

## **Groundwater artificial recharge: actuality, topics and geographical analysis**

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**Abstract.** A computerized bibliographic research on groundwater artificial recharge is carried out, following the same methodology as implemented in a previous bibliographic research in 1987. The facilities of the electronic instruments offered by the host computers and by the database are investigated. The results are analysed and compared with those of the previous research. A critical review of the research strategies is presented. A description of the characteristics of the bibliographic files and information of the costs is also provided. Some more precise explanations concerning the technical terminology are given in the appendix.

### **1. Introduction**

Generally speaking, research involves retrieving information in different domains (science, engineering, technology) and at different levels (theory, practice, methodology, experience). The increasing need for information is also related to the increasing interest in multi-disciplinary subjects. In this context the electronic tools offered by databases and internet facilities are helpful. The question whether greater amounts of data mean higher information quality is an open one.

The aim of this study was to make a critical review of the information retrieval methods used for computerized bibliographic research and a critical analysis of the product obtained.

The subject was chosen in the context of groundwater management problems, following the same methodology as applied in a previous bibliographic research carried out in 1987.

The purpose was to analyse the retrieved documents from a scientific and a bibliographic point of view and to compare them with those obtained in the previous research.

### **2. Research procedure**

Research may be rendered efficient by defining a query strategy based on the characteristics of the IT system and the bibliographic files, as well as on the subject chosen.

#### **2.1. IT system and databases**

An EINS-GEM IT system was used. This system has the advantage of offering easy access, a compact query procedure thanks to a few basic commands (Expand, Select, Limit, Zoom), different output formatting options and a complete overview of the costs associated with the databases.

From a first analysis of the files available in EINS-GEM, 108 files were listed and 10 of them were selected for the present research: Enviroline, Pascal, Geobase, Chemabs, Inspec, Ulidat, Fluidex, Ntis, Eaudoc, Conf.

The choice of the above-mentioned files was based on the scientific subjects covered by the files themselves (Tab.1).

Tab.1 – Subject coverage

DATABASE	CONTENTS
Enviroline (Environmental Sciences Abstracts)	All aspects of environmental sciences
Pascal (French National Research Council file)	Multidisciplinary and multilingual database
Geobase (Geo Abstracts Journals)	Earth sciences, ecology, geomechanics, human geography, and oceanography
Chemabs (Chemical Abstracts Database)	All areas of chemistry and chemical engineering
Inspec (produced by the Institution of Electrical Engineers)	Four sections: Physics, Electrical Engineering and Electronics, Computers and Control, Information Technology
Ulidat (Umweltliteraturedatenbank produced by Umweltbundesamt)	Water, air, waste management, noise, and soil environmental research
Fluidex (Fluid Engineering Abstracts)	Civil Engineering and Process Engineering
Ntis (National Technical Information Service)	Multidisciplinary Database
Eaudoc (Abstract Journal Information Eaux)	Problems and aspects in relation to fresh water
Conf	Conferences and Meetings in science and technology, specifically conferences in energy, physics, mathematics and chemistry

The above-mentioned databases are available on the GEM Web site [www.gemcatcher.com](http://www.gemcatcher.com) through the gateway to Fitz-Karlsruhe. To access the database the Begin command in Command Search and the database number or name is used.

Information concerning the sources, the time span, the database size and the database update were also available (Tab.2)

Tab. 2 – Database description

Bibliographic Files	Date	Total no. of documents	Update	Sources (no. of journals)
Enviroline	1971	316 960	600/monthly	-
Pascal	1984	8 700 000	10 000/weekly	-
Geobase	1980	1 035 377	72.000/yearly	1700
Chemabs	1947	19 320 657	14 000/ weekly	9000
Inspec	1969	6 684 990	6 000/ weekly	4000
Ulidat	1976	420 562	1 900/ monthly	-
Fluidex	1974	450 000	15 000/ yearly	1000
Ntis	1964	2 121 220	100/ weekly	-
Eaudoc	1970	128 741	4 times/ yearly	-
Conf	1976	165 590	200conf+200ref/ weekly	-

(From Infosheet –updated to October 2002)

## 2.2 Research subject and search procedure

The research project was the same as that of a previous bibliographic research carried out by the authors in 1987. The research domain was the same: artificial groundwater aquifer recharge with spreading basins. Attention was focused on the hydraulic of the groundwater flow. The problems related to the management of the recharge plants were included, but the aspects related to the quality of the water were neglected as well as the chemical, biological, and thermal aspects of the phenomenon.

The same search procedure was followed in order to outline the evolution of the electronic means for information retrieval in terms of accessibility to the databases, of quantity of references displayed and of costs.

The search strategy was defined as a sequence of commands (query) which are described in Tab.3. For each step (set) the number of the displayed references (hits) is also shown.

Tab. 3 – Search History

SET	HITS								QUERY
	Enviroline	Pascal	Geobase	Chemabs	Inspec	Ulidat	Fluidex	Ntis	
1	12620	9798	14527	11390	5469	2404	3372	3712	GROUNDWATER
2	354	496	85	87	15	25	12	97	ARTIFICIAL RECHARGE
3	235	207	66	19	9	7	7	6	1 AND 2
4	0	19242	5192	9201	537	8892	1644	17852	WATER QUALITY
5	1491	34971	1215	85999	5423	4838	554	31933	WATER POLLUTION
6	1922	271	31	88385	84	934	2	229	WATER PURIFICATION
7	60	229	66	34	27	14	36	1540	THERMAL POLLUTION
8	0	82	4	279	7	8	1	27	CHEMICAL QUALITY
9	953	43389	4157	40448	27848	3242	3488	10943	WELL
10	235	156	62	19	8	5	5	5	3 NOT 4
11	234	156	62	19	8	5	5	4	10 NOT 5
12	227	156	62	14	8	5	5	4	11 NOT 6
13	227	156	62	14	8	5	5	4	12 NOT 7
14	227	156	62	14	7	5	5	4	13 NOT 8
15	220	142	56	14	7	4	4	3	14 NOT 9

The search procedure was applied to each selected database. It should be noted that it was not possible to take advantage of the possibility of creating clusters – as in the case of the previous research – since this facility was no longer available.

## 3. Results

The query search highlighted 450 references and 2 conferences: 220 documents in Enviroline, 142 in Pascal, 56 in Geobase, 14 in Chemabs, 7 in Inspec, 4 in Ulidat, 4 in Fluidex, 3 in Ntis, 2 conferences in Conf, 0 in Eaudoc.

Enviroline and Pascal were found to be the 2 databases that made the greatest contributions to the results. Chemabs which had the biggest database

with  $193 \cdot 10^5$  documents displayed only 14 references relating to the subject of interest.

### 3.1 Comparison between the results obtained in 1987 and 2002

The evolution of the databases is shown in Fig.3. The size of Chemabs and Inspec has increased 2.5 fold in 15 years. They have probably included new subjects or expanded some subjects. In actual fact, an increase in database size did not correspond to an increase in the number of retrieved documents (Fig.1).

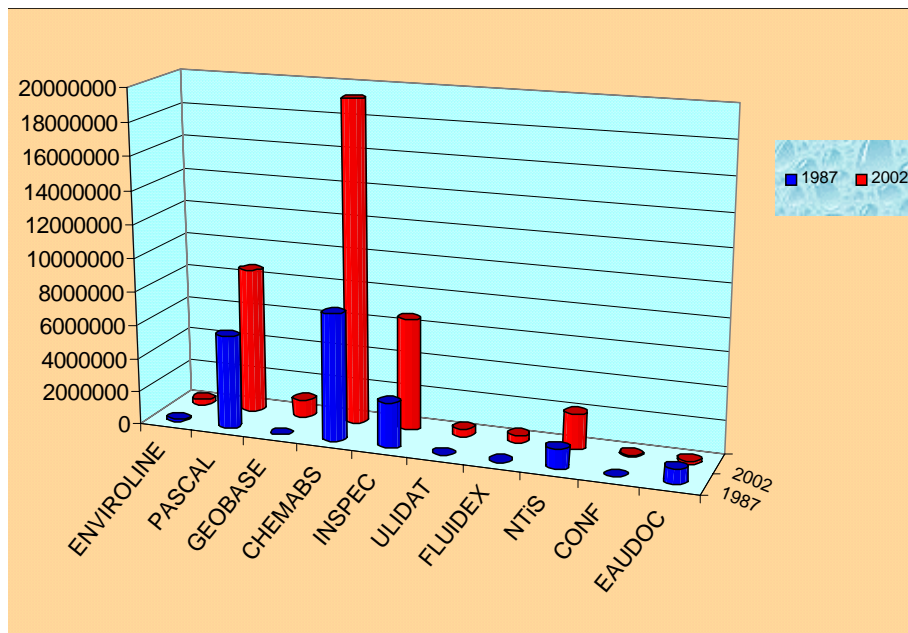


Fig.1 – Comparison between the number of retrieved documents in 1987 and in 2002

### 3.2 Classification

#### Step one

The retrieved documents were first divided into two groups: the first group refers to theoretical aspects, while the second one refers to practical experiences.

It is not always easy to tell whether a document belongs to the first group or to the second one: some documents focus on a general problem and at the same time illustrate a case study, some other documents present a generalisation of the results based on a specific experience.

The abstracts and additional information contained in the controlled terms serve to give a preliminary idea of the nature of the information

contained in the article. The available information in the bibliographic references was used to classify the retrieved documents.

Step two

The documents of both groups were classified: the documents of the first group were classified by subject since they deal with a particular problem or approach, while the documents of the second group were classified by country since they describe case studies or applications.

An overview of the classification based on subjects and countries per database is provided in Tab.5.

	Pascal	Enviroline	Geobase	Chemabs	Inspec	Ulidat	Ntis	Fluidex	Total Document
General Aspects	23	22	13	6	1	3	1		69
Monitoring and realisation	9	7	4	1					21
Mathematical model	10	7	4		2				23
Experimental investigations	5	3	2		1				11
Water quality aspects	13	24	5	2		1			45
Use of waste water	1	16	2	2					21

<b>Experiences in Europe</b>									
Austria			1						1
Belgium	1							1	2
Czech Repub.		1							1
Denmark		2	3						5
Finnland	1	1							2
France	1								1
Germany	8	2	2		1				13
Greece								1	1
United Kingdom	5	6	2						13
Italy	4								4
Yugoslavia	2								2
Lebanon	1								1
Netherlands	5	3							8
Poland	1								1
Spain	1		2						3
Schweden	3	1							4
Switzerland	5								5
Russia	1								1
Hungary		1	1						2

Experiences world-wide									
Australia	5	3	2						10
Brazil	1								1
Canada		2							2
China		3	1						4
Cyrus	1								1
Egypt	2								2
Japan	3								3
Indian	4	2	3	1	1				11
Iran	1								1
Israel	3	8							11
Kuwait	2								2
Mexico			1						1
Nepal	1								1
Oman	1								1
Nigeria	2								2
South Arabia	1	2							3
Sri Lanka	1								1
South Africa	1	1							2
Thailand	1		1		1				3
Tunisia			3						3
United States	5	103	4	1			2	1	116

Tab.4 – Classification

### 3.2.1 Classification by subject

In order to obtain an overview of a multiplicity of investigated subjects some categories were taken into consideration.

The categories of subjects are:

General Aspects
Monitoring and Realisation Techniques
Mathematical Models
Experimental Investigations
Water Quality Aspects
Use of Waste Water

The category General Aspects includes bibliographic researches, overviews and states of the art. It covers the topics of water resources management, planning and optimisation criteria, river restoration, GIS applications. Owing to its general character, this category contains the largest number of references (69 references). The retrieved documents include 2 bibliographic researches (1 in Enviroline, 1 in NTÍS) and 5 States of the Art (4 in Pascal and 1 in Geobase). The States of the Art refer to USA, Great Britain, USSR, Germany and India.

The category of Monitoring and Realisation Techniques shows the same number of references as the category of Mathematical Models (respectively 21 and 23 references). These two categories show a parallel

increase in information and consequently have the same importance within the framework of the research carried out.

Laboratory experiments, grouped in the category Experimental Investigations account for only 11 documents. Experimental work is known to be always time consuming, to often require specialised personnel and sometimes expensive instrumentation.

With the search strategy used, it was not possible to avoid obtaining references related to the water quality aspects in the retrieved information.

The reason for this is that it was not possible to consider all the word combinations which appear in the titles and in the controlled terms, such as quality standard or contamination or water protection or remediation measures or purification costs. Consequently, 45 references concerning quality aspects and 21 references to the waste water use were found.

An overview of the subject-based classification is shown in Fig.2.

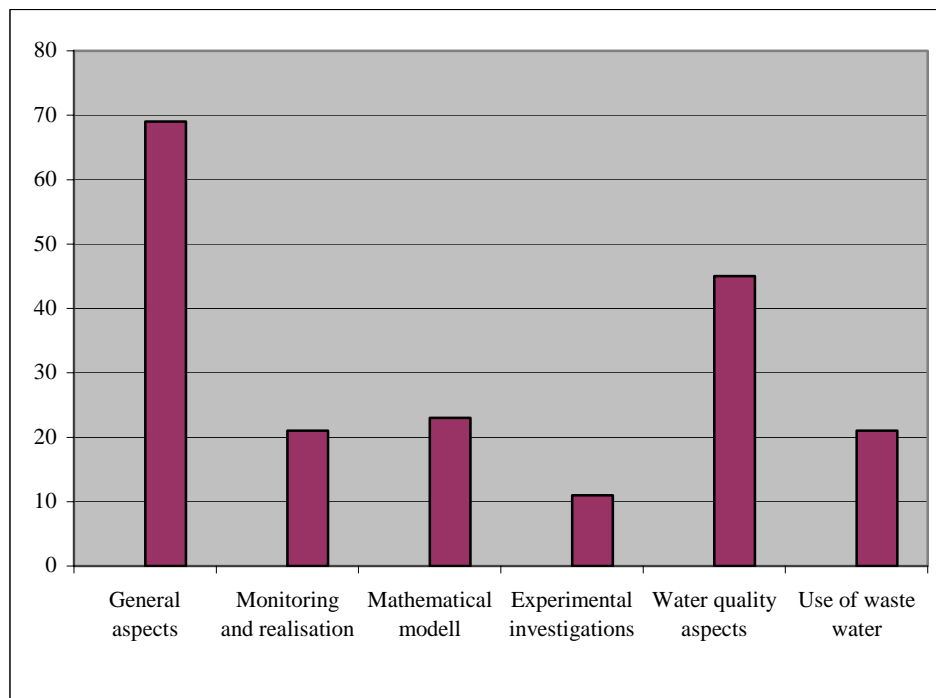


Fig.2 – Number of retrieved documents for each category

### 3.2.2 Classification by country

At world level, the USA accounts for the largest number of documents (116), much more than any other country. It should be noted that some documents refer to the same recharge plants or to the same experiences but focus on different aspects of the study. It should also be noted that almost all of them, 103 out of 116 documents, belong to the Enviroline database.

Within the non-European experiences the countries accounting for the largest number of documents (excluding USA) are India, Israel and Australia (11 or 10 documents each), followed by China, Japan, South Arabia, Thailand, Tunisia with 4 or 3 documents each and Canada, Egypt, Kuwait,

Nigeria, South Africa with 2 documents each. Some countries have emerged which did not appear in the previous research: Brazil, Cyprus, Iran, Mexico, Nepal, Oman, Sri Lanka.

Classification by extra-European country is shown in Fig.3.

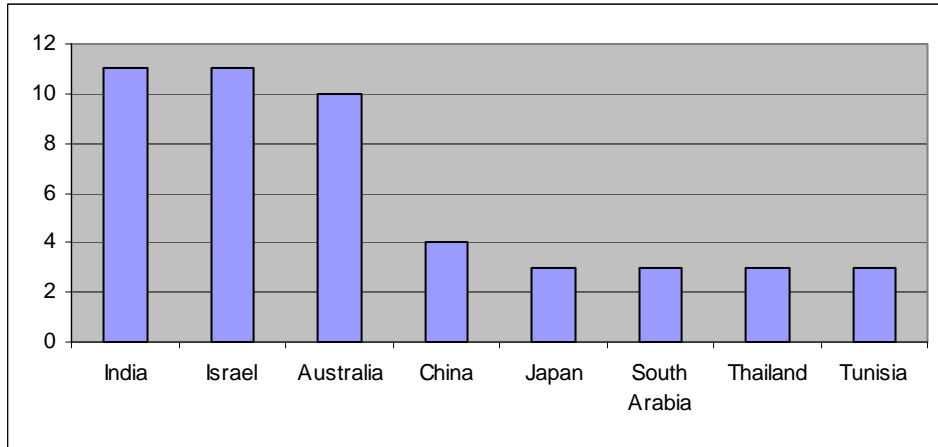


Fig.3 - Number of retrieved documents for each category (extra-European countries)

Within the European experiences the countries accounting for the largest number of documents are Germany, Great Britain and the Netherlands (between 11 and 8 documents each). The Scandinavian countries account for 6 documents, Switzerland 5 and Italy 4. The Italian experiences are related to the recharge plants in Valdarno in Toscana, Cinisello Balsamo near Milan and Piana dei Colli near Palermo in Sicily.

Classification by European country is shown in Fig.4.

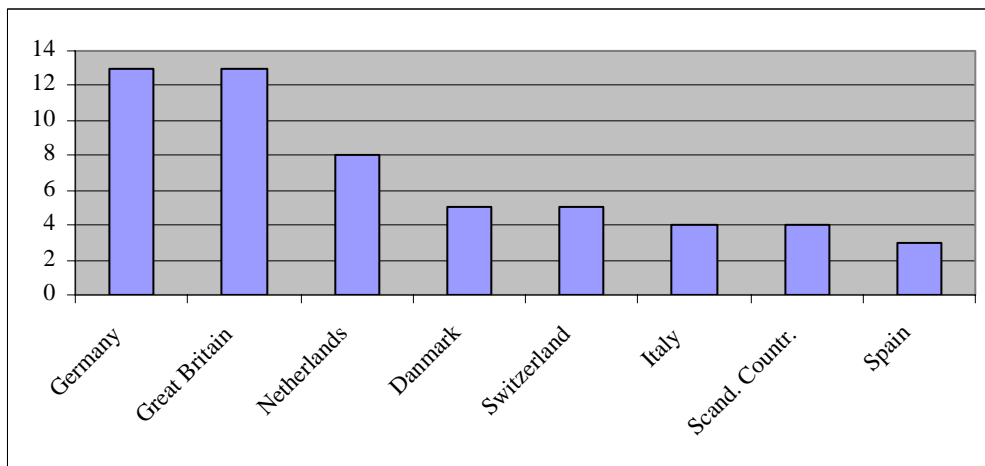


Fig.4 - Number of retrieved documents for each category (European countries).

#### 4. Conclusion

A computerized bibliographic research was carried out in October 2002 on groundwater artificial recharge. This domain was restricted to the



hydraulic aspects of ground water flow, disregarding the aspects related to the water quality. The same methodology and the same search strategy as had been applied in a previous research in 1987 were again followed in order to ensure comparable results.

Some facilities for computerized bibliographic research using the databases available by EINS-GEM were also described: the procedure for accessing the IT system and databases is easy, the search methods have a wide range of applicability and the query syntax is compact.

The number of scientific subjects covered by each database has increased; the subject coverage was found to be broader and spans also multidisciplinary themes. With the search procedure used it was not possible to retrieve only the documents of interest. The variety of terminology used in the controlled terms could not be covered by the few operations defined in the search strategy. As a result, also documents concerning the water quality aspects and the waste water use were also found among the retrieved documents. In addition it should be noted that the bibliographic information is organised in the databases in different ways. This made both the search and the classification of documents time consuming and inefficient.

It was not always easy to classify the documents by subject or country, since some of them depending on the information in the abstract could be associated with more than one category. Sometimes the classification was based on a personal opinion of the authors. Within these limits, and disregarding the documents concerning water quality and waste water use, the results of the classification can be summarised as follows.

The largest category was found to be the category General Aspects, which includes also bibliographic researches, overviews and states of the art. It covers the subjects of water resources management, planning and optimisation criteria, river restoration and GIS applications.

The subjects of the categories Monitoring and Realisation Techniques, Mathematical Models and Experimental Investigations were represented in equal proportions.

Among the applications, the USA reaches in first position. Other important countries in the classification are: Germany, Great Britain, India, Israel and Australia.

It is also interesting to note that countries that were not mentioned in the previous research are represented in the classification of the present study.

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