m/d within 3 months of operation in Varamin. In Garmsar it dropped from 3 m to 2 m/d within one month.

Based on these results, infiltration rates decreasing from 4 m/d to 1 m/d can be expected at the end of 5 months. Accordingly the infiltration areas in Varamin, where a peak water flow of 3,5 m^3/s and a total volume of 42 x 10^6 m^3 p.a. have to be expected, should be extended to 40 ha.
More problems are associated with the sedimentation than with the infiltration. Due to the high solids content of the Ablerud water (often exceeding 6 g/l) which in the form of sludge would have to be removed every year from the type A construction, the type A construction cannot be used in Garmsar. Even at Varamin, the use of sludge scrapers (Caterpillar 637) 1.500 to 2.000 times has to be reckoned within years of high precipitation in order to transport the deposited sediments to a side arm of the Jajerud from where they are carried into the desert by the flood waters.

Concerning the type B construction

According to the tests, an infiltration rate of 0,7 m/day can be predicted.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITEL

ARTIFICIAL RECHARGE OF THE AQUIFER IN THE CHALK AT CROISSY AND AUBERGENVILLE - FLOW REGIMENS

AUTOR (EN)

A. ROBERT (Le Pecq)

This study concerns the results of observations and tests on flow regimens during artificial recharging at Croissy and Aubergenville.

- Evolution of the level in a basin as a function of the flow injected - Apparent infiltration velocity and clogging

  The infiltration capacity of a basin is defined on the basis of simple operating observations.

- Water circulation in the chalk

  The hydraulic parameters of the aquifer were sought, especially at Aubergenville. Piezometric readings and electrical prospecting during dry weather and flood periods revealed the variation of coefficients of permeability as a function of the depth.

- Characteristics of the alluvial deposits

  The alluvia above the chalk have a low permeability.

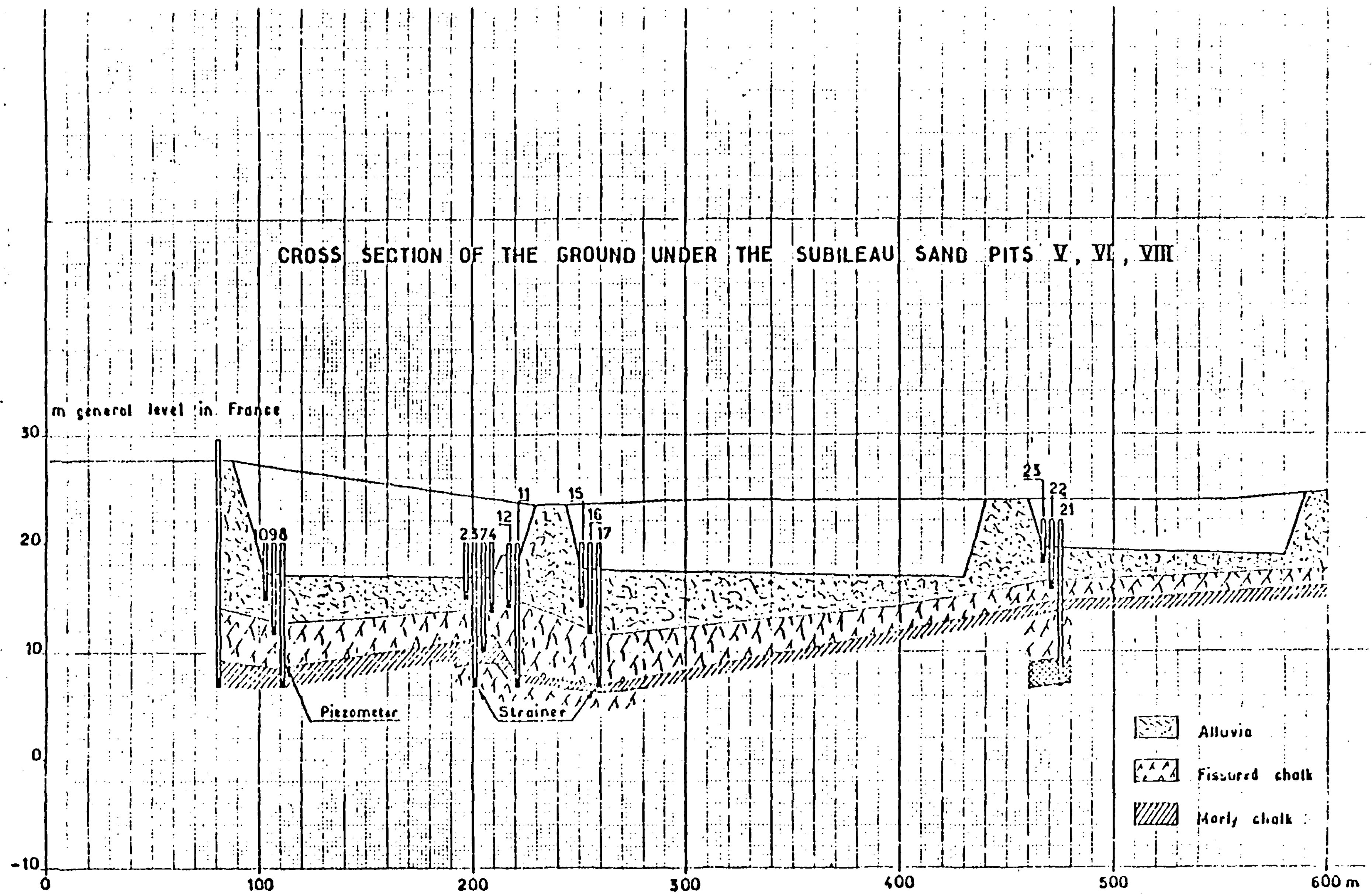
- Different flow phases

  Two superposed media were dealt with:

  - chalk, which can be highly permeable
  - alluvial deposits, which generally have a low permeability

However, care must be taken not to establish general laws based on an overly ideal scheme. Consideration must be taken of the heterogeneity of formations (see cross section) which results in varied and complex types of circulation.

January 29, 1979


CROSS SECTION OF THE GROUND UNDER THE SUBILEAU SAND PITS V, VI, VIII
m general level in France
30
20
10
0
-10
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100
200
300
400
500
600 m
1098
2374
12
11
15
16
17
23
22
21
Piezometer
Strainer
Alluvia
Fissured chalk
Marly chalk

Figure(s)

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INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITEL

Practical applications of artificial recharge in North-Holland.

AUTOR (EN)
R.J. Wildschut (Bloemendaal)

Groundwater under the dunes along the coast of the Dutch province of North-Holland was the main source for drinking water during the last century.
In order to put an end to continuous over-withdrawal of dunewater, infiltration of water from the river Rhine into open canals has been started in 1957. Two infiltration areas are in operation at present at a capacity of approximately 20 resp. 14 x 10^6 m3/a.

The increasing demand for drinking water and the shortage of appropriate area led to studies in order to develop a deep-well injection- and recovery-system in the deeper sand layers under the dunes, feeded by pretreated surface water. The capacity of this project is to arrive finally at approx. 30 x 10^6 m3/a, to be realised partly, or preferably entirely, by means of a deepwell injection-/recoverysystem.
Both Rhine and IJssellake are available as a source of raw water.
The intentions are:

- to obtain biologically reliable water
- to damp out (partly) seasonal quality fluctuations, and
- to create a subsurface storage for emergency purposes.

The injected aquifer has a thickness of about 200 meters, consisting of about 50 m of fresh water and about 150 m of salt water underneath. It is covered by a loam layer of low permeability.
Close under the brackish zone, with a thickness of about 5 - 10 meters, the salt water layer is intersected by a semi-permeable layer. Injection and recovery will take place in the fresh water zone. The final system will include a central row of injection wells of approx. 2 kms length, surrounded by a number of recovery wells. The injection wells will have a capacity of approx. 40 - 60 m3/h each at a filter length of approx. 15 - 20 m.

The recovery wells will have a capacity of 20 - 60 m3/h with a short well filter (10 m), close under the covering loam layer.
Under normal circumstances injection into the central row and recovery by means of the surrounding wells will take place continuously.
This will cause a more or less linear cumulative spread in underground detention times of approx. a full-year, and will considerably smooth fluctuations of important seasonal Rhine and IJssellake water quality parameters, like water temperature and salt concentration.

The main research items are:
- clogging of the injection wells;
- mixing of fresh and salt water, and
- effects in the surrounding area of e.g. potential and quality changes.

It is being studied whether clogging of the injection wells can be reduced by an additional treatment, comparable to slow sand filtration. Another method might be to backwash the wells frequently during short times at velocities of about twice the injection rate.
The phenomenon of mixing by dispersion processes at the fresh salt water interface between might be restricted if the injection process is started by, in the first place, pushing downwards the bottomside fresh-salt water interface, until the underlying semipermeable layer has been reached. After that, it is expected, the interface will be held back within the semi-permeable layer, thus establishing a situation in which the longitudinal flow components alongside the interface are relatively small and, as a consequence, the increase of the brackish water-zone by mixing processes will be accordingly small.

A certain amount of brackish water is supposed to be generated under the injection-/recovery-system. However, the lay-out principle is intended to cause a flushing effect, which might prevent a gradual growth of the brackish zone under the system .

A full scale pilot set-up to test these system principles has been prepared and taken into construction. Dispersion coefficients and other data will be collected and derived, in order to determine certain quality changes of the surroundings.

A small scale deep-well injection pilot system with some comparable features has been built on the isle of Texel. The purpose of this project is to establish a seasonal underground storage, increasing to approx. 300.000 m3, to be generated by pushing downwards the underlying brackish and salt water interfaces.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Aspects of a planned artificial groundwater recharge in the "Fuhrberger Feld"

AUTHOR

G. Peters (Hildesheim)

The so-called "Fuhrberger Feld" north of Hannover is the reliable, nearly inexhaustible basis of the water supply for the agglomeration region of Hannover; this groundwater resource is a part of the vast aquifer of primary stream of the Aller-Valley with its 20 to 40 m thick sand and pebble successions of the pleistozene.

Out of three water catchments are hauled until 53 Mill cbm of groundwater per year; it becomes treated expensively and then moved within 6 pipelines to the town of Hannover. The sequence of the years of low precipitation 1973-1977 led to a lowering of the level of groundwater about 100 cm below the long-term water-surface; inside of the water protective zones was noticeable the dry up of many brooks. The following protests of ecologists pushed ahead the planning for the extension of the basis for water supply i.e a new arrangement in the "Fuhrberger Feld".

The picked out artificial groundwater recharge seems to be the most interesting solution of all plannings and the most economically too.

Conception

1. base and requirements

   On the northern riverside of the Aller, opposite of the "Fuhrberger Feld" falls the river Oertze into the Aller. In its mouth the Oertze is able to deliver, water to a outside terrain, especially during high water.

   The quality of the water of Oertze is good, better than the quality of river Aller, which was also took into consideration.

2. The results of the recharge

   2.1 The groundwater level becomes lifted so much, that the danger of drying up of the brooks in the "Fuhrberger Feld" should be finished.

...

2.2 An additional water demand for sprinkler irrigation should be supplied from the "capacity of providence" without restrictions of other usings.

3. Long-range results of the recharge

The letin and the percolation of the Oertze-water of higher pH-value than the groundwater in the "Fuhrberger Feld" with only pH 5,8 become to the quality of ground-water favourable in the years.

4. Aspect of hydropolicy

It would be an interesting and essential program of providence to get the opportunity to manage big ground-water recources with support of the artificial ground-water recharge in such manner, that water demand on a large scale and years of low precipitation on the other hand would not signify a change in the positive water-balance.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

REPORT ON THE SLOW SAND FILTRATION PROJECT

AUTHOR(S)
E.L.P.Hessing (Leidschemdam)

The internationally coordinated research and demonstration project on Slow Sand Filtration (SSF) is developed by the WHO/International Reference Centre for Community Water Supply and Sanitation (IRC), as part of a programme on the integral transfer of knowledge and experiences on appropriate technologies for water supply and sanitation in developing countries.

The objective of the project is to promote the application of slow sand filtration for the preparation of drinking water. Slow sand filtration is a simple, efficient, and reliable method for the biological purification of water and is very appropriate for application in developing countries.

A programme for applied research and development as well as for the demonstration of the process under local conditions, work is carried out on the basis of international collaboration between eight developing countries: Colombia, Ghana, India, Jamaica, Kenya, Pakistan, Sudan and Thailand.

The programme is divided into two phases:
In the first and preparatory phase applied research on pilot units, field investigations on existing plants, literature studies and additional organizational activities have been undertaken by various participating institutions in developing countries.
In the second phase of the project the possibilities of applying slow sand filtration in developing countries are further developed. Full scale village demonstration plants are constructed in several rural villages under various local conditions. These plants will be used for demonstration purposes and further investigations. Towards the end of the project special seminars will be organized, directed to the transfer of knowledge to other developing countries and to the international community. Actually, the project is a demonstration to and a demonstration by developing countries at the same time. 2...

Slow sand filtration is a purification process in which the water to be treated is passed through a porous bed of filter medium. During this passage the water quality improves considerably through the reduction of the number of micro-organisms (bacteria, viruses, cysts), the removal of suspended and colloidal material and changes in its chemical composition. In a mature bed a thin layer called the Schmutzdecke forms on the surface of the bed. This Schmutzdecke consists of a great variety of biologically very active micro-organisms which break down organic matter, while a great deal of suspended inorganic matter is retained by straining. The slow sand filtration process is essentially distinguished from rapid sand filtration by the Schmutzdecke and the purification processes which take place in this thin surface layer.

Basically, a slow sand filtration unit consists of a box, containing a supernatant raw water layer, a bed of filter medium, a system of underdrains and a set of filter regulation and control devices.

The purification starts in the supernatant raw water layer where large particles will settle onto the filter bed and smaller particles may agglomerate to settleable flöcks due to physical or (bio) chemical interactions. However, the major part of the removal of impurities and the considerable improvement of the physical, chemical and bacteriological quality of the raw water takes place in the filter bed and especially in the Schmutzdecke at the top of the filter bed. In this top layer there is an abundance of micro-organisms such as algae, plankton, diatoms and bacteria, which, through their tremendous biological activity, break down organic matter.

Slow sand filters do not function properly if the raw water has a high turbidity. If the average daily turbidity of raw water is more than 10 NTU pre-treatment is recommended. Pre-treatment is indispensable if the turbidity of the raw water has an average value of more than 50 NTU for periods longer than a few weeks or values above 100 NTU for periods longer than a few days.

The simplest and most appropriate pre-treatment systems are river bed filtration, storage and plain sedimentation. Other suitable pre-treatment techniques are rapid "roughing" filtration and horizontal-flow coarse-material pre-filtration.

3...

In the past two years R & D work has been carried out on the performance of the process under local (tropical) conditions in developing countries. Among the subjects studied were:
The effect of intermittent operation, high loading of the filters, media size, filtration rate, shading, and simple pre-treatment methods. Preliminary results of this work have been reported in country reports.

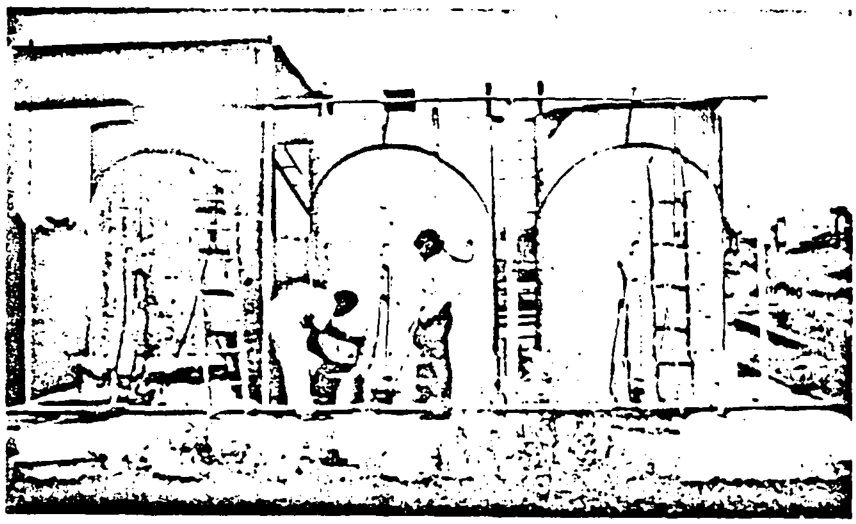
Slow sand filtration has been proved to be a reliable drinking water treatment method, also under tropical conditions, and appropriate for application in developing countries. However, further research and development work is required to improve the performance of the filters.

Watercompanies in Europe are encouraged to make available their knowledge and experience for transfer, application and adaption in developing countries, not only on slow sand filtration but also on other appropriate technologies, such as bank filtration, artificial recharge and other ground water recovery and treatment processes.

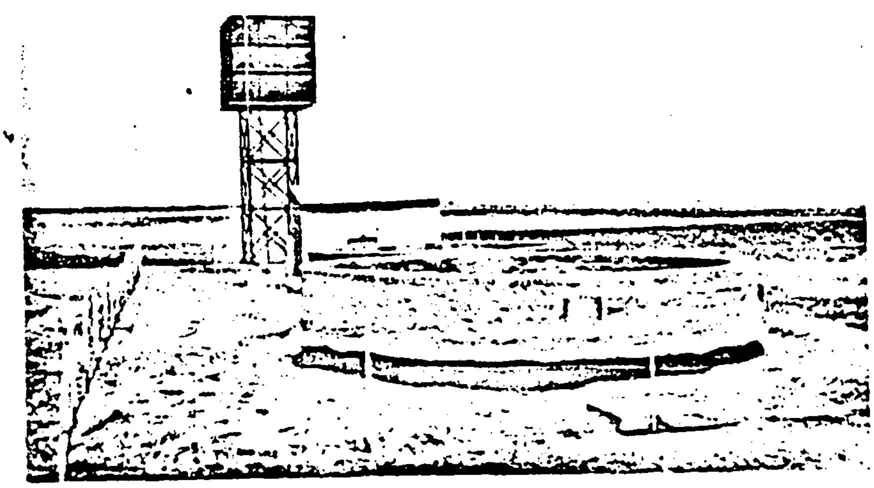
It is the task of the IRC to assist in the transfer of knowledge and exchange of information in the field of Community Water Supply and Sanitation.

4...

Abbildung(en)



Slow sand filtration pilot unit, Nagpur, India (National Environmental Engineering Research Institute).



Circular brick masonry filter, Gezira-Region, Sudan (background: pumphouse and overhead-tank).

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Experiments with infiltration methods in the Hessian Ried area

AUTHOR(S)

N. Wolters (Darmstadt)

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14-18 MAY 1979

TITLE

THE ALBIEN AQUIFER IN THE PARIS REGION NEW POSSIBILITIES OF EXPLOITATION DUE TO ARTIFICIAL RECHARGE

AUTHOR(S)
A. Houdaille (Paris)

The Albien aquifer extends under most of the Parisian Basin (France) at a depth of 500 to 700 m in the Paris Region. This aquifer constitutes a major water reservoir of excellent quality. Since 1953 the exploitation of the reservoir in the Paris region has been limited and strictly controlled.

Due to the great interest in this aquifer it was thought that artificial recharge would permit a more free exploitation. Nonetheless artificial recharge of a deep aquifer raises complex technical problems due, in particular, to the individual properties of the water (i.e. temperature, pressure, chemistry). In order to determine the feasibility of exploiting this aquifer, detailed studies and experiments were performed over the last 10 years:

- Preliminary studies to determine the behavior of the aquifer when injected with surface water (hydrogeology, compatibility of the aquifer water with the injected surface water),
- Economic studies on the relative merits of the different ways of artificially recharging the aquifer.
- Short-term recharge tests of 48 hours and 15 days respectively.
- A long-term experiment during which approximately 500,000 m^3 of water were injected via a bore-hole during a 6 month period followed by pumping over a period of nearly one year.

The results of these experiments will be presented in the expose with a view to shedding new light on the exploitation Albien captive groundwater.

Figure 1: Diagram of the Apparatus Used For Artificial Groundwater Recharge

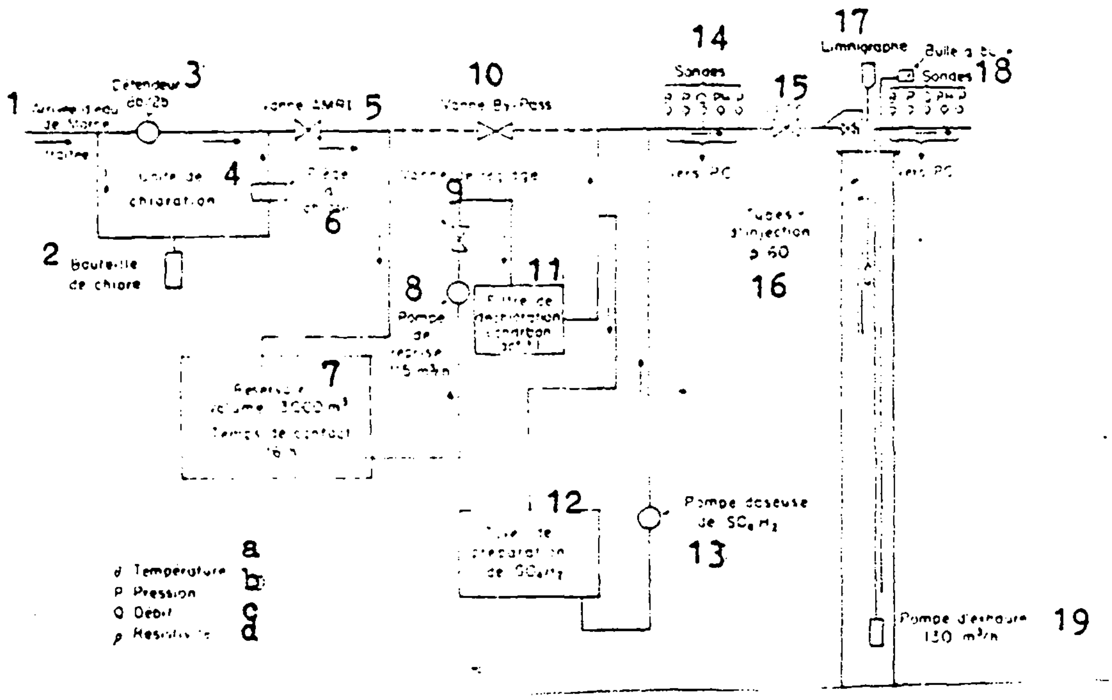
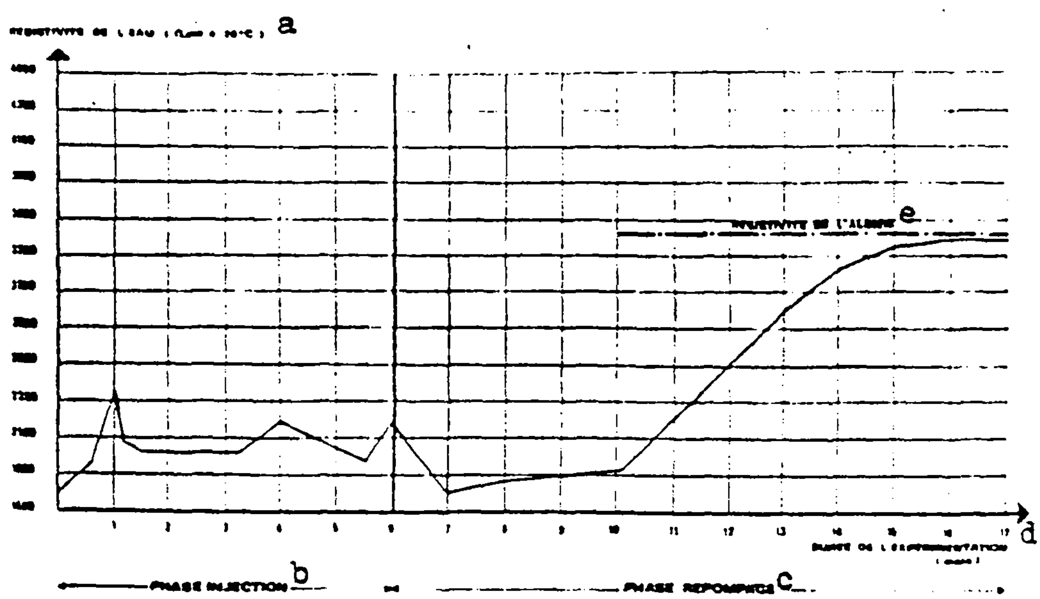


Figure 2: Water Resistivity Change During Experiments



Figure(s)

Key to Fig.1

1 Intake of treated Marne River water
2 Chlorine supply
3 Pressure-reducer 8b/2b
4 Chlorination unit
5 AMRI gate
6 Chlorine trap
7 Reservoir (Volume 3000 m^3)
Contact time: 16 hours
8 Acceleration pump (115 m^3/h)
9 Regulating gate
10 By-Pass gate
11 Dechlorination filter (activated carbon)
12 SO_4H_2 preparation tank
13 SO_4H_2 dosaging pump
14 Probes
15 Gate
16 Injection tubes (ø 60)
17 Limnigraph
18 Probes
19 Vacuum pump (130 m^3/h)
a Temperature
b Pressure
c Flow
d Resistivity

Key to Fig.2

a Water resistivity (Ω cm at 20°C)
b Injection phase
c Pumping phase
d Time (in months)
e Albien resistivity

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE Qualitative and quantitative improvement of drinking water resources through artificial groundwater recharge

AUTHOR(S)
H. Frisch, W. Kriele (München)

Lower Frankonia is a region of Bavaria with a drinking water deficiency.
In 1972/73 a plant for augmentation of water supply was brougth into production. Its capacity at this time is about 1,1 mio. m^3 of water per annum. An increase in capacity to a total of 2,0 mio. m^3 per year is planned for.
To accomplish this, 10 recharge basins of 1300 m^2 surface area and 20 wells are needed. Out of these 4 recharge basins and 11 wells have already been established.

The recharge basins are situated at the edge of the valley floor. The wells have been drilled between the recharge basins and the Main river. The aim of this spatial arrangement is an augmentation of water supply and an improvement in quality of the highly mineralised groundwater rising from the Muschelkalk rock basement and circulating in the quarternary Main valley aquifer, by recharging the aquifer with softer water from the Main river.
The aquifer consists of sand and gravel. These deposits reach a total thickness of 6 to 7 meters. The grain size of this quarternary cover generally increases towards its base. Jointed and groundwater filled rocks of the "Oberer Muschelkalk" form the base of the sand and gravel cover.
The groundwater bearing sand and gravel deposits are overlain by 1,5 to 2,0 m of alluvial loam deposits.
The thickness of the water bearing sand and gravel is about 5,5 m at the average. Permeability coefficients range from 10^{-5} to 10^{-3} m/s have been established on the basis of grain

size distribution, hydraulic borehole tests and well pumping tests.

Employing tracer elements, dominating mean groundwater velocities of 0,10 to 0,37 m/h have been determined between recharge basin and the wells during production. The time needed by the water to seep from the recharge basins to the wells could thereby be determined. Conclusions about the efficiency of the plant and the qualitative improvement of the drinking water can be drawn from the already producing installation and from findings of the testing program.

The results obtained are used as source data in site selection for further recharge basins and production wells and the overall planning of the facilities.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Seepage of accumulated drain water for the maintenance of the natural ground water supply. - Planning and results as shown by the example of the air terminal Munich II

AUTHOR(S)
L. Blasy (Eching)

A new air terminal shall be erected in the vicinity of Munich.

In the flat ground there is, under the approx. 0,5 m thick soil layer, gravel as carrier of ground water to a depth of approx. 10 m. Underneath follows impermeable, cohesive soil. The ground water level lies approx. 1 m below ground and is inclined in the same direction as the ground level with a slope of 2,6 o/oo.

Thus, a broad ground water stream flows in the whole area in a thickness of approx. 9 m.

The level variations are of about 1 m so that at maximum levels the ground water rises up to ground at deep points.

The relatively uniform permeability coefficient of the ground water carrier is 0,003 m/s.

A permanent ground water lowering by means of open drainage ditches is planned above all for the central area of the air terminal; on the one hand, to enlarge the floor clearance of the ground water for protection against flood and frost, and, on the other hand, to obtain more hold-back storage volume for the rain water drainage in the open ditches.

The permanent ground water lowering extracts continuously ground water out of the soil.

As far as possible, the accumulated drain water shall be sinked back into the underground in order to counteract the continuous ground water supply deficiency and the connected far-reaching ground water lowering.

Afterwards approx. 300 l/s, distributed at a length of 4,3 km, shall be sinked in the area of the ground water underflow along the air terminal fence.

The water shall be distributed by a pump station, pressure line, distributor compartments with measuring, control and overrun safety boards; the seepage by a vertical spring well gallery.
In order to obtain the best relation between infiltration capacity and manufacturing costs of the well gallery, as many wells as possible were planned with the minimum acceptable drilling diameter. Out of this resulted 117 wells, each 10 m deep, with a filter pipe enlargement of 150 mm diameter. Consequently, the cheap wildcat well with 206 mm drilling diameter may be worked out. The gap between filter pipe and walls of borehole will not be filled with filter gravel so that a loosening of the walls of borehole is possible at desanding of the well.
Over the period of half a year alternative seepage tests were carried out in the project area: with an horizontal filter mislaid over a length of 150 m as well as with 4 vertical filters. These are the results:
The required pressure water level for the seepage of the wanted quantity amounts for both systems to approx. 1 m with safety margin and, therefore, passes up the ground in the unfavorable case. The banking-up curve, however, droops rapidly at rising distance of the infiltration point. Thus, an exchange of the humus topsoil and an artificial ground elevation with gravel is necessary within a radius of 5 m of the infiltration point.
Whereas the hazard that the wells may ocher is very small due to the water, which is poor in iron and rich in oxygen, it must obviously be guaranteed that the ground water is filtered prior to infiltration since otherwise the wells must be pumped clean too often.
At present the developed planning is being finalized.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Artificial groundwater recharge and river water treatment

AUTHOR(S)

J. Bize (Paris)

During the last 4 to 5 years in France an increasing demand from the water distributors (communal water boards, large companies) for measures of artificial groundwater recharge with river water which also effects a purification of the river water has become apparent.
The concept includes: areas with large alluvial deposits, infiltration through slow sand filters, recovery of water from well batteries at small distances etc. These installations are similar to those in the Ruhr valley, for example, but they are quite different as far as their mode of operation and their role in the river water treatment are concerned. The desired and usually achieved aim is the production of tap-water (or water needing only a final sterilization) directly from raw water during which no treatment other than a partial sedimentation (sand traps) is carried out. A certain degree of silting is desired which is necessary for effecting a very slow percolation rate through a system of mud + sand + alluvions and for supporting a particular type of flow (unsaturated) which is favourable for the natural purification processes (see diagram).
Following an analysis of the observed developments, model studies carried out in the valley of the Moselle, Garonne and Vienne are presented and discussed. A practical application based on these studies has been started.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Some effects of artificial recharge in the Lea Valley, London, England

AUTHOR(S)

K.J.Edworthy and J.B.Joseph (Medmenham)

It is estimated that 1030 × 10^6 m^3 of the Tertiary sands/Cretaceous Chalk aquifer system was dewatered by over-abstraction in the 150 years up to 1965. In the early 70s the Lea Valley in north London was chosen for artificial recharge experiments because of the good transmissive qualities of the Chalk there, and the large volume, 175 × 10^6 m^3, of dewatered aquifer available.

Experiments during 1972-74 showed that although direct recharge of the sands was not feasible, indirect recharge through the Chalk was. At one site, however, recharge of fully-treated water resulted in very high concentrations of some determinands in samples from observation boreholes in the sands; $SO_4^{=}$ rose to more than 3000 mg/l. Water subsequently abstracted from the Chalk showed significant, although less, contamination with the same determinands, because of drainage of water from the sands; the maximum $SO_4^{=}$ concentration in the abstracted water was about 580 mg/l.

In 1978 an operational prototype scheme employing twelve dual-purpose wells and boreholes was used to recharge 52 × 10^6 m^3/d. Detailed studies were made of the Tertiary strata prior to recharge, and three sites were selected for comprehensive investigation of water movement and quality changes in the aquifer system throughout the recharge/abstraction cycle. The sites were instrumented before recharge began, so that piezometric levels and groundwater samples could be obtained from a number of horizons. (See Fig.1.).

At the start of recharge water moved rapidly into the lowest intervals of the sand aquifer. However, clay strata within the sands appear to have retarded continuing upward movement. When abstraction began the water levels in the sands responded in a manner characteristic of a confined aquifer. Unconfined conditions became established within three to seven days, however, at the three intensively monitored sites.

Detailed monitoring of groundwater chemistry and environmental tritium concentrations has shown that, during recharge, the native Tertiary sands groundwater is displaced upwards first by Chalk groundwater and subsequently by recharged water. The recognisable reversal of this sequence of changes during the static and abstraction phases shows that there is little mixing of waters in the short term. During abstraction it was found that the groundwater quality within the Tertiary sands deteriorated rapidly, especially with respect to calcium, magnesium and sulphate, at each sampled level immediately prior to the dewatering of that level. Nevertheless, pumped water quality was better than recharged water quality at eight sites after the first two days abstraction. Calculations based on calcium and chloride ion concentrations indicate that, when 50% of the volume recharged had been abstracted, the pumped water comprised about 60 to 70% native Chalk water, compared with about 30% native Chalk water when pumping started.

The results of the investigation have shown that the very large volume of dewatered sands aquifer can be recharged artificially through the underlying Chalk aquifer. Although slight groundwater quality deterioration can be expected in some localities as a result of artificial recharge, the overall significance of such changes is confidently expected to be small.

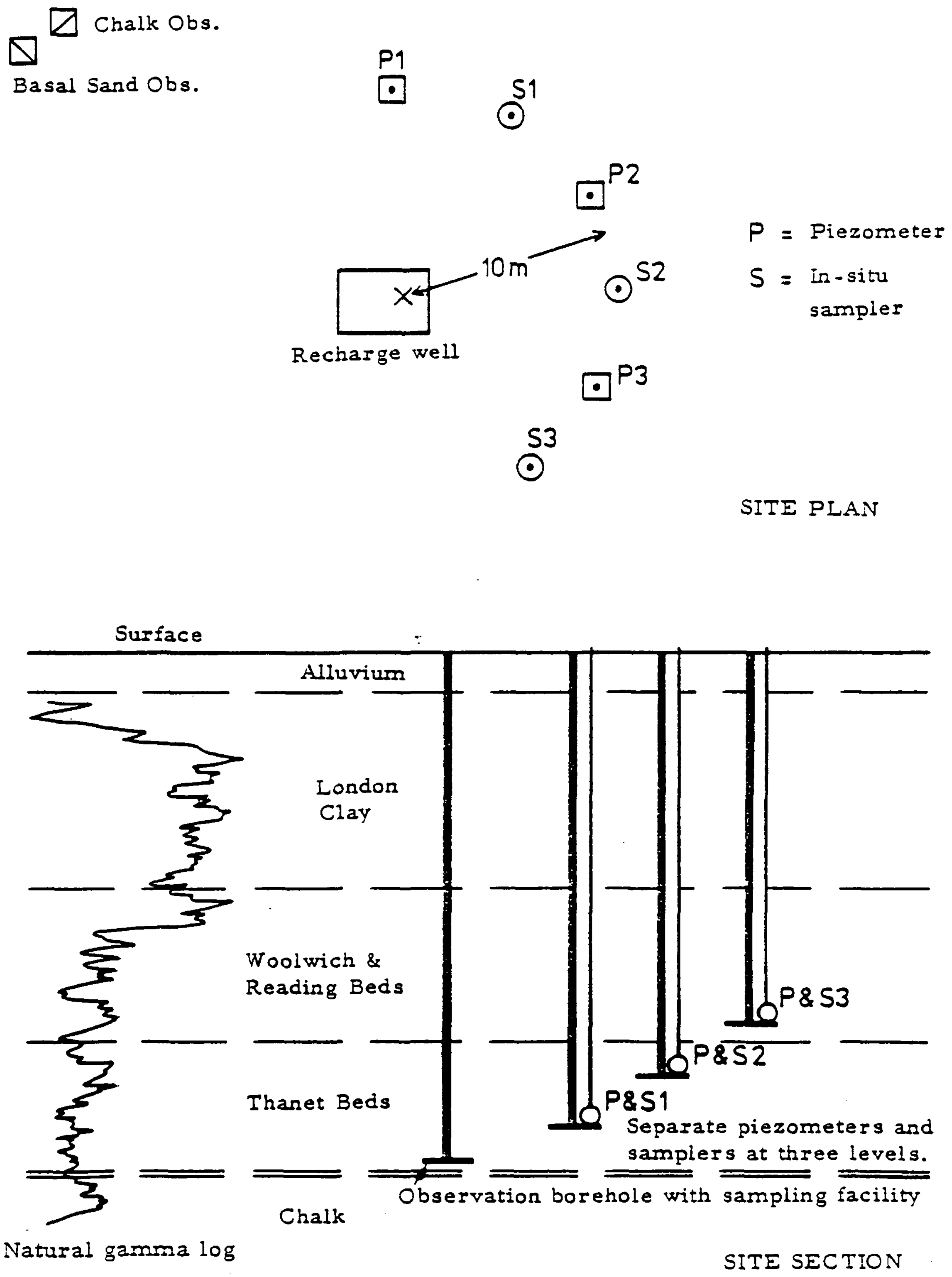


Fig. 1. Instrumentation layout at a site in the Lea Valley.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Experiences with artificial groundwater recharging by recharge valves in Switzerland

AUTHOR(S)

B. Hurni (Liestal)

Since nearly three years, in the lower part of the Birs-valley(north-western part of Switzerland) the groundwater is recharged artificially. First experiences of this recharging are presented and discussed.
The riverwater (up to 0,5 m^3/s) is refined by sedimentation and by gravel- and sandfiltration and then added by recharge valves to the groundwater. Recharge valves are needed because there is a nearly unpermeable layer covering the groundwater. Efficiency of this refinement and properties of the filtration are discussed.
Suspended particles may plug up the recharge valves; observations about maximum load and capabilities of regeneration of these valves are described and interpreted.
On its way in the underground the quality of the recharged groundwater is improved once more. Chemical, physical and bacteriological properties in function of flow distance and time are given and approximated by simple models.
Hydrogeological facts of this aquatic system will be described at this symposium by Schmassmann.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Research with experimental recharge wells in Holland

AUTHOR(S)

T.N. Olsthoorn (Rijswijk)

In the Dutch dunes along the North Sea, artificial groundwater recharge has been applied for over 20 years. However, because of horizontal aquicludes only a portion of the recharge water reaches the lower aquifers. Stock building and replenishment are therefore limited to a relatively thin part of the aquifers available. Using recharge wells it would be possible to include these lower aquifers in the recharge operations in the area. (See fig. 1 and 2.) However, such wells will not be used in practice until it is proved that they will work successfully.

Since 1970 together a number of waterworks, governmental services and an industry have been making researches into the feasibility of wells to recharge purified surface water. Since 1974 these investigations are connected with the KIWA-institute. Much attention has been payed to quality alterations of the aerobic recharge water during its passage through the originally anaerobic aquifers. The emphasis of the researches, however, has been layed on the clogging aspects of the recharge wells. Because of the fineness of the aquifer material ($d_{10} \approx 0.15$ mm; permeability $k \approx 0.2.10^{-3}$ m/s) there is an appreciable danger of clogging, even though purified surface water is used.

The tests are carried out with wells having screens of 10 to 20 m in length in bore holes of 0.2 to 0.8 m in diameter in which 10 to 60 cubic m of water is recharged per hour.
The test wells are located in IJmuiden (in use from 1970 until 1974), The Hague (2 wells in use from 1973 and 1974 respectively), Castricum (since 1975) and Vogelenzang (since 1976). (See fig. 3.)
Also in Vogelenzang there is a model recharge well (in use from 1977 until January 1979) placed in a 6 m high and 2 m diameter steel sand tank.

The well at Castricum has been placed in the deep (third) aquifer just above the salt water interface. The other wells have their screen in the middle, second aquifer (see fig. 2). The treatment of the water to be recharged varies between a simple rapid sand filtration and an extensive purification to drinking water quality.

Though the well with the most extensively treated water did not clog at all during six years of continuous operation, others became blocked within several months. Part of the investigations are concerned with finding a treatment as simple as possible that prevents clogging. Some clogging is acceptable if the wells can be cleaned in some simple way and if this cleaning procedure can be repeated many times. This part of the researches is carried out with water from existing production plants. The wells are backpumped regularly.

Where a complete restoration of the capacity of a clogged well is considered desirable, a severer redevelopment method may be necessary like e.g. backpumping during several months, backpumping discontinuously using compressed air, or by making use of chemicals such as hydrochloric acid, chlorine or polyphosphates. It appeared that with such means a next to complete restoration is possible.

In practice one has to weigh the cost of pretreatment against the frequency and method of redevelopment and to the writing off time of the recharge wells. The Dutch dune area is a nature park and therefore operations related to redevelopment and replacement of the wells will have to be restricted to a minimum.

Figure(s)

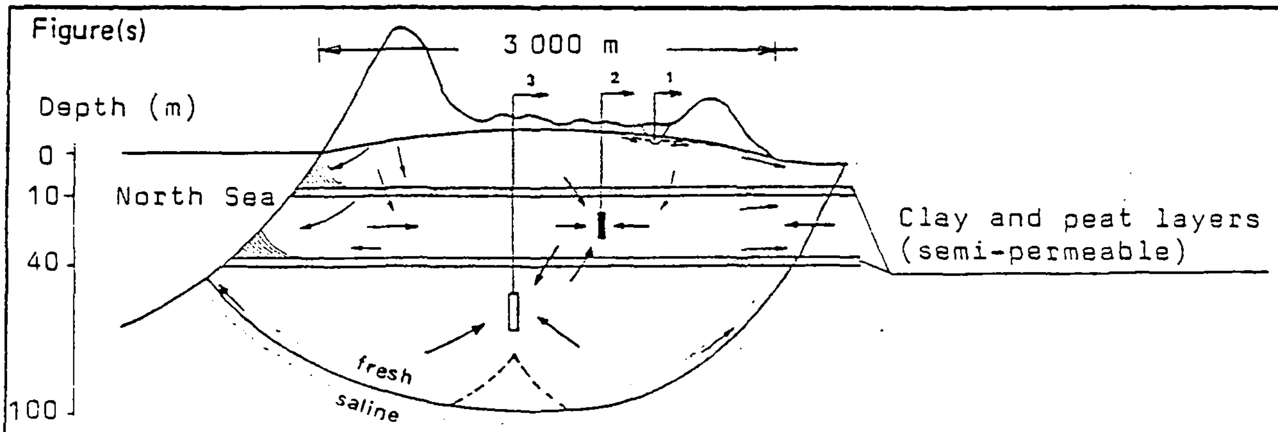


Fig.1: Cross section of the dune area with different ways of ground-water abstraction.

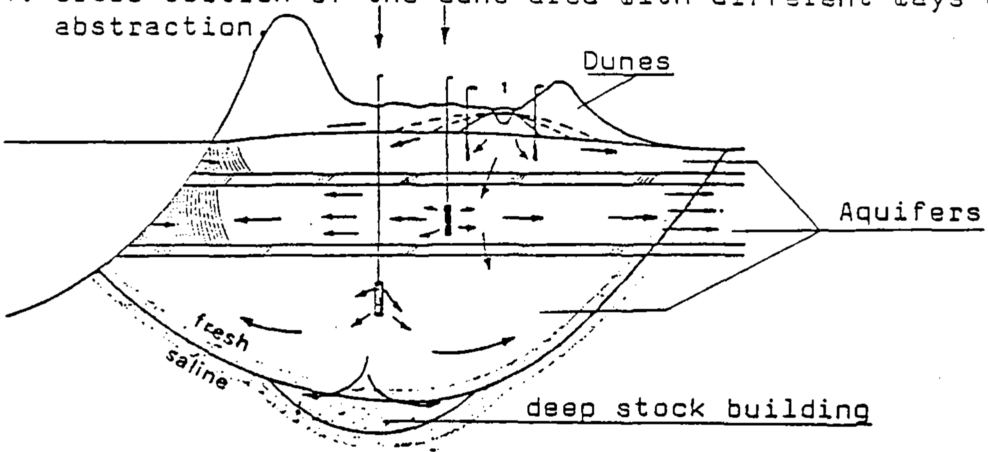
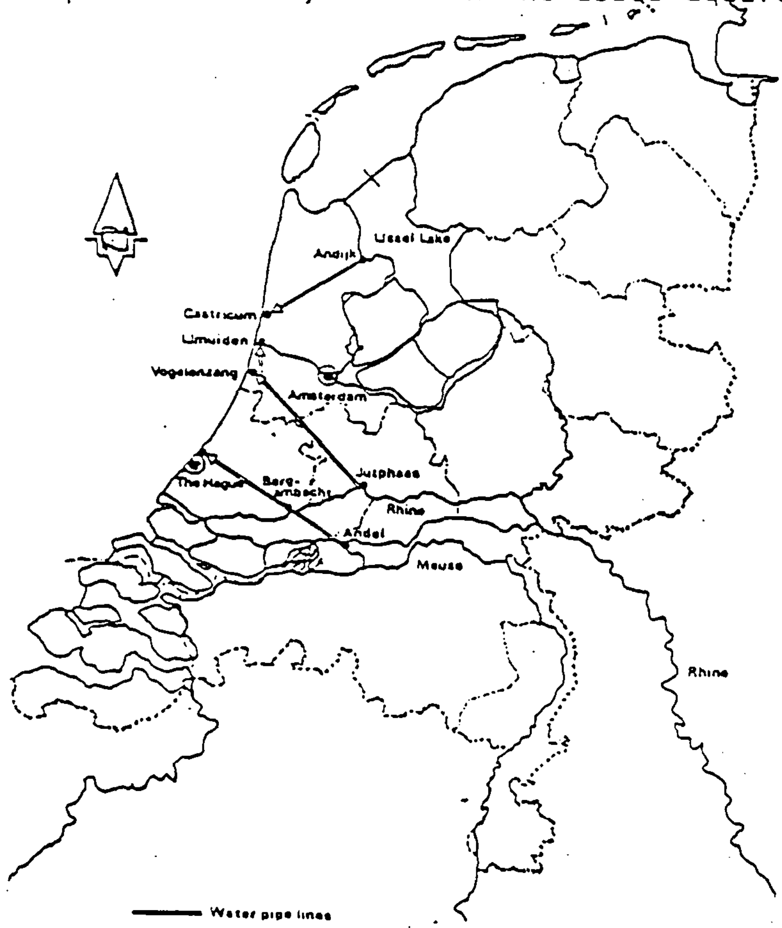


Fig.2: The applied recharge by ponds and canals and the imaginable replenishment by wells in the lower aquifers.



Fif.3: Locations of recharge and origin of the recharge water.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

HORIZONTAL FILTER PIPES FOR GROUNDWATER RECHARGE PRINCIPLES AND IMPLEMENTATION

AUTHOR(S)
E.P. Nemecek (Graz)

In Austria, industry has been forced to turn from groundwater to bank filtered water wherever possible. If in future, treated surface water is to be used for drinking water purposes, it would be preferable to filter it through the upper ground surface of groundwater conservation areas. The two possible methods of doing this is by infiltration or by submersion whereby the former is preferable; the latter, using unsaturated flow is preferred as it provides for a prolonged infiltration time.
The theory of infiltration in the unsaturated zone will be covered followed by a presentation of the processes involved in the unsaturated zone below the "infiltration basin with 'breathing' layers" and below horizontal filter pipes. It will be demonstrated that an unsaturated flow is hardly possible when water is introduced via vertical filter wells.

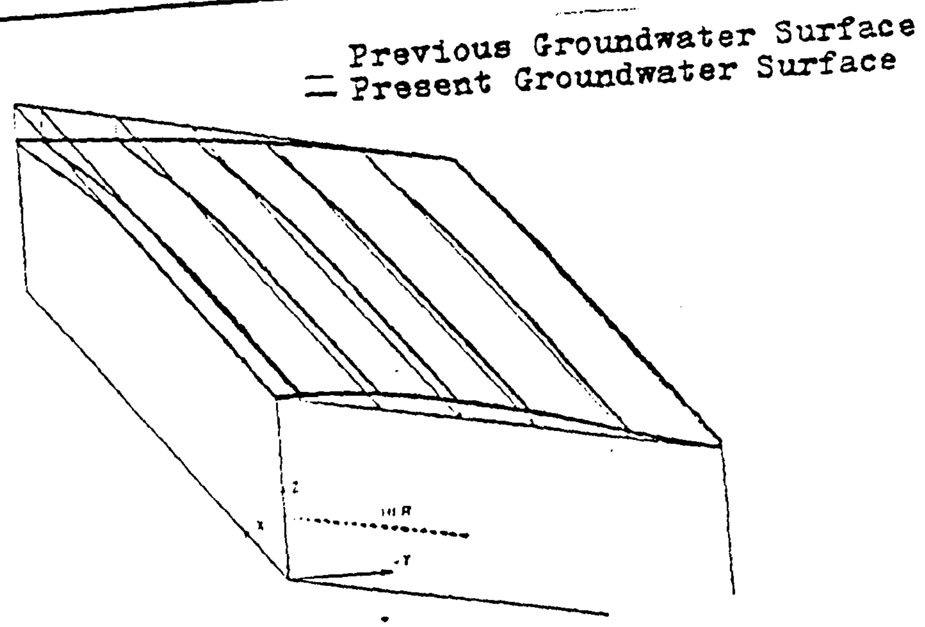
The groundwater hydraulics of infiltration wells (where water is introduced via vertical filter and horizontal filter wells below the water table) in areas with negligible groundwater flow will be compared to those in areas of strong groundwater flow.
The discharge from horizontal filter pipes during groundwater recharge in areas of high-gradient groundwater flow will be shown using the example of Vienna; the Vienna subway cuts through and hinders groundwater flow and made it necessary to divert the groundwater from the dammed side to the flow side.
With the aid of a three-dimensional sand model, it was possible to observe the discharge from the horizontal filter

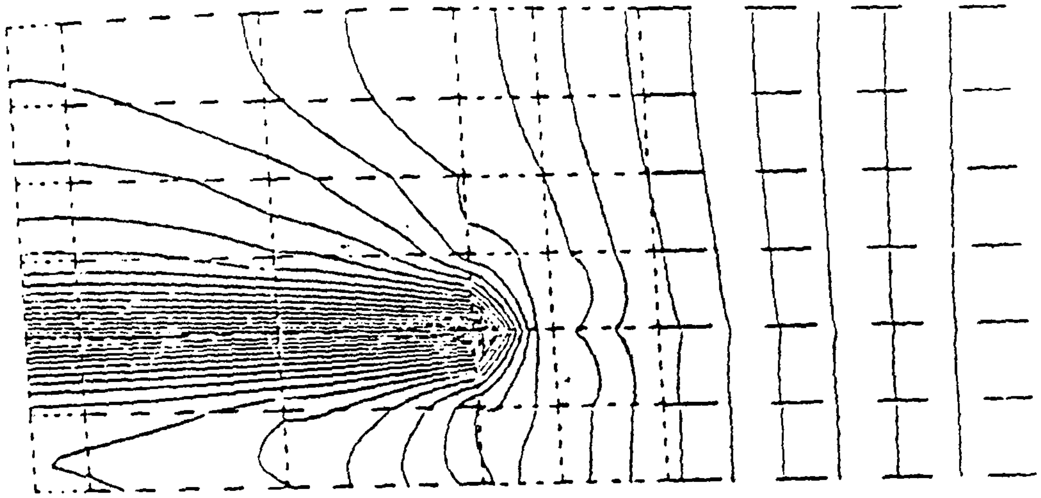
pipes. Using an electronic calculator, the basic parameters were then varied and the potential curves in the characteristic levels were plotted. The form of the water table in the recharge areas in close proximity to the horizontal filter pipes was particularly noteworthy.

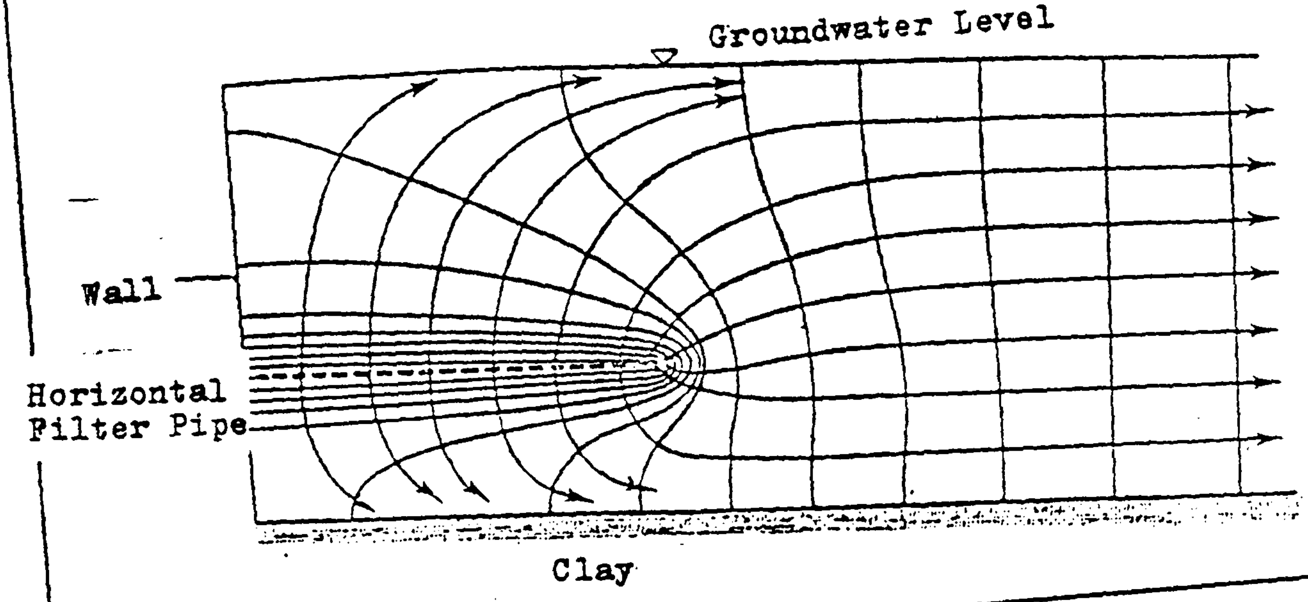
General findings were established which are also valid for groundwater recharge via horizontal filter wells.

The discharge from radial horizontal filter pipes is presently being studied using finite elements. At the same time, equations are being developed both for the exploitation of groundwater using horizontal filter pipes and for groundwater recharge..

Abbildung(en)







INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITEL

Groundwater Recession and Induced Recharge by Disposel Wells in protectiv Zones of Water supply plants.

AUTOR (EN)

H. Schneider (Bielefeld)

Summary

Groundwater recessions in course of engineering constructions (deep cellars, deep garages, subways etc.) are more and more necessary.

In the past the pumped water exclusively has been drained off into neighbouring brooks, rivers ore sewage systems.

In spite of the increase of using the groundwater reserves, especially in overcrowded regions, this annaturel discharge of groundwater interferes with the groundwater balance.

The groundwater taken from the aquifers sometimes come up to many millions m³ per year. This has a very negativ effect in the neighbourhoud of industrial and public wells. Therefore the demand on artificial recharge of the pumped water will be enforced by government.

If the geohydrological conditions are suitable induced recharge by disposel wells can be practised, even if water has to be pumped in a circle between the disposel and the recessions wells.

Especially attention has to be devoted to the construction of the disposel and recession wells and to the chimistry of the pumped ground-water (Fe and Mn.).

These problems shall be illustrated by an example from the Mannheim region.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Special problems of the pretreatment of Rhine-water before infiltration

AUTHOR(S)
K. Haberer (Wiesbaden)

It is an advantage of the artificial recharge (in comparison to the bank filtration) that the raw water can be pretreated and thus the pollution of the subsoil can be decreased.

Former the pretreatment aimed only at the removal of serveral constituents disturbing the operation of the artificial recharge, as Iron-, manganese- and ammonium-ions, particulate matter and bacteria.

Today the objective of the pretreatment is to support the removal of special pollutants from water to meet the drinking water standards, if the efficiency of the subsoil is not sufficient. Furthermore the aim is to preserve the adsorption and exchange capacity of the soil, and to support the efficiency of the microorganisms in the soil. Especially the biological non- degradable organic compounds have to be removed carefully by the physical-chemical treatment before or after infiltration. The most acute problems arise from organic chlorine compounds because these substances partially considered cancerogenic are not or only inadequately retained during subsoil filtration. Even granulated carbon filters show break-throughs, if the water quality changes.

Therefore the formation of haloforms with the pretreatment should be avoided. This may be done

- o by the removal of organic substances before chlorinating
- o by reducing the amount of chlorine or
- o by stopping the chlorination.

Methods are pointed out to solve the problems connected with the pretreatment of the raw-water inclusive the trend of the detention basins toward eutrophication. In the operation practice in Wiesbaden-Schierstein a newly developed two-step-flocculation has proved to be successful. By precipitation with $Ca(OH)_2$ at pH 10,5 and flocculation with $FeCl_3$ at pH 6,0 more than 90 % of highmolecular organic acids are removed.

By this and by reducing the dosage of chlorine the formation of haloforms is decreased. At least in the summer months the ammonia is totally oxidized biologically in the sand and activated carbon filters.

Special brands of powdered activated carbon which are applied in the newly developed powdered carbon filtration process proved to be especially effective in the removal of haloforms from water.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

TREATMENT OF WATER TO BE USED FOR GROUNDWATER RECHARGE

AUTHOR(S)
Y. RICHARD and B. CAPON (Rueil)

Surface water of poor quality is often used for groundwater recharge; treating this water for human consumption is very expensive.

These surface waters are often polluted not only by organic matter of various origins, and mineral and organic micro-pollutants but also contain high amounts of nitrogen and phosphorus.

Water treatment aids the removal of suspended matter which may clog the recharge tanks.

The pre-treatment of the water should improve the quality of the recharge water such that only a finishing role is left to the soil. Pre-treatment should thus eliminate organic and chemical pollution as much as possible. Treatment also allows for the storage of good quality water in the aquifer.

Attempts at chlorinating the treated water before returning it to the recharge tanks were also made.

At the Croissy plant which treats Seine River water downstream from Paris, the pre-treatment consists of coagulation, flocculation, decantation and filtration.

At the Moule plant (near Dunkerque), treatment with activated carbon is necessary due to the organic pollution. In the first stage of filtration, granulated activated carbon is used. Hence, the water passing through the recharge galleries is free of organic matter and thus does not greatly affect the quality of the groundwater (See Fig. 1, Tables 1 and 2).

At the Moulle plant, treatment is performed by decantation using a mud bed decanter. The advantages of treatment by flotation were seen after tests were performed at the plant, and an extension of the plant to include flotation is currently under construction..

Figure(s)

TABLE 1

Key to Fig. 1:

A	Screen (1.5 mm openings)
B	Contact tank
C	Distribution spillway
D	Pulsator flocculator-decanter
E	Aquazur V filter with granulated activated carbon
F	Flocculator
G	Flotator
H	Pressurization
I	Storage of filtered water
J	Return to recharge tank
K	Return to distribution net
L	Flotation of mud from Pulsator
M	Storage of mud after flotation
N	Tank for the addition of lime
O	Filter press
1	Addition of chlorine
2	Addition of aluminum sulfate (or coagulant)
3	Addition of activated silica (or adjuvant)
4	Addition of flotation adjuvant)
5	Addition of lime

Figure(s)

Table 2: Results

	La Houlle (raw water)	Recharge water (filtered water)	Bore-hole water influenced by re-charge	Bore-hole water not influenced be recharge
Temperature	1 - 25°C	2- 25°C	12 - 14°C	11 - 11.5°C
Turbidity JTU	3 - 20	0.2-0.3	0.1- 0.2	
Organic Matter measured in acid milieu mg/l O_2	5 - 15	0.5-3	0.6- 1.0	0.1- 0.5
pH	7.5-8.7	6.3-6.7	7.40	7.1-7.4
TAC in °f	20 - 30	10 - 15	18 - 24	25 - 30
Chloride mg/l	40 - 70	50 -120	40 - 80	25 - 35
Sulfate mg/l	40 -100	70 -120	40 - 90	10 - 16

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Surface water pre-treatment - Simple procedures as a first step before recharge of ground water

AUTHOR(S)
K. Kötter (Gelsenkirchen)

The deterioration of surface water quality and increasing demands relating to the quality and amount of drinking water have caused Gelsenwasser too to look for new methods for surface water pre-treatment and to test them. In 1976 Gelsenwasser started two comprehensive experiments in the precipitation of phosphates and other chemical water compounds in available reservoirs and sedimentation basins. For two and a half years the flocking agent $FeCl_3$ was added into the inflow of a separate impounding basin of the reservoir Haltern in Münsterland. Nowadays we use aluminium-chloride. The basin contains 4 million cubic metres. The theoretical retention time in the impounding basin is about 20 days. The phosphate concentration, the dissolved and particulate organic substances are reduced effectively by this flocculation. The developement of planctonic algae is diminished, too. The purified water runs from the impounding basin into the recharge basins, which have together a size of 285.000 m^2.
In the water catchment area of Witten, a water works in the Ruhr district, we have the possibility of flocculation in two small sedimentation basins. The theoretical duration of the settlement is 12 hours. The flocculant is a mixture of aluminium and ferric salts. We have compared the water quality of recharge basins which have been fed with precipitated water to those which had been filled with water without pre-treatment. The increased water quality after pre-treatment was also found in the recharged ground water.
Surface water pre-treatment before recharging offers not only advantages for the operation but also for the drinking water quality.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Possibilities of artificial groundwater recharge and storage in the Federal Republic of Germany

AUTHOR(S)
K.-D. Balke, H. Schmidt (Tübingen)

By 1985 water consumption in the FRG will have exceeded mean low runoff of 140 mm/a ≙ 34 mrd m^3/a (LIEBSCHER, 1977). Long term fullfilment of water demand will be possible only if runoff is used repeatedly by intercalation of additional water cycles. Artificial groundwater recharge is one of those practices already in use today.

Increasing the existing quantity of groundwater by artificial infiltration of crude water into the ground has two principal purposes:

- artificial groundwater recharge for immediate use and regulation,
- artificial groundwater storage for medium to long term supply.

Possibilities of artificial groundwater recharge are controlled by conditions within the system water (surfacewater/groundwater) = aquifer:

- hydrologic and hydrochemical conditions furnish information on quantity, quality, and duration of availability of crude water suitable for infiltration,
- hydrogeological conditions furnish information on quantity and quality of artificially recharged groundwater. Eventual utilization of an aquifer for groundwater recharge or groundwater storage is determined by quantity of water and its rate of removal, plus duration of availability of infiltrate.

Starting from a genetic classification of porous aquifers, essential hydrogeologic parameters of groundwater recharge are specified for typical aquifers. The parameters involve:

- regional distribution/prospecting
- size and geometry
- outer and inner structure
- nature of clastic material
- type and extent of utilization.

Natural restrictions against artificial groundwater recharge may consist of super_imposed peat layers, seawater intrusions, ascent of saline groundwater, mineralization of groundwater, confined groundwater, etc. Restrictions caused by human influence on aquifers consist of contamination, overstrain, competetive utilization, etc.

Some examples from selected areas illustrate relations between the essential parameters and artificial groundwater recharge, and the influence of competetive utilization.

On the basis of negative and positive factors controlling artificial groundwater recharge, a general map of the FRG (scale 1:1 mio) has been designed. By means of graduated evaluation, areas have been outlined wherein artificial groundwater recharge or groundwater storage appears practicable.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Fundamental Hydrogeological Conditions for Artificial Groundwater Recharge in River Valleys of Northwestern Switzerland

AUTHOR(S)
H. Schmassmann (Liestal)

Specific geological conditions are essential for artificial groundwater recharge as well as optimal arrangement of recharge works. This is discussed conclusively in two case histories from the northwest of Switzerland.

In the valleys of northwestern Switzerland the relief of the base of gravel aquifers is formed through deep erosion of the pleistocene rivers. Thus the position of the aquifer-base and the consequent thickness of groundwater may vary considerably within short distances. It is essential to thoroughly clarify these conditions in advance by means of geological investigations before any schemes can be entered upon.

As is usual in the gaining of gravel groundwater the preferential sites of the wells for pumping artificial recharged groundwater are situated above the deepest parts of the pleistocene river channels. However, the artificial recharge can also be carried out over peripheral zones of the natural groundwater or even beyond this area provided that gravel of adequate thickness and permeability occurs above the plane of groundwater surface. This allows optimal arrangement of recharge and catchment plant, especially as regards best extended flow distances and thus of the available best water qualities.

If a rock aquifer occurs beneath a gravel aquifer, being directly connected with it, it may exercise considerable influence in the hydraulics of groundwater runoff from the recharge area, thus facilitating a recharge in peripheral zones of gravel groundwater.

In river valleys the possibilities of recharging gravel aquifer are often limited by the levels of surface waters, these being cut in the same gravel deposits. However, favourable hydrogeological preconditions for artificial groundwater recharge exist if situated in a valley in which a pleistocene river channel runs, the base of which is filled with gravel so that its groundwater is divided from the present-day river by an impermeable rock bar.

In postglacial valley bottoms, the usually highly permeable pleistocene gravel may be replaced by younger deposits of low permeability. Hence, on such a valley bottom the construction of recharge wells proved to be necessary, thus producing a connection with the deeper layers of highly permeable gravel. As regards the plans for the recharge wells, vertical differences in the permeability have been evaluated by means of various methods of infiltration and pumping tests, these yielding similar and comparable results.

INTERNATIONALES SYMPOSIUM
KÜNSTLICHE GRUNDWASSERANREICHERUNG
DORTMUND, 14. – 18. MAI 1979

TITEL

FIELD RESEARCH ON THE INFILTRATION OF SURFACE WATER INTO GROUNDWATER

AUTOR (EN)
O. Huppmann, J. Kohm (Karlsruhe)

Substances contained in surface waters are producing a clogging of waters-beds by percolation into the aquifer. Clogging causes an increasing of the hydraulic resistivity of porous media near the waters-beds and subsequently flow from the waters into the aquifer will be reduced. With different measuring methods the degree of an existing clogging and the development of clogging in time and space will be seized directly by:

a) research of permeability of the waters-beds;

b) determination of the distribution of the hydraulic potential below the waters-beds;

c) measuring the amount of infiltration water.

Applicability of these methods is limited.

ad a) Determination of permeability in laboratory is faulty among other things because of disturbance by getting the soil sample. To avoid this an appliance was developed basing on known procedures to measure in situ. The received results will be compared with laboratory determination to get the error caused by sampling. By taking a greater number of samples the variance of the permeabilities is considered.

ad b) A potential field will be formed in the subsurface due to soil permeability and difference of piezometric head between surface water and groundwater. Thus information is given on position and extension of the clogged part of the subsurface. The infiltration rate can be calculated by additionally using permeability. The variation in time of the potential field is registrated currently by an automatic platform. For recording the pressure head piezoresistive transducers are applied which seize as well saturated as unsaturated flow. In the case of unsaturated flow the water content is determined by gamma-ray logging.

ad c) Besides these indirect methods (essentialy parameters for modelling the groundwater flow) the infiltration rate is determined by measuring differences of river flow. Therefore plate weirs are installed. Infiltrometers (e.g. seepage meter by H. Bouwer) and lysimeters in the bottom of the waters give additional informations on the variation of percolation in time.

The mentioned methods are completed by measurements in the adjacent aquifer. The data evaluation is done by numerical groundwater models.

The described research should result in simple calculation methods for determining the infiltration rates.

Especially the effect of reliability and number of available data on the accuracy of the results will be emphasized.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14-18 MAY 1979

TITLE

Extension of the water supply capacity on North Sea islands by infiltration of treated waste- and stormwater

AUTHOR(S)
K. Wichmann (Hannover)

Expanding tourism on the North Sea coast and a generally growing domestic water consumption leeds to an increasing demand for drinking water.

So called "fresh water lenses" are forming a limited reservoir for the drinking-water supply an sandy islands. On marsh islands the local supply is depending on cisterns.

If the demand is exceeding the available pumping capacity, there are three possibilites to secure the water supply:

1. Construction of a pipe-line through the intertidal areas to the mainland establishing a connection between the water supply systems (e.g. Baltrum, Wangerooge, Nordstrand, Pellworm).

2. Artifical groundwater recharge by infiltration of treated waste- and stormwaters (e.g. Helgoland).

3. Desalination of sea- and deep groundwater (e.g. Helgoland).

Optimization of the building costs and operation economy may leed to a combination of these noted possibilities. The investigations carried out from the "Sonderforschungsbereich 79" of the University of Hannover are dealing with the optimal use of all fresh water resources an sandy islands. The work started with geological, hydrochemical and hydrological analyses of the substratum of Norderney Island as an example.

The watertypes and -qualities within and in the surrounding of a fresh water lens were determined. The determination of the groundwater recharge rate and the geohydraulic parameters made it possible to perform a mathematical simulation of the fresh water lens.

The first step on the way to an optimal use of the easily treated, high quality groundwater is to optimize the well configuration and pumping rates, so that the future damage to the fresh water lens will be as little as possible.

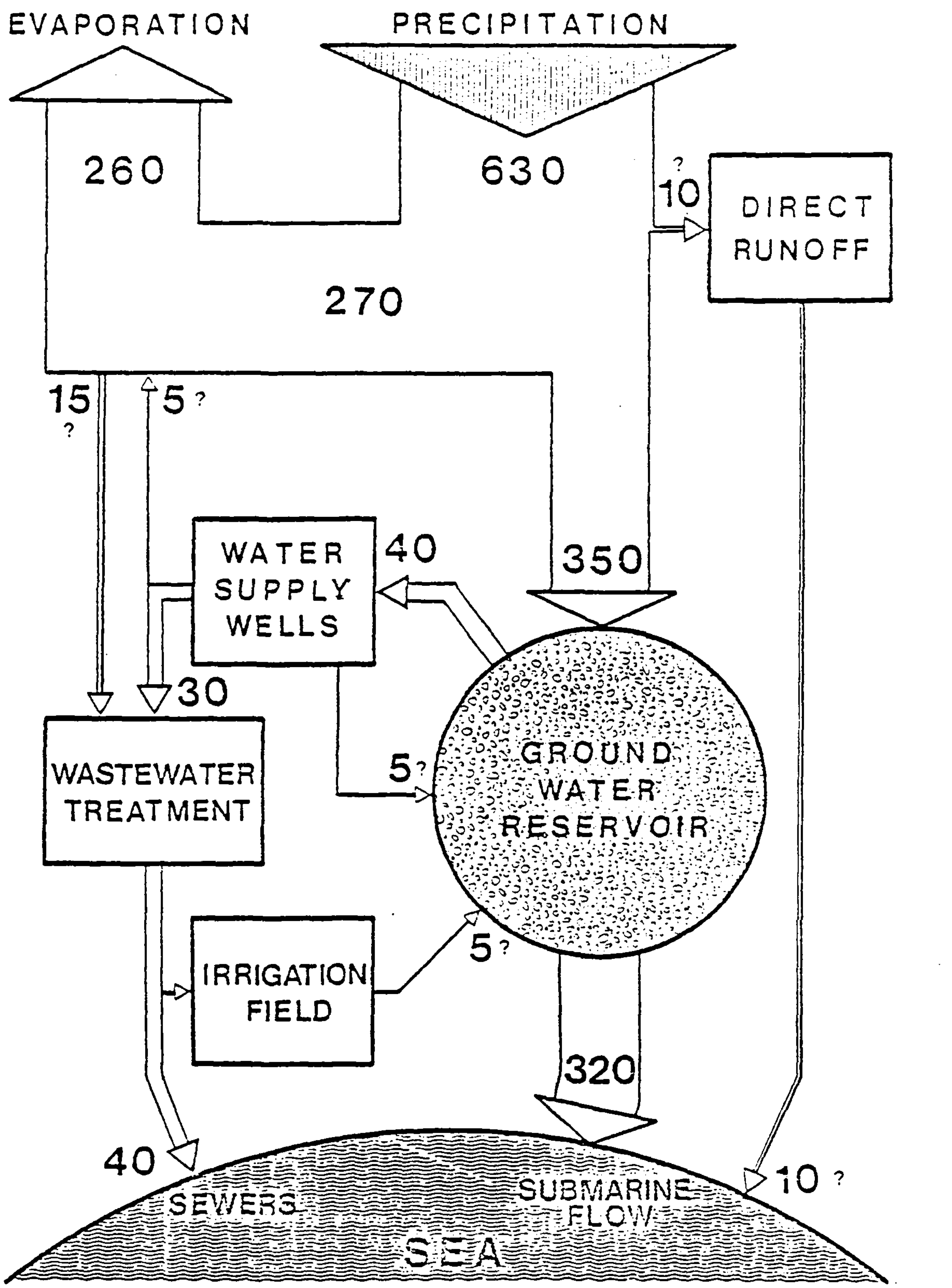
Infiltration for groundwater recharge or construction of a infiltration barrier can be conducted with treated domestic wastewater, stormwater from a separate sewer system and ditch waters.

From pilot plant studies design parameters and operation data for dual-layer-filtration, chemical coagulation/flocculation, microbial nitrification and denitrification and activated carbon adsorption as stages of advanced wastewater treatment were evaluated. The purification performance with soil infiltration of treated wastewater was determined from tests with dune-sand-columns.

The storm runoff in the rainy summertime, which is collected in separate sewer systems, can also be used for groundwater recharge. The pollution and salt contents of these waters and waters from drainage ditches are measured.

The aim of these investigations is to develop planning data and -instruments for an optimal use of the fresh water resources. The results of the simulations of various pumping and infiltration possibilities will be compared under consideration of technical, water balance and economical limitings in a water management-model.

Figure(s)



Note: Figures in millimeter per year (1000 cum/sq km)

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INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE Geotechnical aspects of artificial ground water recharge in arid and semi-arid areas

AUTHOR(S)
H. Völtz (Aachen)

Observations and investigations made during geological field work in the Iran with the objective to establish ground water interrelations between bordering mountain chains and basin sediments, have raised a concept to perform geological prospecting on suitable recharge areas in arid zones. The concept is based on a calculation of the infiltration rate of the natural ground water recharge in coarse grained marginal basin sediments considering reconstructed contemporary water levels. The run-off quantities of different cross sections in the central flow beds of fanglomerate fans, mostly representing a continuous fanglomerate seam, habe been compared.

Distinct indications of individual water levels must be visible in the cross section. The quantity estimates, generally, are based on the "law of continuity". The cross sections have to be measured accurately. Then, the mean flow velocity can be calculated by various irrigation formulas, considering the hydraulic radius, the hydraulic head and the roughness of the flow bed. The infiltrated water quantity between two selected cross sections is employed to estimate the permeability coefficient under flow conditions, which is indroduced as "effective permeability coefficient". The effective permeability coefficient is related to the entire infiltration area in the stream between the two cross sections which is, of course, far greater than the infiltration areas under normal test conditions. This arrangement, furthermore, gives the advantage to obtain a better regional-hydraulic notion of possible infiltration rates of distinctive fanglomerate seams. Additionally, the effective

permeability coefficient allows an estimate of the discharge velocity as a comparing value for the calculation of run-off delay and artificial recharge.
The applicability of the method depends on geologic, morphologic and climatic boundary conditions, which have to be considered in any actual case.

The investigation results in the Djahrom Basin (Province Fars/ Iran, Gulf-area) are drawn as example. They consisted mainly in a selection of areas suitable for ground water recharge. For areas of water demand with periodical run-off and further favourable boundary conditions as regards artificial recharge, geotechnical alternatives to improve the artificial recharge have been considered. Improvements are possible by different means, employed individually or in combination: reduction of the hydraulic head, enlargement of the infiltration area, increase of roughness of the flow bed. Special attention was paid to those measures, which are applicable with relatively simple equipment, thus, avoiding technical problems in less developed areas. The applicable measures comprise drain trenches at the slopes, branching trenches in flow direction, torrent-barriers of gabions and alternating earth-dams.

The prospecting method is applicable in semi-arid areas with periodical rainfalls, and principally also in more arid-areas with episodic rainfalls. In latter case, however, economic apsects must certainly control the theoretical possibilities.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Field experiments with fluorescent dyes for description of water movement in unsaturated loos rocks of the Bavarian Alps

AUTHOR(S)

H.F. Behrens, F. Neumaier, K.P. Seiler (Neuherberg)

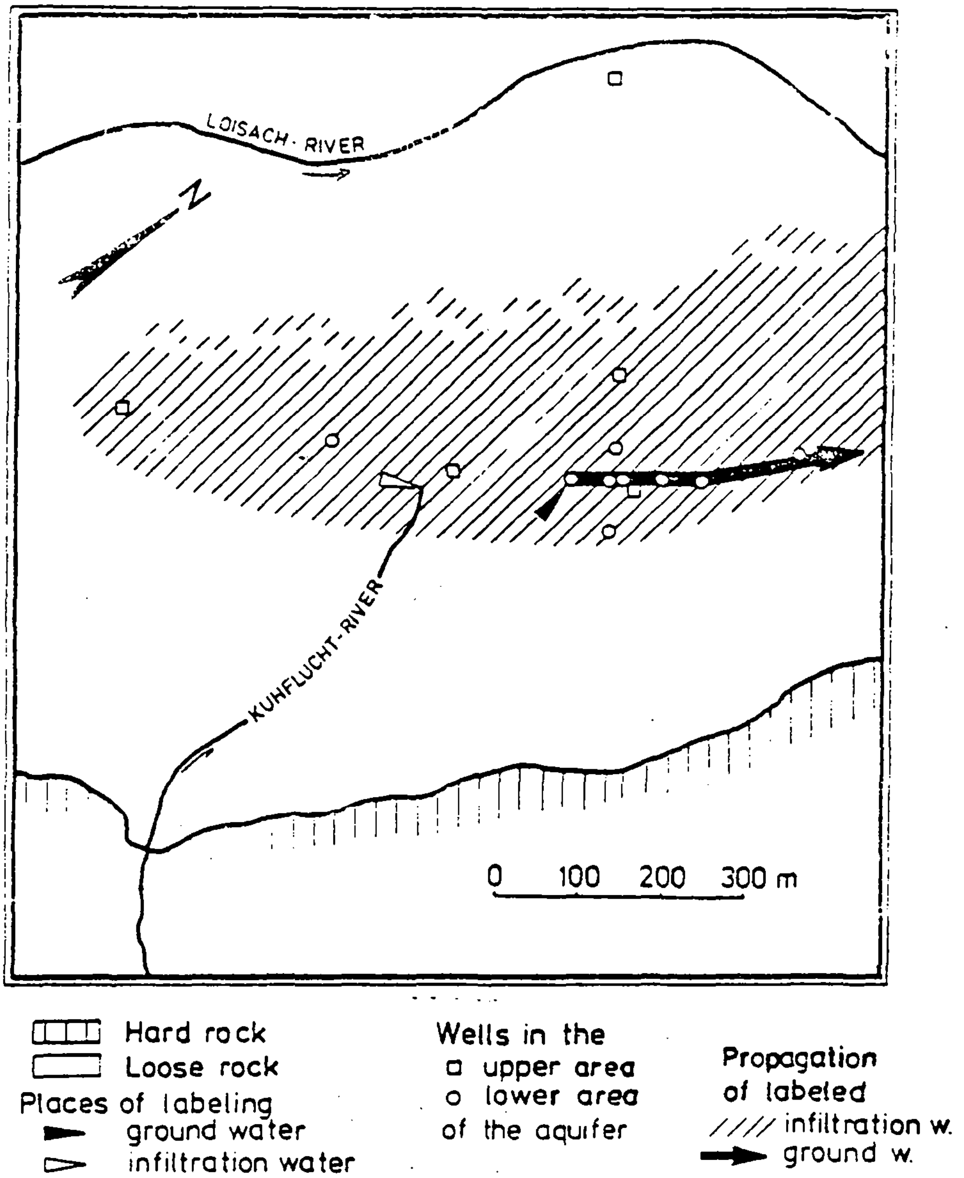
Ground water recharge in gravels of Bavarian Alps is mainly bound on river-infiltration. The quantity of groundwater recharge in its dependance from river discharge and the mechanism of river infiltration is demonstrated by results from the Isar- and the Kuhflucht-river.

The influence of sedimentological properties, especially of stratification of gravels will be explained by means of dye tracer tests. The results of these field experiments will be compared with results of near groundwater tracer experiments; in this way we will get an insight into dispersion in percolation water.

The stratification is the reason why transversal dispersion is more important in percolation water than longitudinal dispersion; in groundwater with its movement parallel to stratification it is just inverse (Fig. 1).

That very important transversal dispersion in percolation water causes, that a conservative tracer reaches after the passage of 4o m unsaturated gravels only 1/1oo to 1/1ooo of the concentration of a tracer, which was injected directly into groundwater and was detected after a passage of 4o m. So the unsaturated zone effects an appreciable dilution for soluted matters, which enters the ground and percolates to the groundwater.

Figure 1



THE PROPAGATION OF LABELED GROUND WATER AND SURFACE WATER SEEPING TO GROUND-WATER

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

RADIO-ECOLOGICAL ASPECTS IN ARTIFICIAL RECHARGE

AUTHOR(S)
G. Matthess, V. Neumayr (Kiel)

In increasing extent surface waters, especially those of rivers and streams, are contaminated by radionuclides. Therefore it is necessary to investigate the possibility of impairment of the quality of artificially recharged groundwater and drinking water by radionuclides.

Hazards for man are possible by drinking water, that was affected by waste and during exposition to air, as well as indirectly by the food chain. In a model calculation using realistic conditions the order of magnitude of these hazards for man by radionuclides are assessed. The model includes the use of river water for artificial recharge and considers the radio-active fluid waste output of a nuclear power plant in the upstream vicinity and furthermore a realistic background contamination by radionuclides from other upstream sources. All models and assessments assume the most unfavourable preconditions.

The assessment of radiation load by radioactive contaminated recharge and irrigation water considers the physical and chemical behaviour of each spesific waste radionuclide. It is feasible to assume the extreme disadvantegous but realistic radionuclide mixture. For this purpose the "ecological index" of the each particular radionuclide was calculated on the base of fixed maximal annual dose for the whole human body, the gastro-intestinal system, thydoid gland and bones.

To obtain a reliable assessment of a possible exposition to radiation two calculation models are used:

1. a limiting maximum concentration is calculated on the base of a model radionuclide mixture with the most disadvantegous ecological composition,
2. the maximal radiation exposition to be expected is calculated on base of the realistic radionuclide load of the rivers.

The results of these calculations reveal the radiation exposition of man by a theoretical consumption of untreated water taken directly from the river. Furthermore other model calculations are set up to consider the processes which reduce the radionuclide concentrations in water.

Considering these decontamination processes the radiation load of the population by incorporation of artificial recharged drinking water can be assessed.

INTERNATIONALES SYMPOSIUM

KÜNSTLICHE GRUNDWASSERANREICHERUNG

DORTMUND, 14. – 18. MAI 1979

TITEL

SUPPLY AND MANAGEMENT OF GROUNDWATER
A MODEL STUDY ON THE MANAGEMENT OF THE GROUNDWATER OF MOULLE (PAS-DE-CALAIS - FRANCE)

AUTOR (EN)

G. Dassonville (Paris)

Abstract

The groundwater catchment area of Moulle is used for the water supply of Dunkerque. Artificial recharge with treated surface water is performed in this area at a rate of 8 millions cu-m per year.

After a few years of operation, an attempt has been made to optimise the quantity of reinfiltrated water, according to the potable water demand.

A mathematical model of this aquifer has been adjusted, which specifies the mechanisms of alimentation and discharge of the aquifer and offers the possibility to make previsions about groundwater levels. We can also determine the quantities of water to infiltrate month after month, according to previous rainfalls and abstraction from wells. The calibration of the model in non-steady conditions, with 3 hydrologic successive cycles, has been made for the first time, seemingly, in this kind of study.

The following points are described :

1 - hydrogeology of the groundwater of Moulle :

- recharge by rainfall ;
- artificial recharge ;
- groundwater abstraction and outflows ;
- hydraulic parameters of the aquifer ;
- groundwater levels and discharge losses.

2 - Calibration of the model.

3 - The different simulations.

.../...

The computer programming used is the NEWSAM programme, by finite differences. Computer gives :

- the distribution of the potentials ;

- eventually the new value of transmissibility ;

- the values of the flow through the limits on which potentials have been fixed ;

- a water balance of the acuifer and, if asked, a water balance for each mesh of the network.

The model will be used in future as a management tool which permit a more economic exploitation of water ressource.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

A MODEL FOR THE TRANSPORT OF INTERACTING SOLUTES THROUGH POROUS MEDIA

AUTHOR(S)
K. HARMSEN (Leidschemdam)

A simulation model was developed to describe the one-dimensional transport of interacting solutes through porous media.
The model would apply to the transport of polluted surface water upon infiltration, or of polluted groundwater (e.g. landfill leachate) through an aquifer.
The physical model considers the following phases:
1. a mobile solution phase;
2. an immobile solution phase, which may include both the water tightly bound to the solid phase or within the reach of the electrostatic double layer, in case of charged adsorbent surfaces, and the solution in "dead end" pores or within soil aggregates; and
3. one or more solid phases, mineral or organic, which may include adsorbing surfaces and precipitates.

Physical processes considered in the model include:
1. transport of solutes through a mobile solution phase, by convection and hydrodynamic dispersion as well as molecular diffusion;
2. diffusion of solutes between a mobile and an immobile solution phase; and
3. interactions between solutes in an immobile solution phase and one or more solid phases.

An essential feature of the present model is that longitudinal transport is confined to a mobile solution phase, whereas interactions between solutes and one or more solid phases are confined to an immobile solution phase. The relation

between solutes in immobile and mobile solution phases is by a first order rate process. Therefore it is rather easy to include adsorption, ion exchange and precipitation in the present model, assuming that instantaneous equilibrium exists between the immobile solution and the solid phases involved.
The relationships between solutes in an immobile solution in equilibrium with one or more solid phases are given by adsorption isotherms, ion-exchange equations or solubility products.
The model may be extended to include more species of solutes, both ionic and non-ionic, simply by including mass conservation equations for all solutes involved.
Hence, if there is no mass transfer between the mobile and immobile solution phases, the present model describes the transport of a non-interacting solute, such as chloride, which is confined to the mobile solution phase.
If the mass transfer coefficient tends to infinity, the model describes the behaviour of solutes in a mobile solution that are in instantaneous equilibrium with one or more solid phases.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Investigations for the subterranean groundwater treatment by recharge of oxygenated water into the aquifer

AUTHOR(S)
P.W. Boochs and G. Barovic (Hannover)

All groundwater in coastal areas of northern Germany has to be prepared before using it for human or industrial purposes, because of its high concentration of iron and magnese. In general the solubility of these substances is diminished by oxidation processes in special devices and then removed by filtration. This method is expensive because of high investment and management costs.

The aim of our work is to initiate the oxidation already in the aquifer, so that the usual surface preparation will not be necessary. Among others it has to be investigated how the oxidation agents are moving and reacting within the groundwater aquifer and which factors must be considered. The transport of oxygen in groundwater on the one side depends on the velocity of groundwater and on the other side of dispersion and sorption processes in the aquifer itself. Furthermore chemical reactions and changes take place. A realiable forcasting of the behaviour of oxidation agents in the aquifer for dimensioning injection rates and wells can only be made when all components are considered.

In this study water, concentrated with oxygen, was injected into a natural aquifer by a single recharging well. Concentration measurements were carried out surround the well at different locations and depths to find out the change of the oxygen distribution. Evaluation and interpretation of the field experiments were made by comparison with a mathematical model.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

A Stable Geophysical System Controlling Water Leakages from Infiltration Reservoirs

AUTHOR(S)

I. LANDA, O. MAZÁČ, B. ŠKUTHAN (Praha)

The lack of high quality sources of ground water requires new effective methods of enriching them to be elaborated. Experience from Czechoslovakia and from abroad indicates that one of the most effective methods of enriching is artificial infiltration.

The technology of artificial infiltration calls for a relatively intensive source of water. Surface water is used as the source usually. This water must be treated prior to infiltration so that the ground water at a certain point will achieve the quality, usually determined as standard. If waste water is used for infiltration, e.g., from various industrial and agricultural plants, problems occur with its temporary storage. Therefore, in industrial areas hydraulic tanks are built, in which the mechanical admixtures of the waste waters undergo sedimentation. Since the requirements for substantial sources of ground and surface waters in industrial areas are large, the infiltration tanks are built as close as possible to the consumer. This, however, requires the solution of two fundamental problems on a relatively limited area, i.e. the protection of the ground waters from pollution by the waters from the hydraulic tanks and also the protection of the ground waters from excessive exploitation, which constitutes the problem of artificial enriching of ground waters.

In the first case it is necessary to develop mostly the method of an efficient limitation of leakages of harmful substances from the hydraulic tanks, in the second, to develop the method of intensifying the infiltration from the tanks for artificial enriching of supplies of ground waters.

We may also have to deal with the cases in which it is necessary to store surpluses of surface or precipitation waters used to enrich the supplies, prior to their infiltration for some time. In this case storage tanks are built. As regards these tanks it is necessary to secure them against water leakage which would result in decreasing the effective capacity of the tank.

Among the most inexpensive techniques of building earth dams of hydraulic storage tanks and reservoirs is the technique of using plastic (PVC) foils as sealing elements.

To indicate points of leakage and of penetration of the foils a stable geophysical controlling system was developed and tested by "Geofyzika Praha".

The principle of the system (Fig. 1) is in introducing a system of electrodes into the sand layer under the foil. The system is connected to a measuring centre. In organizing the measurements and in evaluating them, the theory of resistivity methods, methods of contact resistance and the method of charged body is exploited.

The results of the measurements were verified in an experimental tank by removing the concrete protective layer at the location of the geophysical anomaly and checking the sealing foil. It was found that the foil had already been perforated when the tank had been built. This was unique proof of the considerable information capability of the developed geophysical system. It was also found that the increase in expenses of building the tank with a stable geophysical controlling system are negligible (1 - 3 %).

Figure(s)

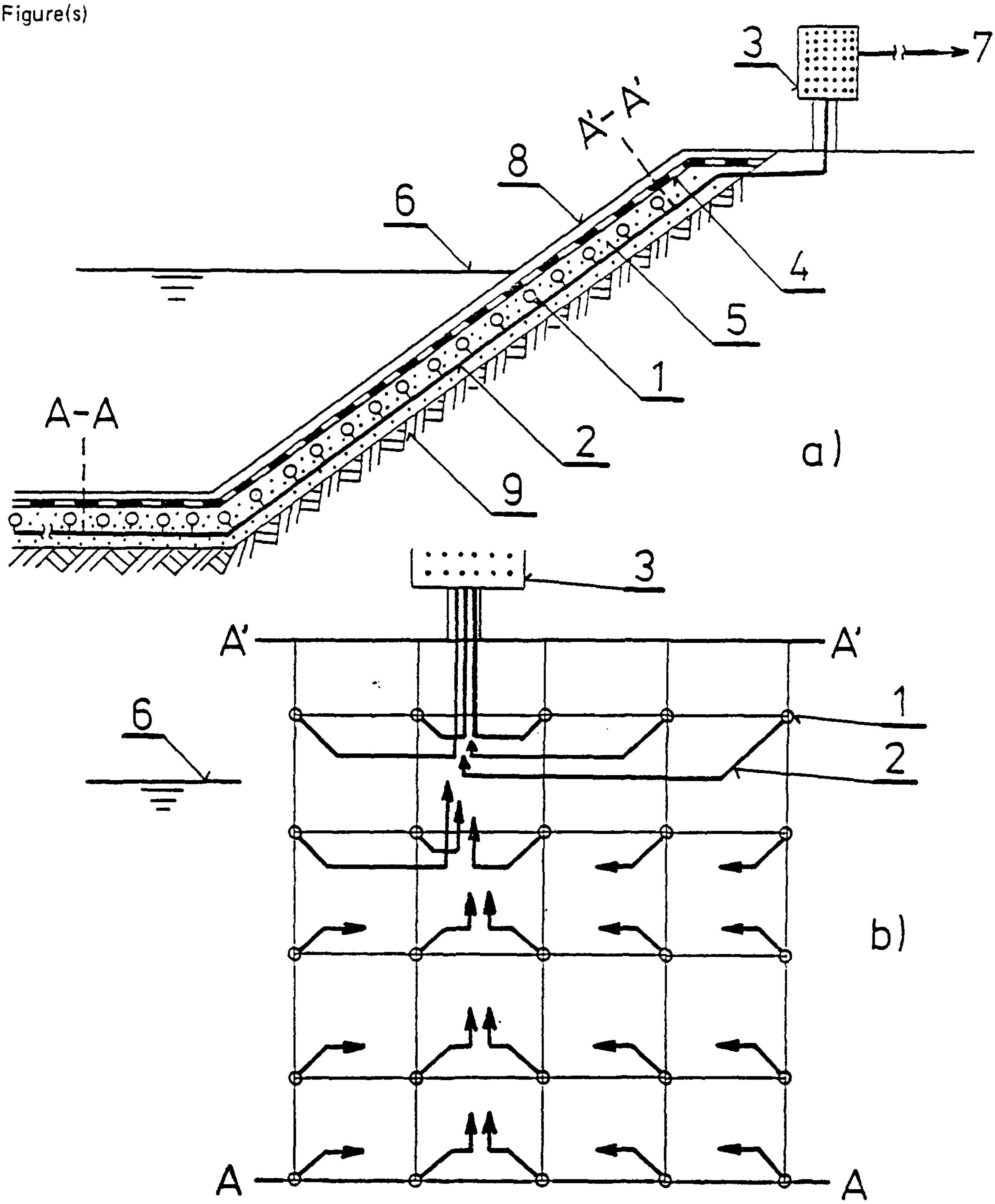


Fig. 1

a) scheme; b) electrode layout;
1...electrodes; 2...cables; 3...measuring centre; 4...sealing foil; 5...sand; 6...water level; 7...computer or warning system; 8...infiltration reservoir; 9...gravel

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Hydraulic dimensioning of drainage and infiltration tunnels for groundwater management

AUTHOR(S)
H. Gerdes (Darmstadt)

The integration of artificial groundwater recharge into the comprehensive system of water resources development for all socially relevant purposes requires additional facilities to use the storage capacity of the ground. Groundwater recharge using treated river water for the purpose of quality improvement has to be coordinated with others (power generation, navigation, protection of the environment). Consequently the pumped quantity and the time element are no longer dominated exclusively by the requirement of high quality groundwater and the capacity of appertaining offtake plants.

The increasing demand of high quality water and a reduction of natural regeneration of groundwater caused by artificial modifications of the environment have blurred the boundary line between a recharge under quality aspects and a storage with respect to quantity only. This requires infiltration and offtake plants with high flexibility and capacity to allow management in the actual sense of the word.

In 1967 MAROTZ has concipated a tunnel for drainage and recharge respectively. It is meant for situations, where modifications in the catchement have increased the speed of flood waves and thereby reduced natural groundwater recharge. This is the case in river valleys with alluvial and diluvial gravel terrasses and high permeability and porosity, which makes them useful for the storage of water. A number of papers already mention the details of layout and construction. In order to permit determination of capacity of the tunnel and a comparison with other technical solutions of recharge, this paper is a contribution to the problem of hydraulic dimensioning.

The mathematic model is supposed to show analytically the influence of the major parameters. It is based on an aquifer with limits to the sides and the bottom. In respect to these conditions the tunnel shows specific longitudinal dimensions with a strong influence on the capacity of recharge. The inflow or outflow along the tunnel is very irregular. Calculation methods which are only based on the vertical cross-section require a current longitudinally constant, calculated per running meter. This is a crude simplification which neglects the influence of important parameters.

The mathematical model using conformal mapping avoids the above simplifications. As an analytical solution it has the advantage to explain the influence of the different parameters in a clear manner. For the verification of this model experimental tests in the elektrolytic tank have been made.

Besides the usual methods of surface and underground infiltration, the tunnel should be regarded as an additional possibility of artificial groundwater recharge. Conventional methods contain a number of "aging problems" such as colmation and incrustation. If the ambient conditions permit, the drainage and infiltration tunnel can be equally good or even better.

Figure(s)

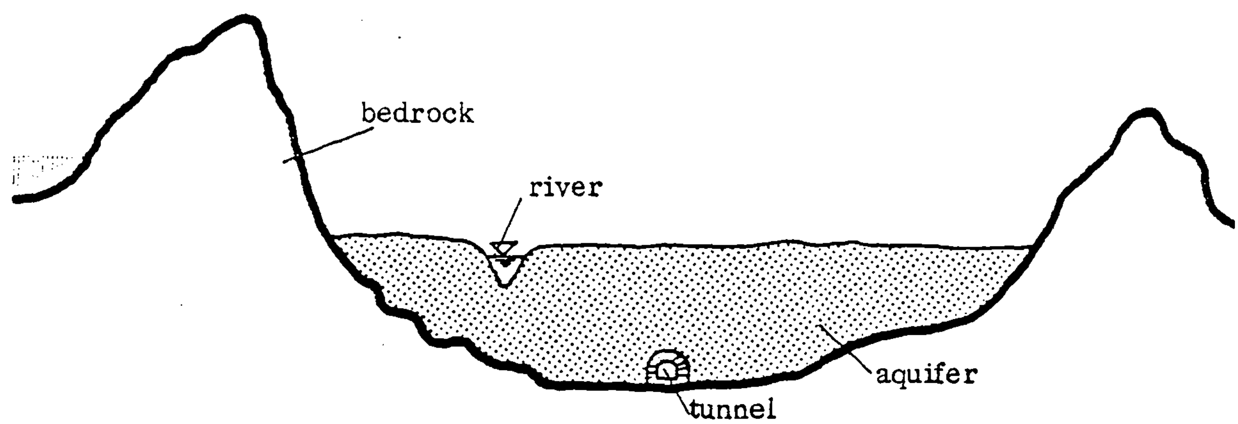


Fig. : Valley with tunnel ,
vertical cross-section

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Similarity conditions for seepage flow

AUTHOR(S)

I. Horvath (Budapest)

In the last decades, scientists and planners have been occupied to an ever increasing extent with the problem of seepage flow in permeable soils. This has been caused by the fact that the econòmical removal of liquids and gases from porous media, e.g. soils and pervious ròcks. has become an important technical problem. For example, the production of drinking water, the delivery of natural gas and mineral oils, the recharge of groundwater as well as the seeping of different liquids, sewage, etc., have brought about serious technical problems of international importance.
This paper deals with studies on the similarity of seepage flows where the liquid has a free surface. Using a hydraulic test model system, special attention has been given to the construction of model definitions.

The influencing factors can be described as follows:

1. In model studies of flow in the capillary zones, the simultaneous influence of three forces: capillary force, friction, and gravity, can be determined when granuls of equal size and the same infiltration liquids are used. As the identity of the three measures of the forces is simultaneously guaranteed, a good approximation to the dynamic similarity is obtained.

2. The similarity of seepages in the capillary zone is characterized by the dimensionless groups I_1 and I_2 of invariants:

$$I_1 = \frac{v \cdot \eta}{\varphi} \cdot \frac{h_c}{d} ; \qquad I_2 = \frac{v \cdot \eta}{\varphi} \cdot \frac{l}{d} \cdot \frac{n_r}{n_m}$$

d = average grain diameter $/d_{50}/$;
l = length of the capillary section examined
h_c = capillary ascension level or height of the capillary zone
v = velocity of the moving liquid
n_m = Number of the menisci at the surface of the capillary zone
n_r = number of the capillaries situated in the direction of the flow
η = dynamic viscosity of the liquid
φ = specific surface tension of the liquid.

3. As also inferred by E. MOSONYI and G. KOVACS, the gravity and the frictional forces are the main forces to be considered within the infiltration region under a lowered area. The identity of the measures of these two forces can be guaranteed assuming that the inertial force can be neglected.

4. The similarity condition for the flow under the lowered area is represented by the dimensionless numbers A_1 and A:

$$A_1 = \frac{Fr}{Re} \cdot i^{-1} \quad ; \quad A = \frac{v \cdot \eta}{\gamma \cdot d^2} = \frac{v \cdot \nu}{g \cdot d^2}$$

Fr = Froude's number
Re = Reynold's numer
i = inclination gradient of the lowered area
g = acceleration due to gravity
γ = specific gravity of the flowing liquid
ν = kinematic viscosity of the liquid.

5. The fact that the relation = exists in the capillary zone and in the area below reveals the kinematic unity of the processes in the whole flow area. However, a calculation of the forces within both areas will be carried out in different ways due to the distortion $h_c'' = h_c''$ (table 1).

λ = measure of the characteristic lenαths

τ = conversion factor for the times

(') = refers to the natural tvpe

(") = refers to the model

Conversion factors of the model technique for seepage flows /character of the distortion d' = d"

conversion factors for:	below the dewateres area	in the capillary zone	
	modelltechniques for the simultaneous influence of		
	gravity and friction	capillary force and friction	capillary force gravity and friction
length	λ	λ	λ
area	λ^2	λ^2	λ^2
volume	λ^3	λ^3	λ^3
time	λ	λ	λ
velocity	λ^0	λ^0	λ^0
acceleration	λ^{-1}	λ^{-1}	λ^{-1}
flow	λ^2	λ	λ
force	λ^3	λ^2	λ^2
work	λ^4	λ^3	λ^3
power	λ^3	λ^2	λ^2

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Gas content in the ground during process of artificial water infiltration

AUTHOR(S)

M. Blazejewski (Poznan)

An investigation of the infiltration velocity and of the gas content and its composition in the groundwater under the bottom of an infiltration pond was carried out. It was found that the gas composition during the exploitation cycle of the pond tends to vary. Immediately after cleaning of the pond the composition corresponds to atmospheric air. During the work period the oxygen content of the gas is decreasing while the nitrogen and carbon dioxide contents are increasing.

On the basis of changes in the infiltration rate it was also found that there are three periods within an exploitation cycle of the pond:

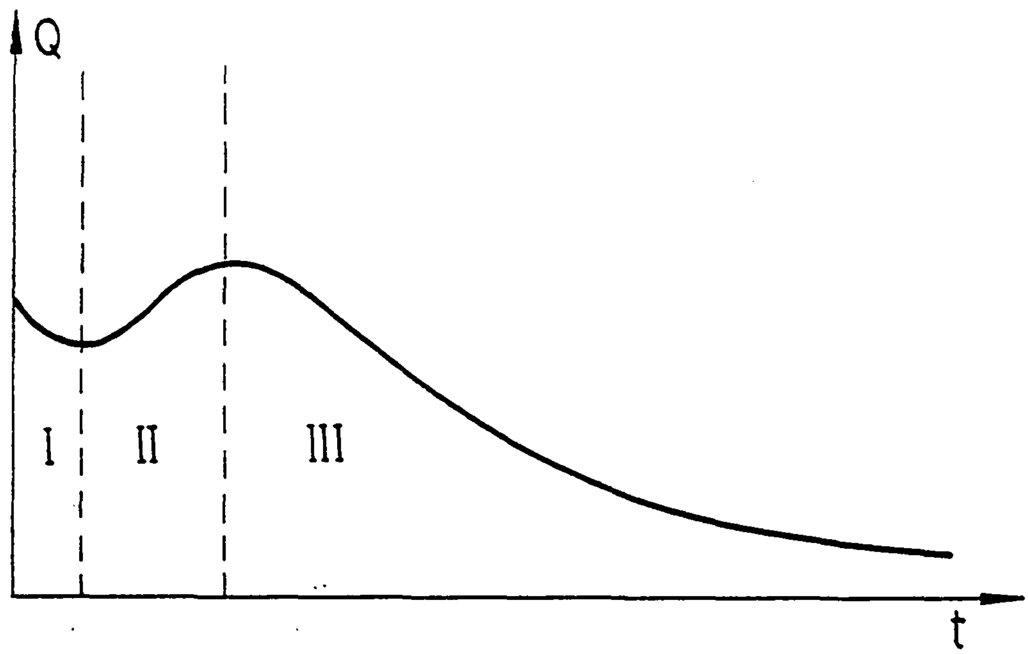
1. Initial decrease of the infiltration immediately after after starting, probably due to the swelling of aluminium silicates in the underground.

2. Increase to a maximum infiltration rate, due to the removal of air which had penetrated into the infiltration layers during the cleaning of the pond.

3. More or less rapid decrease of infiltration as a result of accumulation of particulate organic and inorganic matter at the surface of the filter.

Figure(s)

Changes in the infiltration rate during an exploitation cycle of the pond



INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Practical applicability of ground-water quality models

AUTHOR(S)
K. Zipfel (Koblenz)

Because of the dense population and the high industrialization of Central Europe, the increasing demand for high-quality water has become a very actual problem. Therefore, for the existing as well as for future drinking-water supply, detailed knowledge on possible ground-water pollution and on the expected quality of water pumped by wells is of high importance. In particular, this concerns the groundwater development near surface waters as well as in the surroundings of villages, industrial plants, and roads, or near waste deposits and sewage treatment plants.

In a short form, the variety of sources and types of contamination and infiltration, spreading and transport of pollutants in the underground, will be outlined. This variety results from the type of pollutants and from the hydrogeological, chemical, and biological effects and their superposition.

The development and application of mathematical models simulating water-quality behaviour in ground-water basins, were necessary. They have been realized in a similar youthful stage. Principally, existing models simulate the different processes and reactions caused by the movement of conservative and some non-conservative constituents in water under both saturated and unsaturated soil conditions.

There are a lot of numerical models simulating the quantitative ground-water flow under arbitrary conditions. Such models have numerously been applied in planning.
In contrary to these handy tools, adequate quality simulation requires the employment of more comprehensive data on the

effective parameters. Therefore, along with the development of model methods, numerous labor tests and scale investigations have been initiated in order to evaluate the decisive mechanisms and criteria of dispersion as well as transport of contaminants in the groundwater.
Due to the complexity of these processes, these investigations have, till now, left a lot of gaps in knowledge and, above all, useful data of practical cases are difficult to obtain. Accordingly, the application of model methods for quality simulation is very limited.
There is an urgent need for further evaluating and predicting of qualitative processes in groundwater flow. The increasing utilization of groundwater resources for drinking-water supply unconditionally requires the development of applicability of simulation methods. Possibilities of application are given where condition of groundwater flow and quality are relatively definite. For example, this is the fact with a considerable number of groundwater well systems near surface waters as well as in other special cases with detailed data from intensive measurements.

On the other hand, in numerous cases, simulation models of the groundwater flow already exist. Thus, the possibility to simulate groundwater quality aspects by gathering additional data of quality criteria and inserting them into well-known flow systems, stepwise completing the groundwater flow model, exists. Even in case of serious initial difficulties, this fact brings along better knowledge on the main problems arising with the applicability of quality models.

The simultaneous continuation and extension of systematic basic investigation, in particular on an original scale under controllable conditions, seems to be very important as a basis for more developed models.

The necessary restriction of landuse by determining protection zones for drinking water and by establishing preventive measures for long-term groundwater protection, is, even today, causing great problems. Such problems can only be solved by developing and using prognostic groundwater quality models. Basic simulation techniques already exist.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Impact of Sewage Effluent Recharge on Groundwater in the Chalk for an area in SE England

AUTHOR(S)
K.M. Baxter and K.J. Edworthy (Medmenham)

The recharge of sewage effluent of various types onto the outcrop areas of the major aquifers, as a means of disposal, has been practised for over a century and is common in some areas of the UK. As recharge is often conducted in areas where groundwater forms a substantial part of public supply, there is some concern that there might be local progressive deterioration in groundwater quality and that some sources may be at risk.

Suitable sites for the study were selected and a programme of drilling, sampling and long-term monitoring has been undertaken. Attention has been focused on the Cretaceous Chalk aquifer, but work is also in progress on the Permo-Triassic Sandstone aquifer (Fig.1).

The paper describes work carried out at a site on the Chalk near Luton, in Bedfordshire (Fig.1), where a secondary chlorinated domestic effluent from surburban Luton is discharged at a rate of between 750 and 1100 m^3/d through a buried drain system into the unsaturated zone of the Middle Chalk aquifer. The effluent infiltrates to the groundwater table, 10 to 15 m below surface, and then flows down a groundwater gradient of 0.8%, along the line of the dry valley, to the ESE.

The changes in infiltrating water composition within the immediate disposal area were investigated at eight locations by drilling boreholes, five of which were cored to the water table. A further nine boreholes, each 30 m deep (No's 1 to 9, Fig.2), were located down the groundwater gradient between the sewage effluent disposal area and the public supply borehole, and were fully cored below the water table.

Profiles obtained from the chemical analysis of interstitial water, extracted from core samples by centrifuge, and standing water, for chloride, nitrate, ammonia and TOC show the pattern of effluent infiltration to the water table. It is apparent that considerable dispersion occurs. Analysis of similar samples from the saturated zone point to an irregular decline in concentration down the groundwater gradient with the flow mainly restricted to several narrow intervals (Fig.3). These results clearly reflect the heterogeneity of groundwater flow in the Chalk.

The determination of selected heavy metals and organo-halides in the effluent, beneath the area of infiltration and in the groundwater flowing away from the site, shows that the concentration of these contaminants has fallen to 'background' level within 500 m of travel. Similarly, the virus concentration in the effluent was reduced by three orders of magnitude (99.9%) within 300 m and the *E.coli* count reduced by four orders of magnitude (99.99%) with the same distance of travel. Numbers of micro-organisms in the groundwater at sampling points at the water table, beneath and down the groundwater gradient from the infiltration area ,however, varied considerably. This was due in part to the large variation in the level of residual chlorine in the effluent, which is in turn proportional to the rate of flow.

For all contaminants studied, dilution appears to be the main mechanism for reducing the impact of the recharged effluent on the groundwater catchment, although the unsaturated zone affords a significant degree of treatment by reducing the bacteria and virus concentrations.

The monitoring of water level changes against variable effluent discharge rates has been used to estimate contaminant travel time and aquifer storage. An understanding of the relationships between recharge, abstraction and groundwater quality has been greatly aided by the numerical analysis of the historical quality and quantity data.

The results of the field and desk study from this and other sites will be used in the formulation of improved aquifer management guidelines.

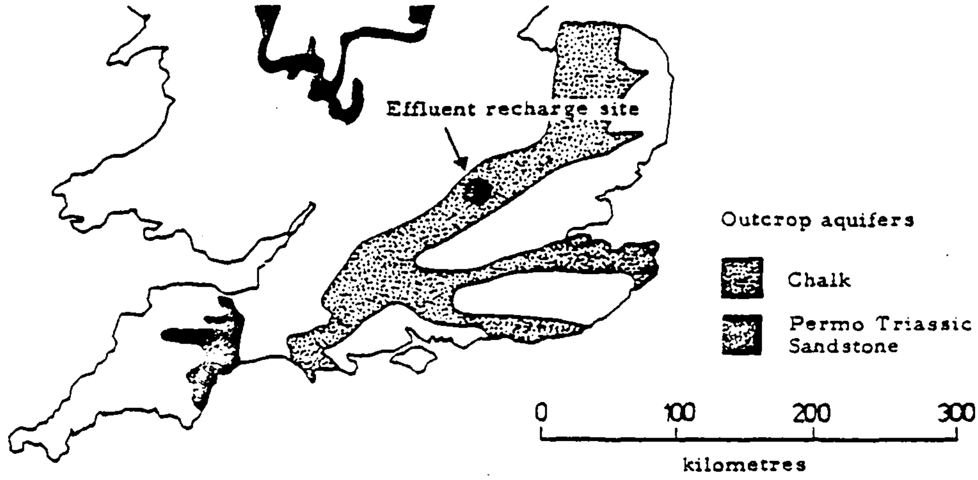


Fig. 1. Location plan showing main aquifer outcrop areas.

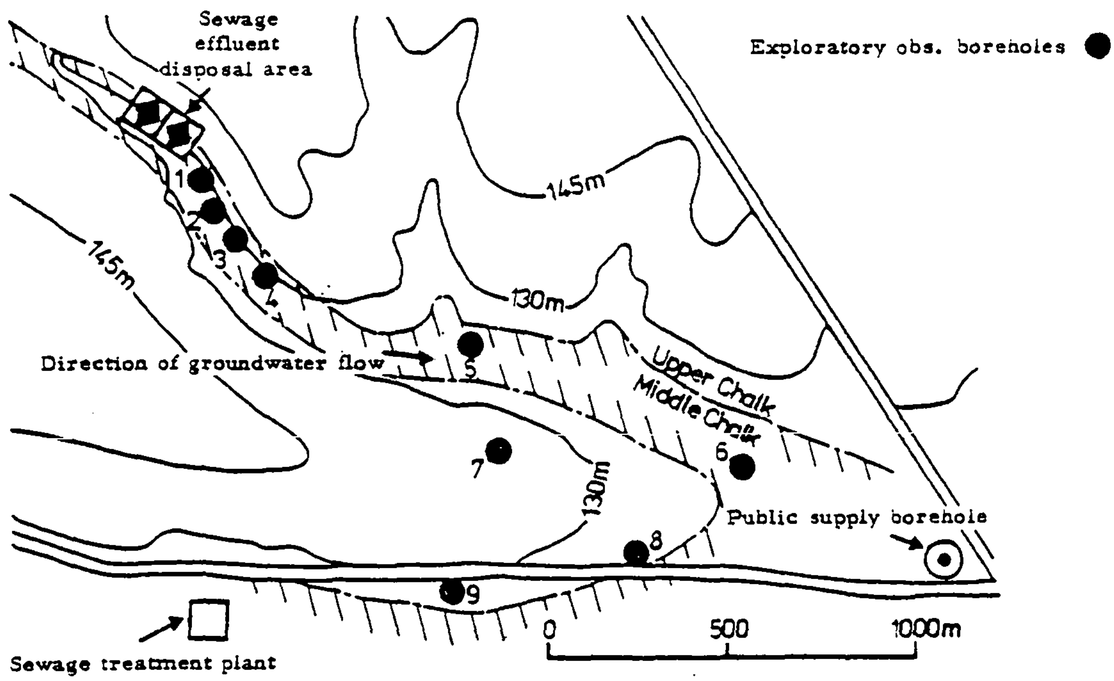


Fig. 2. Effect of effluent recharge on groundwater quality.

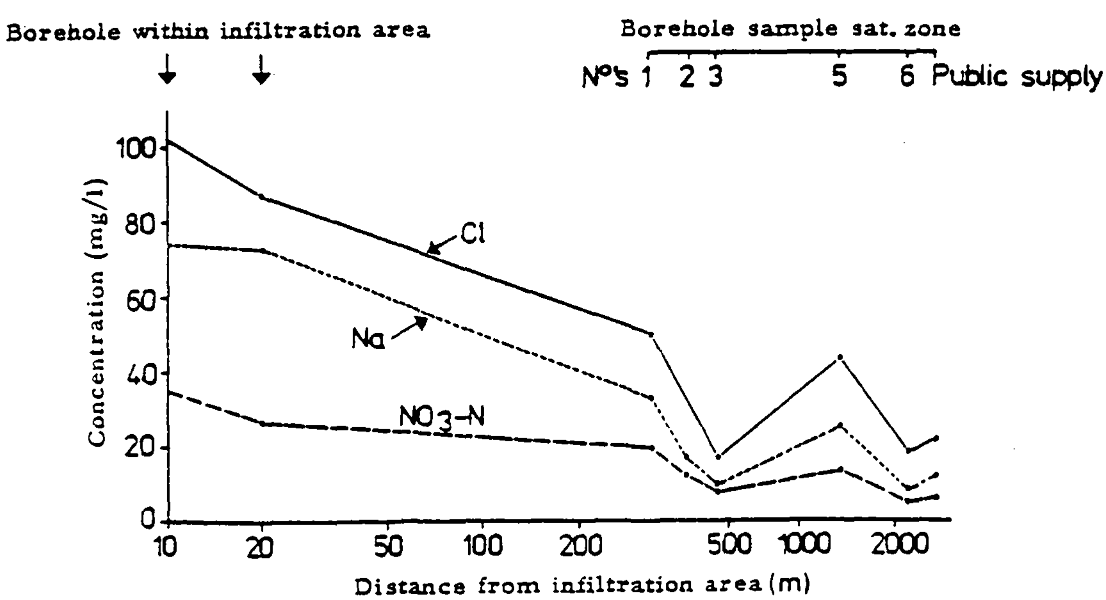


Fig. 3. Quality profile down groundwater gradient away from area of infiltration.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Microbial reactions during bank filtration

AUTHOR(S)

R. Schweisfurth (Homburg)

We know from experience that the purification of river water during bank filtration physically, physico-chemically, and biologically depends upon the properties of the ground and the microflora present. The same microbiological processes also take place during "artificial" recharge as well as during slow sand filtration, as long as the same oxygen and redox-conditions are present. The meaning of purification here is the removal of particular and colloidal substances from the river water and partial removal of dissolved anorganic and organic compounds by adsorption. Furthermore, organic matter will be oxydized microbially and reduced inorganic compounds present will be transferred into the oxydized state in the same way ($NH_4^+ \rightarrow NO_3^-$, $S^{--} \rightarrow SO_4^{--}$) or fixed by oxidation ($Fe(II) \rightarrow Fe(III)$, $Mn(II) \rightarrow Mn(IV)$).

The microbiological steps can only proceed when the water entering the sediment and the embankments contains sufficient dissolved oxygen needed for the decomposition of the quantity of organic matter present. However, as the dissolved O_2-concentration of the water is limited depending on temperature, it is the amount of decomposable organic matter (as well as the flow distance and influents of other waters) which determines the way and the completion of the "purification processes" (fig. 1).

If the biological oxygen demand of the organic matter increases above the O_2-content of the river-water (due to so-called general organic load or in cases of the damming of the rivers), not only the mineralization of the organic matter will be retarded but also microbial products will be formed which impair the chemical quality of the water, and which on being mixed in the water works with water containing oxygen, support a rapid multiplication of bacteria (fig. 2, 3).

The indicator organism for the large number of microorganisms that develop in wells, storage basins and in the distribution system generally seems to be Crenothrix polyspora Cohn. It is described together with its accompanying flora.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Re-infiltration - a method for removing iron and manganese and for reducing organic matters in groundwater recharged by bank filtration

AUTHOR(S)
T. Agerstrand (Vällingby)

Due to geological and climatological conditions in Scandinavia groundwater generally contains iron and manganese. In cases when withdrawal of groundwater induces bank filtration from rivers and lakes the content of organic matters and iron in humic complexes frequently increases. Treatment of such groundwater by oxidation and rapid filtration will normally necessitate the use of other oxidizers than air oxygen or the use of chemical precipitation.

Consulting engineers at VIAK AB in Sweden have developed a simple method called re-infiltration for separating iron and manganese, even in humic complex forms, from groundwater. By this method water is pumped into a suitable area of the aquifer where it is aerated in an overflow cascade and infiltrated to the groundwater reservoir through basins. The sand beds in the basins are designed for a filtration rate up to 0,5 m/h to get retention time for braking humic iron complexes and complete the oxidation of manganese.

The infiltration will form a volume of purified water in the aquifer. This storage can be used directly for water supply by pumping from wells in the infiltration area. The system for infiltration, storage and recovery of water have to be adapted to the hydraulic properties of the aquifer.

The maintenance of the sand beds is quite similar to that of artificial basin recharge. It means that 5 to 10 cm of sand will be removed when the water level rises to 0,5 m in a basin. Due to the voluminous iron precipitation in the first oxidizing stage and to iron bacterias and algae the clogging of the bed surface can be undesirably rapid. To counteract this process a drying time of 6 - 24 hours followed by raking the surface has proved to be very effektive.

When groundwater has high contents of iron and manganese, Fe > 0,5 mg/l and Mn > 1,0 mg/l, the running time for the infiltration basins will be too short. In such cases pre-filtering has to be undertaken before the infiltration. The pre-filter consists of macadam and works as a contact filter with 10 to 30 minutes retention time. The pre-filter is flushable which is normally done by rapid tapping. The efficiency of the pre-filters has proved to be very good. In fact 75 to 90% of iron and 40 to 60% of manganese are usually removed. Today some 40 re-infiltration plants are operating in Sweden. Capacities for these range from a few m^3/day to 7.000 m^3/day.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITEL

OPERATING EXPERIENCES FROM IN SITU REMOVING OF IRON AND MANGANESE ACCORDING TO THE VYREDOX-METHOD

AUTOR (EN)
R. Martinell (Stockholm)

The development of the VYREDOX-method, in situ purification of ground water, mainly removing of iron and manganese, has been carried on since the early fifties. The first permanent municipal waterworks have been in operation since about 10 years.

The VYREDOX-method activates and adapts the natural processes of ground water acquifers to the environment of the production wells and thus, it is an environment-positive water purifi-ation method. As the precipitation and purification processes take place in the ground, the method involves neither sludge problems nor sludge deposition problems as is the case with conventional methods where the water is purified above the ground.

Much attention has been paid to the problems concerning pre-cipitation and clogging at existing Vyredox-plants. Cores with relatively undisturbed sediments have been sampled close to the supply-well and one of the satellite wells at the oldest Vyredox-plant, Grimsås, in Sweden. Those two cores are under investigation. It has not been possible to show any severe precipitation of the interstitial spaces by microscopic exami-nation of those sections. In the lowermost sample, at the middle of the well screen, one or a few percentage of the pore volume show precipitates. The texture of the precipitates can in some cases be interpreted as "bacterial iron stalks" (fig. 1). Also a mineral transformation can be observed, from a brownish aggregate into redish hexagonal plates. It is interpreted as a transfor-mation from ironoxihydroxide (e.g. goethite) into hematite (fig. 2). The bacterialy formed iron precipitates may thus turn into the more stable mineral hematite.

The precipitation products which appear in connection with the purification of water according to the VYREDOX-method cause a reduction of the pore volume. This on a long term results gra-dually in a lower capacity of the production wells. However, up to now it could not be proved that this is the case with the VYREDOX-water purification plants when they are operated in correspondence with given instructions. On the contrary, the

VYREDOX-method is used for a number of precipitated wells in order to increase the capacity and also to maintain a good capacity in these wells. The precipitation kinetic has so far been in good correspondence with the theoretical calculations made in connection with the planning of the different plants. The theoretical precipitations velocity is one permillage a year. Of utmost importance is the spacing of the injection wells around the production well (fig. 3). They must be arranged so that the precipitation products do not come close to the production well.

The energy consumption of a VYREDOX-plant is normally 3-7 Wh per cubic meter purified water and per meter pumping height. This should be compared with conventional purification and an energy consumption of generally more than 9 Wh per cubic meter purified water and per meter pumping height. Thus a considerable lower energy consumption is achieved when using the VYREDOX-method.

Another very important fact is that a VYREDOX waterworks is easy to operate by a minimum amount of people.

INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE

Experiences with micropollutants from sewage during underground passage

AUTHOR(S)

P. Roberts (Stanford)

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Behaviour of organic micropollutants during passage of the soil

AUTHOR(S)
G.J. Piet, C.F. Morra, P. Slingerland (Leidschendam)

The analysis of individual organic chemicals before and after passage of the soil gives an impression of their behaviour once they are introduced into the soil.

Not only in bankfiltration of polluted surface water but also in other infiltration techniques such as dune infiltration and groundwater recharge a knowledge of the chemical and physical processes which take place in the soil is of importance.

Recently also groundwater pollution by careless users of chlorinated organic solvents and by water percolating through land-fills of domestic and industrial wastes has been investigated.

Once when they are introduced into the soil some chemicals, particularly organo-chlorine compounds seem to be very persistent. Even after residence times of several months or even several years they are still present and can deteriorate the water quality.
Among these substances compounds such as tetrachloromethane, tetrachloroethene, trichloroethene, chloroanilines, chlorinated ethers, chlorinated benzenes, tri(2-chloroethyl)phosphate can be mentioned.

Other compounds which could improve the odour and taste of water seem to be formed in the soil. Substances such as 1,1-dimethoxy propane, 1,1-dimethoxy isobutane, bis(3-methoxyethyl)ether, bis(2-methoxy-2-ethoxy)ether and methylisobutyrate are found in groundwater. They have an agreable odour quality.

Several alkanols and aldehydes are present in bankfiltered water after passage of the soil. Among these chemicals cinnamaldehyde and dimethyl benzaldehyde are major compounds. Other oxygen containing compounds such as triethylphosphate are present too.

It is evident that several industrial chemicals are not fully eliminated they pollute the groundwater sources and endanger the drinking water supply. An important reduction of several chemicals however can be reached if the residence times in the soil are sufficiently long.

Organic chemicals which were major compounds in the river before bankfiltration were almost completely removed during passage of the soil. Among these are substances such as nitrobenzene, nitrotoluenes, some anilines, chloro-nitro-benzenes- und chloro-nitro-toluenes, 2(methyl-thio)benzo thiazol and methyl-tert.butyl phenol.

Several processes involving the reduction of organic chemicals during bankfiltration are similar to those during slow sandfiltration where microbial decomposition modifies organic compounds.

There is a correlation between chemicals which are not completely removed by slow sandfiltration and by passage of the soil.

The processes which modify or remove organic chemicals in the soil are filtration of particulate matter with adsorbed substances, adsorption and ion exchange, co-precipitation with carbonates and sulfides, hydrolysis, microbial decomposition under aerobic and anaerobic conditions and a combination of these processes.

A presentation will be given of measurements in The Netherlands under practical conditions. Polluted water before and after bankfiltration with different residence times in the soil, the results of the analysis of 250 raw water sources used for the drinking water supply and some specific cases of groundwater pollution by land-fills and industrial wastes are mentioned.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

The behaviour of organo-halogen compounds during the underground-passage

AUTHOR(S)

H. Kußmaul (Frankfurt)

The production of drinking water from surface waters in the Federal Republic of Germany usually includes an underground passage in order to utilize the considerable purification capacity of the underground for an initial water treatment. In order to determine the purification capacity of the underground relative to the organic load of the surface water, monthly studies in water works using bank filtration on the lower Rhine and in a water works on the middle Rhine below the junction with the river Main have been carried out over a period of several years.

The pumping galleries of the water works on the lower Rhine are situated about 50 m far from the river bank and draw water consisting of about 80% bank filtered river water and 20% native ground water. At the water works on the middle Rhine groundwater recharge is effected using river water which is either aerated over a system of cascades before being infiltrated from basins, or following pretreatment is infiltrated by means of injection wells. Tracer examinations have shown that waters from the heavily loaded Main flowing near to the bank also contribute to the recharge obtained through bank filtration.

The behaviour of the substances in river water prepared in the three ways described - bank filtration, basin infiltration, and well infiltration - was determined. Besides determining the usual parameters of water analysis, the behaviour of halogenated organic compounds was also examined. The organically bound fluorine, chlorine and bromine were analyzed too, and separated into fractions of high and low volatility. The individual substances were also qualitatively and quantitatively determined by gas-chromatographical and mass-spectrometrical methods as far as possible.

A considerable decrease in concentration of the high-volatile organo-chlorine compounds occurred directly within the infiltration area. The remainder of the underground passage had little effect. The concentration of the low-volatile organo-chlorine compounds is mostly reduced during infiltration and treatment, whilst the underground passage effected mainly a concentration balance.

The following substances were regularly or occasionally detected in the river water and recharged ground water: chloroform, bromoform, carbon-tetrachloride, trichloro-, tetrachloroethylene, dibromochloromethane, tetrachloroethane, hexachloroethane, di-, tri-, tetra-, penta-, hexachlorobenzene, hexachlorobutadiene, hexachloropentadiene, polychlorinated biphenyls, hexachlorocyclohexane, aldrin, dieldrin, heptachlor, heptachloroepoxide, DDT and metabolites, endosulfane and methoxychlor.

The behaviour of these compounds during the underground passage is very different. They are either retained to a large extent in the infiltration area, or they penetrate almost without hindrance into the underground. In the latter case activated carbon filters have to be employed in the water works which remove the compounds almost completely from the drinking water.

In summary, it can be seen that when the underground is capable of removing the organo-halogen-compounds from surface waters used for groundwater recharge, this occurs mainly in the direct surroundings of the infiltration area. The remaining underground passage effects mainly a concentration balance.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Organic halogenated hydrocarbons and artificial groundwater recharge

AUTHOR(S)
U. Bauer, Bochum

The fate of organic halogenated hydrocarbons in artificial groundwater recharge is discussed in view of slow sand filtration. The investigations were performed in the River Ruhr valley with the following groups of halogenated hydrocarbons:

1. non volatile chemicals like DDT, HCH, HCB and PCB in a pilot plant water treatment of the Dortmund water works,
2. volatile chemicals like Chloroform, Trichloroethylene, Tetrachloroethylene, Carbon Tetrachloride and Vinylchloride in the water recharge areas of Dortmund and Essen.

Pesticides and Polychlorinated Biphenyls reach groundwater according to their sorption on filter materials in different times. Lindane is revealed as a severe contaminant of groundwater because of it's solubility in water (10 ppm).
Volatile chlorinated hydrocarbons could be eliminated by slow sand filtration insignificantly in spite of the cascades. They are found in groundwaters and will be formed by chlorination of water in addition.
Variations of the Haloform-Reaction by seasons are discussed. The elimination of chlorinated hydrocarbons by artificial groundwater recharge is less effective compared with granular active carbon filters.

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INTERNATIONAL SYMPOSIUM

ARTIFICIAL GROUNDWATER RECHARGE

DORTMUND, 14–18 MAY 1979

TITLE Disinfectants and artificial groundwater recharge

AUTHOR(S)
N. Zullei (Dortmund)

Production and use of disinfectants and preservatives are rapidly increasing. After use, this substances show up again in surface waters. In the river Ruhr for example, phenolic components of commercial disinfectants were found in concentrations from several ng/l up to µg/l range. As phenol and its derivatives may be converted by drinking water chlorination into organoleptically unpleasant chlorophenols, their presence in raw water used for drinking water supply and their behaviour during water purification processes need to be monitored.

To obtain an estimate of the pollution by this substances at different stages of water purification in the municipal water works at Dortmund, samples of the following origin were taken at different times: Ruhr river water, filtrate of gravel filtration, artificially recharged groundwater, drinking water. Preliminary investigations showed that e.g. pentachlorophenol and 2,3,4,6-tetrachlorophenol are reduced to half their initial concentration by infiltration and underground passage. However, their concentration rises again after chlorination. A large variety of other substances was detected by the analytical method applied (liquid-liquid extraction and capillary gas chromatography), some of them only at the detection limit. Several substances cannot be completely removed by any biological chemical, or physical process in the filters and in the underground. Other substances are partly removed after the underground passage but occur again at higher levels after chlorination. Some of our results give rise to the assumption that another group of substances which must be present beyond the limit of detection is revealed only after chlorination.

In addition to these in-situ examinations, tests were carried out in a small-scale pilot plant. The test substances, 2,4-dichlorophenol and 3-methyl-4-chlorophenol, passed through the filter with no fixation on the filter medium occurring.

As there is a dependence of the performance to eliminate phenolic disinfectants from the conditions of filters and the underground passage the results of the pilot-plant tests can only be generalized to a certain extent.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

THE INFLUENCE OF ARTIFICIAL AQUIFER RECHARGE BY BASIN ON WATER QUALITY

AUTHOR(S)
M. RIZET - J. MALLEVIALLE - J.C. COURNARIE (Le Pecq)

The evolution of various pollutants in the recharging basin and in the successive layers of ground passed through, and their influence on the purifying microflora were studied using a pilot installation.

This 10 m deep pilot installation with a diameter of 9 m (fig. 1), reconstituting the aquifer conditions in the nearby Senonian chalk, permitted detailed study of the progression and evolution of the various pollutants of differing origins and natures introduced and of the effect of prechlorination carried out at various doses.

A. The pollutants considered during our experiments represent:

I. <u>either industrial, domestic or agricultural wastes</u>

I.1. Compounds of industrial origin: heavy metals, phenols, hydrocarbons and surfactants

I.2. Compounds of domestic origin: anionic and non-ionic detergents

I.3. Compounds of agricultural origin: pesticides

II. <u>or compounds which may be formed during prior treatment</u>

- Compounds formed during treatment: organochlorine or other derivatives

These products were measured upon introduction upstream of the holding basin, during retention in this basin, then by sampling at various ground levels down to the ultimate point at which the water would be tapped by wells.

Parallely, their impact on the purifying microflora was studied:

- in the basin: by regular determination of the phytoplanctonic, zooplanctonic and bacterial populations

- in the filtering media: by the evolution of the bacterial counts and the relative proportions of the various species present

B. The effect of prechlorination at various doses on haloform formation and the biological purification reactions was studied by regular analyses at various levels of:

- the chlorine derivatives formed
- the various types of nitrogen oxidation
- the purifying microflora

January 26, 1979

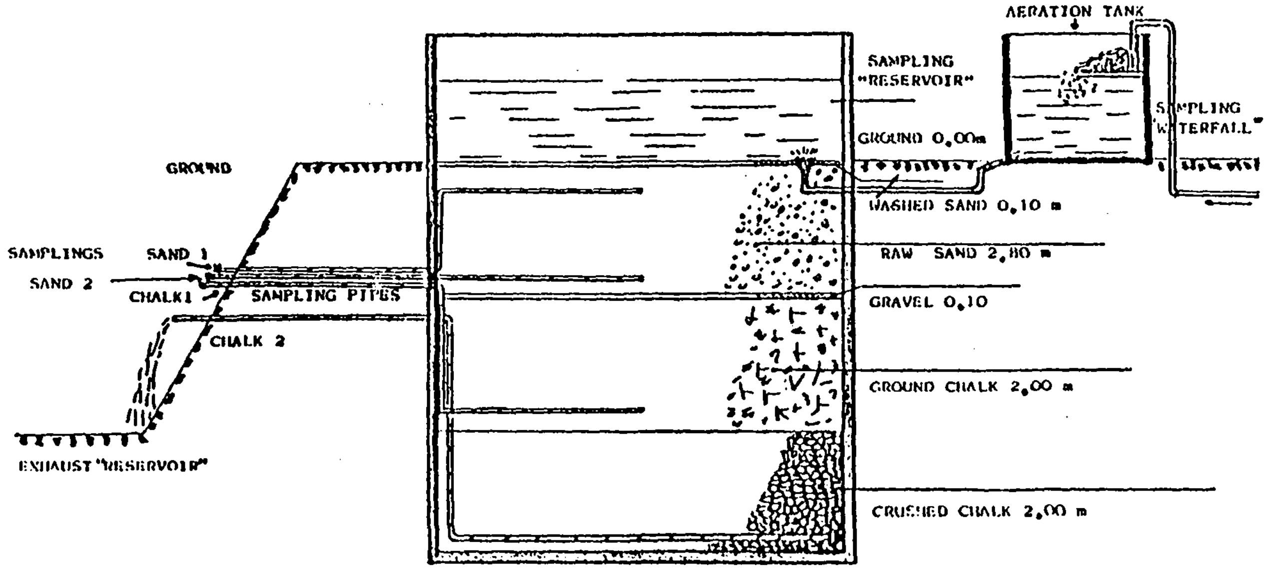


FIG.1. Study of water characteristics during aquifer recharging: experimentation basin at the Aubergenville plant, downstream of Paris

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Heavy Metals in Natural Filtration Systems

AUTHOR(S)

U. Schöttler (Dortmund)

From January 1, 1977 to March 31, 1978 heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, Zn) were analyzed in some selected artificial groundwater recharge areas of the Dortmunder Stadtwerke AG in the Ruhr Valley (fig. 1).

Samples were taken at different points of the treatment system (gravel-pre-filters, slow sand filters and underground passage) and the alternating influence of climatological and technical factors were also registered.

In spite of the same initial conditions (same pre-filtered water) evident differences were noticed, caused by different geochemical and hydrological factors, as shown by comparing the average heavy metal decontamination of the water in the two underground passage sites (fig. 2 and 3).

A statistical analysis demonstrated that bank filtration is the main source of the observed quality decrease in the area 4 - 10.

Figure(s)

INTERNATIONALES SYMPOSIUM
KÜNSTLICHE GRUNDWASSERANREICHERUNG
DORTMUND, 14. – 18. MAI 1979

TITEL Sorption of Heavy Metals in Sand Filters in the Presence of Humic Acids

AUTOR (EN)
U. Förstner (Heidelberg), C. Nähle, U. Schöttler (Dortmund)

In order to determine the cleansing capacity of sand filters for heavy metals, an experimental series was run using four identical filter columns which were continually fed with water from the Ruhr river. The dimensions of the columns were: Ø 20 cm, height: 80 cm flow speed : 10 cm/hr. Column I was used as a standard; In column II, humic acid was added in concentrations of approx. 6mg/l DOC; column III was prepared as column II with an additional 1 mg/l Cu/l; column IV was prepared like column II with an additional 10 mg Zn/l The preparatory period was 6 weeks. This was followed by a 24-hour measuring phase after which a 6-hour period for normalization followed.

Fig. 1 shows the concentrations of zinc and copper in solution previous to, and after passing through the column. Although the amount of zinc in the original concentration is 10 times that of copper, no increase in the zinc concentrations were to be observed after passing through column IV (humic acid + Zn). After a 10-hour flow period through column III (humic acid + Cu) however, the copper concentrations had increased significantly. An increased concentration of copper was also observed in the water outflow of column II (prepared with humic acids), probably due to the remobilization of copper by the humic acids in the filter.

After the experimental series was completed, the filters were cut into sections in the following thicknesses: in the top 10 cm: 2 cm thick; from 10 - 30 cm: 5 cm thick; from 30 - 80 cm depth: 10 cm thick. The < 2µm grain sizes were then separated from the sand in settling tubes and repeatedly chemically leached. The following bonding types of zinc and copper were then determined: (1) the exchangeable metal content by treatment with 0.2 n $BaCl_2$-triethanolamin; (b) the mostly humus-bound metals by extraction with 0.1 n

NaOH, (c) the moderately reducible metals, hydrous Fe/Mn oxides, carbonates, acid hydrolizable organic components etc, by extraction with 0.3 n HCl and (d) the residual fraction by $HF/HClO_4$ solution. The metal content of the extracts was determined by atomic absorption spectrometry.

A comparison of the distribution of zinc and copper in solid substances (figure 2) shows that the added zinc contents in the upper 30 cm of the sand filter are mainly fixed on the moderately reducible components, whereas the copper addition in all three non-residual compounds (a-c) is clearly enriched, also in the lowermost section of filter column III. The slower enrichment rate of the non-residually bound copper in the upper part of column II compared to column I leads to the conclusion that a remobilization effect occurs upon addition of humic acids. The concentration pattern of humic-bound copper in the filter column III parallels the metal contents on organic solid substances that are extractable with 0.1 N NaOH. This fact implies that the migration behavior of copper in these column experiments are determined chiefly by the formation of copper-humate complexes.

Anodic stripping voltametry experiments to the differentiation of labile and strongly bound forms of copper and zinc in the dissolved phase show that zinc bonding forms in the inflow to the sand filter are basically labile. However, at this stage copper is for the most part solidly bound. Upon passing through the filter column, a relative increase of the labile bonding form occurs. The varying rates of elimination of both metal examples can be explained by the fact that zinc is chemically actively bound to hydroxide, which has a high uptake capacity for free metal ions (and weak metal complexes), during flow through the filter. The copper component, which is in a more solidly bound form (greater complexed), partially remains unaffected by the physico-chemical interractions with the filter material. We therefore conclude that the cleansing capacity of a sand filter is less determined by its material composition (adsorption capacity, particle specific surface, percentages of hydrous Fe/Mn-oxide, clay minerals, organic particles) than by the chemical form of the metals in the dissolved phase.

Figure 1 Water data

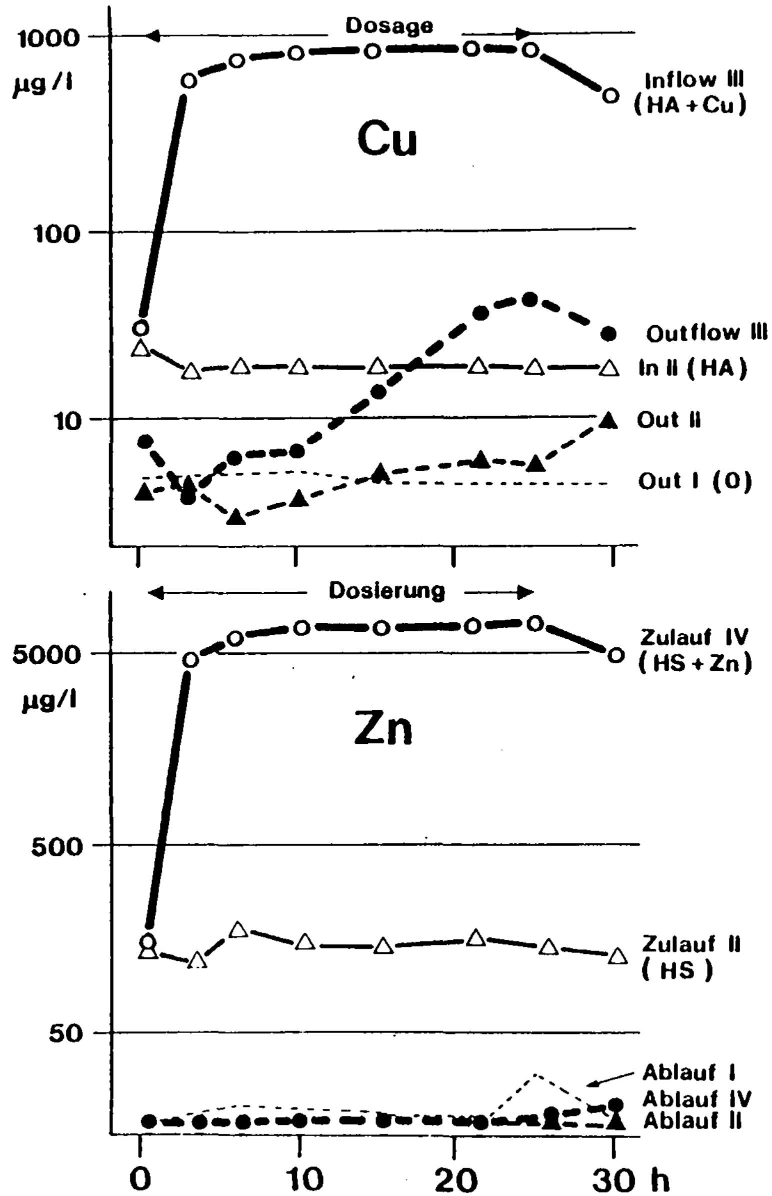
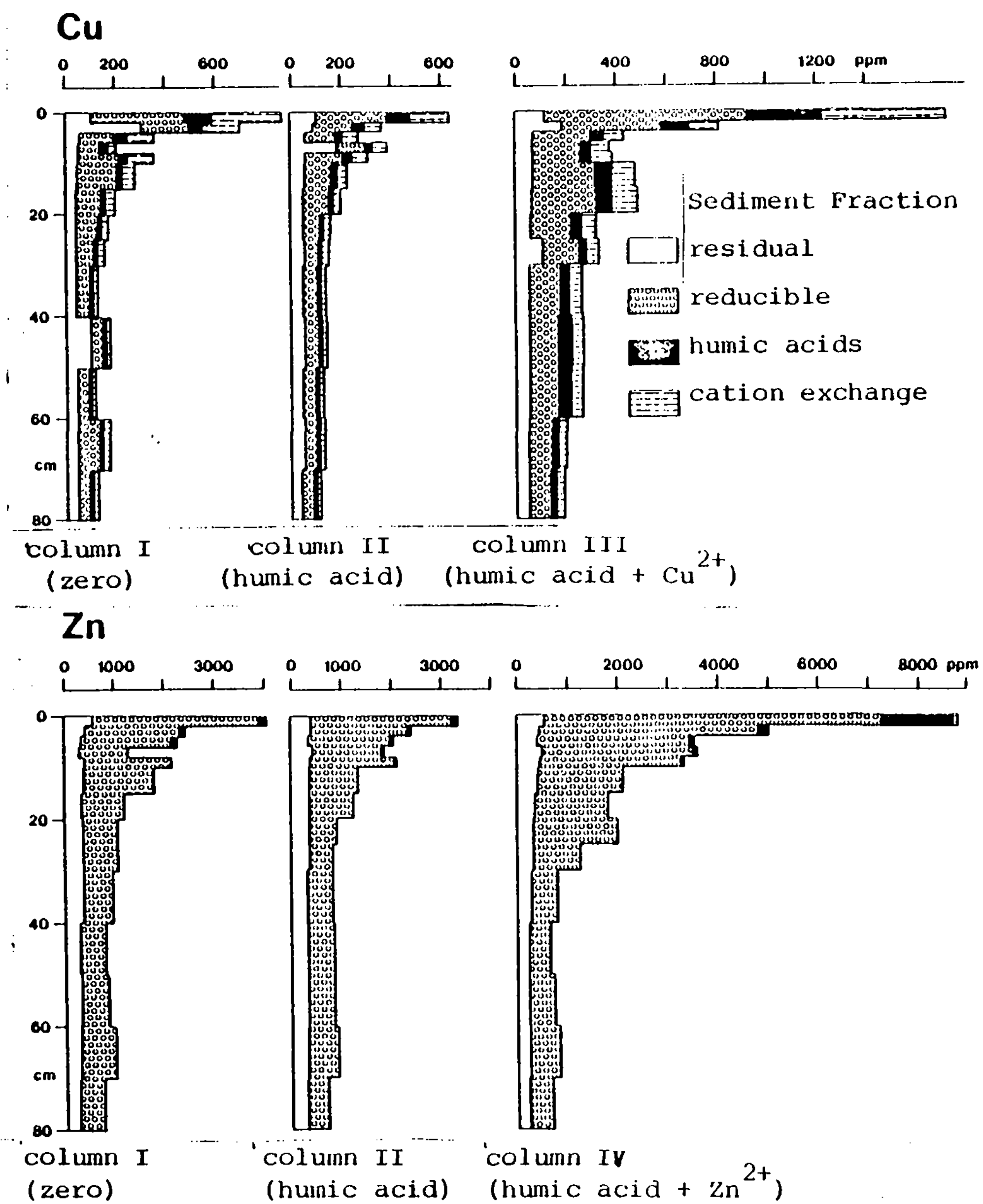


Figure 2 Sediment data



INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Behaviour and effects of biogenic organic compounds in slow sand filters for artificial groundwater recharge

AUTHOR(S)

G. Klein (Dortmund)

The suitability of slow sand filtration for the removal of biogenic organic compounds (indoles, fatty-acids, amines) in several concentrations from contaminated raw waters was tested using model filters in the laboratory and on a semi-technical scale. From the data obtained we calculated the capacity of slow sand filters for indole, skatole and palmitic acid to be about 40 - 48 mg/m^2 of filter surface area.

The micro-organisms within the filter biocenosis start to decompose the organic compounds already in the saturation phase, therefore the amounts of these compounds in the filter will not exceed saturation provided the concentrations are not too high.

The ability of the filter flora to decompose biogenic organic compounds over longer periods of time has been calculated on the basis of the above experiments and ranges from less than 0,05 $mg/m^2 \cdot h$ to about 8 $mg/m^2 \cdot h$. High decomposing activity was found to correlate with high concentrations of contaminants, low activities were found during normal running of the filters without any further addition of pollutants.

Chemical and physical properties of the organic compounds are discussed as important factors affecting decomposition and elimination, as well as the rate of uptake by the microorganisms.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE

Algae in water catchment plants - Possibilities to prevent mass developments

AUTHOR(S)

B. Pätsch, W.D. Schmidt (Gelsenkirchen)

The percentage of prepared surface water for the winning of drinking water increases continuously. The water works in the Ruhr District which cover most of their water demand through the artificial recharge of groundwater, use at present already 88 % surface water.

Algae form a natural component of all sound waters. However, they have become an important factor of disturbance for the operator of water works owing to the interference of men into ecosystem. All conditions are given in the recharge basins to favour an excessive development of algae, viz.:

Supply of nutrients, light and sufficient residence time.

The following difficulties and disadvantages arise from an excessive growth of algae:

a premature clogging of the surface of the recharge basins,

higher expenditure for cleaning,

delivery of organic substances to the water, possibly even of phytotoxines,

taste and odor problems.

Methods to avoid mass developments of algae in water catchment plants are developed and tested, since 1968, in a Working Group of DVGW.

In the past ten years, the following methods were tested:

- increase of the pH
- precipitation of phosphates
- withdrawal of light
- addition of chemicals
- intermittent running
- micro-straining
- rapid filtration

Among these methods, only two proved to be practicable and effective, viz.:

the feeding of potassium permanganate and intermittent running.

The Working Group of DVGW "Suppression of Algae and Problems of Cleaning" intends to publish the experience obtained in the course of the past years in a paper to be published within the "DVGW-Regelwerk".

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE Pilot plant study of artificial recharge of pretreated water from the river Rhine in the Veluwe area

AUTHOR(S) J. Hrubec (Leidschendam)

The need for sufficient water storage capacity in The Netherlands to bridge periods during which the quality of the river water does not meet the required quality standards for use as raw water for drinking water production necessitated studies to evaluate the possibilities of artificial recharge of treated water from the river Rhine in the Veluwe area.
In this area, located in the central part of the country, the geohydrological conditions are favourable for a recharge of Rhine water at a production capacity of 100 - 500 mil./m^3 year. With regard to the management aspects of the recharge plan, that as the location constitutes an unique area of great ecological and recreational importance, it is important to conserve the natural characteristics of the area and to reduce exploitation activities to a minimum.

Some aspects of the artificial recharge in the Veluwe were studied in a pilot plant, located at Leiduin, in the dune area in the western part of the country where river water is infiltrated by the Amsterdam Waterworks.
The most important objectives of the study were to find optimum pretreatment methods in relation to the infiltration rate, clogging intensity of the infiltration medium and to obtain information on changes of water quality during percolation.
The plant consisted of a pre-treatment unit with a capacity of 100 cu. m per day and an artificial recharge unit consisting of six tanks, each 6.5 m high and 2 m in diameter.
The raw water was treated according to the following scheme: breakpoint chlorination, contact upflow filtration, ozonisation, secondary iron dosing, rapid filtration and activated carbon filtration. By means of this scheme it was possible to produce 5 different grades of water.

The pilot plant experiments showed that by the recharge of highly pretreated water of the river Rhine in the Veluwe by means of underground tunnels, high recharge rates of 10 - 20 m/day and long recharge runs in the range of a few years could be reached. As a minimum pretreatment of river water, removal of ammonia, aeration, coagulation and rapid filtration is necessary. The most important quality constituents of the pretreated water, which controlled the rates of clogging of the recharge surface, were the turbidity and the iron content. Maximum values of these parameters for which an acceptable intensity of the clogging by the recharge by means of underground tunnels occurred were in the range of a turbidity of 0.2 JTU and an iron content of 0.05 mg Fe/l.

The depth of the clogged upper sand layer, which has to be removed after the recharge run to obtain a recovery of the recharge rate can be estimated at about 5 cm.
The changes of water quality within the upper layer of a few metres of the recharge medium were controlled in particular by microbiological processes. At recharge rates lower than about 15 m/day similar quality changes can be expected as occur during slow sand filtration. At higher recharge rates these changes will be limited. During recharge, sorption on the medium consisting of relatively clean sand can have a polishing effect through the removal of the phosphate and the trace elements Cu, Cr, Li, Ni and Zn.

INTERNATIONAL SYMPOSIUM
ARTIFICIAL GROUNDWATER RECHARGE
DORTMUND, 14–18 MAY 1979

TITLE Groundwater recharge for the purpose of obtaining drinking water through the method of combining flocculation, filtration and seepage passage (experimental plant in Berlin-Jungfernheide)

AUTHOR(S) H.-J. Altmann, A. Grohmann, U. Hässelbarth, H. Kowalski, F. Sarfert. (Berlin)

Part I. Results of analyses and their significance for the drinking water supply in Berlin.

The "Berliner Wasserwerke" (Berlin water works) have supplied about 180 million m^3 of water a year in the last years, whereby the daily peak delivery amounts to over 1 million m^3. 460 wells are necessary to deliver such a large quantity of water, which reach down as deep as 100 m into the sands of the ancient river valley of the glacial period between Warsaw and Berlin. In order to prevent a sinking of the groundwater level, seepage installations are being operated in Berlin for the groundwater recharge. These are big basins artificially dug, the bottom of which is covered with coarse sand. In the last years, the quality of the surface water has worsened so much and the eutrophization has become so much stronger that the seepage installations have become clogged very rapidly, especially during the algae blooming period. As a consequence of this situation, especially in summer when more water is needed, a reduced quantity of water can be seeped. Moreover, an unfavourable evolution of the quality of the groundwater produced in this way has been observed. After the blooming of diatomaceae in spring and of cyanophyceae in summer and in autumn, pure water may receive a bad taste, particularly when this water has been chlorinated too. For these reasons, an experimental plant was built on the Spree River (Wasserwerk Jungfernheide), with the support of the Federal Minister for Research and Technologie. In this plant, studies have been carried out in the last 3 years to find out how the Spree water can be purified and how the quality of this treated water changes by seepage passage, in comparison to seeped water from untreated Spree water.

The following are fundamental requirements for this experimental plant:

1) Chlorine will deliberately not be used. A possible treatment by ozone should occur only later on.

2) Pure water loaded with as few organic substances and phosphates as possible should be obtained through a suitable dosage of coagulants and coagulant aids.

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3) The method of combining mentioned above must be able to treat water receiving strong increases, within a short period, of turbid substances such as sludge whirled up by shipping traffic on the Spree River.

4) It also must be possible to intercept large amounts of algae during massive algae blooming in the Spree.

5) Three procedures are applied:
   a. Seepage of untreated Spree water
   b. Seepage of Spree water after flocculation
   c. Seepage of Spree water after flocculation and filtration.

The most important results of this experimental plant in respect of the security of the drinking water supply are the following: non-dissolved substances (fig. 1) are eliminated through flocculation and filtration, in so far as the seepage installations must be cleaned only every two years or after much longer periods. Algae blooming and the resulting bad taste of the water will be, in the future, completely eliminated. Moreover, a general reduction of the load of organic substances in the water will take place. This can be measured, for instance, through U.V. extinction at 254 nm (fig. 2). Finally, a reduction of the colony counts to values below ten (fig. 3) can be already expected after the seepage passage of water through 1 m of soil. This makes certain that chlorination of raw water and of treated drinking water as well, can be done away with.

Part II. Evaluation of the clarification efficiency

On the basis of the results of a three year study, the "Berliner Wasserwerke" (Berlin water works) intend to build a plant for the preliminary clarification of the Spree water in order to recharge groundwater. After the starting of this plant, the quality of the drinking water obtained through seepage passage will improve. There will be less organic substances dissolved in water and the water load in bad-smelling and -tasting substances due to massive development of algae in the seepage basins will not occur any more, because such massive developments will be stopped by the preliminary clarification through an extensive phosphate elimination. Besides these very desirable improvements in respect to hygiene, there are still some questions which have to be critically evaluated:

1. the microbiological nature of groundwater obtained through seepage passage
2. the elimination or inactivation of viruses
3. the elimination of heavy metals
4. the elimination of organic impurities
5. the residual concentration in water of additives, which were used for treatment.

Only filtration on granulous material intercepts flocculated turbid substances from surface water, to which may also belong bacteria, viruses and algae, in so far as it meets the requirement for drinking water supply. For a water strongly loaded with turbid substances such as Spree water, a settling tank should be set into the circuit before the filter, in order to hold off the principal part of the turbid substances from the filter and to prevent an excessively frequent rinsing of the filter. Through the method combining flocculation, filtration and seepage passage, the water is so released from reducing compounds and micro-organisms that a chlorination of the drinking water obtained need not take place. Thus, the organochlorine compounds, which are brought into the water by chlorine or which are formed through the reaction of chlorine with humates,are also avoided.

In the Spree River about 10 to 20 virus units in 10 l water samples analysed have been detected. After flocculation and filtration, the result for 10 l is negative. If a filtration rate of 0.2 m/h (4.8 m^3/m^2 per day) for the seepage passage is maintained, a more important reduction of 2 to 4 orders of magnitude can be expected according to the studies of Walter and Rüdiger; this means that the results will also be negative for a water sample of 1 m^3 (or more).

Heavy metals are eliminated in as far as they are adsorbed on turbid substances in water or when they form insoluble carbonates and oxides or when they are held through ionic exchange on clay minerals in the soil. After flocculation and filtration, only residual concentrations resulting from the extremely low but remarkable solubility of these substances, remain in the water. Their concentration lies within the limit values capable of being analytically detected, that is distinctly below the specific limit value for drinking water.

The question whether toxic organic substances are eliminated from the water remains unanswered. The possible diversity of organic compounds and the great difficulties in analysing quantitatively and qualitatively individual substances does not allow any definitive answer. Nevertheless, it was proven, based upon the example of the polycyclic aromatic hydrocarbons, for which a limit value has been fixed because of their carcinogenous properties, for drinking water, that hydrophobic and difficult to dissolve compounds are eliminated through flocculation by application of polyacrylamides. The Spree contains this class of substances with 0.015-0.025 mol/m^3 C (limit value for drinking water 0.02 mol/m^3). After the filtration its' contents are less than the detection limit value of 0.002 mol/m^3. In contrast, the organochlorine compounds contained in the Spree (i.e. 0.4 - 14 µg/l $C_2H_2Cl_4$ or i.e. 0.5 µg/l $CHCl_3$) reach the groundwater in a practically unchanged concentration.

The organic carbon dissolved in the Spree water (5 to 10 g/m^3 DOC) consists of less than 1 g/m^3 DOC of those compounds, which are to be considered as being anthropogenous pollutants. The fractioned reversed osmosis with membranes of different degrees of permeability for substances with molecular weights between 200 and 10 000 show the same pattern for water from the Spree as for a non-polluted water. The fractions, up to that one obtained with the finest membrane, have an U.V.-extinction at 254 nm , which is typical for humates. The analysis with a gaschromatography/mass spectrometer system connected to a computer, after previous extraction with methylchloride, brought no evaluable peaks, wherefrom it can be concluded that the substances under consideration constitute much less than 1 g/m^3 of water in their sum.

The extensive elimination of humates, perhaps by ozone and biologically active A-coalfilters, is not applicable, being so, as long as the effect of the seepage passage on the micro-biological nature of the water remains guaranteed and thus a chlorination of the drinking water obtained needs not take place.

For the flocculation, iron or aluminium salts are used, since they show a pollution of toxic metals which is as little as possible. As a bridge linkage by flocculation, anionic poly-acrylamides serve with less than 0.1 % monomere proportion. The residual polymeres remaining in water are precipitated through a post-flocculation and are intercepted up to the detection limit value of 0.005 g/m^3 in the filter.

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