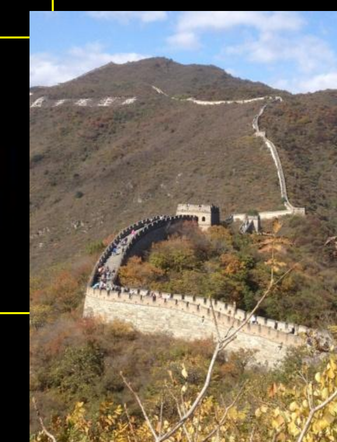
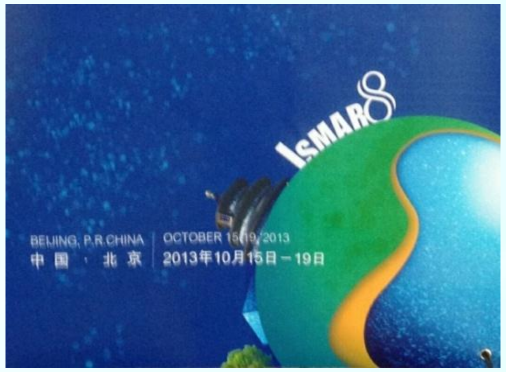
P-ISMAR 8

8TH INTERNATIONAL SYMPOSIUM ON MANAGEMENT OF AQUIFER RECHARGE, ISMAR-8, POSTERS. BEIJING, CHINA



8º SIMPOSIO INTERNACIONAL DE GESTIÓN DE LA RECARGA DE ACUÍFEROS, ISMAR-8, PÓSTERS. PEKÍN, CHINA

EDITOR: ENRIQUE FERNÁNDEZ ESCALANTE



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P-ISMAR 8

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P-ISMAR 8

POSTERS OF THE 8TH INTERNATIONAL SYMPOSIUM ON MANAGED AQUIFER RECHARGE, BEIJING, CHINA

INTRODUCTION

ISMAR 8 "Managing Aquifer Recharge: Meeting the Water Resource Challenge" was held in Beijing, China on the 15-19th October 2013. The symposium was promoted by IAH-MAR Working Group and the universities of Tsinghua and Jinan.

The event was supported by institutions and companies such as UNESCO, China Geological Survey, National Natural and Scientific Foundation of China, Beijing Drainage Corp., Research Center for Eco-Environmental Science, Gaobeidian Sewage Treatment Plant, Beijing Hydraulic Research Institute, Jilin University, Beta Analytic, etc.

149 delegates from 27 countries attended the symposium, which included 6 workshops, 83 oral presentations and 38 poster were exhibited. A total of 121 papers were written, covering five thematic groups; Design and construction of MAR, Operations and maintenance of MAR, Governance of MAR, Applications of MAR in water resources management & Other issues related to MAR. A detailed list can be found at: http://ismar8.org/info/theme

51 papers were selected to be published in special editions of the ASCE Journal of Hydrologic Engineering and Springer Journal of Environmental Earth Sciences, compiling selected papers in engineering, geosciences and governance.

Papers that were not included in the journals were given the opportunity to be reviewed for publishing in monographs on three topics:
1. Clogging - http://recharge.iah.org/recharge/clogging.htm
2. Governance, policy, economics – thematic issue of http://www.mdpi.com/journal/water as a joint activity between the IAH Commission on Groundwater Outreach.
3. Water storage for managing climate extremes and change - special issue of Environmental Research as a joint activity between the IAH Commission on Groundwater and Climate Change.

These, along with the oral presentations will be posted on the IAH MAR WG web site: http://www.iah.org/recharge/

To ensure that all information was disseminated, authors were encouraged by the conference organisers to present posters even if they had written a paper to present orally.

Both classification and editing was carried out by the DINA-MAR research team, with the help of the ISMAR 8 organizers.

The resulting publication consists of 40 posters, compiled from files supplied by the authors and photos taken by the editor (with the permission of the authors), and allows us to share information that may have otherwise been lost.

The titles of the posters and their authors are listed in the index below. Unfortunately, all the exhibited posters could not be collected, and some of the posters listed were not exhibited.

The DINA-MAR research team provides authors with the opportunity to include the missing posters in the future, as well as to replace the existing ones with improved versions (visit their web site www.dina-mar.es or email dinamar@tragsa.es . We would like to thank all the authors, whose support (including permission to publicise their work) is sincerely appreciated. We would also like to thank IAH MAR WG management for their help.

Further information on this event can be found at:
http://recharge.iah.org/recharge/publications.htm
http://ismar8.org/

P-ISMAR 8

POSTERS DEL 8º SIMPOSIO INTERNACIONAL DE GESTIÓN DE LA RECARGA DE ACUÍFEROS ISMAR-8, BEIJING, CHINA.

INTRODUCCIÓN

Entre los días 15 y 19 de octubre de 2013 tuvo lugar el congreso ISMAR 8 en Beijing (China), promovido por el Grupo de Recarga Gestionada de la Asociación Internacional de Hidrogeólogos (AIH) y las universidades de Tsinghua y Jinan, entre otras instituciones, bajo el lema: "Managed Aquifer Recharge: Meeting the Water Resource Challenge".

En él colaboraron varias instituciones adicionales, tales como la UNESCO, NSFC, Ministerio de Recursos Hídricos de China, el Servicio Geológico, la Fundación Natural Nacional de Ciencias de China, Beijing Drainage Corp., Centro de Investigación de Ciencias Eco-ambientales, la Academia China de las Ciencias, la Planta de depuración de aguas residuales Gaobeidian, el Instituto de Investigación Hidráulica de Beijing, la Universidad de Pekín, la Universidad de Nanjing, la Universidad de Geociencias China, la Universidad de Jilin, Beta Analytic, etc.

El simposio reunió a 149 delegados de 27 países y contó con seis cursos de primer día, 121 publicaciones escritas, de las que 83 fueron presentaciones orales. Además se presentaron y exhibieron 38 pósters, dando cobertura a cinco Áreas con numerosas líneas temáticas distintas, que fueron Diseño y construcción de dispositivos de recarga gestionada, Operaciones y mantenimiento, Gobernanza, Aplicaciones de la técnica MAR en la gestión hídrica integral y otros temas específicos relacionados con la técnica MAR. La lista detallada de las líneas temáticas puede ser consultada en: http://ismar8.org/info/theme

El texto de más de 50 comunicaciones escritas quedó recogido en dos "Journals". Las ediciones temáticas fueron del ASCE J Hydrologic Engineering, yEnvironmental Earth Sciences de Springer , recopilando contribuciones sobre ingeniería, geociencias y gobernanza, respectivamente.

Las publicaciones no recogidas en estos *Journals* tuvieron ocasión de ser incorporadas en otros tres monográficos sobre tres temas específicos:

1. Colmatación - http://recharge.iah.org/recharge/clogging.htm
2. Gobernanza, política y economía, para su revisión y publicación en la edición temática de http://www.mdpi.com/journal/water, actividad coordinada con la Comisión de Compromiso *(outreach)* con las Aguas subterráneas de la Asociación Internacional de Hidrogeólogos (AIH).
3. Almacenamiento de agua para la gestión de eventos climatológicos extremos y cambio climatico, como edición especial del "Environmental Research", actividad conjunta con la comisión de Aguas Subterráneas y Cambio Climático de la AIH.

Las restantes ponencias quedan accesibles vía Internet en la dirección: http://www.iah.org/recharge/, así como las ponencias orales enviadas por los presentadores con carácter voluntario.

Las presentaciones tipo póster fueron solicitadas por la organización a los autores, tanto si tenían una publicación paralela escrita como si no., con objeto de evitar que alguna contribución se pudiera perder, con riesgo de desaparecer alguna información importante. Algunos pósters corresponden a fotos digitales tomadas por el editor de esta publicación, siempre con permiso.

El trabajo de recopilación, clasificación y edición se llevó a cabo en el marco del proyecto de investigación DINA-MAR (en su etapa de difusión y transferencia tecnológica), con la ayuda de los organizadores del simposio.

El resultado es la presente publicación, que consta de 40 pósters, bien de fotografías originales o bien de los ficheros digitales facilitados por los autores, que permiten compartir una información que, de otro modo, se habría perdido.

El índice de los pósters allí presentados figura a continuación, con mención del título y autores. Lamentablemente no todos los pósters fueron recopilados, así como no todos los presentados se ajustaban fielmente al programa planificado, pues hubo bajas y sustituciones.

El equipo de investigación de DINA-MAR ofrece su apoyo para incluir o sustituir los pósters ausentes que pudieran surgir en el futuro, o bien aquellos que puedan ser reemplazados por sus materiales originales, bien a través de su dirección web http://www.dina-mar.es/ o del Email dinamar@tragsa.es.

Así mismo agradecemos a todos los autores el apoyo prestado y la cesión de permisos para la difusión en Internet de esta información de carácter científico, así como al Grupo de Recarga Gestionada de la AIH por su apoyo en el desarrollo de esta idea.

Información adicional sobre este evento se encuentra en:
http://recharge.iah.org/recharge/publications.htm
http://ismar8.org/

P-ISMAR 8

北京（中国）第八届国际含水层补给管理研讨会展板集
简介

2013年10月15-19日在北京召开了主题为“人工含水层补给：迎接水资源挑战”的第八届国际含水层补给管理研讨会。这次研讨会由国际水文地质家协会含水层补给管理委员会提出，清华大学和济南大学联合主办。

本次会议得到了联合国教科文组织、中国地调局、中国国家自然科学基金委、北京排水集团、中国科学院生态环境研究中心、北京高碑店污水处理厂、北京市水利科学研究院、吉林大学及BETA实验室等机构和单位的支持。

本次研讨会有来自27个国家的149人与会，有6个分会场研讨会、83个大会发言、38个海报以及121篇书面论文，涵盖了含水层补给设计及施工、含水层补给运行及维护、含水层补给标准及管理规范、含水层补给在水资源管理中应用及含水层补给其它相关事宜5个主题。详细信息请见http://ismar8.org/info/theme。

本次会议将挑选51篇关于工程、地球科学及管理方面的文章，并出版在美国土木工程师学会专刊《Hydrologic Engineering》和Springer期刊《Environmental Earth Sciences》上。

上述两个期刊没有包含的文章将会分成如下3个专题整理编辑成论文集：

1. 堵塞—http://recharge.iah.org/recharge/clogging.htm。
2. 管理、政策和经济—http://www.mdpi.com/journal/water此链接上的专题作为国际水文地质家协会地下水委员会的一个共同活动。
3. 应对气候极端变化的水库—《Environmental Research》的专题，作为水文地质家学会地下水委员会和气候变化委员会的一个共同活动。

论文集以及大会发言将会公布在IAH MAR WG网站上：http://www.iah.org/recharge/。

为了确保所有信息都能够散播出去，虽然作者们写了文章作了口头发言，但是会议组织者仍希望作者们能够提供海报

所有分类和编辑工作将由DINA-MAR和ISMAR8 组织者共同完成。

最终将出版40个海报，这些都是由作者提供文件或者由编辑拍照（已经作者允许）而获得的，允许我们分享信息以防遗漏。

海报的标题及其作者列在下面的链接中。很遗憾，并不是所有的海报都可能被收集，也并非是列出的所有展板都在当时展示。

今后DINA-MAR科研团队提供支持来收集遗漏的海报，以及用改进的版本（可访问其网站www.dina-mar.es或者邮箱dinamar@tragsa.es）来替代现有的海报。我们衷心感谢所有支持此次会议及允许出版他们研究成果的作者们。我们还要感谢IAH MAR WG对我们的帮助。

关于本次会议的更多信息可在
http://recharge.iah.org/recharge/publications.htm
http://ismar8.org/进行查询。

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NEXT: P-ISMAR 9

ISMAR 9 First preparative meeting. UNAM, August 30th 2013. D.F. District
Primera reunión preparativa del ISMAR 9, México DF, 30 de Agosto de 2013

2nd Workshop on MAR. Field trip to building works for the future biggest WWTP in the world
Segundo Workshop. Visita técnica a las obras de la futura mayor depuradora del mundo.

Previous workshops hold in Mexico on MAR:
Enlaces a las jornadas técnicas celebradas en México:
June / Junio 8-9th, 2011:
http://www.agua.unam.mx/acuiferos_presentaciones.html
August / Agosto, 28-29th 2013:
http://www.agua.unam.mx/jornadas2013/resultados_acuiferos.html

9th International Symposium on Managed Aquifer Recharge

SOLUTIONS TO SUSTEINABLE WATER MANAGEMENT SUBJECT TO SCARCITY AND CLIMATE CHANGE

Mexico City, Mexico

Venue to be Determined

The Engineering Institute of the National Autonomous University of Mexico (UNAM), will hold the 9th International Symposium on Managed Aquifer Recharge (ISMAR 9) in México City, Mexico in the Summer of the year 2016.

Organizations:

- National Water Commission
- National Autonomous University of Mexico:
  - Engineering Institute
  - Water network
  - Geology Institute
  - Engineering Faculty
  - Geophysics Institute
- Water System of Mexico City (SACM)
- Federal Commission of Electricity (CFE)
- Mexico Valley Basin Water Agency (OCAVM)

ISMAR9 will include the following:

- Pre-conference activities and workshops
- Plenary session with key note lectures
- Technical and poster sessions
- Round table discussions
- Technical tours
- Post-conference excursions
- Social program

Local attractions include:

- Subsidence features
- National museums
- Pyramids
- Active volcanoes
- New state-of-the-art treatment plant
- Local culture
- Social program

Sponsors:

- Degremont Technologies
- CH2MHill

INSTITUTO DE INGENIERÍA UNAM
Red del Agua UNAM
CONAGUA COMISIÓN NACIONAL DEL AGUA
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Artificial recharge scheme proposed for Crestatx, a limestone aquifer in the island of Majorca, Spain. The role of suspended solids in the artificial recharge process. Preliminary design of an AR plant.

IWRA INTERNATIONAL WATER RESOURCES ASSOCIATION
Asociacion Internacional de Recursos Hídricos
Association Internationale des Ressources en Eau

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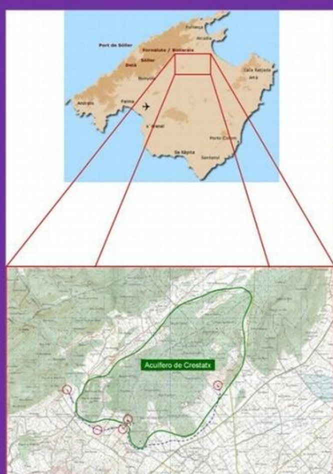


Location of Crestatx aquifer

Introduction

Crestatx aquifer is a limestone structure located in the eastern part of the Tramuntana Range, on Majorca island, Spain. Currently, it is used for urban supply of coastal villages around the Alcudia bay. Water extracted is about 1.5 Mm3/year. The aquifer is isolated from the sea, and thus it has no seawater intrusion problems. Groundwater quality has been good since data are available.

The southern limit is in contact with the Inca-Sa Pobla plain aquifer, formed by Quaternary detritic materials. There exists a natural water transfer between the two aquifers, from Crestatx to Inca-Sa Pobla. On the Inca-Sa Pobla surface there is a large area of intensive agriculture, which is the origin of some pollution problems, such as high nitrate content. To alleviate this problem, the water authority has planned to close several pumping wells in Inca-Sa Pobla and replace the water they are currently exploiting with water coming from Crestatx aquifer. This should imply an increasing of groundwater exploitation in the Crestatx. To compensate for this, and comply with water rights in Crestatx, an artificial recharge has been proposed. Recharge water will come from Ufanes de Gabelli springs surpluses. These fountains are located some kilometers upstream of Crestatx and their water quality is excellent.

In a geological view, Crestatx massif has 4 main thrust faults and another one smaller. In a hydrogeolgic sense, two aquifers have been defined: Navarra and Crestatx. Navarra includes the first 3 thrust faults and Crestatx the last two ones. The hydrogeological model is the same for the two aquifers: recharge comes from rainfall infiltration, and the outputs are produced by pumping or groundwater transfers to adjacent aquifers. Water exploitation is 0.26 Mm3/year in Navarra aquifer, and 1.25 Mm3/year in Crestatx aquifer, both used for urban supply. Groundwater transfers in Navarra aquifer go in 2 directions, due to a groundwatershed: on the one hand, to the NE, and on the other hand to the south, to the Inca-Sa Pobla plain aquifer. Crestatx aquifer has groundwater transfer only to the Inca-Sa Pobla aquifer. It also has a natural drainage, known as S'Ull spring, located in the east wedge, but it does not drain since the beginning of its exploitation.

Results & Discussion

Ufanes springs are the natural discharge of a karstic aquifer known as "Ufanes". Discharges are diffuse and they respond rapidly to high precipitation. Water is driven by the San Miguel torrent, which flows into the Mediterranean sea after crossing the Inca-Sa Pobla plain and the Alcudia lagoon, in the northern part of the island of Majorca.

Ufanes springs and water catchment location in the San Miguel river

To study the water discharge and determine surpluses for AR, we have analyzed the data from a gaugue station located in San Miguel torrent, named 11/04 "Torrent de San Miquel". It has a historic series of 31 years, from 1976-1977 to present. It means a total of 11.323 records.

The main features obtained are the following:

- 67,5% (7.653 days) of the total records, have no flow.
- Discharges usually happen from December to May.
- The highest monthly average values occur in December, with an average water flow of 3,22 Mm^3, January (3,06 Mm^3) and February (2,15 Mm^3).
- December, January and February gather 52% of the total annual water inflow.
- The lowest monthly average values occur in July (0,03 Mm^3), August (0,07 Mm^3) and September 0,11 Mm^3).
- Water discharge is very rapid. It takes place generally in periods of less than a month. The total atenuation of discharge is 18 to 20 days, though most of the times springs stop flowing after 5-6 days from the beginning of the flow.
- The highest peak flow registered in the series analyzed was 33 m^3/s, and the minimum one (excepting zero) 0,03 m^3/s. Average value is 0,6 m^3/s.
- Percentile 75 is 2 m^3/s and percentile 90, 3,5 m^3/s.

Suspended solids content in Ufanes de Gabelli water have been studied and analyzed. There are not historic series of data regarding this parameter. During an important discharge event, from 16th to 20th April 2007, some samples were taken. The hydrograph for this discharge event shows an atenuation time of 10 days. With these data a regression curve of suspended solids content vs. water flow has been calculated. The equation in exponential form is the following:

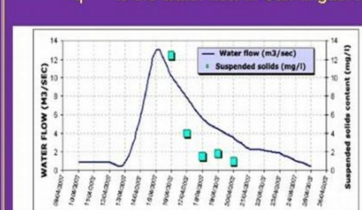
$$Ss = 0.26 \exp (0.363338\ q)$$

Where:
- Ss is the suspended solids content in mg/l and
- q is the water flow in San Miguel torrent, in the gaugue station nr. 11/04

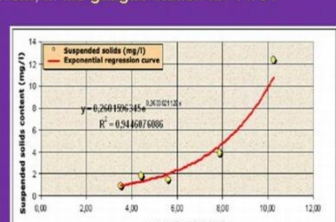
The extrapolation of this equation to the whole flow series in 11/04 gaugue station (october 1967 to September 2007) allows to generate a daily synthetic series of suspended solid content in the water flow. In general, the validity of this extrapolation can be discussed, because we have used only one event of discharge and the measurements obtained during it (the only one available) to obtain a 31-year long suspended solids content series. Once we have generated this synthetic data, we have performed a statistical analysis of the new suspended solids series. Results (in mg/l) are:

Minimum:	0,26
Average:	56,0
Maximum:	47891
Percentile 75:	0,57
Percentile 85:	0,71
Percentile 99:	64,95

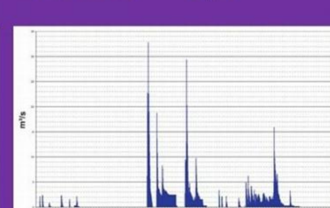
Data analysis show that the average suspended solids content is 56 mg/l, and the maximum is 47891 mg/l. We must say that this extremely high value comes from the exponential expression of the regression curve. Percentile 99 is 64.95 mg/l, what means that this maximum value is exceptional and corresponds to a water flow higher than 30 m3/s, the maximun value recorded in the water flow series. This datum has not much physical sense, and cannot be considered as a restriction for the AR project. It only indicates a mathematical operation and thus a theorical value. On the other hand, these exceptionally high flows are obviously impossible to be used in the AR plant. Another important conclusion from the examination of the data is that the average value of the series is highly influenced by these maximum values, and so it is not truly representative of the physical phenomenon we are studying. The most useful data are the percentiles. They give a very good idea about the suspended solids content behaviour versus water flow. Data show that 85% of water flows have a suspended solids content lower than 0.71 mg/l, what make them useful for AR experiences.



Water inflow of San Miguel torrent during the discharge event of april 2007, and suspended solids content of the water samples



Regression curve, water inlow vs. suspended solids content

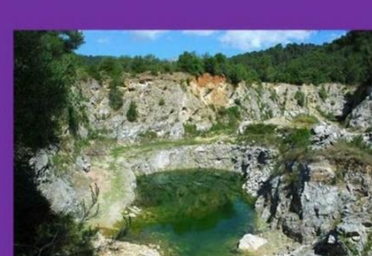


Average daily flow measured in the gaugue station

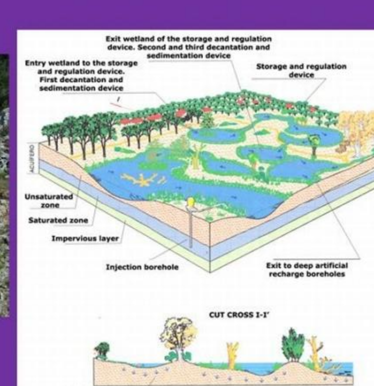
Conclusions. Artificial recharge plant preliminary design

- Elements for regulating and decantation
  - Regulating reservoir (Coma S'aigua abandoned quarry)
  - Decantation device (artificial wetland to be constructed)
- Recharge plant
  - Injection boreholes
  - Monitoring devices

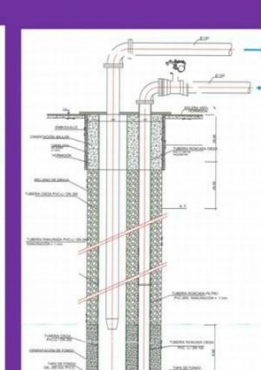
This AR plant is a mixed one combining both surface and underground methods, trying to obtain the best benefits of each one. On the one hand, surface devices will allow to take AR water, regulate it and channel it to the infiltration devices. Using an abandoned quarry as regulating system will allow to recover an environmentally degraded zone. The artificial wetland will give an aditional value to the environment, because it will allow people to make a recreation use of the AR plant, and an ecological improvement of the AR area. On the other hand, injection wells will be cheaper than surface infiltration devices, like ponds, due to the high land price in the island of Majorca.



Regulating reservoir
(Coma S'aigua abandoned quarry)



Decantation device (artificial wetland)



Injection boreholes

October 15th-19th, 2013 Beijing, P. R. China

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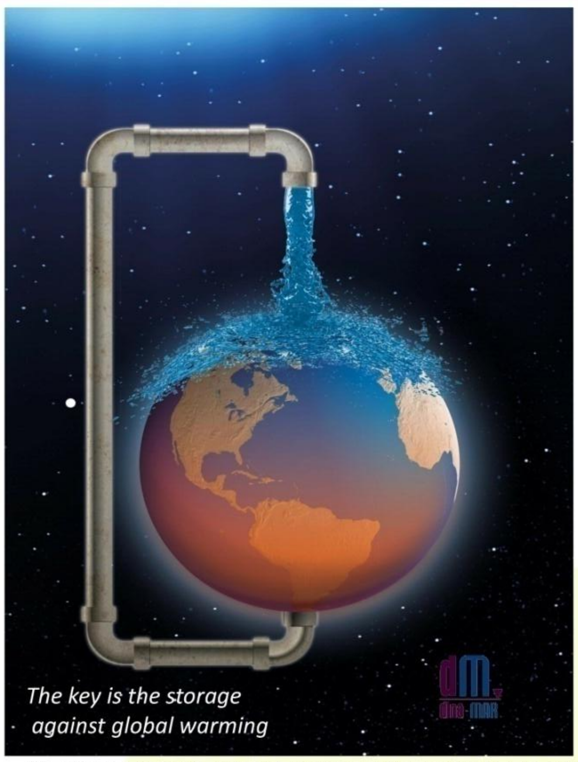
INTEGRATED AND PREVENTIVE WATER AND FOREST MANAGEMENT TECHNIQUES TO COMBAT CLIMATE CHANGE ADVERSE EFFECTS

INTRODUCTION

The devastating capacity of high flow flood events is such that, once unleashed, it is impossible to stop its catastrophic effects. On the other hand, the effect of long term droughts may not be fought by means of specific and isolated actions.

Fortunately, it is viable to apply preventive techniques to mitigate risks and impacts. In Spain, where water resource is sufficient but not excessive, and where forecasts show a negative future scenario, it is necessary, at least: to know the relationships between human activities and their impacts on the water cycle, to educate those involved in territory planning, to improve water quality as well as its use in its circuit along the territory and to, urgently, transform any opportunity into an action.

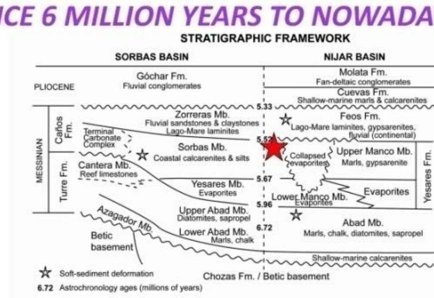
COMBAT THE ADVERSE EFFECTS OF CLIMATE CHANGE BY INTEGRATED ACTIONS



EXTREME WATER RELATED EVENTS

A "PROBLEM" IN THE MEDITERRANEAN ARC SINCE 6 MILLION YEARS TO NOWADAYS

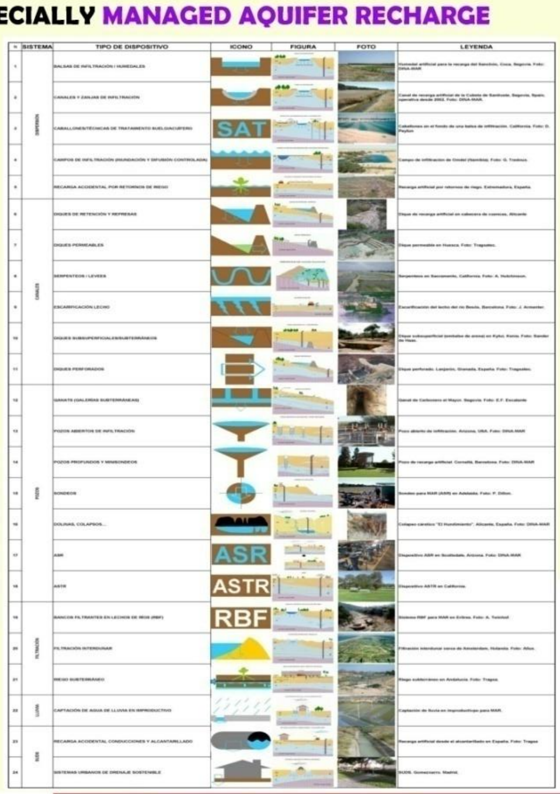
1980 2012



Hucmocky stratified outcroop in the Upper Manco Member calcarenites from Upper Messinian, Níjar basin, Gafares, Almeria (Spain) 37° 1'15.52"N, 1°57'49.05"O. So high energy agent could have been a "Gota fría" overfllood. Photo: C. Dabrio

DROUGHT

MEASURES BASED ON INTEGRATED WATER MANAGEMENT TECHNIQUES, SPECIALLY MANAGED AQUIFER RECHARGE



OVERFLOODS

MEASURES BASED ON TERRITORIAL PLANNING PLUS WATER & FOREST MANAGEMENT

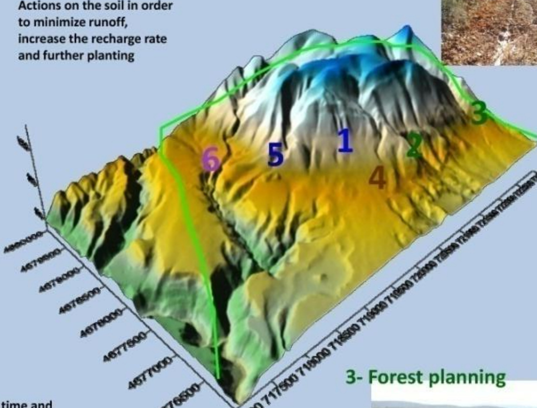
FORESTRY ACTIONS ON BASINS FOR WATER MANAGEMENT

1- Afforestation & selviculture to enhance deep recharge

Forests willing to allow an "ordered" runoff as well as high seepage rates

2- Mechanized preparation of soil so as to improve infiltration rate

Actions on the soil in order to minimize runoff, increase the recharge rate and further planting



6- Retention structures for river lamination

Lamination dike to slow down concentration time and enhance the aquifer recharge

3- Forest planning

5- Leveraging runoff water

SCHEMATIC PROPOSITION ON WATER AND FOREST MANAGEMENT TECHNIQUES

Diversion of river water towards proper forests to decrease runoff volume and speed up recharge rates

BAJO GUADALHORCE
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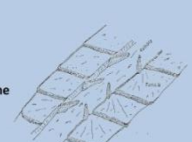
4- Terraces restoration & maintenance

Boqueras: Long furrows which divert high volumes of water in the overflood taking it towards crop lands

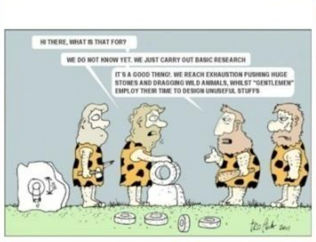


Atochadas: structure made of sand furrows and dikes crossed to the basin flow direction, with lateral diversions allowing the flow from one *atochada* to the next one

COMBINED ACTIONS FROM UPSTREAM WATERSHED TO THE SEA

TRANSFORM ANY OPPORTUNITY INTO AN ACTION

ACTING LOCALLY, BUT DESIGNING GLOBALLY



SUMMARY AND CONCLUSIONS

• Mediterranean climatic conditions are so special that require special facilities and schemes, as well as there are very few analogous sceneries in the world affected by similar processes.

•Based on the principle of "prevention of damage from its origin", R&D projects carried out by Tragsa Group as DINA-MAR, PTA and GIAE are developing lines of action to influence the causative agents, proposing infrastructures and techniques spread throughout the whole water path, from the watershed top to the coast line. The cast of actions requires a comprehensive and distributed vision of the scenery, applying the premise of "acting locally, but designing globally".

•In the case of extraordinary over floods, It is worth to remark forest management techniques in the basin's heads, creating structures of retention and diversion of high volumes of water outside the river beds, as "*boqueras*" & "*atochadas*" (complementing those allocated in rivers and streams), terracing the slopes, dams and dikes in locations deducted by complex processes, specific architectural elements implanted in the cities, etc., with special attention paid to their design. A proper spatial planning is needed.

•For prolonged drought periods, on the premise "the key is the storage", actions are based on the implementation of distributed managed aquifer recharge facilities, in order to promote the storage of water in the aquifers along the management chain.

•It only seems viable to combat the adverse effects of climate change by means of combined actions.

•MAR technique is not able, by itself, to control extreme floods or droughts, but it is helpful within the frame of water management for a whole river basin, from upstream to the sea.

MANAGING THE WATER BUFFER WITH 3R

A pragmatic approach for delivering results

Friedemann Scheibler

IGRAC (International Groundwater Resources Assessment Centre), Delft, The Netherlands

Introduction

People living in drought-prone areas are one of the most difficult groups to reach with the millennium development goal efforts. Climate change and increased incidence of extreme weather events will even have a further negative impact on water security. This challenge requires innovative solutions, one of which we refer to as 3R. It is a promising development track, which deserves promotion and funding, combining rainwater harvesting, groundwater management and efficient water use.

What is 3R?

3R stands for **Recharge**, **Retention** and **Reuse** of all types of water including groundwater.

Recharging water is a hydrologic process in which rain- and storm water moves downward from surface water to groundwater. Water **retention** refers to the technologies for the storage of water, which may vary according to local conditions and available materials. **Reuse** of water involves technologies, which enable available water to be recycled in times of need and scarcity.

3R is both an approach and an initiative that deals with the management of the water buffer. It presents an alternative concept in storing rain and storm water in the landscape. Water is stored in many small systems, in tanks, groundwater, soils moisture or surface water reservoirs. It will be available in the dry period. Through a range of simple 3R technologies, the buffer function of an area will improve. This can be applied at different levels, from watershed scale to farm/community level. A combination will lead to maximum resilience.

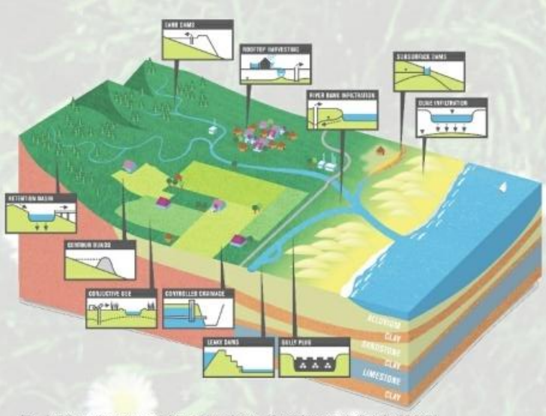


Fig. 1: 3R applications within a river basin (Steenbergen & Tuinhof 2009)

Examples of 3R techniques are sand- and subsurface dams for riverbed storage, valley dams and ponds as open reservoir storage, rock catchments and rooftop harvesting for storing in closed tanks. The use of bunds, terraces and mulching helps in retaining more water in the soil profile (Figure 1).

For information on two current 3R projects in Tanzania and Bangladesh please refer to the posters presented by Rolf et al. and Matin.

Managing the Water Buffer with 3R

The advantages are plenty. 3R solutions are decentralized solutions that when applied at scale do not disrupt the local environment, but add value to it. 3R technologies can be applied in many different circumstances. Combined with relative low investment costs this makes 3R an alternative that is highly feasible for sustainable water supply on a local scale. By storing water in the soil profile 3R technologies can also contribute to diminish the risk of crop failures in rain-fed agriculture.

A combination of 3R techniques, specifically designed for the local context, allows for short term results (increased water supply) as well as effects on the longer term (e.g. resilience to climate change). It systematically improves the resilience of local communities and businesses to water scarcity, food insecurity and climate change.

Fig. 1: A typical sand storage dam during the dry season in the Kitui District, Kenya

In general the benefits of 3R interventions are:

- Sustainable water supply
- Water and food security
- Mitigation of effects of longer dry periods
- Diminished risk of floods during intense rainfall events
- Increased resilience of communities
- Low investment costs
- Flexibility in application and appearance

How do we work?

3R partners work on projects and programs aiming to deliver a structural contribution in solving water scarcity issues. We promote technologies to assist people in water scarce areas and to maximize the use of available water with a systematic approach (see box on the right).

3R partners try to stimulate major planning and financing agencies and also the private sector to include these effective technologies in their programs and investments. In recent 3R projects our systematic approach has proven to be a valuable contribution to larger donor programs with a primary focus on water & sanitation or water & agriculture. The 3R approach combines a technological basis with capacity building and training of local water practitioners, always based on a demand driven inventory.

Some stunning 3R facts

- Water harvested from a rock outcrop of 1 hectare can harvest around 900.000 litres of fresh water from a mere 100 ml of rainfall;
- Plastic mulch is successful in decreasing the amount of water lost through evaporate-transpiration and increase yields up to 50%;
- The average time spent to fetch water decreased from 140 to 90 minutes after the introduction of sand storage dams;
- Grass strips planted along contour lines help in slowing down runoff and augmenting soil moisture with yields increases of up to 40%.

Where is 3R? In many countries, like

Mozambique	The Netherlands
Kenya	Senegal
Nepal	Uganda
Mali	Ethiopia
Burkina Faso	Bangladesh

What are we looking for?

The 3R group actively seeks:

- Program partners - to develop and implement effective programs to increase water availability and climate resilience;
- Financing - to leverage and develop programs or implement pilot projects which serve as an example for up scaling;
- Network and support- to promote this innovative approach, find partners and funding to join forces and to exchange useful information and experiences.

The 3R Roadmap

Which 3R technique, or combination of 3R techniques, is most favorable depends on both the physical as socio-economic circumstances. The 3R consortium developed a step wise approach, in which different phases are distinguished to translate the request and the local demands into a selection process of the most favorable 3R technique(s) and their implementation. Key in the stepwise approach is that both the landscape and the local possibilities and preferences play an important role in the selection of the techniques. Capacity building during all phases is an important part of the approach.

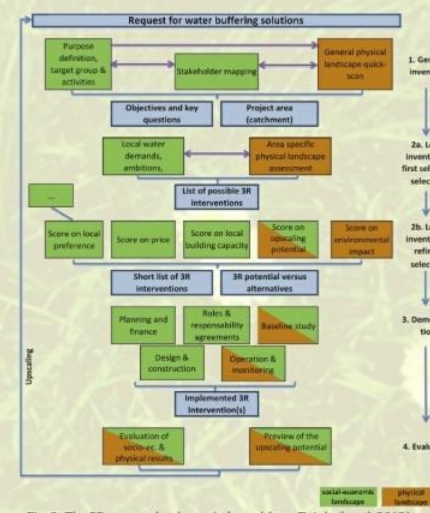


Fig. 3: The 3R approach scheme (adapted from Tuinhof et al. 2012)

1) General inventory

On the one side an inventory of the socio-economic landscape has to take place; what target group and relevant stakeholders, target activities (kind of use, scale, challenges, i.e. climate change) and what is the target region. Next to that a quickscan should be done of the geo-physical landscape, to indicate what areas have high 3R potential.

2) Local inventory

a - first selection: The local inventory focusses on local water demands, ambitions and challenges in a local stakeholders process. The area will be further analyzed be means of desk and field studies, also looking at local existing situation, 3R opportunities, expected impact of climate change, population change etc.

b - refined selection: Promising 3R interventions should match the local context and demands and scored on environmental impacts, resulting in a first list of possible 3R interventions. This leads to a clear idea on the water demand and if this van be best addressed with (the selected) 3R solutions. This is a go/ no go moment in the process.

3) Demonstration

Before starting the pilot implementation phase, the a socio-economic and physical baseline & goals should be noted, including a monitoring plan. Agreements will be made concerning roles and responsibilities for construction, operation and maintenance.

4) Evaluation

Evaluation and documentation of socio-economic and physical results are important input for determining upscaling potential, and preview financing opportunities. Upscaling might lead to integration of the 3R approach into policies, trainings or existing (governmental) programs. Large scale 3R area inventories can be part of that process. Sharing of results, knowledge and documenting best practices can further improve the 3R approach.

Cited Literature

Steenbergen, F. van & A. Tuinhof. (2009): Managing the water buffer for development and climate change adaptation. Groundwater recharge, retention, reuse and rainwater storage. Wageningen, The Netherlands: MetaMeta Communications.

Tuinhof, A., F. van Steenbergen, P. Vos & L. Tolk (2012): Profit from Storage. The costs and benefits of water buffering. Wageningen, The Netherlands: 3R Water Secretariat.

What do we offer?

- Growing network with ongoing programs and implementing partners, both from public and private sector in many countries;
- Developing & sharing tools and knowledge;
- Expertise to help face water buffering challenges and development of new programs.

Further Information

For more information please contact the 3R Secretariat or visit our website

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Rainwater Harvesting Implementation Network

Bundesanstalt für Geowissenschaften und Rohstoffe

GEOZENTRUM HANNOVER

A methodological concept for the development of potential bank filtration sites in India

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Saph Pani – Clean Water

Motivation

Bank filtration (BF) is gaining awareness as a sustainable alternative and supplement to the direct abstraction of surface water for drinking in urban and rural India (Figs. 1 & 2). However, interactions with Indian water supply organisations have revealed the need for a scientifically based methodology to systematically select, investigate and evaluate potential BF sites. Such a methodology will serve as a tool to enable the development of new full-scale BF systems in India and to address the imminent threat to BF sites from monsoon floods (Fig. 3).

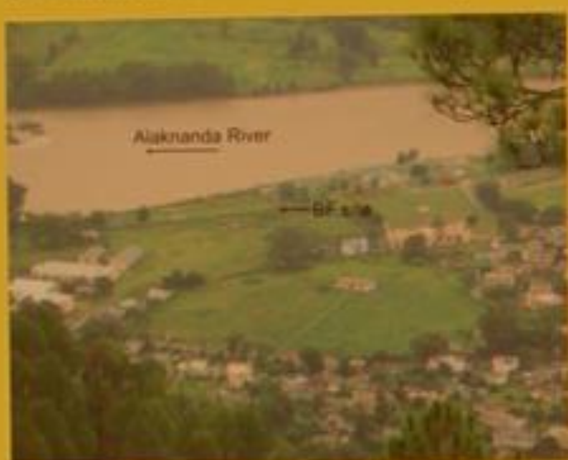

Fig. 1: Location of new BF site under development in Srinagar in monsoon (August) 2011 (Photo: Ebermann)

Fig. 2: Production well (left), control-panel (extreme left) and generator of BF site in Srinagar in March 2013 (Photo: Voltz)

Fig. 3: Deposition of ~1.5 m sand at BF site in Srinagar after extreme flood in June 2013 (Photo: Sandhu)

Methodological concept

The methodological concept is based on hydrogeological investigations and data evaluation (Fig. 5 & Tab. 1) conducted for water supply systems at Haridwar and Patna. Thereafter, the investigation stages 1 to 4 (Fig. 5) were applied to construct (in 2010) and develop four new sites in Srinagar, Agastmuni, Karnaprayag and Satpuli (Fig. 4). The concept has now been modified to include a risk assessment (Fig. 6).

Fig. 4: Locations investigated in India for BF (modified from Sandhu et al. 2011)

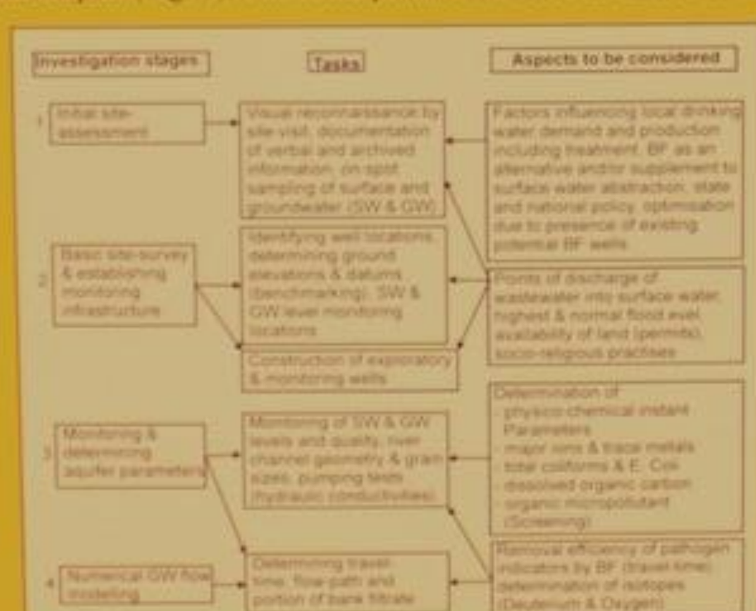

Fig. 5: Methodology to investigate Haridwar and Srinagar for BF

Fig. 6: Modification of the concept to include a risk assessment (after Bartak et al. 2013)

Results

Tab. 1: Summary of results methodology (in Fig. 5)

Parameters	Haridwar	Patna	Srinagar
Production capacity [m³/day] (# of wells)	>43,000 (22)	>3,500 (6)	>4,000 (4)
Aquifer thickness [m]	17	>90	21
Hydraulic conductivity of aquifer [m/s]	1.2×10[illegible] – 4.7×10[illegible]	1.4×10[illegible] – 5.6×10[illegible]	7.7×10[illegible] – 4.0×10[illegible]
Travel time of bank filtrate	2 – >100 days	ND	~2 years
Mean TOC concentration in well-water [mg/L]	1.0 (n = 23)	2.5 (n = 11)	1.2 (n = 3)
Log_{10} removal of Total Coliforms	2.5 – 4.7	2.3 – 4.4	2.8
Log_{10} removal of E. coli	3.5 – 4.4	ND	>3.4

ND: not determined

A summary of some of the main parameters indicates that suitable conditions for BF exist at the investigated sites (Tab. 1). Furthermore, all other water quality parameters were within the limits for drinking water (Indian Standard), except high nitrate in BF well-water in Srinagar.

Main conclusions for the application of the methodology for the investigation of potential BF sites are: 1) Limitations of access for well drilling equipment in mountainous areas; 2) aquifer thickness in hills is limited, thus use of horizontal collector-pipes can be an alternative to vertical wells; 3) the extreme flood of June 2013 in Uttarakhand underlined the importance of constructing flood proof wells, an assessment of the deposition of sediment and preventing bank erosion; 4) contamination from land-side groundwater is usually a threat for BF sites downstream of habitations, the source of which can be traced by including an analyses of organic micropollutants, 5) presence of confining clay extending beneath the riverbed in the lower courses of the Ganga and its tributaries can be a limiting factor for BF.

HOCHSCHULE FÜR TECHNIK UND WIRTSCHAFT DRESDEN

Acknowledgement

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GROUNDWATER NATURAL RESOURCES AND QUALITY CONCERN IN KABUL BASIN, AFGHANISTAN

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INTRODUCTION

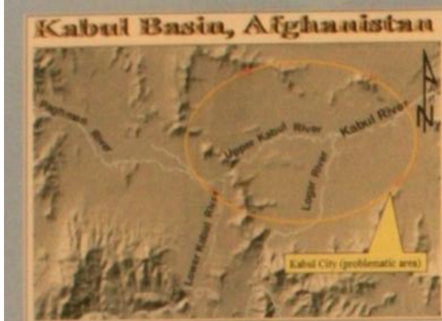

Figure 1. Kabul basin, Afghanistan

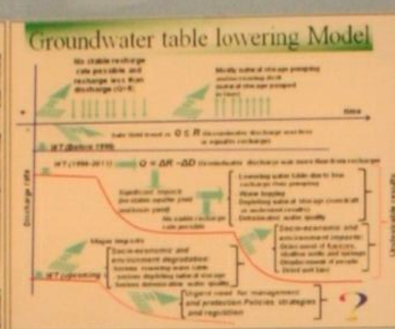

Figure 2. Groundwater table lowering model and early warning signal

A large percentage of people living in Kabul (approximately four and half million) depend on groundwater as their primary source of domestic/drinking water. Kabul Basin, especially Kabul city, has encountered a scarcity of surface water due to the distribution of precipitation during 34 month. The Kabul River flows only for three months and is extremely contaminated; therefore groundwater resources have played the lead role in the development of socialeconomic growth. Approximately only 20% of the inhabitants of Kabul city have access (intermittently) to the central water supply system. The rest depend on shallow wells equipped with handhand pumps which draw water mainly from the shallow groundwater aquifer and a multitude of illegal boreholes with small submersible pumps for household use.

In Kabul Basin specially Kabul City, the national groundwater monitoring wells network have indicated quantitative and qualitative concerns. Inhabitants of this basin have frequently been affected by contaminated waterborn related diseases and children are the most vulnerable.
As Kabul population continues to grow, there is increasing pressure to further exploit groundwater for various purposes which are basically not possible because of shallow and low productivity of the aquifers. This trend will cause further negative consequences on the groundwater quality and quantity that will challenge our socio-economic development and environmental security. This vulnerability of the aquifer may not be reversible and the city of Kabul will face a severe shortage of drinking water and potential subsidence could occur.

RESULTS & DISCUSSION

Main impact of extraction of groundwater on Kabul Basin
The main impact of extraction of groundwater on the Kabul Basin include: 1) many springs, karezes and shallow wells have dried up; 2) increased deterioration of water quality; 3) increased water logging and salinization; 4) declining groundwater water levels; 5) increased evapo-transpiration; 6) Imbalanced streams/river and aquifer interaction and; 7) marshes dried up in several areas of the river basin, leaving salt crust on the surface.

Main groundwater quantitative and qualitative concerns
Figure 3 shows that the water level has progressively declined due to over-exploitation, evaporation and low recharge and the water quality has progressively deteriorated. The declining groundwater has created a large hydraulic gradient in the aquifer which has resulted in increased infiltration of pollutants from polluted rivers, soak pits and septic tanks. This trend has progressively elevated concentration of boron, nitrate, hardness and fluoride due to lowering water table, poor sanitation and poor protection.

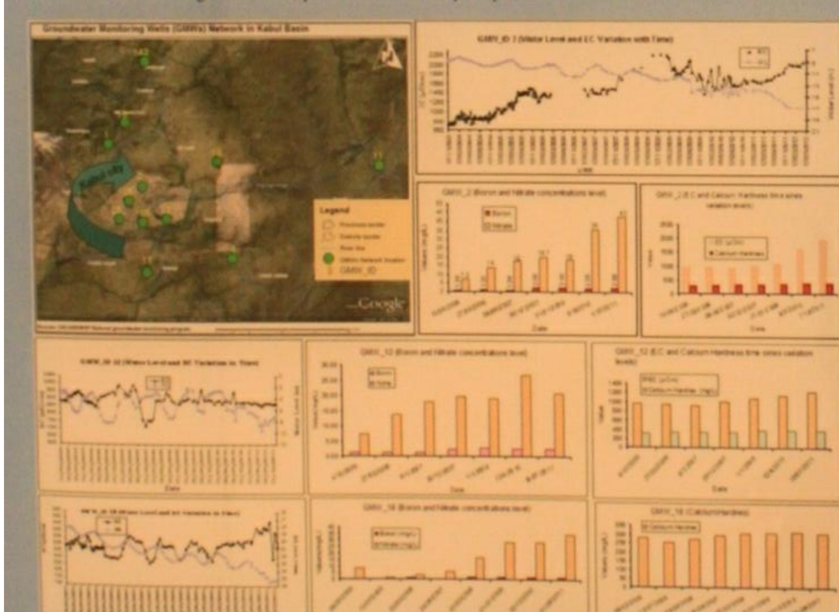

Figure 3. Time series groundwater table and water quality variation

Main cause of groundwater contamination include: 1) urbanization without sewerage system and poor solid waste management; 2) poor land use ; 3) poor sanitation and hygiene practices: 4) permeable characteristic of overlying layers of aquifers ; 5) poor legislation and regulation for groundwater quality protection; 6) lack of awareness about water quality; and 7) cross contamination in wells due to poor construction.

The distribution of EC (Electrical Conductivity or Salinity) in Kabul Basin groundwater ranges between 306 and 13,899 µS/cm with clear increases from recharge (up gradient) zones to the discharge (down gradient) zones. In the recharge area the EC of water is lower than 1,000 µS/cm but in the discharge zones of Kabul Basin, especially in Kabul city, the EC values progressively increase from 1,500 to 13,899 µS/cm due to combination of dissolved minerals and relative enriched salts as a result of strong evaporation, percolation of sewage from countless drainage pits and anthropogenic emission from Kabul and Logar Rivers. The 66% of measured drinking water points of Kabul city shows that the EC values are higher than the WHO limit of 1,500 µS/cm (Figure 4), however this value is lower than 1,500 µS/cm in the rural areas (upstream) of the Basin.

47% of water samples from the urban areas of Kabul Basin groundwater indicated that the nitrate concentrations exceed the WHO limit of 50 mg/l while only 2% of water samples from the rural areas of Kabul Basin indicated that the nitrate concentrations exceeded the WHO limit of 50 mg/l. Sewage, leakage from septic tanks, soak pits, pit latrines and waste disposal are responsible for high nitrate concentrations in Kabul city (Figure 3).

The hardness of groundwater has progressively increased over time and this study shows that 82% of water samples from drinking water points are classified hard or very hard water. This significant hardness gives the water a high capacity against acid immissions (emission & dispersals)(Figure 3).

The boron concentration in the urban areas of Kabul Basin is higher than in most rural areas. 76% of water samples from the drinking water points in the urban areas indicate that boron concentration exceed the WHO limit of 0.5 mg/l, however 24% of water samples from the drinking water points in the rural areas indicate that the boron concentrations exceeded the WHO limit of 0.5 mg/L (Figure 3).
This study indicate that 59% of the analyzed water samples of Kabul Basin have significant bacteria contamination (Figure 3).


Figure 4. percentage of concern elements in the groundwater of Kabul Basin

CONCLUSIONS

1) Kabul Basin natural groundwater systems is characterized by three hydro geologic units: 1) crystalline rocks; 2) upper Tertiary (Neogene) aquifers and aquitards system; and 3) Quaternary sediments. The crystalline rocks act as a barrier to the groundwater flow due to the absence of primary fracture and the secondary fractures of these rocks are not potential for water bearing. Upper Tertiary (Neogene) aquifer-aquitard systems underlain crystalline rocks which mainly consist of mud stone and inter bedded silt, sand and gravel. The thickness of this unit is between 600 -700 m. The historical and recent investigation indicates that the Neogen low thickness alternate aquifers are not considered a major aquifer in Kabul Basin. The Quaternary interconnected aquifers are the potential aquifers in Kabul Basin and the average thickness of this unit is not more than 50 m. This aquifer has deflated due to over-exploitation and the quality has progressively deteriorated.
2) Historical temperature, precipitation and evaporation data was reviewed and compared with the data recently collected. The result shows adverse changes in temperature, precipitation, evaporation and consequently affect groundwater recharge.
3) The major quantitative concerns include: 1) declining water table exceeding the recharge; 2) depletion of natural storage; 3) water logging and salinization; and 4) perhaps land subsidence.
4) The major quantitative concern include: 1) progressive increase of salinity over time; 2) classified as hard and very hard; 3) progressive increase of nitrate concentrations over time; 4) progressive increase of coliform bacteria; and 5) progressive increase of boron concentrations.
5) The high rate of fecal coliform bacteria and high concentrations level of nitrate indicates that Kabul Basin's drinking water systems are contaminated by fecal coliform (microbial pathogens) and nitrate (anthropogenic) contamination and pose a threat to the health of Kabul's inhabitants.
6) The recharge condition of the flow system is characterized by: 1) recharges from river beds; 2) direct recharge from precipitation; 3) foot hill recharge from snow melts; 4) recharge from irrigation channels; and 5) recharge from percolation of sewage, leakage from septic tanks, soak pits and pit latrines.

8th International Symposium on Managed Aquifer Recharge (ISMAR8),
Beijing, P.R. China, October 15—19, 2013.

Towards implementation of Managed Aquifer Recharge in Semi-arid areas of Nigeria: Possible contributions from large irrigation schemes

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ABSTRACT

The potential of managed aquifer recharge (MAR) implementation in semi-arid areas of Nigeria was evaluated using the Kano River irrigation Project as a case study. Groundwater recharge was evaluated daily for 3 years (2009-2011) using the water level fluctuation (wlf) method; 15 piezometers were installed randomly on a selected 26.9 ha surface irrigated experimental farmland to monitor water level changes. Temporal and spatial analyses of recharge were done using Microsoft Excel® spread sheet and ArcGIS® 9.0 software. Groundwater recharges obtained range from 17 - 32 mm/day. Further analysis showed that about 8 mm of water is added to storage daily. The resulting waterlogging problems has implication for salt build up in the area and could be ameliorated by implementing a conjunctive use of both surface water and groundwater drained from the land. By this, more water can be freed from the dam to recharge the Chad formation aquifers downstream of the Hadejia River in a systematic MAR implementation; however, additional modelling studies and aquifer characterization are required.

INTRODUCTION

Water is important for life and livelihood. It shapes the earth's landscape through soil erosion, transportation and deposition by rivers, glaciers, and ice sheets; through evaporation, water drives the energy exchange between the land and atmosphere, thus controlling the Earth's climate. At the basin scale, the influence of climate change has led to increased variability of freshwater resources especially in sub Saharan Africa leading to surface water scarcity, groundwater depletion and environmental degradation (ICPC, 2007). A good example is the Yobe River basin in Northern Nigeria which has been reported to contribute about 2.5 % of the inflow to Lake Chad (UNEP, 2004); an important tributary to the Yobe River is the Hadejia River which was also reported to be responsible for about 48 % of the flow in the Yobe River (Sobowale et al., 2010). It was also reported that about 1, 535 million m^3 of water is recharged into the quartenary sediments of the Lake Chad formation via stream channel seepage at the hydrogeological divide between the upstream basement complex areas and the downstream Chad formation, this occurs at the middle course of the Hadejia River downstream of Wudil town just before the river bifurcates and enters the Hedejia – Nguru wetlands. It is therefore pertinent to evaluate the feasibility of managed aquifer recharge (MAR) in the area. The objective of this research was to investigate groundwater recharge in an active irrigation project in Northern Nigeria as a prelude for evaluating the potential of implementing managed aquifer recharge in the semi-arid areas of Nigeria.

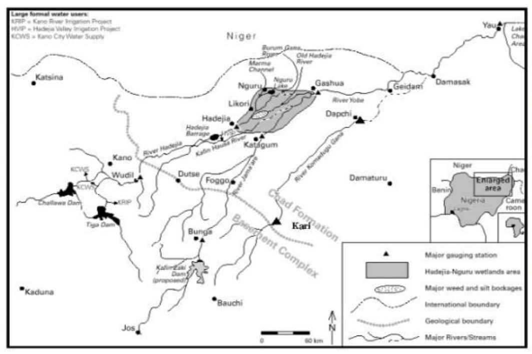


Figure 1: Lake Chad basin in Nigeria

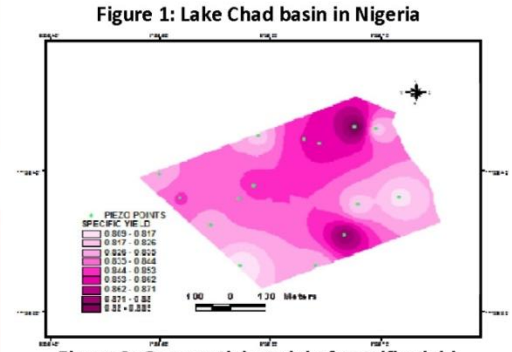


Figure 2: Geo-spatial model of specific yield

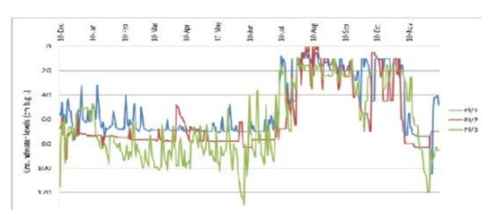
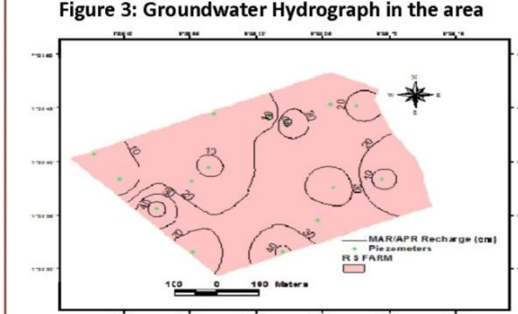


Figure 3: Groundwater Hydrograph in the area



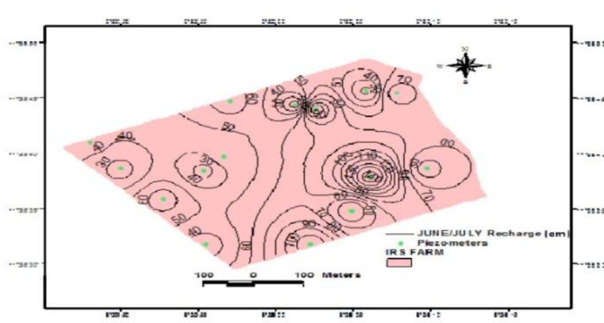


Figure 4 and 5: Groundwater recharge contour at the site

METHODS

The Kano river irrigation project was established by the Kano state government in 1970, with the aim of developing over 62,000 ha of agricultural land for crop production by irrigation using water from the Tiga dam. The project is located 24 km south of Kano city and lies between longitudes $8^0\ 30^1$ and $9^0\ 40^1$ E. and latitudes $11^0\ 30^1$ and $12^0\ 03^1$ N. within the Yobe River basin (Oyebode, 2002). The area is a portion of a dissected peneplain developed on the crystalline Precambrian rocks of the basement complex. The main rock types are granite, gneisses and schist, complex glimmer schist and quartzite. The top of the basement complex is deeply weathered and on this zone, a lateritic iron pan layer is developed. The area belong to the Sudan savannah agro-climatic zone with three distinct seasons namely: wet season (early June – late September (4 months)); cool dry season (October – mid February (4½ months)); and hot dry season (mid-February – early June (3½ months)). The experimental area is made up of 4 irrigation blocks: F-3.4, F-3.5, F-3.6 and F-3.7 with a total area 26.9 ha; each block is well laid out and intensively cropped with vegetables, wheat, onions, tomatoes, rice etc. The soils are mostly derived from Aeolian drift, while some are developed from colluvial and alluvial materials.

Specific primary data used in the study include: Meteorological data (rainfall, temperature, evaporation, relative humidity); Land use data/Map; Soil data; Groundwater level data; Irrigation data; while the secondary data included Topographic data/map, Soil map and Hydrogeological data/map. Daily Data collection of water level commenced on 11 December, 2008 and ended on 10 December, 2011 (3 years) using a combination of a water level sounding device and a floating gauge. Owing to errors that may occur due to vicissitude of sampling, all observational data were subjected to quality control before their use for analysis. The spatial analyst extension of ArcGIS® 9.0 was used to generate Digital Elevation Models for ground water recharge on the farmland using the Inverse Distance Weighted (IDW) approach.

RESULTS

Analysis of the groundwater data showed that water level changes rapidly in response to events of irrigation in the dry season and rainfall in the wet season. This observed behaviour was due to the continuous cropping practiced on the farmland throughout the year; it was observed that water levels were generally high (near ground surface) in the wet months, worthy of note was the observation that most parts of the farmland is completely waterlogged with a water level ranging between 0 and 190 mm below ground level (b.g.l.) in the month of July, August, September and some parts of October making the field only suitable for lowland rice production at those periods. Figure 3 shows a typical groundwater hydrograph in three selected piezometers on the farmland.

The use of the specific yield, Sy values as a factor for estimating actual recharge for the water level fluctuation (WFL) method was found to be really appropriate for the area as the findings corroborates the result of earlier recharge studies. Annual groundwater recharge range between 2, 907 mm and 4, 770 mm on the farmland; while groundwater recharge was least in Pa3 soils, it was highest in Pl soils. The total numbers of days in a year that recharge took place range from 146 days in Pb soils to 176 days in Pa3 soils. The study revealed that there are more discharge days than the number of days that recharge event took place. Mean daily recharge obtained for the farmland range from 17 mm (Pa3 Soil) - 32 mm (Pb Soil). It is pertinent to report that averagely, about 8 mm) of water is added to storage daily on the farmland; this point to the fact that conjunctive use of groundwater and surface water is very much possible in the area. Correlation analysis shows that there is no significant correlation between the groundwater recharge and discharge values in all the identified soil profile types on the farmland. The implication is that each of the installed piezometers indicate differential groundwater recharge and discharge regimes; this is largely due to the non-uniform irrigation scheduling on the field and the variation in soil properties across the five soil groups found on the farmland.

Figure 4 and 5 present the Geo-spatial models of monthly groundwater recharge on the experimental farmland for selected months of the year. The groundwater recharge contour show clear evidence of seasonal variation and the influence of land use on recharge. Monthly recharge with closely spaced recharge contour indicate increase in recharge rate, this observation was also corroborated by the Geo-spatial model of porosity and specific yield; areas on the farmland with the high porosity reveal higher recharge values.

It is also pertinent to report that the influence of the growing season can be readily seen as the land use affects the amount of water recharge on the land. Prior to the commencement of the cool dry season in November/December of every year, groundwater recharge was found to be very low due to the maturing, drying and harvesting of rice from the previous wet season cropping, the period of maturity of the rice usually witnesses very little or no irrigation and/or cessation of the rains, hence the low recharge values obtained.

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Temporal-spatial variation of ecotoxicity and distribution of heavy metal in the hyporheic zone of Shima catchment, Dongguan, China

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Introduction

The Pearl River Delta (PRD), is one of the most developed area in China, where undergone a period of rapid industrialization and urbanization. Water and soil environment, consequently, had been polluted to a certain degree. To protect potable water resources in PRD, bio-toxicity test and chemical analysis (e.g. heavy metals) of water and/or soil were performed in Shima catchment which is located at the middle of PRD. Shima river (site R1-R7) is the largest tributary of Dongjiang river basin in Dongguan city, it originate from Baoan district where is a dense industrial area in Shenzhen City. The river water discharge through the outlet (R6) to Dongjiang River where is an important water source area in PRD. Three dams are located in Dongguan canal, named Xiakou (R8), Shigu (R9) and Xinji (R10) which are employed to drain to Dongjiang River (south main stream) due to the occurrence of heavy rainfall. River water, ultimately, flow into the Pearl River estuary through Humen dam (R11). Therefore, water quality of Shima river is an important factor to keep water supply safe.

Fig. 1. Study area

Results & Discussion

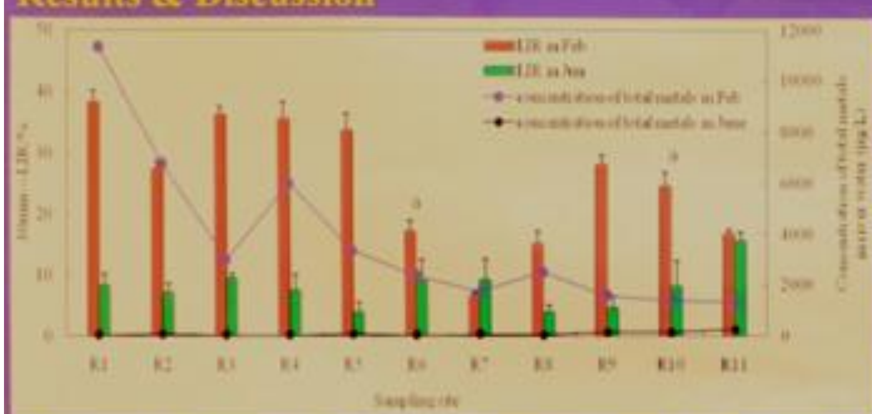

Fig. 2 Luminescent inhibition rate (LIR) of water sample and total concentration of heavy metals in river from upstream to downstream site in February and June 2012. a: LIR did not show significant differences at P<0.05

- The highest concentrations of total heavy metals were detected at site R1 in dry season (Feb). It indicated that there were abundant heavy metals released from upstream, especially those were discharged from industrial effluent in Baoan district, Shenzhen city.

- The most toxic effect of water sample to *Vibrio fischeri* was identified at site R1 with the LIR of 38.4%. The LIR of most samples exceeded the PE (percentage of effect) value (20%) which was considered as slight acute toxic. In contrast, metals level of river water collected in June were relatively lower than that in dry season (February) which was likely due to precipitation in rainy season. Furthermore, water samples did not show acute toxicity. It suggested that toxic effect may be attributed to heavy metals of river water.

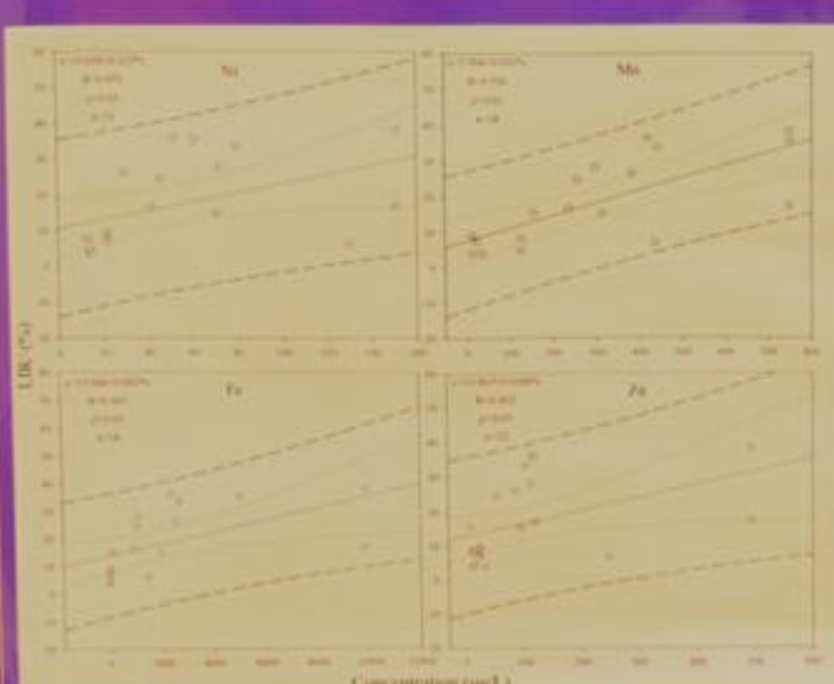

Fig. 3 Fitting relationship between LIR and heavy metals concentration in two investigated periods. P<0.05 means significant positive relationship between heavy metal level and LIR; The short and long dotted line represents 95% confidence and prediction interval

- 50% effective concentration (EC_{50}) of heavy metals to *Vibrio fischeri* were reported as 420-858μg/L for Zn. It could confirm that Zn level (494μg/L) of water samples in dry season made the greatest contribution to the toxicity.

- Both LIR and heavy metals level of groundwater samples (not shown) were significant lower in two investigated periods. It could be explained by the adsorption of metallic ions by soil particles in aquifer during the process of interaction between river water and groundwater. In other words, soil quality could be deteriorated by polluted river water.

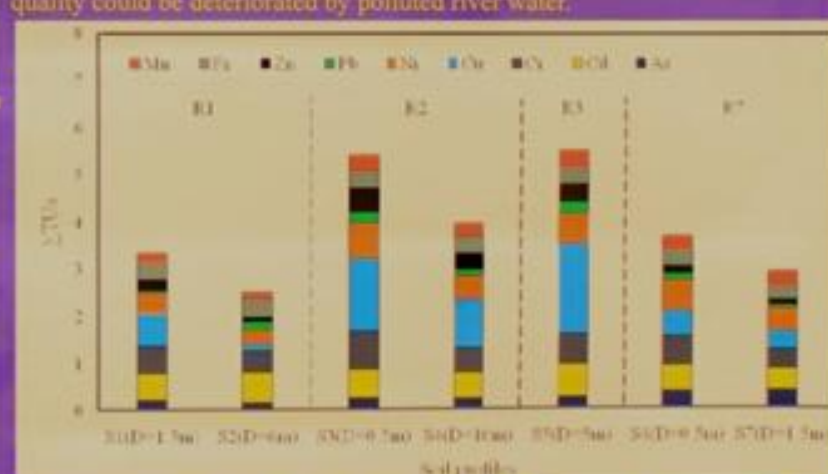

Fig. 4 Average ∑TUs of varied soil profiles at different sites from upstream to downstream of Shima river. R1, R2, R3 and R7 represent water sampling site in corresponding to soil profile site; D means the distances between soil profile site and river channel

- Toxic unit (TU) was defined as the sum of ratio of the determined metals level to SEL (Sever Effect Level) value. ∑TUs of soil profiles located at midstream (S3 and S6) were higher that at upstream and downstream sites, it was probably resulted from soil properties (e.g. organic matter, particle size, etc.). They were considered as moderate toxic as ∑TU was greater than 4.

- Significant decreasing trend of ∑TU from closer to further site of river channel could illustrate that less combined heavy metals contamination occurred at further site along Shima river.

Conclusions

※ River water was severely contaminated by heavy metals in dry season (Feb) which imposed slight acute toxicity on aquatic eco-system. Zn of river water made the greatest contribution to ecotoxicity.

※ Accumulation of heavy metals by soil is affected by soil properties and distance between the sampling sites and river channel. ∑TU of soil profiles decreased from closer to further site of river bank

Main references

(1) **Lei Gao**, Jianyao Chen, Zhiting Ke, *et al.* Temporal-spatial difference of ecotoxicity and heavy metals pollution in Shima catchment, Dongguan. Environmental Science. 2013. 34(8):3079-3087 (in Chinese)

(2) **Lei Gao**, Jianyao Chen, Jiang Wang, *et al.* Study on heavy metal pollution and ecotoxicity of soils along Shima river, Dongguan. Acta Pedologica Sinica. under review. (in Chinese)

Applications of Managed Aquifer Recharge to Improve Groundwater Quality in the Khulna-Satkhira Coastal Belt of Bangladesh: Results and Findings

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Introduction

Figure : (a) Rain water harvesting (RWH) (b) Pond water collection (PSF), (c) Inundation due to storm surges, (d) Fresh water supply, (e) Fresh water supply, (f) Fresh water supply

The Khulna-Satkhira coastal belt is one of the most vulnerable areas in Bangladesh in terms of access to safe drinking water mostly because of salinity problem. There is no available deep groundwater and shallow groundwater mostly saline or brackish. Local communities rely mostly on rain water during the monsoon (Figure a) and for the rest of the year they rely on pond water (Figure b). It is of great concern that these existing surface water options which serves as the reliable source of fresh water during the dry period are becoming saline or brackish due to frequent storm surges with higher intensity and magnitude like the cyclone Aila. The groundwater is also vulnerable to climate changes (Ahmed *et al* 2010) such as inundation due to sea level rise, decreasing monsoon rainfall, reduced surface water flux from the upstream etc.

The study area is situated in the south-western part of Bangladesh with annual rainfall amounting to 1500 to 2000mm, 70% occurring during the monsoon. Geologically the area belongs to the tidal delta and is composed of floodplain deposits mainly sand, silt, clay, silty clay and sandy clay of Quaternary age. This region is characterized by multi layer prolific aquifers composed of deltaic sediments (Ahmed. 2005). The shallow aquifer is either saline or brackish with high chloride concentration or has high arsenic level (Ahmed 2011).

Results and Discussions

Figure : (g) GIS mapping (h) Exploratory drilling

Integrated GIS and RS mapping along with field investigations are essential and have been reported as an effective and proved method to identify suitable sites for MAR (Ahmed et al 2010).

After the GIS analysis different physical, physico-chemical, hydrogeological, geochemical, social and economic criteria have been investigated in the field. Exploratory drilling have been carried out to investigate subsurface lithology (Figure h). Easily accessible areas with significant size of roof and pond were the first criteria for selecting sites.

Following the completion of final site selection, innovative well design and construction has been carried out using locally available materials and drillers (Figure k & l). The conceptual design of the Assasuni site consists of the collection of source water from both roof and pond (Figure i) whereas in Batiaghata site source water will be collected only from the pond and primary accumulation in a storage tank.

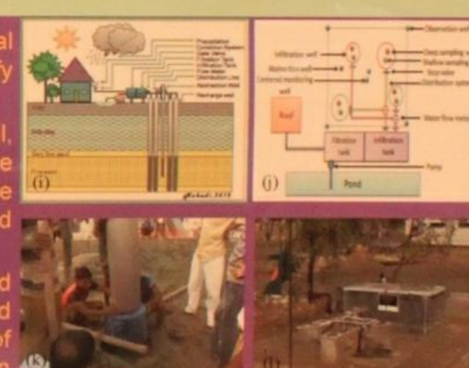
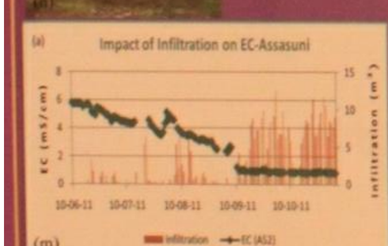
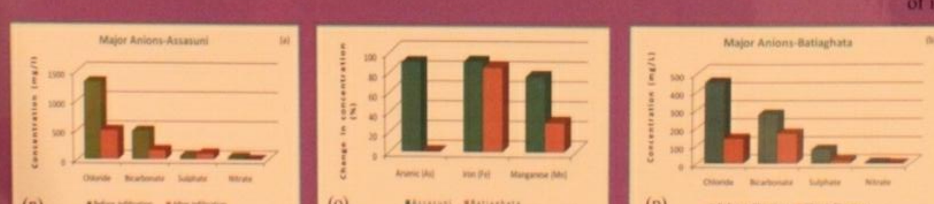


Figure: (i) Sectional view of the MAR system (j) Plan view of the MAR system(k) Construction of infiltration wells (l) MAR system





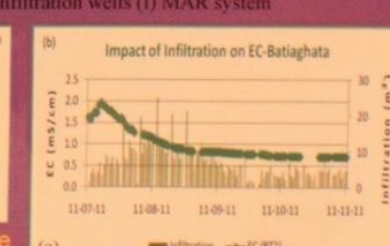


Figure: (m) Impact of infiltration on EC (Assasuni) (n) Reduction in concentration of major anions (Assasuni) (o) Change in concentration of trace elements

Infiltration rate: A total of 392m³ of water has been injected in Assasuni with the average of 2.93m³/day. The maximum rate of infiltration has been found to be 12.4m³/day when both rain water and pond water has been injected simultaneously during the monsoon of 2011. In Batiaghata site 827m³ of water has been injected. At this site the average rate of infiltration found to be 6.95m³/day with the maximum of 25m³/day.

Source water quality: Pond water has been injected at both sites which is characterized by high turbidity fluctuating between 29 to 52ntu. But the filtration system has been found to be effective since about 97% turbidity is removed after filtration. The electrical conductivity of pond water ranges from 4.0 to 0.8mS/cm. But during the monsoon due to the addition of rain water, pond water becomes fresh enough to be injected into the shallow brackish aquifer.

Ground water *Electrical conductivity:* A positive impacts of infiltration on groundwater electrical conductivity has been found (Figure m & q). Initially the electrical conductivity of the centered monitoring well in Assasuni and Batiaghata were 5.82mS/cm and 1.79mS/cm respectively. At the end of the infiltration the electrical conductivity has been lowered to 0.82mS/cm in Assasuni and 0.79ms/cm in Batiaghata respectively.

Figure: (p) Reduction in concentration of major anions (Batiaghata) (q) Impact of infiltration on EC (Batiaghata) (R) & (s) Collection of safe water from MAR system

Conclusions

GIS analysis has been conducted in a systematic way and field criteria have been found to be successful to identify suitable sites for MAR. Site specific and innovative well design has been performed for both sites. Four injection wells of 22 or 12 inches diameter have been drilled to a depth of 60 to 75 feet. The whole construction phase has been carried out using locally available materials and drillers. A total of 392m³ and 827m³ of water has been injected in Assasuni and Batiaghata respectively where both rain water and pond water has been injected in Assasuni simultaneously. Significant reduction of groundwater electrical conductivity and concentrations of dissolved constituents of concern indicates the improvement of groundwater quality due to recharge where simultaneous infiltration of both rain water and pond water shows better performance. The findings of this study clearly demonstrate that roof top rain water and pond water induced MAR is feasible in the coastal belt of Bangladesh.

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Sustainable Development of Palestine Aquifers
Gaza Aquifer Case Study

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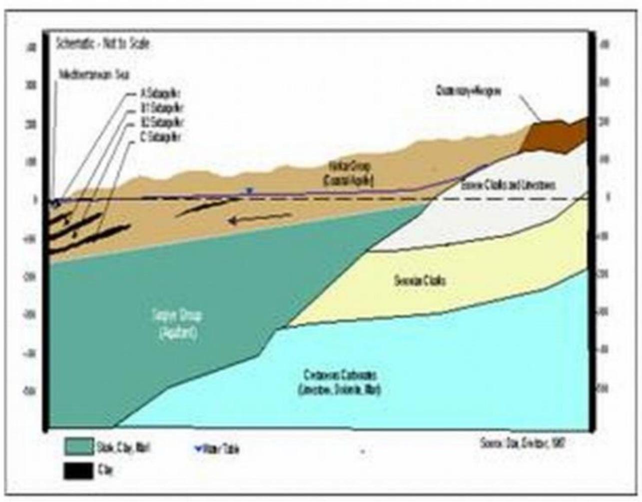
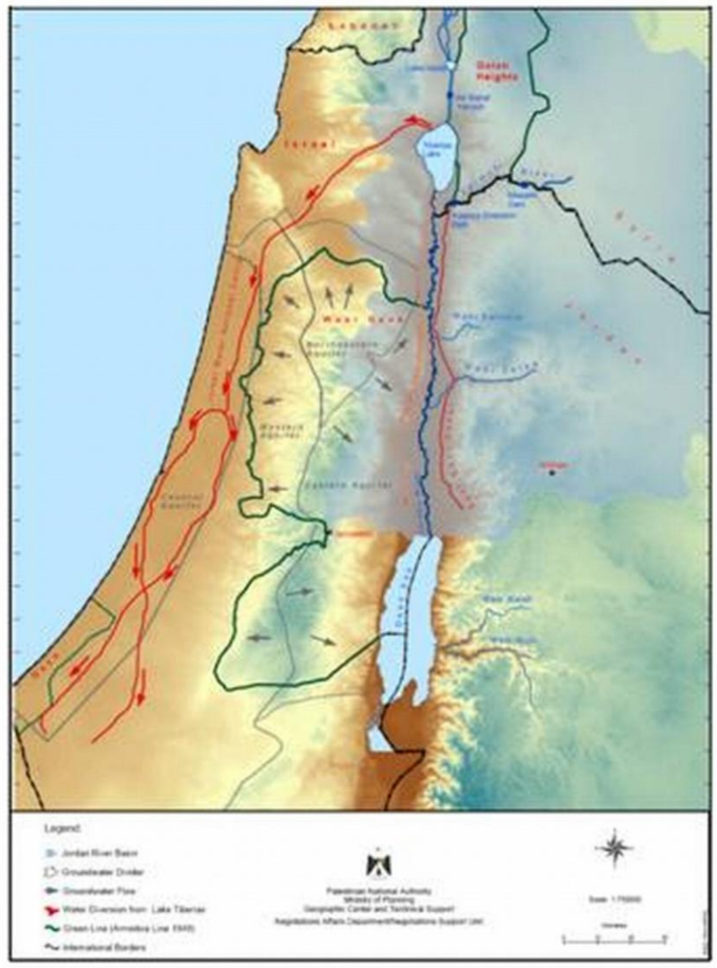
Groundwater is the only access able source to Palestinians in West Bank or Gaza. Israel use more than 80% of abstracted water from West Bank and Gaza Aquifers to supply settlements for domestic, agricultural and industrial needs.

Hydrological Background

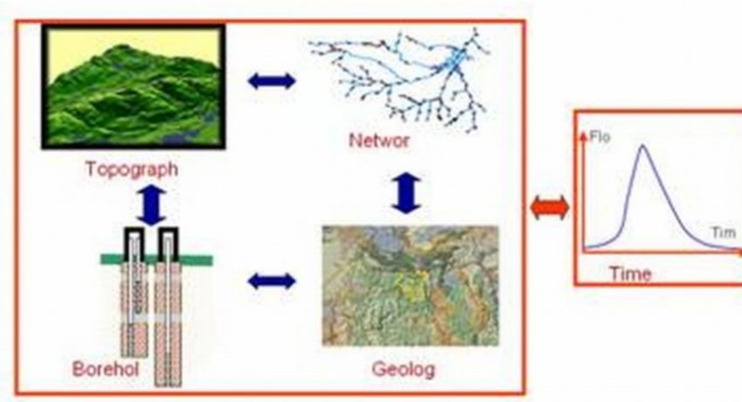
Palestine aquifers includes six main aquifers ranked from youngest to oldest: Valley Aquifer (Valley Alluvium and Pleistocene Lisan Formation), Beida Aquifer (Neogene age), Eocene, Turon (Subseries of the Upper Aquifer), Upper and Lower aquifers. Gaza Aquifer is mainly calcareous sandstone Kurkar formations covered by windblown sand and alluvial deposits in various thicknesses (10 to 25 m) as shown below. The alluvium and upper aquifer systems are the most vulnerable ones.





Gaza Water Crises

Although the World Health Organization (WHO) calls for minimal water consumption of 100 liters per capita per day (l/c/d) for a quality level of health· Palestinians percapita average 50 -70 liters (l/c/d). Moreover, Israeli capita usage averages 400 l/d and Israel settlers in the Palestinian Occupied Territories average 800 l/c/d. Thus, Israelis average almost five times more water consumption than Palestinians.



Conclusions and Recommendations

* The study presented and illustrates a new technology using GIS software (ArcGIS , ArcSDE &Oracle Spatial) in order to assist in developing a Information System related to PWA.
* GIS was useful in Management of large data sets as GIS proved to be efficient in managing large amounts of Water data
* GIS Technology is required in Decision Support System DSS to reach to the optimal Decisions and Solutions.
* It would appear that there are few perceived problems with the GIS technology, the strategy and plans for implementing new technology. The obstacles to using IT effectively would appear to stem from a general lack of awareness in using the new technology within the planning profession. This manifests itself in a perception that the lack of staff and financial resources in Palestinian Institutions is the biggest obstacle to using GIS Technology effectively and Lack of an information strategy is also a significant obstacle.
* It would be recommended to prepare a clear strategy planning to use GIS Technology in Palestinian Institutions related to that.

SEJONG UNIVERSITY

Effects of silver nanoparticles on the performance of managed aquifer recharge: column study

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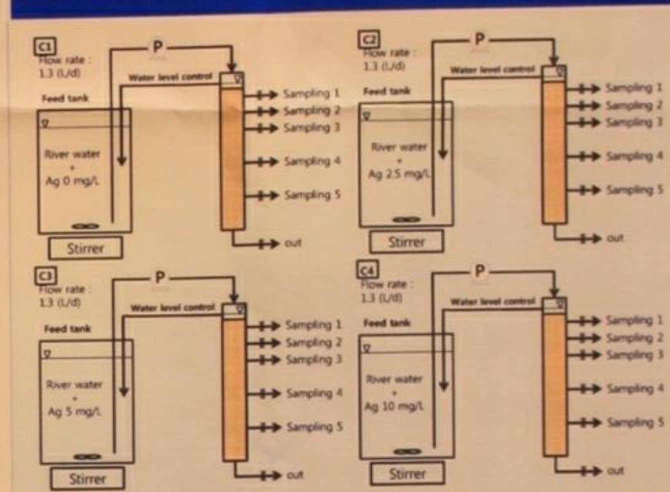
Background

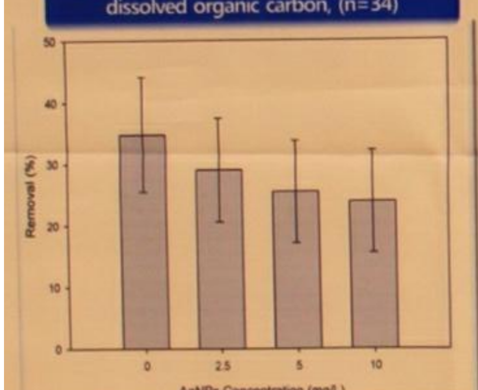
Managed aquifer recharge (MAR) systems such as bank filtration and artificial recharge and recovery have been recognized as an effective barrier in the multi-barrier approach for the attenuation of organic micropollutants such as pharmaceuticals and estrogens. However, there are only a few studies on the effects of silver nanoparticles (AgNPs) on the removal of pharmaceuticals and bulk organic matter during MAR. The goal of this study is (1) To investigate effects of AgNPs on the organic matter characteristics during MAR using advanced organic matter characterization tools during MAR; (2) To investigate effects of AgNPs on the removal pharmaceuticals. Column experiments were performed and fed with river water collected from Tancheon River in Seoul, Republic of Korea. ATP and flow cytometry were used to estimate microbial activity to provide more insight on the removal of pharmaceutical via biodegradation at different concentrations of AgNPs (0, 2.5, 5, and 10 mg/L).

Schematic diagram of column set ups (C1, C2. C3 and C4)

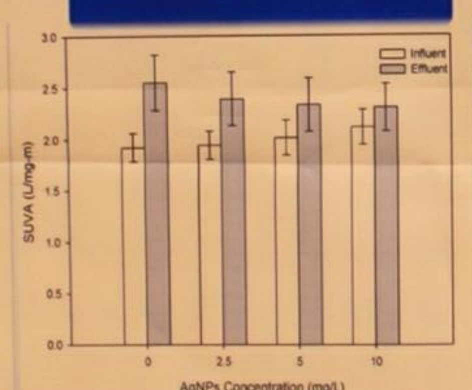


C1 : River water (Control)
C2 : River water + AgNPs 2.5 mg/L
C3 : River water + AgNPs 5 mg/L
C4 : River water + AgNPs 10 mg/L

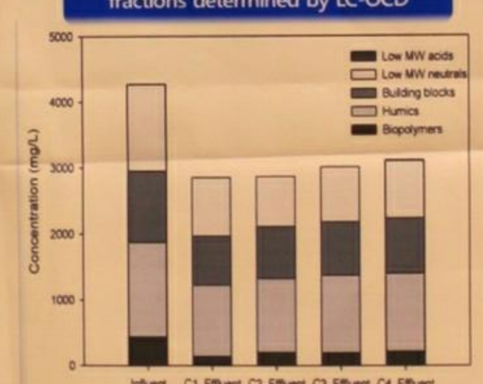
Effects of AgNPs on the removal of dissolved organic carbon, (n=34)



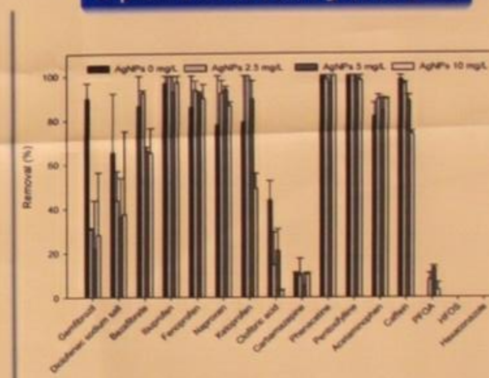
Effects of AgNPs on SUVA, (n=34)



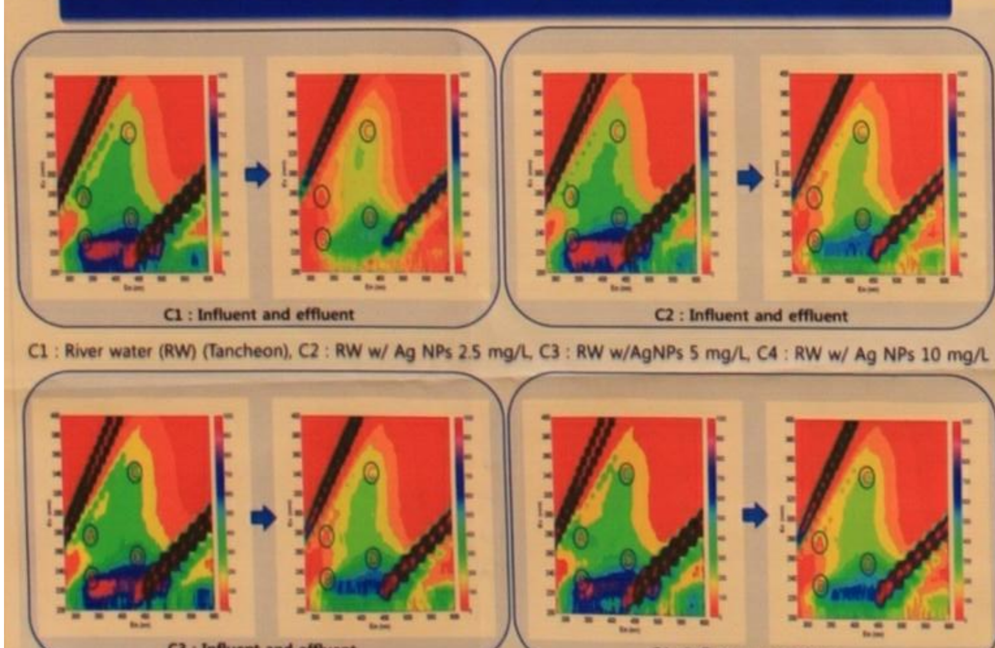
Effects of AgNPs on organic matter fractions determined by LC-OCD



Effects of AgNPs on the removal of pharmaceuticals during MAR, (n=2)



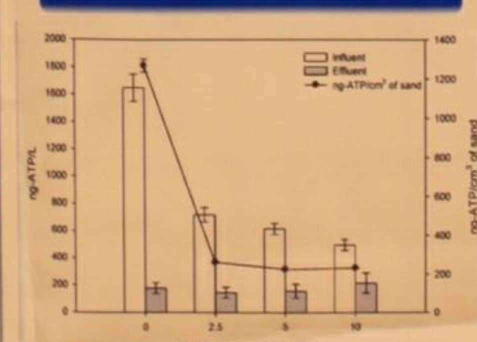
Fluorescence excitation-emission matrix (F-EEM) spectra at AgNP 0, 2.5, 5, and 10 mg/L



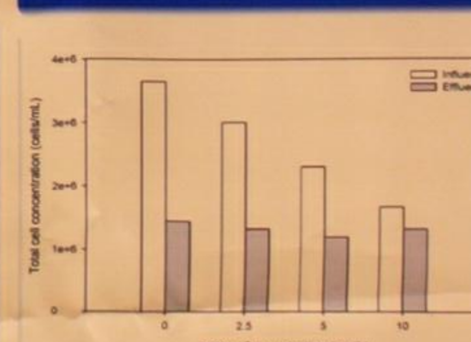
C1 : River water (RW) (Tancheon), C2 : RW w/ Ag NPs 2.5 mg/L, C3 : RW w/AgNPs 5 mg/L, C4 : RW w/ Ag NPs 10 mg/L

A:Tryptophan protein-like peak, B: Aromatic protein-like substances, C: Humic-like peak, D: Fulvic-like peak

Microbial activities determined by ATP (n=9)



Flow cytometry total cell counts (cells/mL)



Conclusions

Based on result of this study, the following conclusions can be drawn.

- The removal of dissolved organic carbon was reduced as AgNPs increased, and this may be due to AgNPs effects on the biodegradation by reducing microbial activity.
- SUVA, F-EEM and LC-OCD showed that changes in the bulk organic matter characteristics were not significant at different concentrations of AgNPs
- ATP and flow cytometry clearly demonstrated effects of AgNPs on microbial activity, but it was not significant in filtrates.
- Some pharmaceuticals removal were reduced as AgNPs increased, but further study will be needed to determine effects of AgNPs on the removal of pharmaceuticals during MAR. For now, compounds that influenced by AgNPs are biodegradable compounds that are sensitive to microbial activity or heterotrophs.
- Nitrification was more pronounced at higher AgNPs, and autotrophic nitrifying bacteria less influenced by AgNPs compared to that of heterotrophs.

Acknowledgements

This work was supported by the KIST Institutional Program (Project No. 2E24280)

DRY SPRINGS?

boost the yield by ARTIFICIAL RECHARGE

Artificial Recharge of Runoff Rainwater to Improve Spring Water Catchment.

Pilot research study , Usambara Mountains, Tanga Region, Tanzania

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[3] SamSamWater Foundation, The Netherlands www.samsamwater.com
[4] Chamavita, Chama cha Maendeleo Vijijini Tanga, Lushoto Tanzania

RESEARCH PROJECT

Tanzania, Usambara Mountains, Kwemakame Gravity Water Scheme (S 4° 43' 40" E 38° 19' 50")

- NGO Chamavita Foundation, Lushoto, Tanzania
- Funding by Aquanet and Aqua for All, the Netherlands
- Monitoring and Field work since 2008
- Pilot construction 2010 - 2012
- Pilot operation and post-pilot monitoring 2012 - 2013
- Presently: data analysis, reporting en dissemination

ANALYSIS

- Lack of groundwater recharge
- causing low yields
- due to deforestation?

but meanwhile:

- major unutilized overland runoff flows

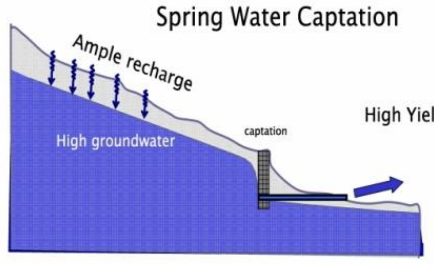
STRATEGY TO IMPROVE: Artificial Recharge

Catch this runoff water, store it underground, boosting groundwater level and spring yield

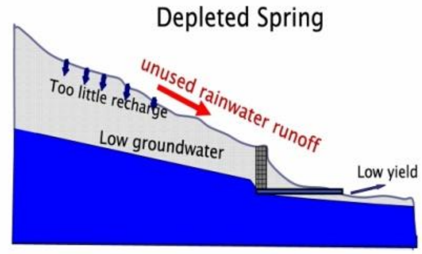
The underground is the biggest and safest tank to store water!

Tested in a pilot project Dindira Catchment Area of the Kwemakame gravity Water Scheme

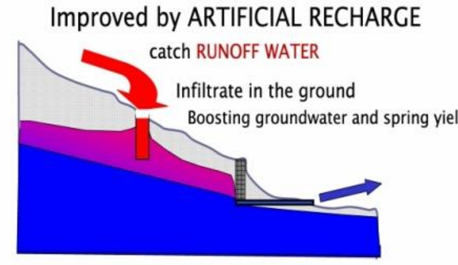
Spring Water Captation

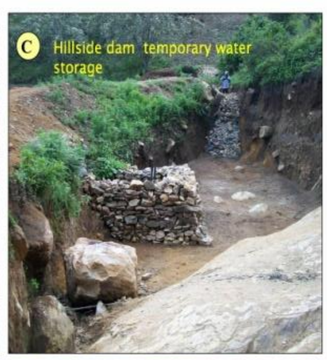


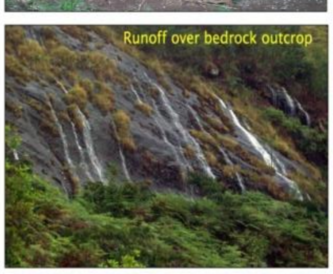
Depleted Spring

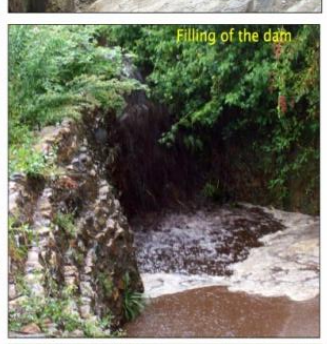


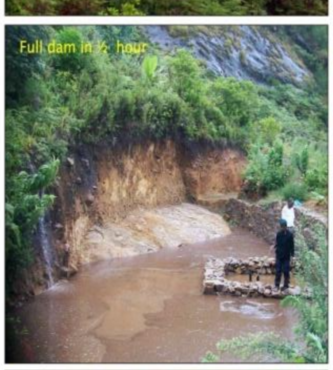
Improved by ARTIFICIAL RECHARGE

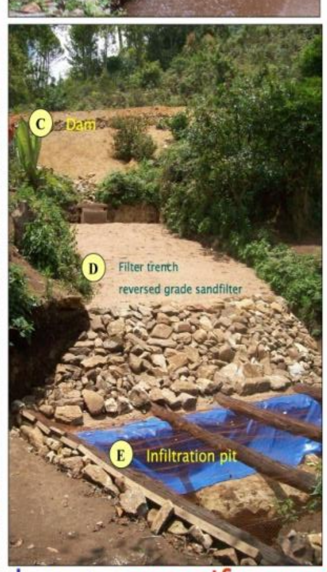










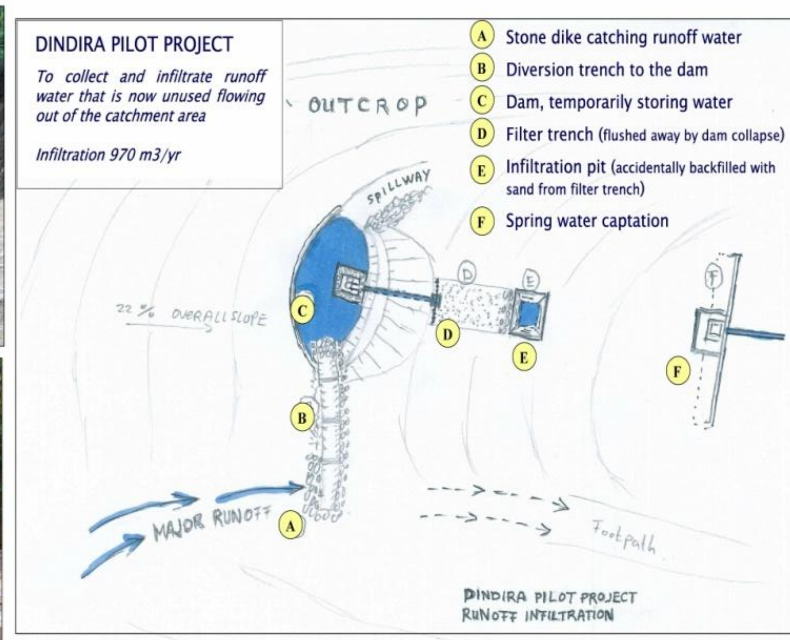


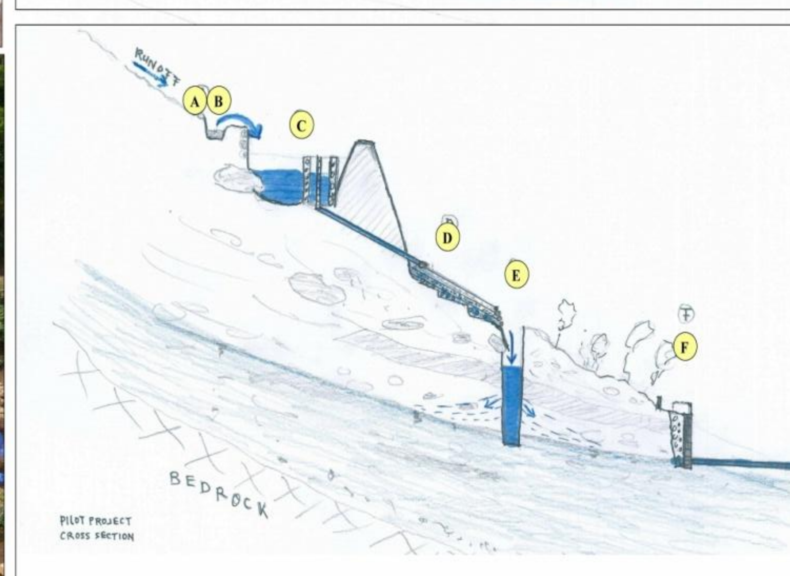
DINDIRA PILOT PROJECT

To collect and infiltrate runoff water that is now unused flowing out of the catchment area

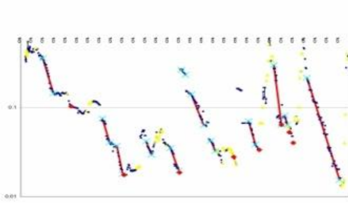
Infiltration 970 m3/yr

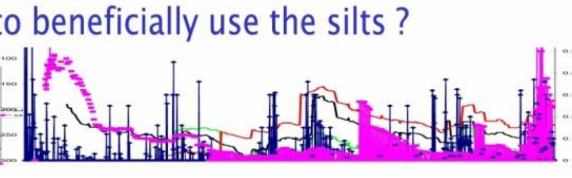
- A Stone dike catching runoff water
- B Diversion trench to the dam
- C Dam, temporarily storing water
- D Filter trench (flushed away by dam collapse)
- E Infiltration pit (accidentally backfilled with sand from filter trench)
- F Spring water captation





Challenges to discuss: how to quantify runoff volumes in advance ?
how to design for proper recoverability ? (% recovery and delay in time)
how to prevent silts in the dam or to beneficially use the silts ?





8TH INTERNATIONAL SYMPOSIUM
ON MANAGED AQUIFER RECHARGE
October 15th-19th, 2013 Beijing, P. R. China

College of Environment and Resources
Jilin University, P.R. CHINA

Experimental study of high sediment-surface water seepage to groundwater in Nalingguole River

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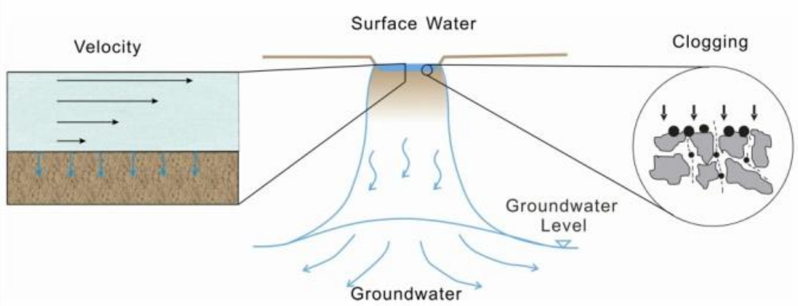
Introduction

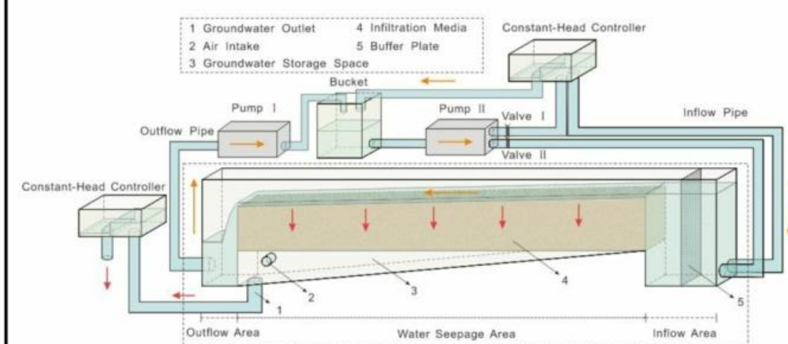
The interactions between groundwater and surface water are complex, an understanding of the basic principles of interactions between groundwater and surface water (GW–SW) is needed for effective management of water resources (Marios Sophocleous, 2002). Chemical, biological and physical properties of surface water and groundwater are indeed different , in the transition zone a variety of processes occur, leading to transport, degradation, transformation, precipitation, or sorption of substances (E. Kalbus et al., 2006).Generally, it's important to consider the effects of the suspended solids content and velocity of surface water on the exchange rate between surface water and groundwater.



Methods & Materials

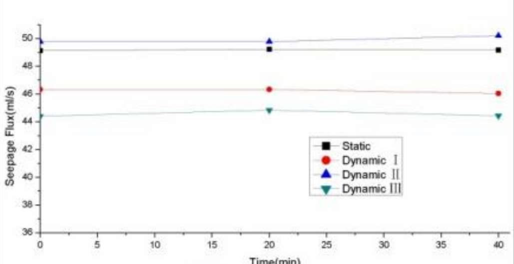
A 2-D river tank model made of Plexiglas included three parts: water supply devices, drainage devices and seepage tank (290 cm in long, 15 cm in width, 60 cm in height). When opening the valve Ⅰ, a constant water level can be provided to start the static seepage experiment, or opening the valve Ⅱ, a constant flux can be provided to start the dynamic water seepage experiment. During the operation period, the flux from the groundwater outlet was monitored every 20 minutes.

In order to simulate the situation of Nalingguole River, sand in diameter of 0.25-0.5 mm was adopted as the infiltration media, and TSS with diameter of 0-0.075 mm in surface water was set to 5000 mg/l.



Results & Discussion

Unsaturated Seepage Experiment

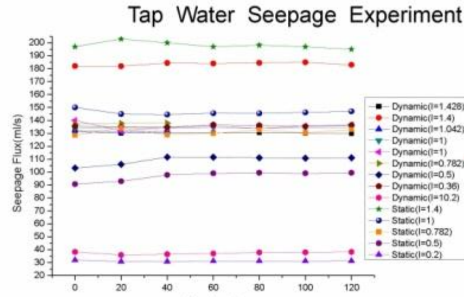


Seepage Flux Average(Q)

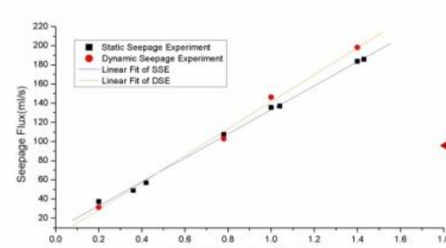
	Dynamic Ⅰ	Dynamic Ⅱ	Dynamic Ⅲ
Q_D (ml/s)	46.23	49.91	44.56
Q_S (ml/s)		49.18	
Q_D/Q_S	0.94	1.01	0.91

Saturated Seepage Experiment

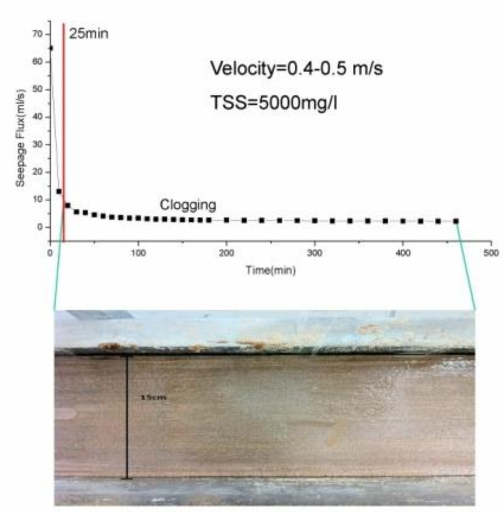
Tap Water Seepage Experiment



Statistic Analysis



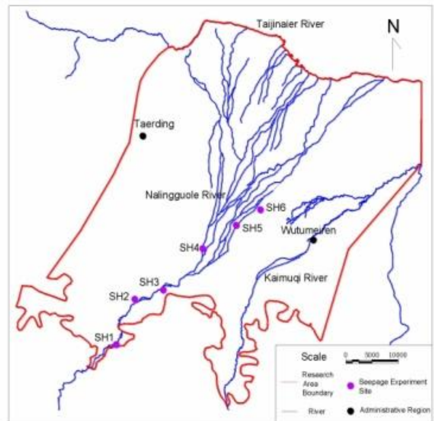
High sediment-water Seepage Experiment

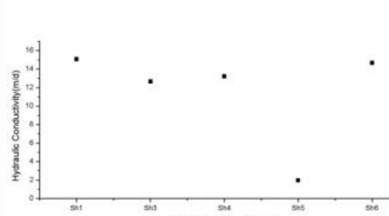


Conclusions

Ⅰ. Under the unsaturated condition, the seepage flux of surface water largely depends on the water-gas composition in the vadose zone, because gas will resist infiltration.

Ⅱ. Under the saturated condition, the seepage flux of surface water is affected by velocity. In this experiment, Q/I is 140.62 under static condition and Q/I is 125.29 under dynamic condition. Hydraulic conductivity which got from seepage experiment in the field should be modified to reveal the real situation.





Ⅲ. We can see that there is no significant change of the hydraulic conductivity of river bed which got from field seepage experiment except SH5. Because channel become wider, the flow rate decrease in SH5 area, and this resulted in precipitation of suspended solids and river bed clogging.

Summary

Due to the extremely arid climate in the western Qaidam Basin, the groundwater almost becomes the single water source for local residents and industrial production. As the largest river in the basin, Nalingguole River plays an important role in solving the water resource among this area, which is the most important recharge source of local groundwater. The suspended solids concentration of Nalingguole River is up to 10-20 grams per liter .It is necessary to know the reliable information on the high sediment surface water seepage to the groundwater, which is very important to evaluation of reasonable exploitation of the groundwater resources. In addition, the result will contribute to the study of artificial groundwater recharge clogging mechanism, prediction methods and recovery techniques. The seepage rate and the quantitative recharge will be identified through many comparative experiments, which will provide a scientific basis for the determining of high sediment- surface river water to groundwater infiltration.

Acknowledgement

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Marios Sophocleous, 2002. Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal , 10(1) :52-67.

Simulation of physical clogging at RBF sites using a laboratory channel experiment

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Motivation

Riverbank filtration (RBF) has been used for several decades in Europe, where riverbed clogging is limited or regularly removed during floods. While the turbidity of rivers in Europe is typically below 20 NTU, in other regions, e. g. in Asia and South America, much higher turbidities are observed, especially during monsoon or floods, where it reaches values of more than 200 NTU. Clogging impacts riverbed hydraulic conductivity, reduces the capacity of RBF wells and increases energy consumption. As there is limited information available on the practice of RBF along rivers with such high sediment loads, a laboratory channel experiment was conducted to investigate physical clogging by using different flow conditions, as well as high suspended sediment concentration and high infiltration rates.

Methodology

A small-scale laboratory channel made of plexiglass (1.70 x 0.2 x 0.15 m) was developed to simulate a river at high (0.1 m s^{-1}) and low (0.01 m s^{-1}) flow conditions, and worked as a closed system (Fig. 1). Three 0.5 m long PVC columns were connected to the bottom of the flume with piezometers at different depths. Initial infiltration rates of 3.0E-4 m s^{-1} were established by using outlet devices connected to the columns, and recorded every 30 min for 12 h (Fig. 2). Fine sand (0.1 – 0.3 mm) was used to fill the columns and as channel bed. Kaolinite with an average grain size of 0.004 mm was added as suspended sediment at a concentration of 200 mg L^{-1} (around 300 NTU), and checked every 30 min with a turbidity meter. Wet sieving analysis was conducted with the material from the columns to determine the mass percentage of Kaolinite at different depths.

Fig. 1. Experiment setup in the laboratory

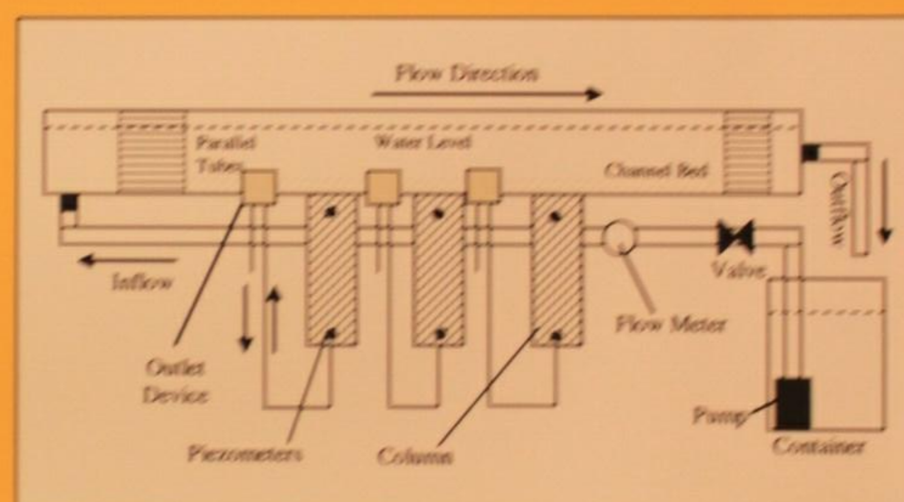

Fig. 2. Schematic representation of laboratory channel experiment

Results

- Results show that with a **turbidity of around 300 NTU, a flow velocity of 0.1 m s^{-1} and Shields parameter of 0.05**, **a reduction of almost two orders of magnitude in K-values** of the first 10 cm of sediment can occur in as little as 12 hours during high infiltration rates and high flow conditions in the channel (Fig. 3).
- A **similar K-value reduction** was also observed during low flow conditions (**flow velocity of 0.006 m s^{-1} and Shields parameter of 0.002**) in the same period of time when the turbidity and high infiltration rates remained unchanged (Fig. 3).
- **Fine sediment was entrapped mainly in the top layer**, however, due to suspended sediment grain size, grain uniformity and gradation of sediment bed, intrusion of fines was also observed in the lower layers (Fig. 4).

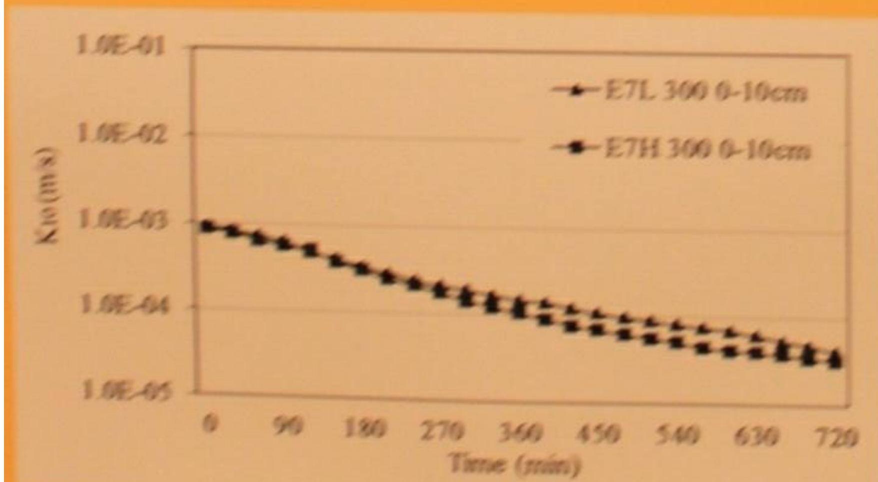

Fig. 3. Hydraulic conductivity reduction (K normalized to 10°C water temperature) from the top layer (0-10 cm) at low (E7L) and high (E7H) flow condition in the channel and turbidity of 300 NTU

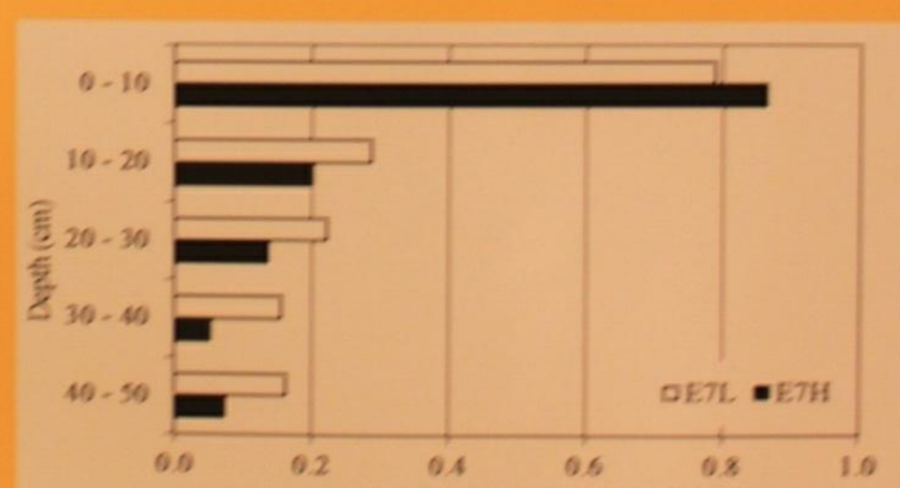

Fig. 4. Mass percentage of Kaolinite at different depths in the columns at low (E7L) and high (E7H) flow condition in the channel

Acknowledgement
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Development of Managed Aquifer Recharge in China

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Abstract

China has a long history in managed aquifer recharge (MAR), the development divided into 4 stages based on the summary combined with typical MAR projects. The first stage is MAR applied in agricultural production, the second is MAR applied in industrial production and alleviation of agricultural, the third is MAR applied in ecological protection and augment of urban water supply, the fourth is multi-source MAR. In addition, geothermal reinjection and ground source heat pump are also effective use of MAR. Nevertheless, the system of MAR is defective, the study on water quality is lacking and the recharge rate of most projects is low etc. It is condude that China has achieved a great effect on industrial and agricultural production, ecological protection, drinking water supply and urban reclaimed water reuse etc. However, there are still many issues. It is suggested to develop a feasible, convenient and economic technique of MAR fitting to local hydrogeological conditions, establish guidelines of MAR and management regulations together to make sure the MAR projects running successfully. MAR will make a great difference on improving potable water quality, alleviating geological hazards, long distance diversion, urban water supply and agriculture irrigation etc

Introduction

The water resource occupied per capita in China is only 1/4 of the world average level. Moreover, groundwater mainly recharged by precipitation, which is distributed unevenly for the multi-average rainfall varied in time and space. In North China, groundwater capita accounted for 32.3% of the whole country with a serious water shortage and over-exploitation. This triggered a series of environment problems, such as land subsidence, seawater intrusion and deterioration of water quality etc. Consequently, MAR is an effective measure for the integrated management of water resources. Although, China has successfully constructed many artificial groundwater recharge projects for different purposes since 20th90s, there is a lack of technical regulations, namely China has no scientific guidelines of MAR for conduction and supervision.

Stages of MAR in China

First stage- MAR Applied in Agricultural Production

Chinese people began to exploit groundwater extensively since 2000~1000 BC. In Warring States period(475～221BC.), channels were dug to facilitate the surface water to infiltrate groundwater, improving groundwater water quality and saline land. In Qin and Han Dynasties(221BC～220AC), people dug artesian wells with depth of 10～200m. The Karez was invented during this period and used to intercept groundwater for agriculture irrigation and residential water consumption. Karez is generally comprised of shaft, under drain, open channel and waterlogging dam (fig.1& fig.2). Karez guaranteed a stable delivery of irrigation water for a few evaporation of groundwater, which is scarcely affected by surface temperature. The ancient farmers of Huantai county in Shandong excavated transverse gallery along the Wu River during the Qing Dynasty. This system is comprised of river, transverse gallery, shaft and a manual lifting device(fig.3). Shafts were usually excavated at depth of 7～8m below surface and the length of transverse gallery could stretch several kilometers. There is a shaft for every 30m, which is convenient for construction and lifting. The groundwater is recharged by diverting river water during flood seasons. So then, the water table is raised quickly. At that time it is a perfect groundwater recharge project with a much higher efficiency of infiltration than any other facilities.

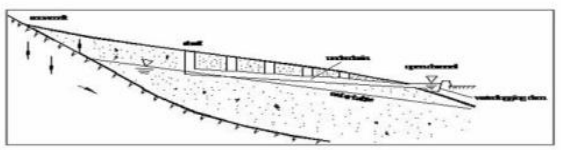

Fig.1 Schematic diagram of a Karez

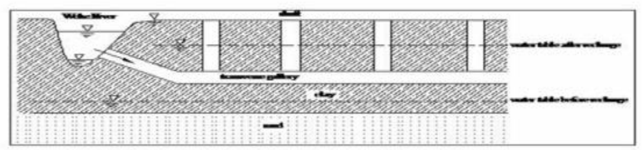

Fig.3 Schematic diagram of a transverse gallery

(a) Shaft (b) Underdrain (c) Open channel (d) Inlet

Fig.2 Elements of a Karez

Second stage- MAR applied in industrial production and alleviation of agricultural disasters

Most established engineering of MAR in China played a prominent role in restoring water table, saving energy and cost, controlling land subsidence and augment of industry water supply etc. For example, Shanghai conducted groundwater recharge with deep wells since 20th60s to control land subsidence by regulating groundwater exploitation and decreasing water demand. In 1965, five cotton companies in Shanghai carried out injection test with 4 different water sources, the result shows that injected water has a low velocity and a little variation on temperature. Subsequently, groundwater recharge with tube well was explored gradually and developed a style to offer new cold source and heat source for factory with aquifer, that is "water was recharged into aquifer in winter while exploited in summer" and "water was recharged into aquifer in summer while exploited in winter". By 2000, the total amount of groundwater recharge with tap water has reached 6×10^8 m3 in Shanghai, the annual average of groundwater recharge was 2×10^7 m^3, urban land subsidence was controlled effectively. At the same time, technique of recharge groundwater in winter and reuse in summer was applied in Beijing, Tianjin, Xi'an and Nanchang etc. For example, Beijing conducted groundwater recharge with deep well in industrial area from 1981-1999 with a total volume of 1.07×10^8t.

In North China, drought, waterlogging and salination are the most serious natural disasters. The key is to solve the problem of water shortage by diverting discarded water in river or transferring extraneous water etc. according to local conditions. Wells, ponds, ditches and basins were widely applied in artificial recharge combined with adjusting exploitation volume, which would increase the water resources and ensure the agriculture with bumper harvest and stable production. For example, the irrigation district of Renming Shengli Channel carried out combination of well and channel, which use channel water for irrigation and recharge groundwater during the dry seasons, while use well water in contrast. In 1975, the irrigated area reached 300,000 hectare and the water table was maintained at 2m, the area of saline land decreased and grain yield increased year after year. For another example, the Wuqiao county of Hebei province applied shallow well-deep groove system, carrying out the combination of river, well, swag and channel, as well as using surface and underground water together to realize the comprehensive treatment of drought, waterlogging and salination. It is generally retained surface rainfall with canal and swag in flood seasons to recharge groundwater, and discharged groundwater retained in river sluice at the end of flooding season. Water in river is diverted to irrigation in winter. Shallow groundwater is pumped to irrigate farmland with lowering water table and vacating underground capacity in spring. Thus, the level of drought control and waterlogging prevention was improved gradually. However, most aquifer recharge projects scraped without sustainable management. In addition, it is feasible to build intercepting underflow project in arid region with little surface flow and more underflow relatively. It is a practical technology to alleviate the contradiction between supply and demand of water resources effectively and strengthen the agricultural drought resistance. For instance, Alxa League city of Inner Mongolia has built 70 intercepting underflow projects since 1970s. Among them, the largest one in Alxa Zuoqi resolved tens of thousands of people's drinking water with 90L/s of daily water supply; the least one in Alxa Youqi resolved 1000 livestock's drinking water with 0.3L/s of intercept flow. Intercepting underflow projects is an effective measure to exploit and utilize ground water of riverway and valley plain in hilly area.

Third Stage-MAR Applied in Ecological Protection and Increasing Urban Water Supply

In China, costal intrusion area has reached 1500km² for over-exploitation of groundwater. Many underground reservoirs were built since 20th90s, which could transfer exceed flood to prevent seawater intrusion (shown in table1). For example, the Huangshui River Underground Reservoir, which was composed of 2518 infiltration wells, 6 sluices and 448 infiltration trenches. The aquifer was recharged by riverbed leakage. Several pictures of underground dam are shown in fig.4, fig.5 and fig.6.

Tab.1 Underground reservoirs built in costal area of China

Name	Total storage capacity (Million m³)	Water supply quantity (Million m³/a)	Area of reservoir (km²)	Length of underground dam (m)	Average depth (m)
Balisha River in Longkou city	0.3	0.5	14	756	8.5
Huangshui River in Longkou city	53.29		51	5842	10
Wang River in Laizhou	53.26	23.55	68	14500	10
Shiren River in Qingdao	1.3	1.2	21	620	17

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UNESCO IAH

Fig.4 Underground dam of Huangshui River

Fig.5 Underground dam of Shiren River

Fig.4 Underground dam of Wang River

In addition, water consumption increased sharply with social economic development. What is more, there is a serious water shortage in partial downstream plains. Since 2000, some reservoirs have turned into integrated ecological type instead of flood control and water supply merely. For example, the Wohushan reservoir in Jinan City turned on the water in dry seasons to recharge groundwater indirectly with use of channel leakage and promote spring protection. For another example, in dry seasons, the water in Taihe reservoir in Zibo City is discharged to supply downstream groundwater source by infiltration.

Fourth Stage- Multiple source MAR

Various water sources could be storied in MAR, such as stormwater, reclaimed water, tap water or groundwater from other aquifer, which reused for drinking water supply or agricultural irrigation. For example, the first and biggest urban reclaimed water recharge project in China, Gaobeidian Groundwater Recharge Pilot Project in Beijing, which was completed in 2003 and reached 200m³/d of recharge amount under the design condition, composed with a surface recharge system and rapid infiltration shaft system(fig.7). Moreover, China University of Geosdences carried out a reclaimed water injection test in Zhengzhou city province since 2002. Municipal wastewater is reclaimed by artificial wetland and the wastewater treatment system and conducted into infiltration basins for recharge. The results shown that recharged groundwater can generally satisfy criterion of groundwater quality standard (GB/T14848-1993) and can be used for fishery, industry and agriculture. For another example, a pilot project of karst aquifer recharge with urban treated roof water was established in the University of Jinan in Aug.2011 and still keeps running(fig.8). The continual monitoring results shown that both quality of roofwater and groundwater basically met groundwater quality standard with a recharge amount of 300m³ until Sep.2012.

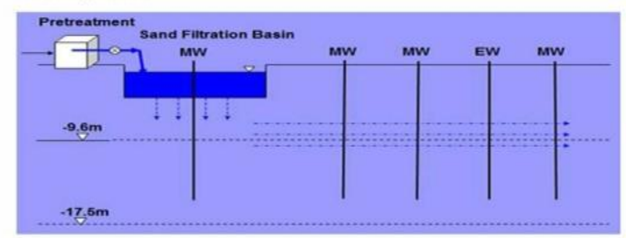

Fig.7 Groundwater Recharge in Gaobeidian WWTP of Beijing (Zhao Xuan, Tsinghua University)

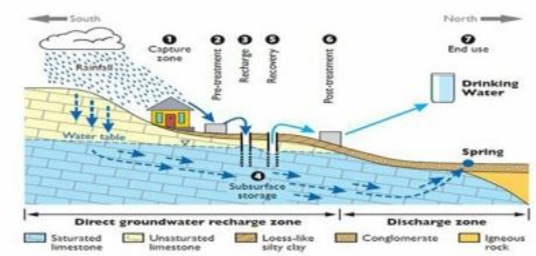

Fig.8 karst aquifer recharge with urban treated roofwater in University of Jinan (CSIRO)

Furthermore, geothermal reinjection and ground source heat pump are also effective utilization of MAR. In early 1982, a geothermal tail water recharge test was conducted in Beijing. Now, geothermal reinjection has popularized at a large scale in Tianjin city. In recent years, ground source heat pump (GSHP) technique developed quickly. For example, a kind of GSHP with thermal storage by deep well could save 20-30% energy compared to geothermal reinjection, which could also control land subsidence effectively. In 2009, the national technical code for ground -source heat pump system (GB50366-2005) was issued, which contributed to the development and application of GSHP technology.

Problems

Imperfect system of MAR

Although some rules on MAR were established in China, such as the deep well management regulation in Shanghai (issued in 1963 and revised in 1979) and Interim Regulation for Groundwater Resources Management in Beijing (1981), there is a lack of scientific and complete administrative system for MAR. Consequently, it is needed to draft a series of technical criterion for the evaluation, construction, operation and later management etc. of MAR.

Few study on water quality of MAR

In coastal area, the treated& untreated sewage will make a long-term difference on water quality of underground reservoirs when upstream pollution control is incomplete. In addition, aquifer recharge with urban reclaimed water still needs further study. It is suggested to transfer study concentration from water quantity to water quality by monitoring and sampling in site combined with numerical simulation. Thus, the recharge effect may be quantified.

The investor is inconsistent with the beneficiaries and most attentions were paid on construction rather than management

Urban industrial enterprises use MAR to store heat and cool water with a small influence radius of recharge well and high economic benefit under the self-management. In rural areas, MAR has a much higher economical and ecological benefits. The high tide of artificial groundwater recharge emerged before 1978, the rural MAR developed quickly under collective ownership. Later, the household contract responsibility system was implemented in countryside. Then many recharge projects dedined or even discarded for deposition without maintenance. Therefore, the artificial groundwater recharge in rural areas depended on state investment construction gradually. Groundwater recharge in urban area simply used to recover water table and increase groundwater resources, which is also involved in problems of investment and maintenance. Moreover, reservoir administrative department still has no compensation mechanism on channel infiltration recharge of groundwater by releasing water. In short, government should be the investor to offer enough funds for MAR projects.

The recharge rate of GSHP is low.

Although there are many applications of GSHP in China, most projects still could not reach the ratio of recharge to pump water at 100%. The key is to develop groundwater recharge technique and avoid damage of GSHP for groundwater resources. Secondly, a further investigation of already built GSHP is needed to discover problems and summarize experiences for sustainable operation.

Conclusion

China obtained a great achievement on land subsidence control, energy storage, geothermal utilization, prevention of seawater intrusion, augment of urban water supply, agriculture irrigation and alleviation of agricultural disasters etc. with MAR. However, there are still many problems. It is needed to develop a feasible, convenient and economic technique of MAR fitting to local hydrogeological conditions, establish guidelines of MAR and management regulations together to make sure the MAR projects running successfully. In addition, development of MAR depended on the support of government and investment.

Acknowledgements

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NNSFC CSIRO

Study on the Influence of Groundwater Source Heat Pumps on Groundwater Quality

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October 15th-19th, 2013 Beijing, P. R. China

Abstract

The groundwater source heat pumps have been accepted by majority of users with higher energy efficiency, lower operation cost and broad applicable scope. However, the influence of groundwater source heat pumps on groundwater quality hasn't been confirmed. Selecting Weifang region as the study area and choosing four groundwater source heat pumps works in Anqiu center hospital inpatient building, Weifang transit authority dormitory building, Weifang Chenlong hotel and Changyi Haojiachenghou residential building respectively as research objects on the basis of the regional application status investigation, the groundwater quality in the project area was observed and tested continuously. The changing trend of groundwater quality was analyzed by the software for mathematical statistic named SPSS, especially selecting the high-risk items of groundwater. The results show that the concentrations of TDS, nitrate nitrogen, ammonia nitrogen and some other indicators have changed. Groundwater quality changes more obviously when the open type groundwater source heat pumps are used, so it's important to make sure that the groundwater source heat pumps are closed completely. In addition, even if the system is sealed, the groundwater quality may also change because that some substances may be taken into the aquifer from the upper layer because of the raised water level during the recharge in the area of deeper groundwater depth. Therefore, in the region, the groundwater source heat pumps are not completely free from contamination in the current technology conditions. So the government should forbid the application of groundwater source heat pumps in underground drinking water source protect areas and limit strictly in other functional areas such as the groundwater source of drinking water recharge areas in order to protect the groundwater environmental security.
Keywords: groundwater source heat pumps; groundwater quality; Weifang

Introduction

The groundwater source heat pumps have been accepted by majority of users with higher energy efficiency, lower operation cost and broad applicable scope[1]. Many studies on the ratio of energy to efficiency of groundwater source heat pumps show that about 4kw of heat or cold energy is obtained when 1kw of electric energy is consumed and it has better properties of economy and energy saving[2-3]. In addition, The groundwater source heat pump is a kind of green technology without poisonous gas[4]. The sketch map of operating principle of the groundwater source heat pumps is shown in the following Fig.1. There are many studies on groundwater source heat pumps, and most of them study on the influence of groundwater source heat pumps on groundwater flow and temperature field, but there are less study on the influence on groundwater quality. If the influence of groundwater source heat pumps on groundwater quality is confirmed, it will be the important evidence for the available groundwater source heat pumps. So in this paper, the groundwater quality in the project area was observed and tested continuously and the changing trend of groundwater quality was derived, selecting four groundwater source heat pumps works in Weifang as monitoring points.

Fig.1 The sketch of operating principle of the groundwater source heat pumps (http://www.baidu.com)

Groundwater Monitoring Points

The groundwater samples were collected continuously on the four groundwater source heat pumps works in Anqiu center hospital inpatient building, Weifang transit authority dormitory building, Weifang Chenlong hotel and Changyi Haojiachenghou residential building respectively and the interval of collecting samples was between ten and fifteen days. In addition, the samples were tested by Shandong Analysis and Test Center. Based on the water quality reports, the influence of groundwater source heat pumps during the heating period on groundwater quality was analyzed especially.

Monitoring Items and Method

The analysis items were 23 indicators as chroma, turbidity, smell, pH, chloride, sulfate, total hardness, TDS, COD, fluoride, NH3-N, NO3-N, NO2-N, Cr^{6+}, As, Hg, Pb, volatile phenol, Cd, Fe, Mn, cyanide and conductivity. These items were all-sided to reflect the changes of groundwater quality. The changing trend of groundwater quality was derived from the analysis by the software for mathematical statistic named SPSS, especially selecting the high-risk items.

Monitoring Results and Analysis

• Analysis of TDS

Fig.2 The trend of TDS in Anqiu center hospital inpatient building

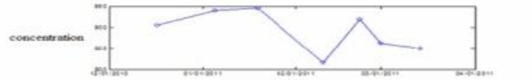

Fig.3 The trend of TDS in Weifang transit authority dormitory building

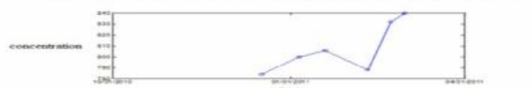

Fig.4 The trend of TDS in Changyi Haojiachenghou residential building

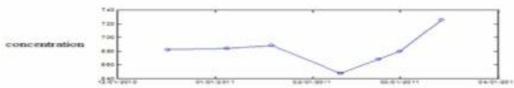

Fig.5 The trend of TDS in Weifang Chenlong hotel

It's shown that the concentration of TDS of the groundwater source heat pumps in better-closed condition is more stable, while the concentration of TDS in poor-closed condition is on the rise, and the poorer the sealed condition is, the more obvious the rising trend is. It is proved that in the current technology conditions, if the groundwater source heat pumps are not fully closed, the groundwater will contact and react with the air, and the concentration of TDS will be increasing, which will lead to the change of groundwater quality.

•Analysis of Total Hardness ($CaCO_3$)

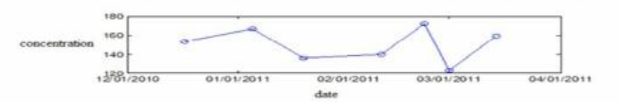

Fig.6 The trend of total hardness in Anqiu center hospital inpatient building

The results show that the concentrations of total hardness are all in the stable state during the operation process of different kinds of groundwater source heat pumps. It's indicated that the concentrations of Ca^{2+} are stable and there is no obvious influence on water-rock interaction so that the groundwater can be used for drinking.

• Analysis of Chloride

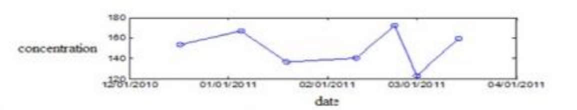

Fig.7 The trend of chloride in Anqiu center hospital inpatient building

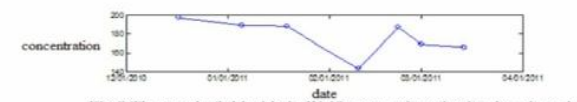

Fig.8 The trend of chloride in Weifang transit authority dormitory building

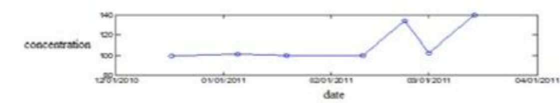

Fig.9 The trend of chloride in Weifang Chenlong hotel

The results show that the concentrations of chloride are all in the stable state during the operation process of different kinds of groundwater source heat pumps. It's indicated that based on the guarantee for recharge, the change of groundwater volume is small and there is no obvious influence on water-rock interaction so that there is no risk of groundwater salinization.

•Analysis of 3-Nitrogen

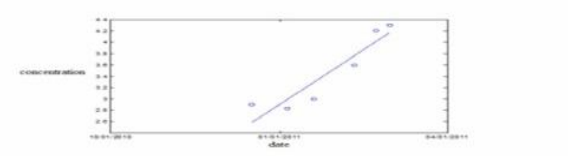

Fig.10 The trend of NO_3-N in Changyi Haojiachenghou residential building

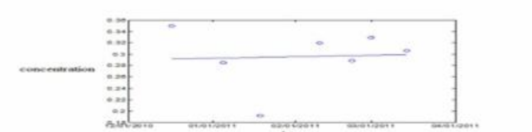

Fig.11 The trend of NO_2-N in Anqiu center hospital inpatient building

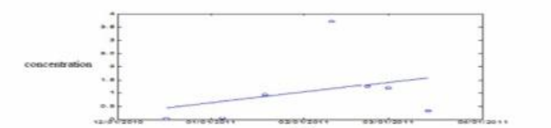

Fig.12 The trend of NH_3-N in Anqiu center hospital inpatient building

The analysis results of "3-nitrogen" indicate that the concentration of NO3-N is on the rise when the groundwater source heat pump is in operation in winter. One reason may be that the nitrates on the upper aeration zone are taken into the ground aquifer during the recharge. The other reason may be that the air flows into the aquifer with the water, so the nitrite and ammonia nitrogen are oxidated to nitrate nitrogen by nitrobacterium. The mass concentration of nitrite nitrogen which is taken into the aquifer is basically equal to that of which is oxidated to nitrate nitrogen, so the mass concentration of NO2-N is stable. Otherwise, the mass concentration of NH3-N is rising at initial stage due to its high solubility. After complete solution at later stage, the NO2-N is oxidated predominantly, so that its mass concentration is decreasing.

Conclusion

On the whole, there is no obvious influence of groundwater source heat pumps on groundwater quality, and most water quality indexes have no change to a certain degree. The groundwater quality changes when the open type groundwater source heat pumps are used, so it's important to make sure that the groundwater source heat pumps are sealed completely. In addition, even if the system is sealed, the groundwater quality may also change, which is because that some substances are taken into the aquifer from the upper layer because of the raised water level during the recharge. Therefore, in the region, the groundwater source heat pumps are not completely free from contamination in the current technology conditions and the application should be controlled and managed strictly.

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Research on Index Scale Method for Suitability Division of Shallow Geothermal in Yinchuan City

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Removal of dissolved organic matter in municipal effluent with ozonation and soil aquifer treatment

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Introduction

Water shortage and groundwater overexploitation have risen as globally urgent issues. Managed aquifer recharge (MAR) using reclaimed water is a promising technique for solving such problems. During MAR, soil aquifer treatment (SAT) plays an important role in wastewater purification through a combination of biological, chemical and physical processes.

Dissolved organic matters (DOM) in reclaimed water are complex mixtures of natural and synthetic DOM, as well as soluble microbial products (SMPs), which affect directly or indirectly the water quality. DOM derived from municipal effluent can be removed by 30-80% during SAT. The removal efficiency was affected by many factors, among which the composition of DOM should not be ignored.

Figure 1: Water Recycling through MAR

The apparent molecular weight (AMW) distribution is an important characteristic of DOM, which can now be easily detected by the high-pressure size exclusion chromatography (HPSEC). Furthermore, different types of DOM can be monitored using various detectors, like organic carbon (OC), UV absorbance and fluorescent detectors.

Here, the fate of DOM during SAT was monitored in a lab-scale MAR system using HPSEC with multiple detectors (OC, UV and fluorescent detectors). The removal ratios of total DOC and specific DOM (aromatic DOM, fulvic acids and soluble microbial products) with different MW sizes were detected. The refractory DOM was then identified.

Results & Discussion

➢ *Lab MAR System introduction*

The secondary effluent from a wastewater treatment plant was used as raw water. The MAR system was simulated in the lab with five soil columns in series. C1 was used to simulate the unsaturated vadose layer, with retention time of 0.8 d. C2-C5 were used to simulate the saturated aquifer layer, with retention time of 28 d in total.

Table 1 Water samples

Short name	Water source
SE	Secondary effluent
O3E	Ozonated effluent
VE	Effluent of C1
AE	Effluent of C5

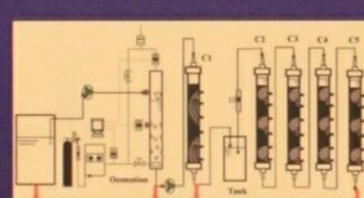

Fig. 1 Schematic diagram of lab MAR system

➢ *Bulk DOM parameters*

- DOC: 66% removed by vadose layer, and further 20% reduced through saturated aquifer layer, reaching 1 mg/L in the final effluent. (Fig. 2)
- UV_{254}: 68% removed by ozonation, and 15% removed by SAT.
- SUVA: 2.4 L/m/mg in SE was reduce to 0.7 L/m/mg after ozonation, and then kept increasing to kept increasing to 1.8 L/m/mg during SAT.

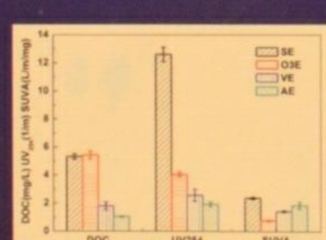

Fig. 2 Average of water quality (n=5)

➢ *AMW distribution of DOM*

The AMW distributions of total organic carbon and aromatic were detected by HPSEC with OC (Fig. 3) and UV detector (Fig. 4), respectively.

- OC: removal of humic substances and low molecular weight acids were higher here than previous report, which may due to ozone pretreatment. Low MW acids rather than large MW fractions were reduced by ozonation. The removal ratios of total OCD peak area were consistent with removals of DOC.
- UV_{254}: Ozone was quite effective in destroying aromatic structures, especially for larger AMW fractions; saturated aquifer layer was more prone to remove aromatic DOM than the vadose layer.

Table 2 Removal ratio of peak area by the three treatment steps (%)

peak	signal	ozonation	vadose layer	saturated aquifer
biopolymer	OCD	15.7	100.0	100.0
	UV_{254}	100.0	100.0	100.0
humic substance	OCD	-15.0	58.2	71.8
	UV_{254}	65.0	73.8	81.8
low AMW acids	OCD	55.1	69.4	84.2
	UV_{254}	11.7	17.4	41.2
Total	OCD	18.2	65.1	78.6
	UV_{254}	44.8	52.3	66.3

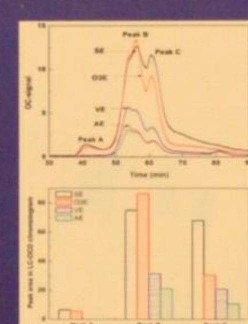

Fig. 3 LC-OCD chromatogram (top) and peak area (down)

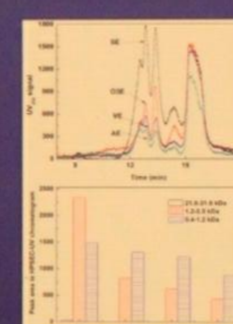

Fig. 4 HPSEC-UV_{254} chromatogram (top) and peak area (down)

➢ *AMW distribution of fluorescence DOM*

Fulvic acid-like substances were monitored at Ex=245 nm, Em=418 nm (Fig.5)

- The medium AMW (0.7-4.6 kDa) and low AMW (<0.5 kDa) fractions composited 76.5% and 19.5% in SE, respectively.
- O3 effectively removed 88%-100% fulvic acid, except only 41% of AMW 0.5-0.7 kDa fraction.
- Increases were found after SAT, especially higher for AMW 0.7-4.6 kDa fraction.

SMPs were monitored at Ex=280nm, Em=358 nm (Fig.6).

- The medium AMW (0.8-4.1 kDa) and low AMW (0.4-0.8 kDa) fractions composited 52.1% and 33.8% in SE, respectively
- O3 effectively removed 76%-100% SMPs, except only 24% of AMW 0.4-0.8 kDa fraction.
- The peaks kept decreasing during SAT, especially higher reduction for the small AMW fractions (0.2-0.8 kDa).

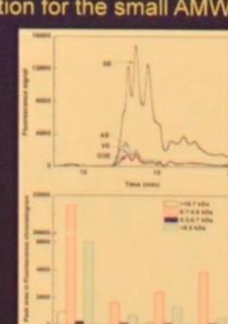

Fig 5: HPSEC-fluorescence chromatogram (Ex=245nm, Em=418 nm, fulvic acid) (top) and peak area (down)

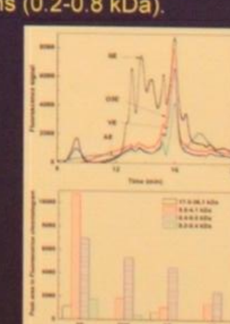

Fig 6: HPSEC-fluorescence chromatogram (Ex=280nm, Em=358 nm, SMPs) (top) and peak area (down)

Conclusions

In this study, the compositions of DOM (organic carbon, aromatic DOM , fulvic acid –like substances and SMPs) in SE were monitored using HPSEC, as well as the removal characteristics of DOM with different AMW through ozonation and SAT. Ozonation was quite effective in removing aromatic and fluorescence DOM. SAT was prone to remove large and medium AMW fractions (biopolymer and humic substances), but not the fluorescence DOM (fulvic acid and SMPs). Comparing VE and SE, humic substances, aromatic low AMW acids (0.4-1.2 kDa), SMPs with AMW of 0.4-1.1 kDa and fulvic acids with AMW of 0.5-4.6 kDa were resistant during the treatments.

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Managed aquifer recharge to mitigate fluoride contamination in groundwater in a part of southern India

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Introduction

- Occurrence of fluoride in groundwater due to geogenic sources
- Fluoride in drinking water is a health hazard
- Groundwater with high fluoride concentration is common in several parts of India

Objectives

- To establish the relationship between the fluoride concentration in groundwater and rainfall recharge
- To predict the effect of MAR to reduce the fluoride concentration in groundwater

Study Area

- A 600 km^2 part of Pambar River sub basin in southern India
- **Temperature** - 38^{0}C in summer (April-June) and 25^{0}C in winter (November-December)
- **Rainfall** – 900 mm / yr
- **Topography** - slopes from north to south
- **Elevation** – Maximum of 1200 m in Yelagiri hill at northeast and minimum elevation of 340 m at south
- **Drainage** – the Pambar river forms dentritic drainage pattern

Geology

- Archaen gneisses and charnockite as basement
- Igneous intrusions of Proterozoic age
- Rocks rich in fluorite, fluorapatite, hornblende and biotite minerals
- Fluoride is the important constituent of these minerals

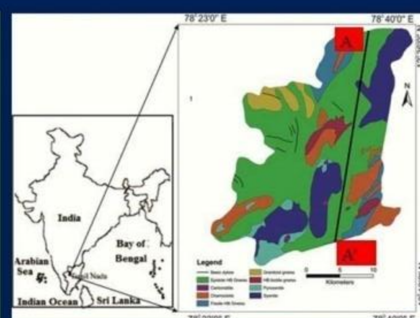

Fig. 1 Location of study area and Geology map

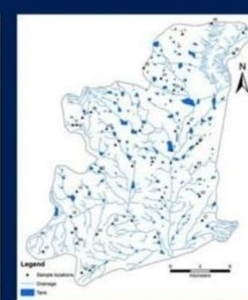

Fig. 2 Drainage map of the study area and sample locations

Methodology

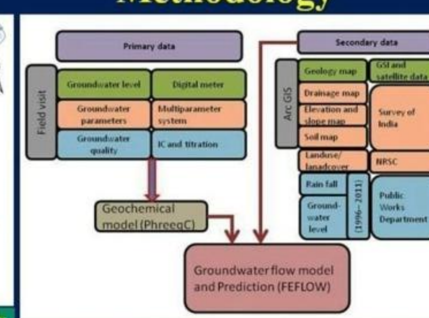

Fig. 3 Methodology adopted in the study

Results & Discussion

- **Fluoride** – concentration in groundwater varies from 0.1 to 4.3 mg/l and exceeds the permissible limit of 1.5 mg/l provided by BIS (2004)
- Source for fluoride are fluorite, fluorapatite, hornblende and biotite minerals in rocks

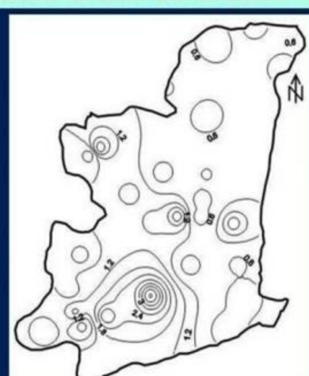

Fig.4 Spatial distribution of fluoride(mg/l) in groundwater in April 2011

- **Type I wells** – groundwater level fluctuates from 4 m to 10 m bgl and the dilution of groundwater occurs during recharge.
- **Type II wells** – groundwater level fluctuates between 10 and 22 m bgl and rise in fluoride concentration occurs during recharge

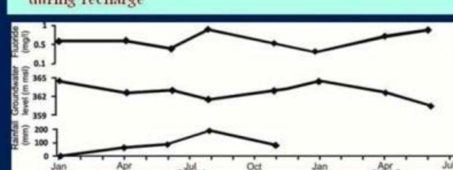

Fig. 5 Temporal variation of rainfall, groundwater level and fluoride concentration (type I)

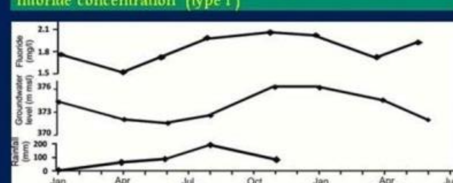

Fig. 6 Temporal variation of rainfall, groundwater level and fluoride concentration (type II)

- Area around wells with type I relationship are suitable for artificial recharge.
- Managed Aquifer Recharge at these sites will result into dilution of fluoride concentration in groundwater
- Finite element groundwater modelling was carried out to predict the effect of Managed Aquifer Recharge

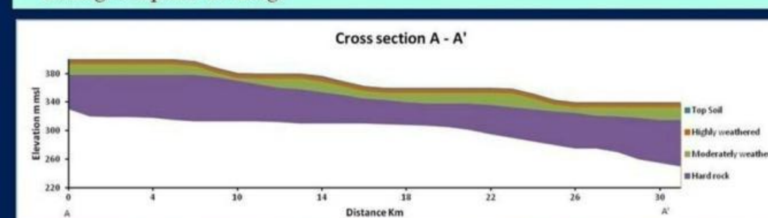

Fig. 7 Cross section of the study area along the line AA' shown in figure 7

- the Top soil thickness varies from 0.5 to 2 m
- Highly weathered layer thickness varies from 3 to 5
- Moderately weathered rock layer varies from 4 to 15 m
- Hard rock thickness varies from 40 to 60 m

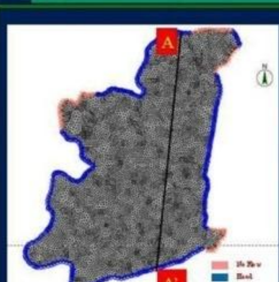

Fig. 8 Boundary conditions of the aquifer

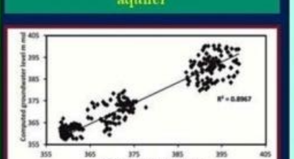

Fig. 9 Transient state calibration

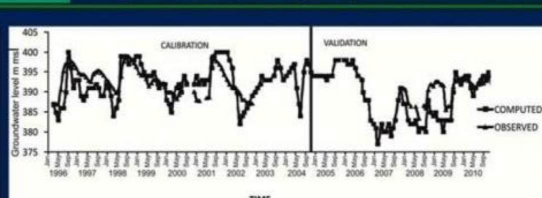

Fig. 10 Observed and simulated groundwater level in PWD monitoring well

- Groundwater level data – Public Works Department
- Rainfall data – Rain gauge stations of PWD for the period from April 1996 to December 2011
- Recharge from rainfall – 1 to 12 % by GEC norm (1997)
- Discharge of groundwater for irrigation purpose -report of Tamil Nadu Agricultural University
- Groundwater discharge for drinking needs - 100 liters per person per day

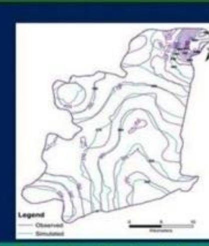

Fig. 11 Simulated and observed groundwater level in July 2011

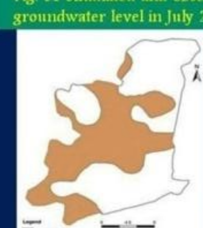

Fig. 12 Map showing the suitable areas for MAR

Fig. 13 Predicted groundwater level with increased recharge in monitoring well no. 3

- The model was used to study the effect of MAR
- The prediction was made for 10 years from December 2011.
- The model predicts the increase in groundwater level by 5 m to 12 m.
- This in turn reduces the fluoride concentration up to 0.5 to 1.8 mg/l

Conclusions

- ✓ Managed Aquifer Recharge at the identified locations result in increase in groundwater level by upto12 m
- ✓ Increase in groundwater will result in decrease in fluoride concentration from 0.5 to 1.8 mg/l

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Tailor-made high-frequency filter sand cleaner for high-capacity MAR basins

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Motivation

Drinking water production at the waterworks Dresden-Hosterwitz, Germany was first based on riverbank filtration and later expanded to include artificial recharge of pre-treated river water.

Due to the predicted rise in water demand, the capacity of the recharge basins had to be increased. However, additional land was not available and a solution had to be found for the existing basins.

Since the clogging layer was the limiting factor and was traditionally removed by hand, a special unit was developed to more efficiently clean the upper filter layer.

Waterworks Dresden-Hosterwitz

History

Development and model testing of the first unit called FIREG (filter regeneration) started in the 70ies. This was followed by the improved KUROF system (short cycle surface filtration).

The goal was to achieve an infiltration rate of 15 m/day and clogging removal without interrupting the basin operation.

Current infiltration rates in the high performance basins range from 7 to 10 m/day.

Fig. 2: Mobile Unit KUROF

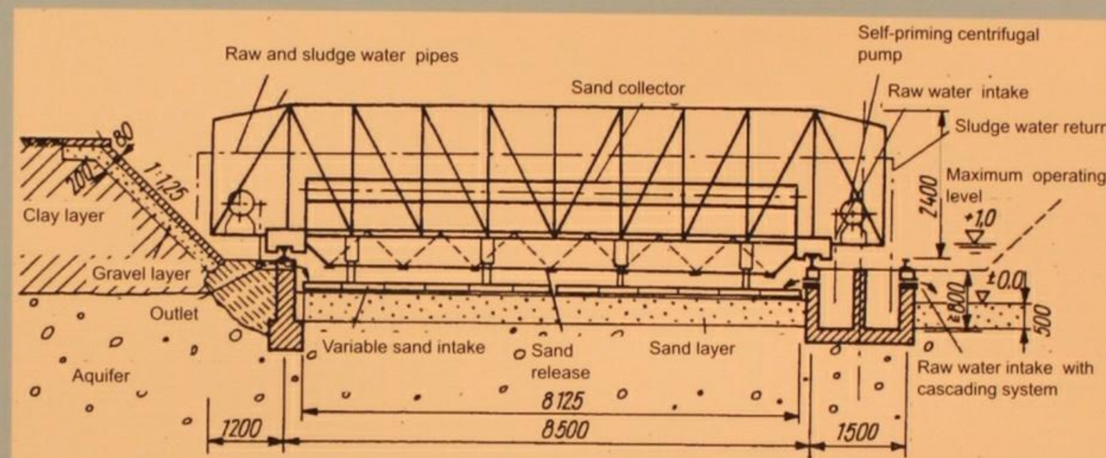

Fig. 3: Schematic of Mobile Filter Sand Cleaning Unit (Löffler, 1967)

Fig. 4: Washing Drum and Rake

Fig. 5: Washing Drum and Motor

Fig. 6: Working KUROF Unit

Fig.7: Rails between two Basins

Technical Details

- Tailor-made cleaning trolley runs on rails spaced at 8.5 m (Fig. 3)
- Rails are mounted on the concrete walls of the basins (Fig. 7)
- 8 m long washing drum is used to lift and wash the upper sand layer (Fig. 4 and 5)
- Washing depth can be set between 0 and 0.4 m
- Washing depth is typically 0.05 m but 0.1 m if sand surface affected by wind
- Two pumps transport turbid wash water into open channel running alongside the basin
- Forward trolley velocity between 0.1 and 1 m/min during cleaning
- Cleaning process for 150 m long basin typically takes 6 to 7 hours
- Backward velocity (without washing process) about 1.5 m/min
- Energy supply of max. 16 kW needed for pumps, motor, automation

Fig. 8: Filter Surface Sensor

Advantages and Disadvantages

- A large volume of water can be recharged over a limited area
- Proven high infiltration velocity of up to 10 m/day
- KUROF units can be easily transferred between basins
- Parallel operation and cleaning process
- Adjustable washing depth
- Operation in winter possible at river water temperatures > 3°C (Fig. 6)
- One person can operate the unit
- Flushing water pumps need frequent replacement as the high sand content affects the performance (4 of the 12 pumps are replaced annually)
- Weed growth (> 5cm) affects the operation and requires removal prior to cleaning the sand layer
- Relatively high maintenance costs due to the frequent changing of the pumps, corrosion protection, the maintenance of the measuring and control system and the lubrication of the moveable bearings

→ Interesting technique for the efficient operation of narrow high-capacity MAR basins

RESTORE: Research for Subsurface Transport and Remediation

Numerical Simulations of Community-Scale Aquifer Storage, Transfer and Recovery Technology

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1. Background

Frequent extreme weather events and naturally brackish aquifers in the south-west area of Bangladesh result in seasonal freshwater shortages. Community-based aquifer storage, transfer and recovery (ASTR) systems are being tested as a potential cost-effective, disaster-resilient water supply alternative. Numerical groundwater modelling is being used to assess the technical feasibility and to improve the engineering system design.

Fig 1: Bangladesh (study area in red). (US Dept of State, 2012)

Fig 2: ASTR scheme layout at Assasuni, Bangladesh

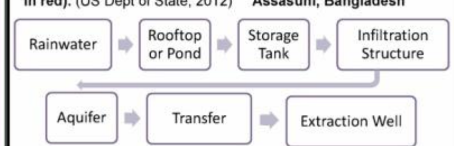


Fig 3: Progression of water through ASTR scheme.

2. Pilot Test Site

The Assasuni ASTR site, one of 20 sites now implemented in south-west Bangladesh by Dhaka University, has been operational since June 2011, making it the oldest and best characterized site. Freshwater collected from rooftop rainwater harvesting and a near-by surface pond is injected into the shallow aquifer during the monsoon season (4 months), while extraction takes place over the full year. A thick clay aquitard overlies a sandy aquifer at the site. Data from this test site was used to calibrate the numerical model.

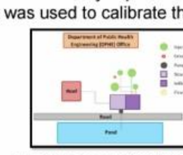


Fig 3: Assasuni field site set-up.

Table 1: Assasuni field site parameters.

Parameter	Assasuni Site	
Depth [m]	Aquitard	Aquifer
	z = 0 to -13	z = -13 to -24
Hydraulic conductivity [m/d]	Aquitard	Aquifer
	K_x = 1e-4 K_y = 1e-5	K_x = 6.41 K_y = 0.5
Initial Head [m]	-0.58	
Injection Head [m]	1.58	
Injection Concentration [g/L]	0.587	
Injection Rate [m³/d]	4.57	
Initial Salt Concentration [g/L]	4.85	
Extraction Concentration (1 yr) [g/L]	0.60	

3. Model Development

SEAWAT-2005, a variable-density groundwater flow and transport model, was used to simulate the ASTR system. A model was first developed to simulate the Assasuni site with parameters from Table 1 adopted.

Model Set-up:

- 800 m x 800 m domain size
- Constant head external boundaries with no hydraulic gradient
- Infiltration for 120 days via four injection wells
- Extraction via one abstraction well for 365 days at a rate of 1.029 m³/d
- Model run for a 5 year period

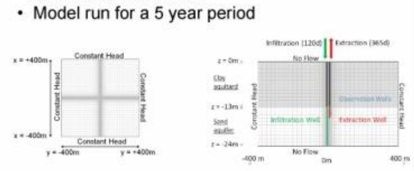


Fig 4: Model domain.

4. Model Calibration

The numerical model of the Assasuni ASTR system was calibrated by adjusting field parameters (e.g. *Kx, Ky,* α_L) until there was a close match between observed and simulated extraction concentrations and injection rate.

Table 2: Summary of Assasuni model calibration.

Parameter	Assasuni Model	Assasuni Field Data
Extracted GW Concentration (after 1 year) [g/L]	0.67	0.60
Injection Rate [m³/d]	4.85	4.57

5. Base Model Results

The Base Model was developed to simulate the Assasuni site based on the existing system design and to evaluate the long-term performance of the site. The performance of an ASTR system is assessed based on the following criteria:

i. TDS of the extracted water must be at or below the Bangladesh Drinking Water Standard (BDWS) of 1 g/L;
ii. RE should be maximized (RE is the ratio of volume of water extracted below 1 g/L to the injected volume); and
iii. an aquifer residence time of > 2.5 days must be achieved for the removal of microbial contaminants

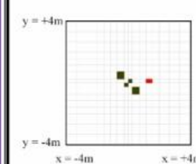


Fig 5: Magnified plan view, injection wells (green) and extraction wells (red).

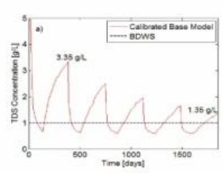


Fig 6: TDS concentration at the extraction well.

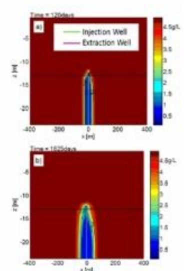


Fig 7: Distribution of TDS in aquifer after (a) 1 yr, (b) 5 yrs.

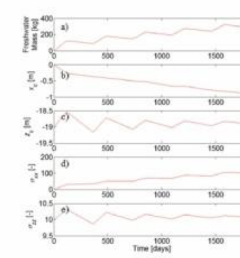


Fig 8: Spatial moments analysis: (a) freshwater mass, (b)-(c) plume centroid, (d)-(e) spread of plume.

6. Sensitivity Analysis

Sensitivity analysis was conducted on the base model to quantify the influence of various hydrogeological and design parameters.

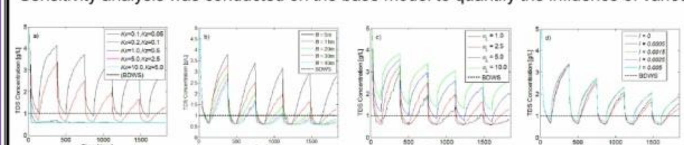


Fig 9:TDS concentration of extracted water over 5 year simulation period for models with varying a) aquifer K_x and K_z (longitudinal/transverse and vertical planes, respectively), and b) aquifer depth (*B*), c) aquifer longitudinal dispersivity (α_L), and d) regional hydraulic gradient (*i*).

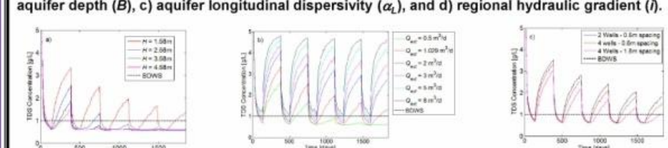


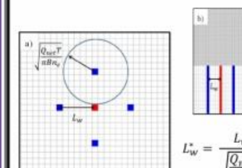
Fig 10:TDS concentration of extracted water over 5 year simulation period for models with varying a) injection head (*H*), b) extraction rate (Q_{ext}), and c) number of injection wells.

- Systems installed in aquifers with higher transmissivity (*K* or *B*) will perform better as the increased injection rates will reduce extraction water TDS concentrations
- Increasing the design injection head and/or number of injection wells will similarly improve the system
- In settings with high hydraulic gradient (i > ~0.005), RE will be reduced because of freshwater plume migration and greater brackish-freshwater mixing
- Other factors shown to influence the system performance, although to a lesser extent, include the aquifer dispersivity, spacing of injection wells and extraction rates

7. Non-dimensional ASTR Design Guidelines

A generic ASTR system design was adopted to provide design recommendations for future systems. The generic system simulated used:

- Clay aquitard (B = 13m, K_x = 1x10⁻⁴ m/d, K_z = 1x10⁻⁵ m/d), sandy aquifer (B = 11m, K_x = 0.2 m/d, K_z = 0.1 m/d), n_e = 0.25
- A design injection flow rate was specified rather than a constant head injection
- Injection and extraction rates were based on the daily water demand required for a 100-person community and a 52% RE
- The injection wells-extraction well configuration was modified from the Assasuni case (Fig. 11)



$$L_w^* = \frac{L_w}{\sqrt{\frac{Q_{net}T}{\pi B n_e}}}$$

Fig 11: Well spacing a) plan view, b) cross-sectional view (red = extraction, blue = injection).

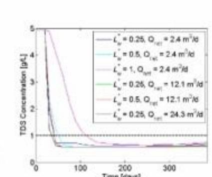


Fig 12: Effect of L_w^* on extraction TDS concentration.

$$R^*_{Disp} = \frac{\sqrt{\frac{Q_{net}T}{\pi B n_e}}}{\alpha_L}$$

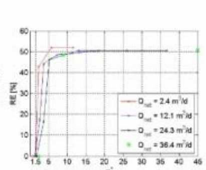


Fig 13: Effect of non-dimensionalized ratio R_{Disp}^* on RE for different scale models with 4 injection wells and L_w^* = 0.25.

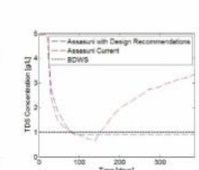


Fig 14: Influence of incorporating design recommendations.

7. Conclusions

- ASR systems have been widely studied, however, research on ASTR systems is limited especially at the community scale.
- ASTR is a feasible alternative for providing drinking water in south-western Bangladesh if the systems are designed properly.
- Future ASTR systems should consider K , α_L, i and Q_{ext} and incorporate a design which maximizes injection head.
- Non-dimensional design recommendations show that L_w^* = 0.25 improves system efficiency when R^*_{Disp} > 1.5.

8. References

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Combining geophysical and geochemical measurements for subsurface characterization at a full-scale aquifer recharge and recovery site

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MAR for Sustainable Water-Curtain Cultivation Method in Rural Area

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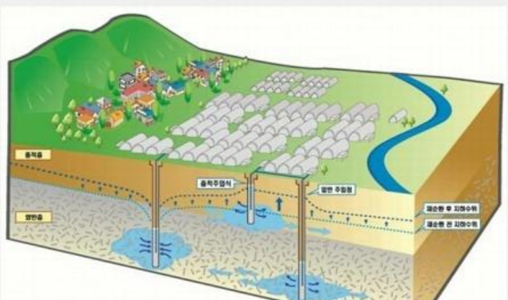
ABSTRACT Over 100 km² of rural area in South Korea is covered by water-curtain protected cultivation facilities, which use heat source in groundwater to keep warm inside of the green house during winter night by splashing groundwater inner roof of the green house. Those cultivation methods can produce various vegetables and fruits in winter, but induce groundwater level decline over a large area because it discharge the used groundwater to the stream via drain ditch. This study is to evaluate the underground circulating water-curtain cultivation method which injects the used groundwater through nearby injection well into aquifer. The water-curtain protected cultivation facility coupled with aquifer recharge is evaluated to be energy saving, groundwater protecting and sustainable system for the protected cultivation facility in a cold area. A test bed of water-curtain protected cultivation facility coupled with aquifer recharge for two 0.1-hectare green houses is installed at rural area of Nonsan, South Chungcheong province, South Korea. There are equipped with one pumping well, one injection well of 15-m apart, one observation well between pumping and injection well, splashing system, recovery and storage tank, injection system and control system. Hydraulic conductivity is estimated as 3.47×10^{-6} from pumping test and effective porosity, linear velocity, longitudinal dispersivity are estimated as 0.105 and 2.68×10^{-6} m/s, 0.8m, respectively, from dye tracer test. Separate pumping-injection well system is found to be more effective in temperature and head recovery rather than single pumping-injection well system from the results of thermal tracer tests. The underground circulating system reduced groundwater level decline up to about 3m compared to non-circulating system and also raised temperature of injected cool water close to ambient groundwater temperature of 15 °C during migration from injection well to pumping well.

Introduction



Schematics of ACWCCS

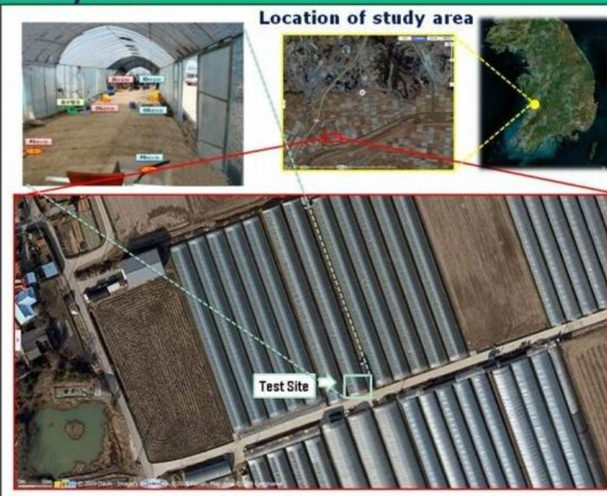
- Water curtain cultivation method uses groundwater heat to keep inside temperature of green house over 5 degree of Celsius.
- The number of water curtain cultivating green house has increased since 1990 and still in increasing trend due to the increase of oil price
- A tremendous amount of groundwater is pumped and splashed on the greenhouse and then discharged away through drain pipe to near stream.
- Groundwater level has been declined by over-extraction forcing new well to be installed bigger and deeper.
- Sometimes farmers dispute with their neighbors about the authority of groundwater use.

- Develop a aquifer-circulating water curtain cultivation system (ACWCCS) to make use of groundwater sustainably.
- Evaluate the efficiency of the circulating system at field scale.

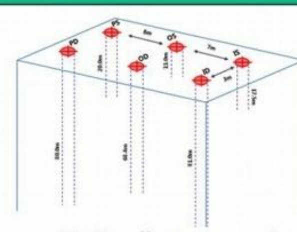
Method & Results

Study Area

Location of study area



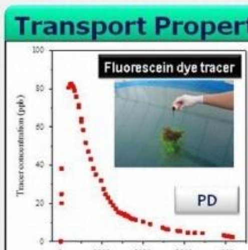
- Nonsan, South Chungcheong Province where is suffering from groundwater depletion by over pumping

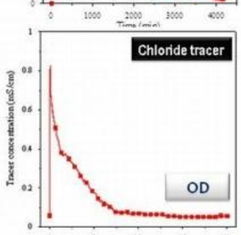


Test well arrangement

- Aquifer-Circulating Water Curtain Cultivation System (ACWCCS), which also harvest rainwater, was established at Nonsan in April 2010.
- Well arrangements for extraction, injection and observation are installed in alluvial aquifer and fractured aquifer.

Transport Properties (tracer tests)



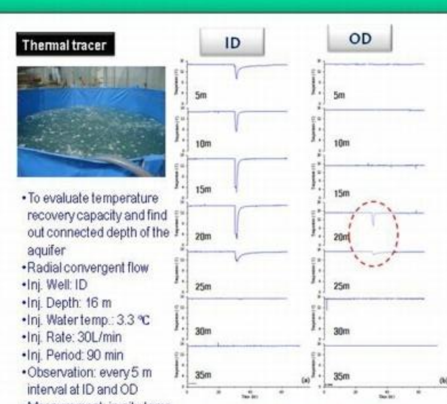


BT curves during tracer tests

- To find out hydrodynamic properties Fluorescein dye (Uranine) tracer test
  - Radial convergent flow condition
  - Conc. of tracer solution: 2,870 μg/L
  - Injection well: ID
  - Pumping/observation well: PD
  - Conc. measurement: fluorospectrometer
  - First arrival: 20 min
  - Peak arrival: 83 min (127ppb)
- Chloride tracer test
  - Natural gradient flow condition
  - Conc. of tracer solution: 2,000 mg/L
  - Injection well: ID, Observation well: OD
  - Conc. measurement: in-situ EC senor
  - First Arrival: 10min
  - Peak arrival: 60 min (5.46 mS/cm)
- Analysis of breakthrough curve
  - Moment Analysis (Yu et al., 1999)
  - CATTI (Sauty and Kinzelbach, 1992)

Hydraulic parameters estimated from tracer test

n_e	v (m/s)	α_L (m)	D_L (m²/s)
0.105	2.68×10^{-5}	0.8	2.15×10^{-5}



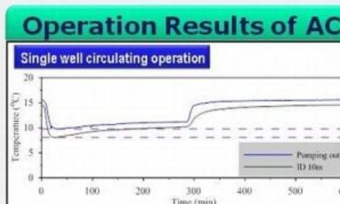
- To evaluate temperature recovery capacity and find out connected depth of the aquifer
- Radial convergent flow
- Inj. Well: ID
- Inj. Depth: 16 m
- Inj. Water temp.: 3.3 ℃
- Inj. Rate: 30L/min
- Inj. Period: 90 min
- Observation: every 5 m interval at ID and OD
- Measurement: in-situ temp. sensor

Temperature BT curves with depth during the thermal tracer test

- Temperature change occurred only at 5-25m at injection well and 20-25m at observation well
- Temperature in the injection well was recovered to background temp. of 16 ℃ after 9 hours
- Temperature in the pumping well did not change during the test which means the cooled injection water recovered during the transport to pumping well.
- It is found that ACWCCS is efficient but still need to monitor long-term operation with cooled water during winter time to evaluate the full scale system

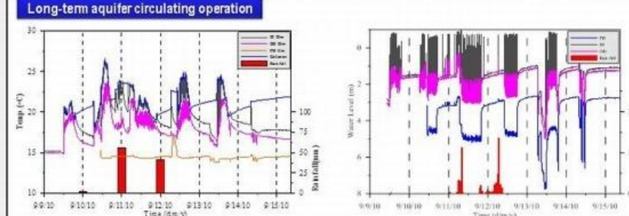
Operation Results of ACWCCS

Single well circulating operation



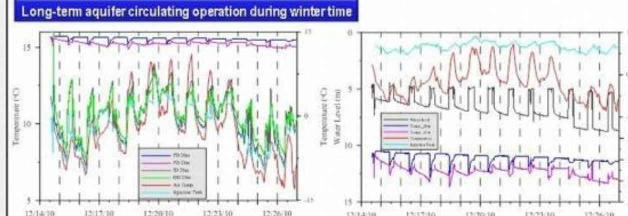
- To evaluate single well circulation efficiency compared with multi-well aquifer circulation efficiency
- Testwell : ID
- Injection water temp. : 6.3 ℃ (30L/min for 280 min)
- Injection/withdrawal depth: 7m/15m
- Observation depth: 10 and 15 m
- Temperature of the pumped water did not recover to background temperature which means that single well circulation method is not efficient enough to operate water curtain cultivation sustainably.

Long-term aquifer circulating operation



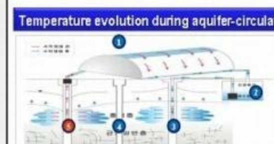
- Inject warm water of 26.4 ℃ into ID for 8 hours and then stop for 16 hours and repeat injection for 5 days.
- Observe temperature change at the depth of 20 m where connecting fracture zone exists
- Influence of the injected warm water diminishes as it flowing from injection well to pumping well
- After 5days operation during summer season, temperature at ID and OD has increased amount of 2 ℃ and 1 ℃, respectively
- Water level at ID and OD increased about 2 m and the water level at PD recovered to its original level after 5 days operation.

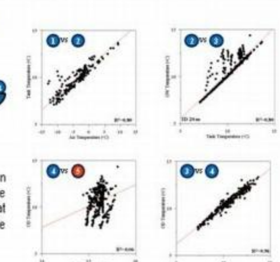
Long-term aquifer circulating operation during winter time



- Temperature and Water level change were monitored during real-scale aquifer circulating operation during winter time to evaluate system efficiency.
- Monitoring period: 14 Dec. 2010 ~26 Dec. 2010 (12 days)
- Temperature at ID and OD has large change and positively related to air temperature
- Temperature at PD has miner change compared to those at ID and OD. The temperature change rate at PD is about 0.0292℃/day which means about 3.5 ℃ is expected to be lowered after the whole period of operation during winter time, that is, 120 days.
- After 12 days operation, water level at PD lowered about 0.8 m, which is very effective based on the fact that the water level lowered more than 4 meters during non-circulating operation.

Temperature evolution during aquifer-circulating operation





Temperature at air(1), recovery tank(2), injection well(3), and observation well(4) is proportionally changed with air temperature whereas temperature at pumping well has rare relationship with air temperature, which means that the injected cooled-water is recovered to natural groundwater temperature during aquifer circulation.

➡ Sustainability of the aquifer-circulating water curtain cultivation system!

Discussions & Conclusions

1. Aquifer circulating water curtain cultivation system was built at a rural area in Nonsan, South Korea.
2. The field site has high hydraulic conductivity of 21.22 m2/d which is good for aquifer circulation.
3. Highly transmissive fractured zone is located about 20 m depth which connects well injection well and pumping well.
4. Inter-well aquifer circulating operation is more efficient in recovering temperature compared to single well circulation.
5. Aquifer circulating operation system turn to be sustainable system recovering the temperature of the injected cooled-water to natural groundwater temperature during transport through aquifer.

ACKNOWLEDGEMENT This work was supported by the research project of "Advanced Technology for Groundwater Development and Application in Riversides (Geowater+)" in "Water Resources Management Program (code 11 Technology Innovation C05)" of the MLTM and the KICTEP in Korea.

Management of groundwater quality at Spratly islands in context of climate change

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Fig 1: Spratly island – when sea level rises 0.5 m

Introduction

This paper presents results on impacts of climate change to groundwater quality of the Project "Studying the impact of the sea level rise by global climate changes of Spratly archipelagos". Purpose of this Project is to evaluating impacts of sea level rise and proposing adaptive solutions for reducing the natural disasters.

Viet Nam is one of the five countries which are most vulnerable to climate change and the Spratly islands is one of the first parts which can be affected by the climate change. Those effects can make enforceable problems, increasing and make danger for coastal areas: increasing the flooding risks, increasing the salt instruction and making coast line erode; changing the coastal ecology…that entire problems will directly affect the human life at the coastal areas of Vietnam. In this report we focus on groundwater quality at some islands of Spratly islands. Amount of rain-water will be harvested on each island around 100,000 – 120,000 m^3/y, that is a very precious source as artificial recharge or supplying domestic needs on these islands

Results & Discussion

GEOLOGICAL, HYDROGEOLOGICAL AND CLIMATIC SETTINGS

The Spratlys are one of 3 archipelagos of the East Sea which comprise more than 30,000 islands and reefs, locating at from 6°30 N to 12°00 and from 111°30 E to 117°30 E. It lies at ocean tropical climate area. There are 2 seasons: a long rainy season (June-December) and a short dry period in the rest of the year. The annual average precipitation: 2,200 - 2,300 mm; the average evaporation: 203 - 234 mm/month, average temperature: 26.7- 28^{o}C and air humidity: 79-86% *(Fig.2)*.

The study area includes very small islands with their elevations range from 2 to 6 m a.s.l . The upper geological structure of these islands are the same: the surface layers are mainly composed of friable coral with osmotic rate 10-15 m/day and dewatering coefficient: 0, 3-0,5, that why the rain-water will be osmotic into the deeper layers, it only a bit can make small flow on the surface layer. The geology structure affects strongly the rain-water collection and accumulation. The hard coral structure can't hydrophilic and storage rain-water, only the friable coral sand and the crumbing coral have a certain porosity which can observer and accumulate rain-water. That why the ground water in the Spratly archipelago only can be found at the friable coral layer or weathering-coral have a big porosity, distributing from the surface to the depth of 6-8 m. The form of ground water occurs in the form of 'freshwater lenses', static water level fluctuates from 0, 4-1,5 m, depends on the season and tidal regime: Water level rise and drop according to the tide, the diphase is slower 40 minute (edge of island) and 2-3 hours (central of island). At the dead tide period, level of ground water always higher 5-10 cm than tide ones at maxim mum tide and 40 cm at minimum tide.

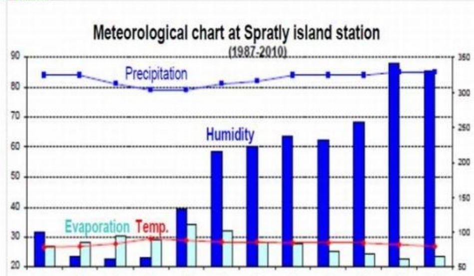

Fig. 2: Distribution of rainfall, evaporation, humidity and temperature at Spratly island station

WATER CHEMISTRY AND WATER STABLE ISOTOPE DATA

Based on results of chemical and stable isotope analysis of water samples, hydrogeological and geophysical investigations characteristics of water resources and situation of groundwater quality at some islands of Spratly islands (Spratly isl. (TS), Southwest Cay (STT), NamYit Isl. (NY), Sin Cowe Isl. (ST) showed that: salinity in the groundwater is increasing and water type also changes (Fig. 3a), particularly in the areas where the exploited dug wells are located. Among studied islands, the salinity in groundwater is the smallest at Spratly island and the highest at Nam Yit and Sin Cowe islands. Isotopic values from dug wells at the Spratly island: δ^{18}O: -5.7 – -7.3 ‰ SMOW; δ2D -51.4 – -35.9 (‰) in 2009 and δ^{18}O: -3.7 – -6.3 ‰ SMOW; δ^{2}D -39.1 – -24.7 (‰) SMOW in 2010; at the Southwest Cay δ^{18}O: -5.3 – -6.3 ‰ SMOW; δ^{2}D -43.6 – -35.9 (‰) SMOW ; rainwater in this area: δ^{18}O: -1.0 ‰ SMOW; δ^{2}D -18.2 (‰); Sea water: δ^{18}O: -0.4 - 0 (‰) SMOW, δ^{2}D: -10.5 - -3.5 (‰) SMOW. The water isotope composition (Fig. 3c) values of Oxygen-18 and Deuterium confirm the trend of increasing salinity of groundwater resources from 2009 to 2010, putting in evidence a decrease in percentage of fresh water in the coastal aquifer according to the application of "Two Components Mixing Model".

Two components mixing model:
A - Fresh water (-7.3 δ18O(‰)), B - Sea water (0 δ18O(‰)
X= ∂S- ∂B/(∂A- ∂B) = % A

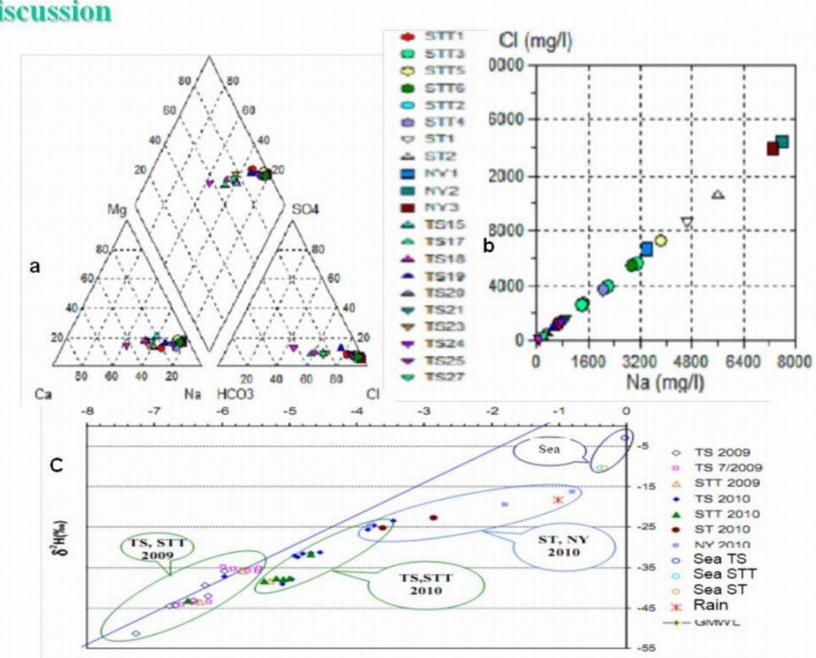

Fig. 3: Results of chemical (a,b) and isotope analyses (c) of groundwater at some islands: Spratly isl. (TS), Southwest Cay (STT), NamYit Isl. (NY), Sin Cowe Isl. (ST)

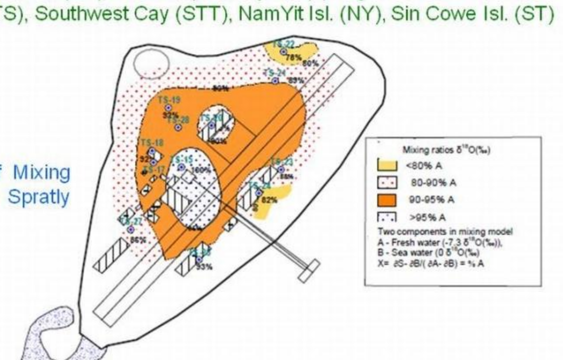

Fig. 4: Distribution of Mixing ratio δ^{18}O(‰) in the Spratly island

CHOSING MAR SOLUTIONS

Rain-water harvesting: According to the calculation results showed that the annual effect of precipitation and evaporation of the Spratly Island average about 1,260 mm/year, so that rain water amount in the Spratly islands is about 138,600 m3. Water sources can be used as a source of recharge is the rest part after the rainwater infiltrated into ground. At the Spratly island, rainfall infiltrated into the ground about 20,079 m^3/year, so the output can be used as a source for artificial recharge is about 118,521 m^3/year (~ 86 % of water from rainwater annually). And at the Southwest Cay Isl., there is about 99,373 m^3/year (~ 85% of water from rainfall annually) can be used as a source of recharge .

Infiltration galleries: for protecting and managing water quality


Fig. 5: Schema of Infiltration galleries (UNESCO, 1991)

Conclusions Acknowledgment

The project will attempt to address the current water resources complex situation and will set the basis for climatic changes adaptation measures to be developed within the local government and institutions as well as the interested communities.

Funds for the project were made available from the Vietnamese Government (Programme "Sea & Islands"), UNESCO Office Jakarta and IMELS.

Groundwater quality at Southeast coastal zone in Vietnam

United Nations Educational, Scientific and Cultural Organization
Italian Ministry for the Environment, Land and Sea
VAST
ISMAR8 October 15th–19th, 2013 Beijing, P. R. China

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Introduction

This report presents results of the project "Adapting to climate change: Solutions for managing coastal aquifers in the context of climate change" in Ninh Thuan Provinces, Viet Nam. The purpose of this project is to evaluating impacts of sea level rise by climate change on coastal zone in Ninh Thuan, proposing solutions for managing aquifer recharge to improve groundwater quality in coastal zones. In this work, authors focus in change of groundwater quality in time and their causes .

The coastal province of Ninh Thuan, due to its disadvantaged geographic location, unfavorable climate conditions and the limited social and economic development is among those more likely to be affected by climate change impacts such as sea level rise. One of the potential effects of sea level rise in these areas is the risk of saline water intrusion into fresh water coastal aquifers.

Results of chemical and stable isotope analysis of water samples as well as monitoring data at a monitoring well network from 2008 to 2012) showed that the groundwater quality changes in time and this is more evident in the higher elevated area, salinity in the groundwater is increasing and water type also changes and the reasons cause these change and MAR is a chosen solution to resolve these problems.

Results & Discussion

GEOLOGICAL, HYDROGEOLOGICAL AND CLIMATIC SETTINGS

Located in the driest part of Vietnam, Ninh Thuan has a tropical climate with 2 marked seasons: a short rainy season (August-September to November-December) and a dry period in the rest of the year. The annual average precipitation: 700 - 800 mm in the coastal area and gradually increases to more than 1800 mm in the mountainous areas; the annual average evaporation: 1670 - 1827 mm, average temperature: 27°C and air humidity: 71-75% *(Fig.1)*.

Geography of the Ninh Thuan is quite low and flat that the effects of the sea level rise and be seen clearly and wholly *(Fig.2)*. The geological setting of the study area, located mainly along the coastal zones of Ninh Thuan is characterised by a magmatic bedrock of Cretaceous age (granite, granodiorite,…) overlain by Pleistocene-Holocene marine deposits of both terrigenous and calcareous type. Recent and ancient sand dunes occur in the southern part of the Province (Lu Thien, Son Hai and Mui Dinh) and in the northern coast (from My Hoa to Vinh Hai). The hydrogeology is characterised by the occurrence of unconfined aquifers in loose sediment at different elevations (maximum elevation reached by the investigation was 40 m a.s.l.) exploited through both drilled wells (up to 28 m deep) and hand dug wells (the majority) with diameter: 0.7 - 6 m & depths: 3 - 9 m from ground level, besides fractured aquifers (bedrock).

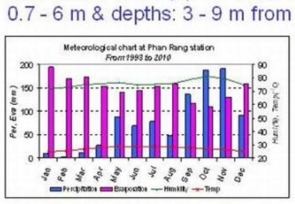
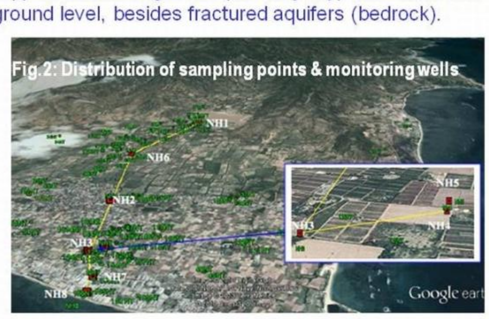


Fig.1:Distribution of rainfall, evaporation, humidity and temperature at Phan Rang station



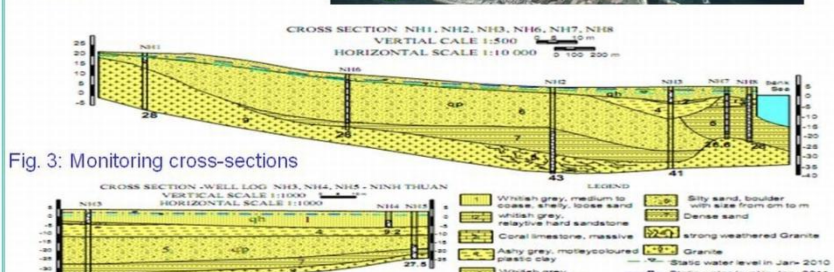


Fig. 3: Monitoring cross-sections

WATER CHEMISTRY AND WATER STABLE ISOTOPE DATA

From 2008 to 2010, water samples were collected for chemical and stable isotope analyses (O^{18} & H^2) *(Fig.4);* The results indicate the occurrence of the water types: Na-Cl type (majority), Cl-SO_4, Ca, Mg-HCO_3, Na-HCO_3. Major ions are Na & Cl with subordinate occurrence of HCO_3. Chemical composition of groundwater changes with time and this is more evident in the higher elevated area. Isotopic values from wells, springs, sea water and water ponds in Ninh Thuan area: 0.1 – -7.8 δ18O(‰), -50.2 – -2.5 δ2D(‰). The isotope composition of a representative number of groundwater samples (general related to the surficial unconfined aquifer) and the distribution values along a transect from the coast line to the hill area, account of a prevailing mixing process between two end members namely sea and freshwater. Positive isotopic values related to salt ponds usually located near the coast line as well as far away from the sea, give a clear evidence of the evaporation process characterizing the salt pans in the area.

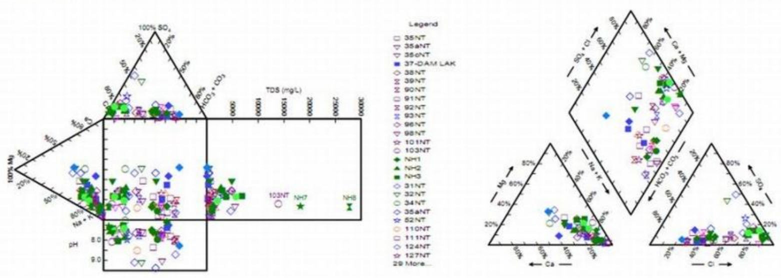
GROUNDWATER MONITORING

A monitoring well system including 2 transects were installed. The first one is 3 km long, lies on the perpendicular direction with the coast, the second one is 0.2 km long, perpendicular with the first one.

The purpose first transect (NH1,NH6,NH7 & NH8) is to monitor fluctuations of water level, physio-chemical parameters (TDS, Salinity, EC, T) at intergranula and NH2 at fractured aquifers; The second transect (NH3,NH4 & NH5) is to investigate groundwater under and upper the plastic clay at the intergranular aquifer.

Results obtained from this system showed that (Fig. 5):

- At the intergranular aquifer (qh), EC of groundwater at NH8 and NH7 (close to the coast line) is rather high (~ 40 mS/cm), meanwhile at others EC ranged between 1.25 mS/cm (NH5) and 37 mS/cm (NH3). At the fractured aquifer, EC of groundwater ranged between 7 mS/cm and 2.7 mS/cm.
- At the intergranular aquifer, EC of groundwater changes by vertical and horizontal, the under part of this aquifer (under the clay layer), EC is rather stable, meanwhile at the upper part, EC changed so strong, between 2.5 mS/cm and 37 mS/cm (NH4).



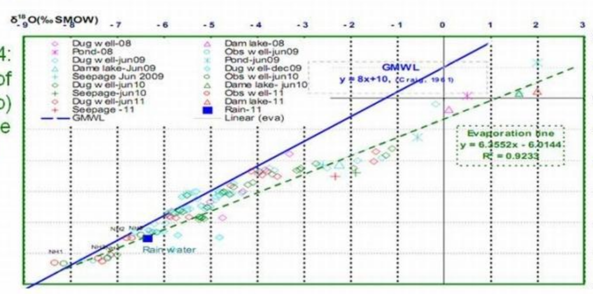


Fig. 4: Results of chemical (a,b) and isotope analyses (c)

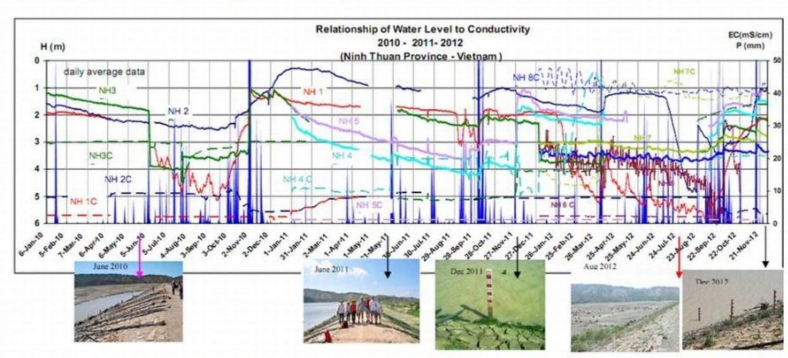


Fig. 5: Fluctuations of water level, EC of groundwater at intergranula and fractured aquifers, precipitation and water level at the lake Ong Kinh Dam (2010-2012)

CHOSING MAR SOLUTIONS

In this area, rainwater is one of major components of water resources for irrigating and therefore the lake of Ong Kinh Dam takes a important role for meeting demands. The results obtained from observed well system showed that the relationship between water level and EC is inverse ratio: during the time water level is increasing, EC is decreasing (Fig. 5)

At the coastal area close to the sea there is a plastic clay layer (at the depth of 5 m) dividing the intergranular aquifer two part: under and upper. EC of groundwater at the under part of intergranular is rather stable and smallest (< 1.3 mS/cm) although water level changes strongly (about 2.5 m) (NH5). But at the hill area (close to the Lake of Dam Ong Kinh), EC of groundwater is rather stable and ranging about 2-3 mS/cm (NH1 and NH6).

Based on obtained results, MAR solutions were proposed:
- Rain harvesting; all houses should be equipped with such simple systems
- Use of infiltration trenches (for rain water capturing) both parallel and longitudinal to the dam wall extension at different distances to reduce the high salinity of the shallow aquifer which is currently used by all settlements through shallow wells
Constructions of small canals from the dam to the infiltration trenches during the rainy season for salinity reduction of the shallow aquifer.

Conclusions and Aknowledgment

The project will attempt to address the current water resources complex situation and will set the basis for climatic changes adaptation measures to be developed within the local government and institutions as well as the interested communities.

This project is part of UNESCO-IHP (International Hydrological Programme) "Water Programme for Environmental Sustainability WPA II" (Vietnam component), funded by IMELS (Italian Ministry for Land and Sea). Funds for the project were made available from the Vietnamese Government (Programme "Sea & Islands") , UNESCO Office Jakarta and IMELS.

Using electrical conductivity measurements to monitor infiltration, recharge rates and clogging during managed aquifer recharge

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Motivation

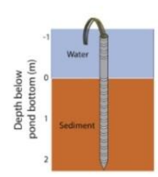
In managed aquifer recharge systems where water is recharged via infiltration from a pond, the rate of infiltration is important for optimal MAR performance. If the infiltration rate is too slow due to clogging, not enough water will enter the system. If the infiltration rate is too fast, influent may not be able to penetrate lower permeability layers, causing the water to move laterally away from the storage zone or the influent will not spend enough time in the vadose zone to realize the added cleaning benefits of filtration through the zone. Knowing how fast the water is infiltrating from the pond and moving through the vadose zone would inform maintenance and operation decisions for optimizing infiltration rates for improved MAR performance. In this work, we develop a set of equations for estimating infiltration rates and clogging directly from electrical conductivity measurements, which have advantages over traditional hydrologic measurements because they can be made in-situ, in real-time over large areas and at a high resolution.

Electrical resistivity methods

Electrical resistivity imaging is a geophysical method that consists of inducing current between two electrodes and measuring the voltage difference between two other electrodes. The measured voltage difference is a function of the induced current, the geometry of the electrodes and the electrical conductivity of the surrounding soil.

By performing many measurements for different configurations of electrodes in a given area, a resolute image of the electrical conductivity in that area can be formed.

A new vertical electrical resistivity probe has been used in previous years to monitor infiltration during MAR. These probes provide vertical profiles of electrical conductivity which we hope to exploit to gain information about infiltration rates and clogging (Pidlisecky et al., 2013).



Using hydraulic conductivity as a proxy for infiltration rate

Infiltration and unsaturated flow rates, *q*, can be defined by Darcy's law:

$$q_{in} = -K(\Theta)\left(\frac{\partial h}{\partial z}+1\right)$$

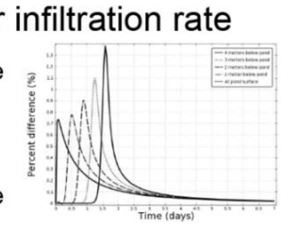
where *K* is the hydraulic conductivity, which in the unsaturated zone is a function of effective saturation, Θ, and $\frac{\partial h}{\partial z}$ is the vertical pressure gradient.

In steady-state, the vertical pressure gradient is zero and so:

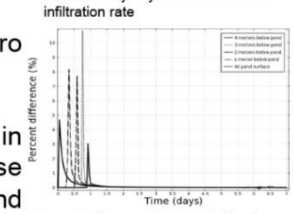
$$q = -K(\Theta)$$

We find that the pressure gradient is negligible in transience typical of MAR (see figures) and we can use hydraulic conductivity as a proxy for infiltration and unsaturated flow rates:

$$q(t) \approx -K(t)$$



Percent difference between infiltration and hydraulic conductivity for 0.1 m/day/day linear increase in infiltration rate



Percent difference between infiltration and hydraulic conductivity for 1 m/day/day linear increase in infiltration rate

Relating hydraulic and electrical conductivity

Brooks-Corey Equation + Archie's Equation* = relation between K and σ

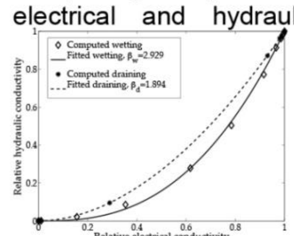
$$K(\Theta) = K_s \Theta^{\frac{2+3\lambda}{\lambda}} \quad + \quad \sigma(\Theta) = \sigma_s \Theta^n \quad \longrightarrow \quad K(\Theta) = K_s\left(\frac{\sigma(\Theta)}{\sigma_s}\right)^{\frac{2+3\lambda}{n\lambda}}$$

This relationship was supported by numerical experiments in which 15 sphere packs were partially saturated through morphological operations for multiple saturations and then their electrical and hydraulic conductivities were computed and compared. These experiments resulted in:

$$K_r(\Theta) = \sigma_r(\Theta)^\beta$$

Where for wetting: $2.45 \le \beta_w \le 3$

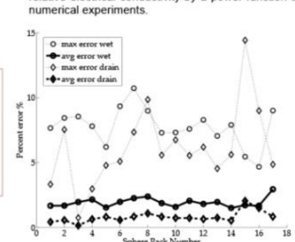
And for draining: $1.6 \le \beta_d \le 2.2$



Relative hydraulic conductivity was seen to be related to relative electrical conductivity by a power function through numerical experiments.

Using hydraulic conductivity as a proxy for Infiltration and recharge rates, *q:*

$$q(t) \approx K_s\left(\frac{\sigma(t)}{\sigma_s}\right)^{\frac{2+3\lambda}{n\lambda}} \quad \text{or} \quad q(t) \approx K_s\left(\frac{\sigma(t)}{\sigma_s}\right)^{\beta}$$



Average and maximum percent error seen for estimating relative hydraulic conductivity using $K_r(\Theta)=\sigma_r(\Theta)^{2.1}$ for different sphere packs during wetting and drainage

Monitoring infiltration efficiency

To avoid needing saturated hydraulic and electrical conductivity, infiltration efficiency, a ratio of infiltration rate to maximum rate can be monitored using an electrical conductivity measurement:

$$E(t) = \frac{q(t)}{q_{max}} \quad + \quad q_{max} \approx q(t_0) \quad + \quad q(t) \approx K_s\left(\frac{\sigma(t)}{\sigma_s}\right)^{\beta} \quad \longrightarrow \quad E(t) = \left(\frac{\sigma(t)}{\sigma(t_0)}\right)^{\beta}$$

For changing fluid electrical conductivity, σ_f:

$$E(t) = \left(\frac{\sigma(t)}{\sigma(t_0)} \cdot \frac{\sigma_f(t_0)}{\sigma_f(t)}\right)^{\beta}$$

Monitoring clogging factor

Infiltration during MAR is fully controlled by the clogging layer at the bottom of the pond (Bouwer, 2002). Infiltration through this layer can then be defined as:

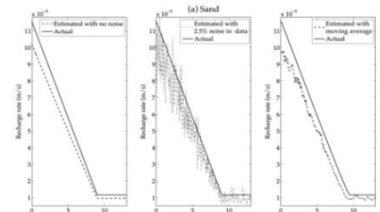
$$q_{in} = \frac{K_c}{L_c}(h_p - h_{up})$$

where K_c[m/s] is the hydraulic conductivity of the clogging layer, L_c [m] is the depth of the clogging layer, h_p [m] is the depth of the pond, and h_{up}[m] is the pressure head below the clogging layer.

Bouwer's + Brooks-Corey + infiltration = equation for monitoring
equation equation estimate clogging factor

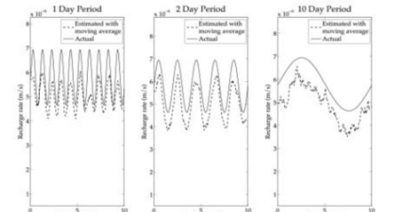
$$\frac{K_c}{L_c} = \frac{q_{in}}{h_p - h_{up}} \quad + \quad \Theta = \left(\frac{\alpha}{h}\right)^{\lambda} \quad + \quad q(t) \approx K_s\left(\frac{\sigma(t)}{\sigma_s}\right)^{\beta} \quad \longrightarrow \quad \frac{K_c}{L_c}(t) = \frac{K_s\left(\frac{\sigma(t)}{\sigma_s}\right)^{\beta}}{h_p - \alpha\left(\frac{\sigma_s}{\sigma(t)}\right)^{\beta}}$$

Monitoring decrease in infiltration rates



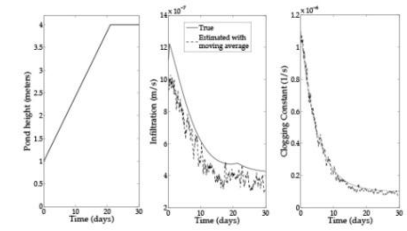
Despite noise and incorrect soil parameters, the equations in the red box can be used to adequately monitor decreases in infiltration rates over time using only a measurement of electrical conductivity in the subsurface.

Identifying changes in infiltration



Using the red boxed equations to monitor infiltration allows changes in infiltration to be identified over various time scales. Estimated rates above use synthetic measurements with 2.5% added noise and parameters estimated by soil type.

Delineating effects of pond height and clogging



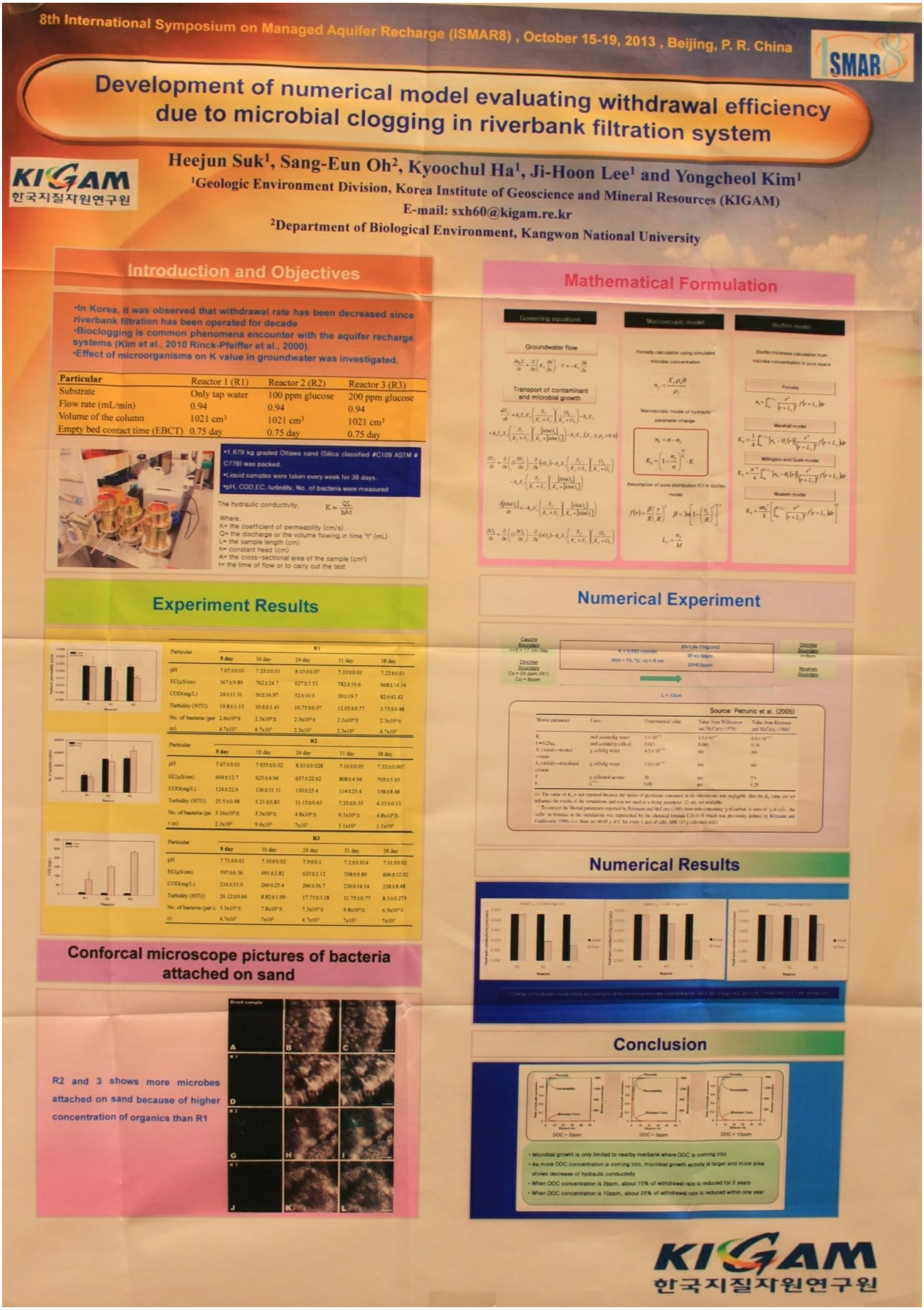
By monitoring infiltration rate and clogging constant, the effects of a rising pond height and a decreasing clogging constant can be delineated. Estimated rates use the red boxed equations and clogging equation with synthetic electrical conductivity measurements with 2.5% added noise and parameters estimated by soil type.

Conclusions

Relative electrical and hydraulic conductivity seem to be related by a power law. Hydraulic conductivity can be used as a proxy for infiltration and recharge rates with negligible added error. Combining these findings, we developed a number of equations that use an electrical conductivity measurement to monitor parameters of interest in MAR operations: infiltration and recharge rates, clogging factor and infiltration efficiency. These relationships allow the bypassing of hydrologic inversions, which are usually necessary for obtaining infiltration information from electrical conductivity data.

*Assuming relative water content is negligible

References: Bouwer, H. 2002. Artificial recharge of groundwater: hydrogeology and engineering. Hydrogeology Journal 10:121–142. Pidlisecky, A, A.R. Cockett and Rosemary Knight. 2013. Electrical Conductivity Probes for Studying Vadose Zone Processes: Advances in Data Acquisition and Analysis, Vadose Zone J :12.


8th International Symposium on Managed Aquifer Recharge (ISMAR8) , October 15-19, 2013 , Beijing, P. R. China
ISMAR8
Development of numerical model evaluating withdrawal efficiency due to microbial clogging in riverbank filtration system
KIGAM
한국지질자원연구원
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Introduction and Objectives
•In Korea, it was observed that withdrawal rate has been decreased since riverbank filtration has been operated for decade
•Bioclogging is common phenomena encounter with the aquifer recharge systems (Kim et al., 2010 Rinck-Pfeiffer et al., 2000).
•Effect of microorganisms on K value in groundwater was investigated.
Particular | Reactor 1 (R1) | Reactor 2 (R2) | Reactor 3 (R3)
Substrate | Only tap water | 100 ppm glucose | 200 ppm glucose
Flow rate (mL/min) | 0.94 | 0.94 | 0.94
Volume of the column | 1021 cm3 | 1021 cm3 | 1021 cm3
Empty bed contact time (EBCT) | 0.75 day | 0.75 day | 0.75 day
•1.679 kg graded Ottawa sand (Silica classified #C109 ASTM # C778) was packed.
•Liquid samples were taken every week for 38 days.
•pH, COD,EC, turbidity, No. of bacteria were measured
The hydraulic conductivity, K = QL / hAt
Where,
K= the coefficient of permeability (cm/s)
Q= the discharge or the volume flowing in time "t" (mL)
L= the sample length (cm)
h= constant head (cm)
A= the cross-sectional area of the sample (cm2)
t= the time of flow or to carry out the test
Mathematical Formulation
Governing equations
Macroscopic model
Biofilm model
Groundwater flow
Transport of contaminant and microbial growth
Experiment Results
Numerical Experiment
L = 13cm
Source: Petrunic et al. (2005)
Numerical Results
Conforcal microscope pictures of bacteria attached on sand
R2 and 3 shows more microbes attached on sand because of higher concentration of organics than R1
Conclusion
DOC = 2ppm
DOC = 5ppm
DOC = 10ppm
• Microbial growth is only limited to nearby riverbank where DOC is coming into
• As more DOC concentration is coming into, microbial growth activity is larger and more area shows decrease of hydraulic conductivity
• When DOC concentration is 2ppm, about 10% of withdrawal rate is reduced for 2 years
• When DOC concentration is 10ppm, about 25% of withdrawal rate is reduced within one year
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Attachment-detachment Dynamics of Suspended Particle in Porous Media: Experiment and Modeling

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Introduction

- In the progress of artificial recharge of storm-water to groundwater aquifer, clogging problem in infiltration system remains a key restricting factor in practice.
- Up to now, researchers have made some important progress in the study of clogging mechanism by means of indoor simulation tests. As for physical clogging modeling of porous media, theoretical and empirical models have been developed in some cases, and the key parameters of the clogging model were mostly from the fitted or empirical values in prior studies.
- However, in fact, these parameters are actually changing during the water injection process and they are not constant values.

In this study, a mathematical model for simulating porous physical clogging has been developed by coupling the model of particle transition-deposition in porous media and relationships among permeability coefficient, porosity and concentration of deposited particles, providing a systematic description of the occurrence and development of physical clogging.

Physical clogging model

The particle TD model can be set up as:

$$\begin{cases} \frac{\partial}{\partial t}(nC+C_S)+\frac{\partial}{\partial x}(Cv_x)=0 & 0\le x\le L,\ t>0 \\ \frac{\partial C_S}{\partial t}=\alpha C-\beta C_S & t>0 \\ C|_{t=0}=0.0 & 0\le x\le L \\ C_S|_{t=0}=0.0 & 0\le x\le L \\ C|_{x=0}=C_0 & t>0 \end{cases} \quad (1)$$

The reducing porosity:

$$n=n_0-\gamma C_S \quad (2)$$

Kozeny-Carmen equation:

$$K_t=K_0\frac{n^3}{(1-n)^2}\frac{(1-n_0)^2}{n_0^3} \quad (3)$$

The relative permeability coefficient

$$k=K_t/K_0 \quad (4)$$

Where n is the porosity of the sand media (dimensionless); C is particle concentration in the bulk phase of suspension (kg·m^{-3}); C_s is deposited particle mass in unit pore space (kg·m^{-3}); v_x is the seepage velocity vector (m·s^{-1}); α is the particle attachment efficiency (s^{-1}); β is the particle detachment efficiency (s^{-1}); n_0 is the initial porosity of aquifer media (dimensionless), γ is a constant parameter (m^3·kg^{-1}); K_t is the instantaneous saturated permeability coefficient during recharge (m/d); K_0 is the initial saturated permeability coefficient before recharge (m/d).

Measurement of the major parameters

a. Materials and setups

Sand sample: collected and from an unconfined aquifer near the Dagu River in Qingdao, China (average diameter 0.497 mm).

Suspended particles: collected from the storm-water of the Dagu River and particles with less than 0.038 mm in diameter were extracted.

The measurement setup:

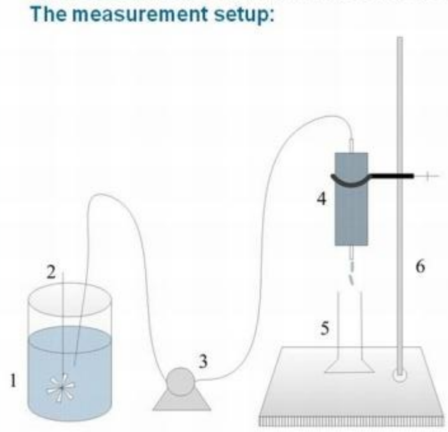

Fig. 1. Setup for particle attachment and detachment parameters
(1-feed water tank; 2-stirrer; 3-peristaltic pump; 4-organic glass column; 5-sample bottle; 6-iron support stand)

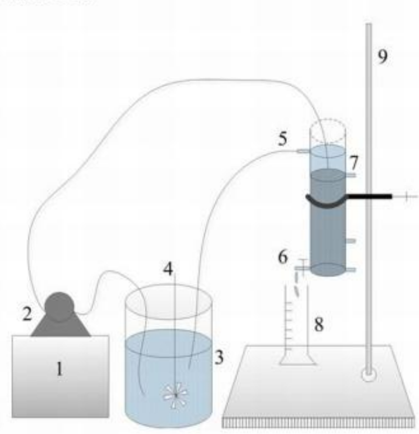

Fig. 2. Setup for pore volume occupied by unit mass deposited particles
(1-support table; 2-peristaltic pump; 3-feed water tank; 4-stirrer; 5-flow off; 6-water outlet; 7-pressure tap; 8-measuring cylinder; 9-iron support stand).

b. Determination of particle attachment and detachment parameters

When the temporal variation of suspended particle concentration in pores is ignored, the following equation can be obtained:

$$\begin{cases} \frac{\Delta C_S}{\Delta t}+\frac{v_x\cdot(C-C_0)}{h}=0 \\ \frac{\Delta C_S}{\Delta t}=\alpha\cdot C-\beta\cdot C_S \end{cases} \quad (5)$$

when the time interval, seepage velocity v_x, suspended particle concentrations of inflow and outflow C_0, C, and column length h are known (C_s =0 at the beginning of recharge), and C_s at time t can be calculated, then α and β under the corresponding velocity v_x can be obtained eventually.

$$\alpha=f_1(v_x)=49301v_x^2+16.319v_x+0.0068,\quad R^2=0.9174 \quad (6)$$

$$\beta=f_2(v_x)=663.13v_x^2-0.2983v_x-5\times10^{-5},\quad R^2=0.9262 \quad (7)$$

c. Calculation of pore volume occupied by unit mass particles

n_0 can be measured based on the following eqution:

$$n_0=1-\frac{\rho_c}{\rho_s} \quad (8)$$

Where ρ_s is the density of the sand used (kg/m^3) and ρ_c is the bulk density of the porous media (kg/m^3).

During the experiment with the setup in Fig. 2, the permeability coefficients Kt at different periods were measured. Relative permeability coefficient k and media porosity n can be calculated respectively through Eq. (3) and Eq. (4). Through the linear fitting method, the measured porosity and the deposited particle mass in unit pore space can be obtained:

$$n=n_0-5.1\times10^{-3}\cdot C_S,\quad R^2=0.9941 \quad (9)$$

Verification and analysis on PC Model

a. Modeling and verification

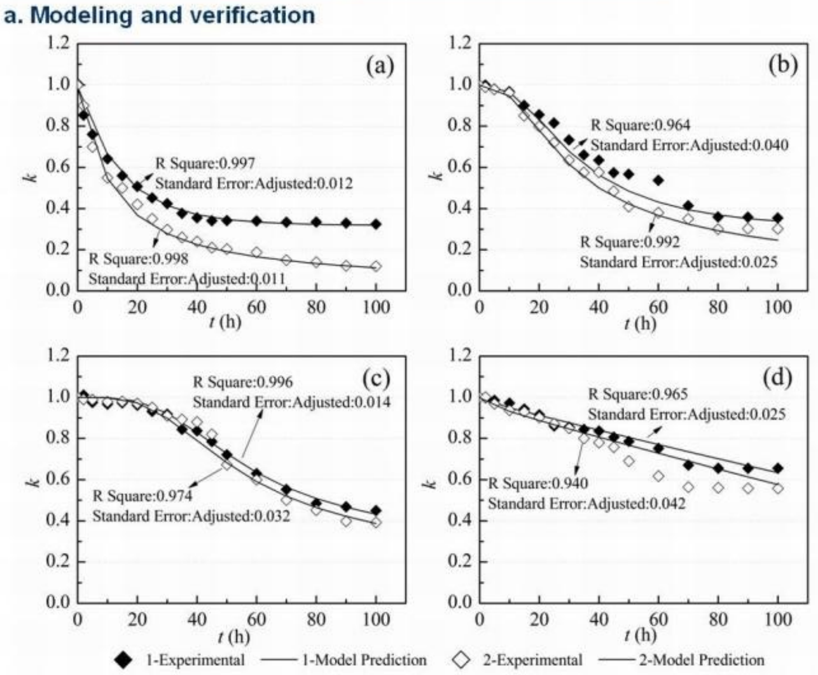

Fig. 3. Varieties of measured and calculated relative permeability coefficients with time for layers OA (a), AB (b), BC (c) and OD (d) under suspended particle concentrations of 100mg/L (test 1) and 200 mg/L (test 2).

b. Model sensitivity analysis

The sensitivity analysis is conducted based on the relative sensitivity index $S(k, X_i)$ to examine changes of output quantity (k) related to the change of each modeling parameter (X_i) in Eq. 10.

$$S(k,X_i)=\left|\frac{\Delta k/\Delta X_i}{k/X_i}\right|=\left|\frac{\Delta k/k}{\Delta X_i/X_i}\right| \quad (10)$$

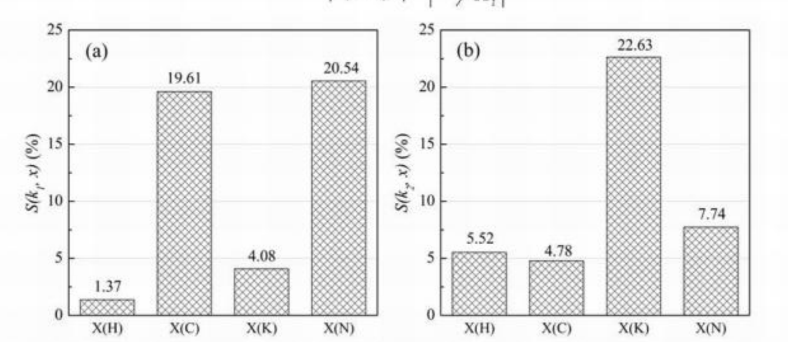

Fig. 4. Model sensitivity analysis for the surface sand layer (a) and the whole sand column (b)

Conclusions

- The particle detachment process does not take place under low seepage velocity, but it does exist until the pore space is completely clogged.
- The particle attachment and detachment parameters are not constant values. Actually, they are changing with the seepage velocity.
- The experimental values are well fitted with the calculated results of the model. All the R^2 are above 0.90 with the standard errors less than 0.05 for each sand layer and the whole sand column. Therefore, the model can be further used for the prediction of the clogging process.

Acknowledgements

This work was supported by the Natural Science Foundation of China (No. 41172209), the Public Welfare Industry Science and Technology Project of China (No. 201301090), and the "Twelfth five-year" National Science and Technology Plan Project of China (No. 2012BAB12B03).

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Survival of Escherichia coli in Alluvial Aquifer Recharged with River water

Jeong-Ho Sohn and Yeonghee Ahn

A Study on Classification of Groundwater Aquifer using the Principal Component Analysis in Linpien Basin, Pingtung, Taiwan

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INTRODUCTION

Pingtung County is an agricultural developed region, the surface water of Kaoping, Tungkang and Linpeing Rivers become the main water resource in Pingtung Plain. In terms of measurement data (WRA 2008),Typhoons and thunderstorms during the wet season from May to October bring about 80% of annual precipitation(2,503mm), primarily in the mountains region, while only 10% of the rainfall occurs during the dry season (Nonmember to April), a great quantity of annual rainfall in this area. This uneven distribution in the monthly rainfall poses a major problem to the planners is difficult to utilize. Hence, groundwater became the main water resources in Pingtung Plain, Taiwan. The purpose of classification is to determine a hydrograph pattern that describes the water level trend over a 10 years period for each layer by adopting Principal Component Analysis (PCA) in interpreting the groundwater type in both time and space. The study conducted an analysis to understand the area distribution of various types of water level patterns and determine whether groundwater should be explored for utilization. To do so, groundwater data were collected daily from three Aquifer wells located at the Linpien River alluvial plain from 1999 to 2009.

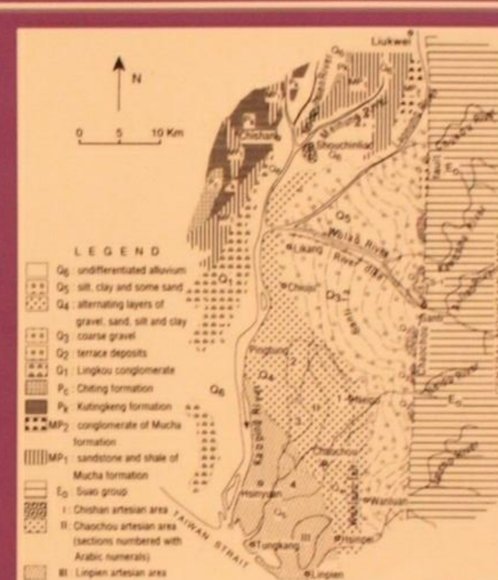
Environment of study area

Geology

The following informations are based mainly on Ting (1997) and PGDB (1961). As already mentioned the Pingtung Plain is surrounded by mountain ranges to the east and north and to the west by foothills. In the south the plain is bounded by the Taiwan Straight. The subsurface geology of the plain can be divided into the consolidated rocks of the mountain region, which are of Tertiary age, and the unconsolidated sediments of quaternary age as Fig 1.

Hydrogeology

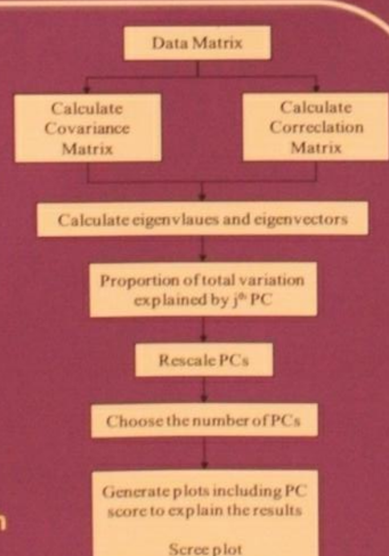
The study area consists mainly of coarse gravel . The natural recharge function of this region is quite reasonable. Pumping tests in the Pingtung Plain (PGWBD, 1961) were analyzed, and the average values of the various hydrogeological parameters are as follows: Zone 1 is composed mainly of coarse material with a transmissivity of about 900 m2/day and a phreatic storage factor between 0.01 and 0.3; Zone 2 is mainly constituted by coarse gravel with pebbles, with a transmissivity of about 9,000 m2/day and a storage coefficient of 6x10-3; Zone 3 lies adjacent to Zone 2, with the combined transmissivity of its upper and lower aquifers estimated to be about 2,500 m2/day and a storage coefficient of approximately 9×10^{-4}.



Geological map of the Pingtung Plain region (PGWBD, 1961)

Analytical Methods

Principal Component Analysis represents a powerful tool for analyzing data by reducing the number of dimensions, without important loss of information and has been applied on datasets in all scientific domains. On the other hand, PCA is known as an unsupervised dimensionality reduction technique that transfers the data linearly and projects original data to a new set of parameters called the factors, while retaining as much as possible of the variation present in the data set.



Principal Components Analysis steps (Irina Ioniţă, 2010)

Conclusions

Various factors influence groundwater dynamics, including topography, water movement, weather, and other human-related factors. The results indicate that the exploitation type must be in the coastal area, and the recharge area is located upstream, as described below.

1. Meteorology factor-The groundwater source has almost been recharged entirely by rainfall near the proximal fan or in front of the mountain area, which is a recharge zone with a high infiltration rate. The lateral recharge of the mountain area is the source of the deep Aquifer (100 m to 250 m). Consequently, rainfall in the mountain affects the groundwater dynamics on the proximal fan and the deep aquifer, whereas the river affects the groundwater dynamics in the shallow aquifer. For example, in Shibupyi Station, where the river and the aquifer interacted, the water is obtained midstream and the level remains balanced with the groundwater until the river becomes the gaining river.

2. Exploitation factor-In terms of the groundwater trend, aquaculture abstraction occurs frequently in the coastal area. Furthermore, complex groundwater fluctuations are observed in Aquifers 2 and 3.1, specifically in the Datan (2), Tungkang (3), Kangtung (3), and Chifeng (3) Stations. As a result, groundwater is gradually reduced during both dry and rainy seasons.

Aquifer (1) Aquifer (2) Aquifer (3.1) Aquifer (3.2)

Classification of groundwater type

Reference

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MAR in Flanders (Belgium): Overview & Opportunities

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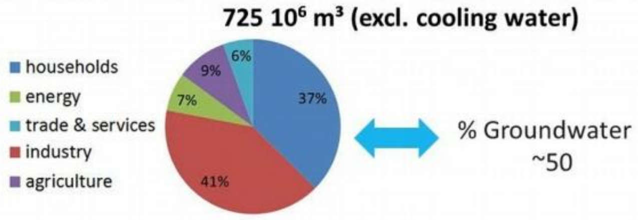
Water Use in Flanders (2010)

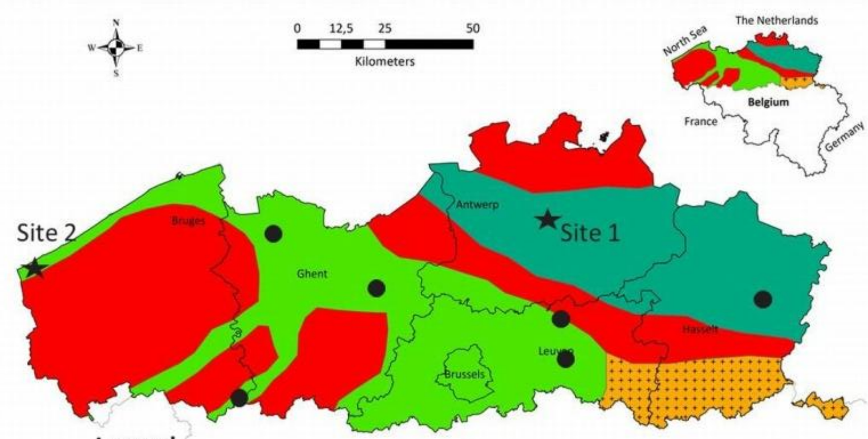


Bottleneck

MAR production sites

	Site 1 Grobbendonk	Site 2 Torreele/St-André
MAR-elements		
1. surface water	canal water	treated waste water
infiltration volume	400 000 m^3/yr	2 500 000 m^3/yr
2. pre-treatment	$FeCl_3$, sand filtration, active coal filtration	tertiary treaded effluents
3. MAR technique	infiltration pond	infiltration pond
4. subsurface storage	coarse sandy semi-freatic aquifer	sandy freatic aquifer
5. recovery	abstraction wells	abstraction wells
numbers of wells	30	112
filterdepth (m-bgl)	30 - 60	8 - 12
6. post-treatment	aeration - sand filtration	chlorination - aeration - sand filtration - UV
7. end use	drinking water	drinking water
References	. Feyen (2001) . van Hoorick & Feyen (2001)	. Vandenbohede et al. (2013) . Van Houtte et al. (2012)

Opportunities



Legend

very suitable	Sandy deposits with high permeability (K : ~8 m/d) Sufficient aquifer thickness (up to 200 m)
suitable	Permeable sands Suitable for large infiltration ponds
less suitable	Low permeability
not suitable	Heterogeneous geology Outcrop of thick clay layers Very high secondary porosity → no control on groundwater movement
●	Potential sites of "De Watergroep" for MAR application (to be investigated)

Suitable techniques for MAR in Flanders

Infiltration basins & Riverbank Filtration
- availibility of space
- presence of aquifers with good hydrogeologic conditions
- proximity of surface waters

ASR theoretically possible but
- possibility of clogging due to Fe-precipitation
- low permeability

Riverbed MAR techniques because of river characteristics
- draining rivers
- insufficient storage capacities
- permanent

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Development of a European MAR catalogue

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INTRODUCTION

The European Managed Aquifer Recharge (MAR) catalogue is developed to:

- provide information platform of key parameters during MAR
- improve trust in the performance of MAR for stakeholder
- identify knowledge gaps
- identify characteristic performance parameter for different MAR types

Materials and Methods

- The catalogue is a relational database (MS ACCESS)
- Data entry, display and modification by graphical user interfaces
- Information acquired from more than 250 research paper, reports, water agencies/utilities or web sites (data entry by DEMEAU partner)
- Quality assured by logical and statistical checks

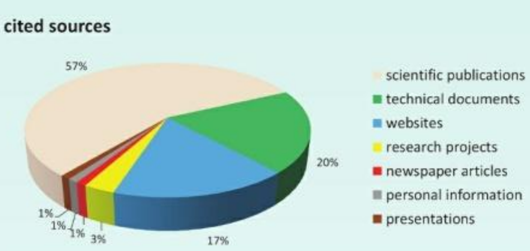


Figure 1: Relative distribution of information sources used in the MAR catalogue

- The MAR catalogue includes 5 main MAR types (subdivided into specific types)
- About 300 MAR sites, 6200 entries and 43 parameter (with different degree of record completeness)
- Parameter include general site information, operational information, water quality, references

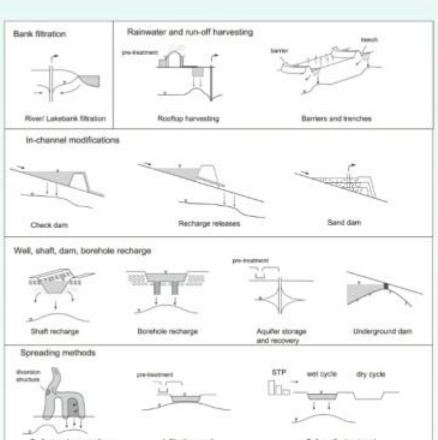
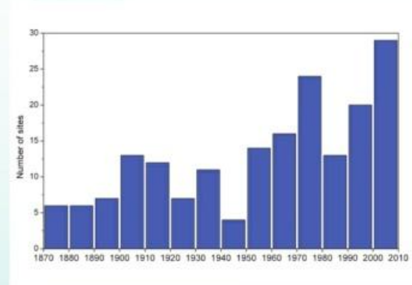


Figure 2: Sketches of MAR types included in the MAR database (modified after Dillon 2005)*

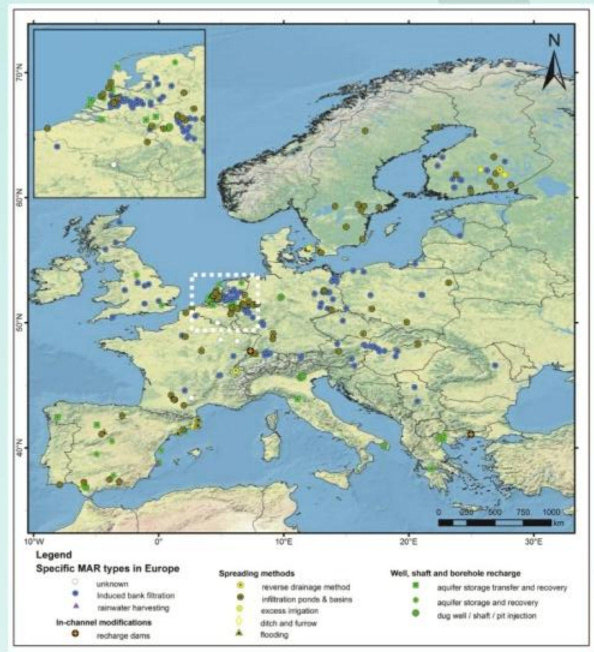
*Dillon, P. (2005) Future management of aquifer recharge. Hydrogeological Journal13:313-316

RESULTS



- First water works using Bankfiltration and Infiltration ponds in 1870`s (mostly in Germany and Netherlands)
- Increasing number of new sites in last decades

Figure 3: Historical development of MAR sites in Europe showing new sites per decade



- Induced BF (51%), Infiltration ponds (23%)
- BF at Rivers and Lakes in central, east and north Europe
- Infiltration ponds and injection in south Europe (mostly Spain)

Figure 4: Spatial distribution of MAR types in Europe

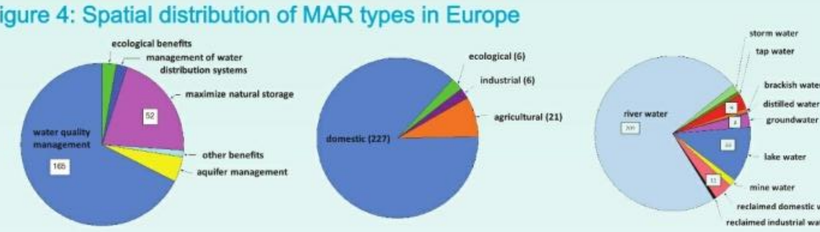


Figure 5: Distribution of objectives (left), final use (middle), source water type (right)

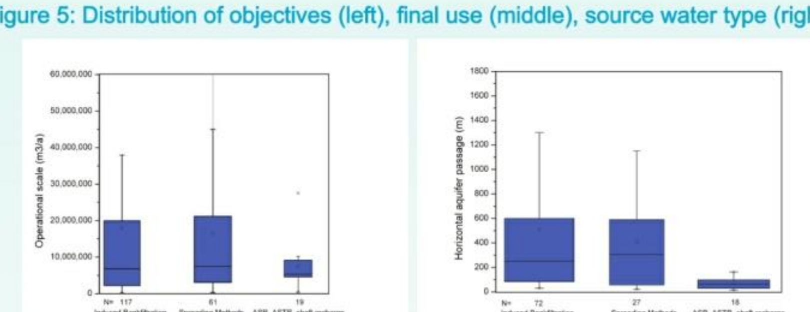


Figure 6: Operational scale (left) and horizontal aquifer passage to abstraction well (right) for main MAR types

If your MAR site is not included, please contribute to the MAR catalogue

Entry form available at:
http://demeau-fp7.eu/MAR_database_test or email to
hannappel@hydor.de

This research has received funding from the European Union's Seventh Framework Programme under the grant agreement no. 308339
PROJECT COORDINATOR: KWR Watercycle Research Institute, Theo van den Hoven: Theo.van.den.Hoven@kwrwater.nl
DISSEMINATION PARTNER: Ecologic Institute, mail@demeau-fp7.eu

http://demeau-fp7.eu DEMEAUFP7 DEMEAU FP7 Project

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Effects of inorganic carbon limitation on nitrite oxidizing bacteria

Young Mo Kim and Kartik Chandran

Large diameter shallow wells in unconfined aquifer recharge: a new MAR integrated project in the province of Treviso (Northern Italy)

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2. Provincia Treviso – Treviso - Italy

INTRODUCTION

Since the 80s, a contamination from PCE has been found in a private well in province of Treviso, in Veneto region where the dense industrial areas, often included within an urban context, have given rise to some historical episodes of pollution of the aquifer. Thanks to the FOKS project (Central Europe - Focus on Key Sources of Environmental Risks), some investigations were carried out between 2009 and 2012.

In addition to this, it should be remarked that since the 60s the water reservoir of the hydrogeological system in Veneto has been gradually decreasing.

At the end of the FOKS project, the public administration decided to follow up the investigations, funding a pilot project involving the achievement of an integrated system for MAR.

In this case the expected objectives are:

- the increase of the natural recharge during the autumn/winter period, when the surface water network can supply a considerable amount of water;
- the compensation of the water withdrawal carried out in summer by existing deep wells: therefore, there will be no impact on the aquifer water balance;
- the mitigation of the transport of the historical chlorinated solvent plume, favoring the MNA (monitored natural attenuation) processes in the areas upgradient the plume;
- the develop of specific monitoring and numerical models in order to improve the aquifer parameterization and to optimize the operational management of artificial recharge in other work in progress sites.

The project, starting in 2013, concerns the injection into unconfined aquifer of surface water during the agricultural off-season, through the construction of large diameter shallow wells in the unsaturated zone.

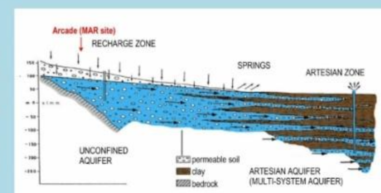
GEOLOGY and HYDROGEOLOGY

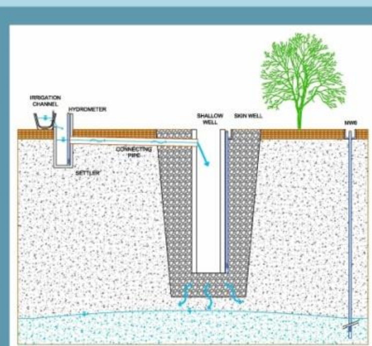
The site is located in the upper alluvial plain where a highly transmissive unconfined aquifer exists.

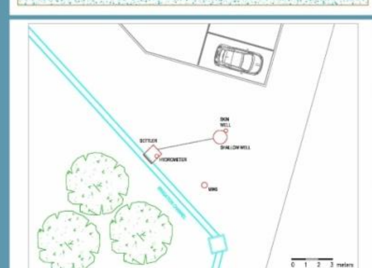
As regards the overall geologic-stratigraphic layout, the soils are constituted by alluvial deposits linked to major sedimentation phenomena that have given rise to the subsoil of the upper plain, also helping create the different hydrogeological structures present in the middle and lower plain.

The investigation area is characterized by a powerful undifferentiated mattress of gravel and sand, formed by interpenetration of the alluvial megafans deposited by the rivers at different times.

The hydrogeological situation of the subsoil is strongly conditioned by the particle size and structural characteristics of the alluvial mattress and, above all, by the different distribution of high permeability materials (K = $1{,}4 \times 10^{-2}$ m/s). The site is characterized by a unconfined aquifer.







CONSTRUCTION DETAILS OF SHALLOW WELL

Pilot initiatives of MAR have been launched through a system that does not require large areas.

The plant:

- has been constituted by precast perforated chamber rings; the modular elements are placed one above the other for a total height of 6.0 meters and intercept gravel with pebbles in sandy matrix with a medium-high hydraulic conductivity ➔simple and low cost construction; resulting usefully to be used in this area, which are particularly suited to this purpose under the geological profile and also for the hydraulic aspects;
- has been completely underground and surrounded by a layer of gravel and pebbles, which forms the drainage base and it is in lateral continuity with the natural unsaturated soil ➔ allow the complete usability of the area for other uses;
- are connected to irrigation network ➔ using groundwater surplus water during the off-season irrigation

The well joined by a pipe connected to an adjacent irrigation channel: the link between the well and the water irrigation pipe is constituted by a protective filter and a flow control slide gates to regulate the quantity of water introduced.

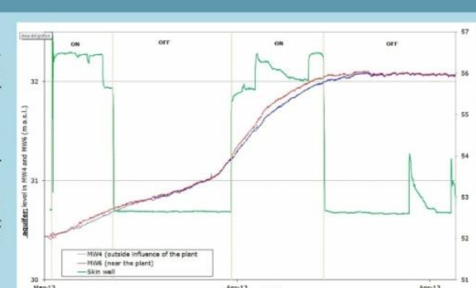
Along the pipe is also installed a manhole for inspection, verification of functionality in the medium term and for any maintenance work in progress.

MONITORING

The site at which artificial recharge pilot-actions were activated through shallow wells has structured with automated continuous monitoring stations (flow, groundwater levels, temperature). Hydrochemical monitoring plans for surface water and groundwater were also provided in order to assure the quality of the MAR effects.

To evaluate the efficiency of the system, a rigorous program of control is carried out, divided into automatic and continuous measurements of flow derived from irrigation ditches and of groundwater levels and in samplings of water to maintain a constant hydrochemical control over waters that are used.

To evaluate the flow rates in input, a level gauge has been installed within manhole placed along the joint pipeline and some campaigns of flow measurement are carried out by acoustic digital current meter to reconstruct the analytic function that links the input levels to the seepage flow.



RESULTS

In recent years, pilot projects were carried out in the high alluvial Veneto plain to evaluate the possibility of the aquifer recharge using simple technologies, among which large diameter shallow wells are included.

Considering the preliminary measures obtained in the Arcade site during the first period (2 months of activation) about 100.000 m^3 of water were reintegrated into the aquifer.

This volume, which varies over time depending on the availability of water from the irrigation network corresponds to an average annual flow of about 1700 m^3/d.

The project activities for the next 18 months include about 8 months of recharge of the aquifer through the large diameter well. During this time it is expected to inject into the aquifer about 600.000 m^3 of water. This amount of water corresponds to a flow rate of groundwater recharge of 2500 m^3/d.

Considering a daily average of water demand of around 250 l per person, the pilot plant will be able to reintegrate into the aquifer a volume of water equal to the water consumption of about 10,000 people (double of the population residing in the municipality in which are placed the MAR plant).

Regarding the existing chlorinated solvents contamination, a detailed monitoring plan has been planned, with investigation of groundwater and surface water, in order to test artificial recharge long term effects on the pollution plume. Preliminary data indicate that the dilution effect of PCE contamination should be considerably attenuated in the future: PCE concentrations halved in monitoring wells nearly located downgradient the large diameter well. It can be assumed that the recharge activity, in this case, carries out an Enhanced Attenuation action.

In a reasonable scenario of "full-scale" extension of the project, assuming at least 10 similar installations, suitably distributed on the territory in function of predisposing factors (i.e. geology and hydrogeology) and in function of determinants factor (i.e. availability of water in irrigation network, ability to supply flood flows that would otherwise flow to the surface), it would derive potential recharge volumes on the order of 15 million cubic meters per year. This volume is relevant in terms of regional basin hydrogeological water budget.

The well developed today with simple system configurations, highlights a number of other favorable elements that, taken together, suggest the opportunity to further develop the initiative:

- the ease of operation and cost of completion of the works,
- the reduced need for operating spaces, useful to positioning in small areas, the limited environmental impact (because the infiltration wells are completely underground and not visible externally),
- the effective dispersing ability, attested by the experiences to date carried out in the territory of Treviso,
- the ease of controls of quantity and quality to support the highest standards of hygiene and public health and protection of drinking water resources,
- lack of security issues.

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Scope for Large Scale Application of Managed Aquifer Recharge in Bangladesh for Sustainable Domestic, Municipal and Irrigation Water Supply

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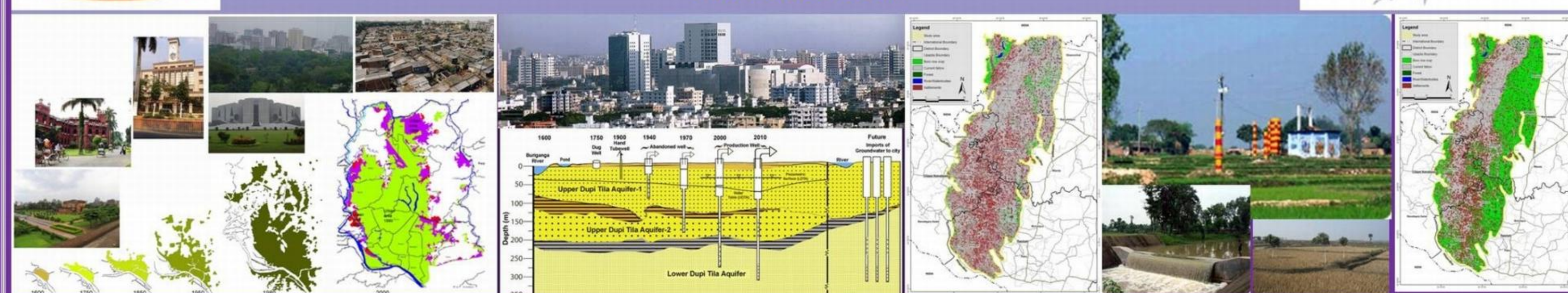
Introduction



Figures: a) Physical growth of Dhaka Megacity; b) evolution of water supply in Dhaka over the last four centuries; c) Barind before irrigation; d) Irrigation wells and landforms of the Barind Tract; d) Barind after introduction of groundwater irrigations

Dhaka has evolved as a megacity over the last four centuries where the current population is over 15 million (Ahmed et al, 2011). The domestic and industrial water supply in and around the city is heavily dependent on groundwater abstracted from the Dupi Tila aquifer, the second most important aquifer of the country. Due to overexploitation, water level is declining very fast with a huge cone of depression developed under the city (Sultana, 2009). The Dupi Tila aquifer, on the other hand, provides water for thousands of irrigation wells installed on the Barind Tract in NW Bangladesh (Ahmed, 2004). Here also water level is declining very fast raising concerns about the sustainability of the irrigated agriculture (Huque, 2012). Both these areas have potentials for applications of managed aquifer recharge for augmenting the depleting groundwater resources (Ahmed et al, 2010; Sultana et al, 2012; Shamssudduha et al, 2012).

Results and Discussions

Highlights of MAR Potentials in Bangladesh: High rainfall, extensive shallow unconsolidated aquifers, shallow groundwater levels

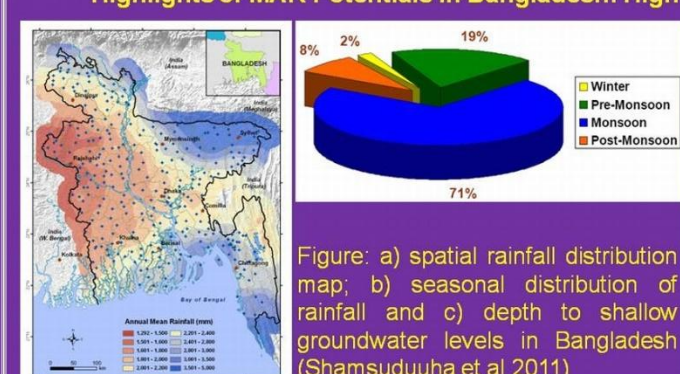
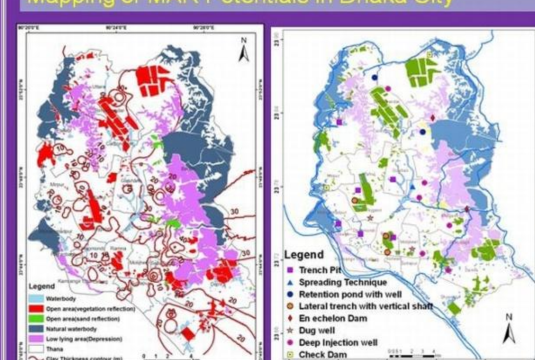


Figure: a) spatial rainfall distribution map; b) seasonal distribution of rainfall and c) depth to shallow groundwater levels in Bangladesh (Shamsuduuha et al 2011)

Areas for potentials applications: Dhaka City: Quantity augmentation for municipal abstractions; Barind and Madhupur Tracts: Quantity augmentation for Irrigation and industrial abstractions; Flood Plains: Quality improvements and quantity augmentations for domestic and irrigations abstractions; Hill Tracts: naturally low recharge areas, quantity augmentations for domestic and irrigations demands; Coastal Plains: Quality improvements for domestic and irrigations abstractions.

Mapping of MAR Potentials in Dhaka City



No of Locations	Clay thickness (m)	Method
6	10 – 15	Trench pit
6	40 – 50	Injection well
2	3 – 7	Dug well
3	5 – 15	Lateral trench with vertical shaft
1	0 – 10	Spreading Technique
2	20 – 25	Retention pond with well
2	25 – 35	En-echelon Dam
2	15 -30	Check dam

Figures: a) Natural recharge potential map of Dhaka city; b) Map showing the suitability of different areas for application of different MAR types (After Sultana, 2009)

Groundwater in Dhaka is overexploited by hundreds of municipal and industrial wells. Natural recharge has reduced substantially due to urbanization. Sustainability of the municipal and industrial water supply is under risk. Site specific methods can be applied in Dhaka city for augmenting the Dupi Tila aquifer. It is also possible to use hundreds of abandoned wells of DWASA to use as recharge shafts.

The Barind Tract Investigations

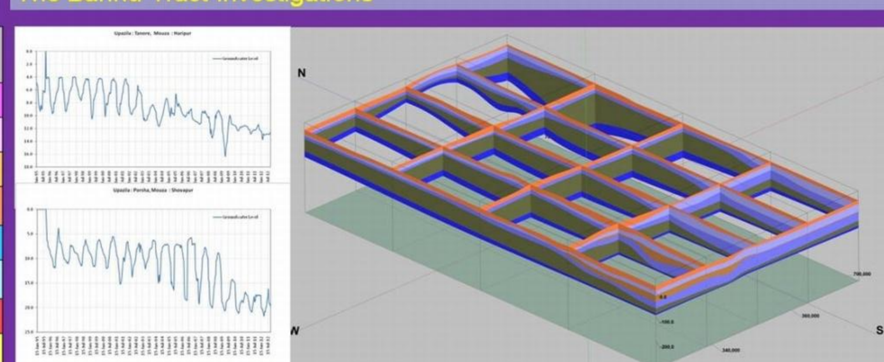


Figure: a) Declining groundwater levels; b) Dupi Tila aquifer geometry (after Huque, 2013)

Groundwater irrigation has brought in number of positive changes on the Barind. However, large scale abstractions from the confined Dupi Tila aquifer with limited vertical recharge has made the aquifer vulnerable to overexploitation. The terraced landform creates opportunities for catching surface runoff for infiltration through recharge wells/pits and percolation tanks. Check dams can be constructed on the natural canals for enhancing recharge.

Conclusions

There is scope for application of large scale managed aquifer recharge in various places of Bangladesh for augmenting the aquifers overexploited for domestic, irrigation and industrial abstractions. Good quality source water is available during the monsoon and also there is space at the shallow subsurface for storage . Encoraging results have been obtained from the coastal areas with small scale MAR Aapplications (Sultana et al 2012).

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ISMAR8: International symposium on managed aquifer recharge
October 15-19, 2013, Beijing, China

Modeling managed aquifer recharge capacity of crystalline aquifers in semi-arid context (South India): Implementing natural percolation tank dynamics into MARTHE code

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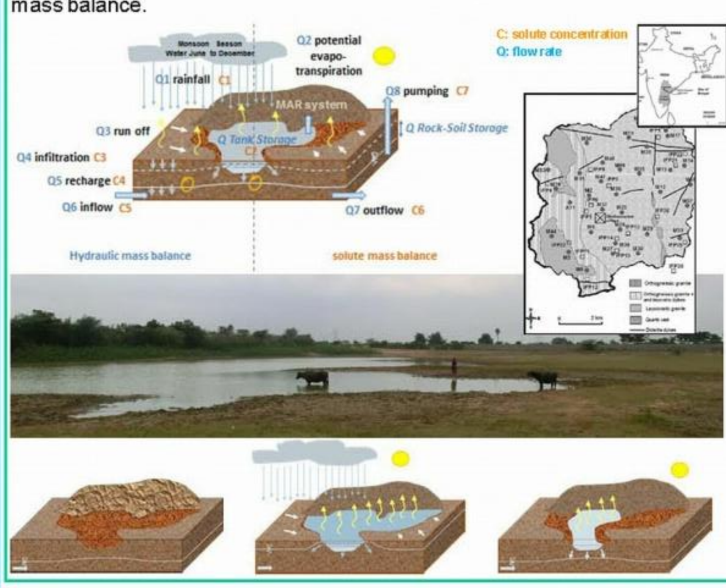
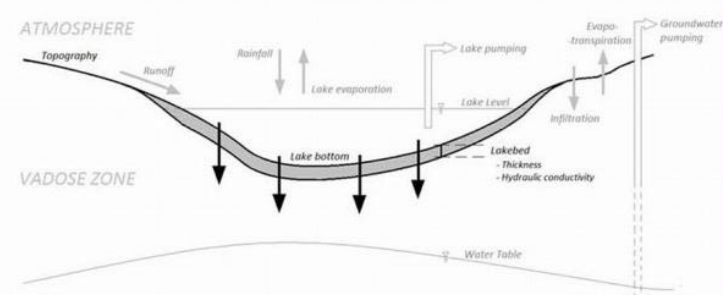
This work is part of the SaphPani project and particularly focuses on assessment of MAR performance. The 3D transient groundwater numerical code MARTHE was optimized by implementing 3D non-perennial surface water bodies in continuity with groundwater via an unsaturated zone to be applied on Maheshwaram percolation tank (South India).

1) Conceptual model of Maheshwaram percolation tank and implementation in the MARTHE code

Conceptual model of spatiotemporal evolution of the Tummulur percolation tank studied in Mahesharam in accordance with hydraulic balance and solute mass balance.





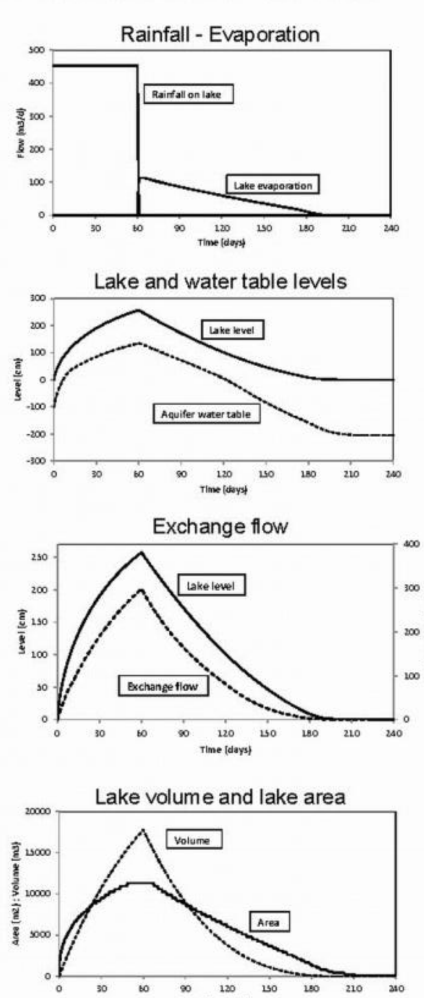
Storage = Rain – Evap. + Runoff + Upstream – Downstream + Inject. – Pumping

Concept used for implementing managed aquifer recharge by percolation tank and groundwater interactions.

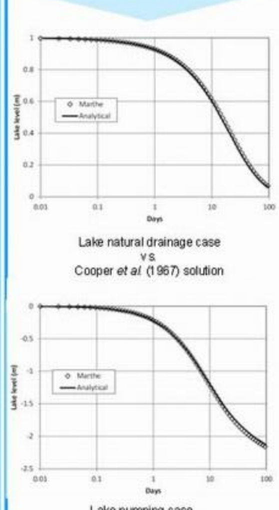
Results 1) >The rainwater is stored at the surface, where artificial topographic modifications delays superficial water flow during the monsoon season. Part of the water flows into the soil and deeper, toward groundwater and another part of water is evaporated during monsoon and dry periods.

2) Test simulations with the MARTHE code

MARTHE simulation results of a hypothetical case representing the filling of the percolation tank during a heavy rainfall period, followed by a drying period



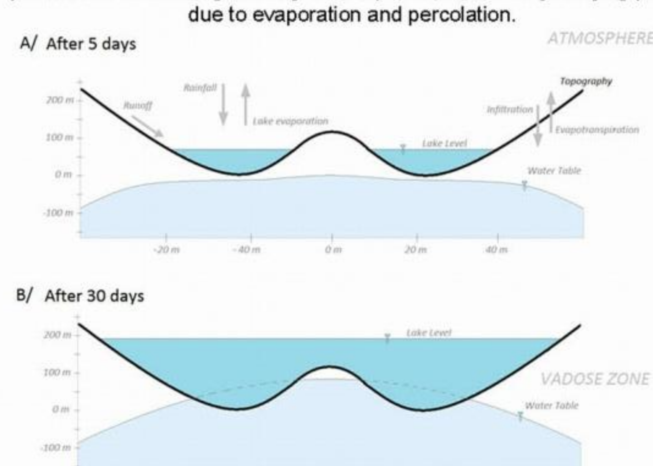
MARTHE simulation results compared to analytical solution



Lake natural drainage case vs. Cooper *et al.* (1967) solution

Lake pumping case vs. Papadopulos and Cooper (1967) solution

MARTHE simulation results of a hypothetical case representing the filling of a percolation tank during a heavy rainfall period, followed by a drying period due to evaporation and percolation.



Results 2) A new feature allowing for interaction between surface water bodies and groundwater is implemented to *i)* Increase understanding of the recharge capacity measured on percolation tanks *ii)* Assess the quantitative effects of monsoon water recharge on an overexploited semi-urban aquifer *iii)* Evaluate the impact on groundwater recharge of future MAR implementation at basin scale.

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Key legal and regulatory Issues for sustainable Development of large-scale ASR in Korea

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Introduction

■ 5-year long national R&D project has been initiated on June 2013 in Korea

①Title – Aquifer storage and water quality enhancement of surface water
②Total Research Fund – 13.5 billion won (12.6 million USD)
③R&D Objective

	Large-scale	Small-scale
	Objective	Objective
Technology Development	Large-scale ASR Total Solution (10 mil. m^3 Storage Capacity and 0.1 mil. m^3/day Recovery Rate)	Small-scale ASR Total Solution (In dry season, 50 m^3/day Recovery Rate for 30 days)
Technology Validation	Lab.-scale Hydraulic Model Technology Validation Pilot Project (1 mil. m^3 Storage Capacity and 2,000 m^3/day Recovery Rate)	Lab.-scale Hydraulic Model Technology Validation

④Final R&D Deliverables

Category	Final Research Outputs
Large- / Small-scale	A Model National Draft Code for accommodating ASR or Managed Underground Storage (MUS) in Water Resource Management
Large-scale	Large-scale ASR Total Solution Package and Manual Development
	Large-scale ASR Technology Validation Report
	Large-scale ASR Pilot Project (Integrated O&M Manual)
Small-scale	Small-scale ASR Total Solution Package and Manual
	Small-scale ASR Technology Validation Report

Research Objective

① Review of domestic relevant laws and regulations in relation to the development and use of clean underground water storage

② Identification of Key legal and regulatory issues for accommodating ASR project in an integrated water resource management in Korea

③ National legal and regulatory draft code development direction set-up

Research Flow

Results & Discussion

■ Current legal system regarding the development and use of clean underground water storage and recovery

Laws	Main Relevant Provisions and Contents
Underground Water Act	Regulating basic issues of development, use, conservation and management of groundwater
Management of Drinking Water Act	Regulating water quality control, development, manufacturing and sale of drinking water, spring water and salty underground water
Water Supply and Waterworks Installation Act	Regulating artificially developed underground water resources for water supply source and plant
Civil Act	Regulating water right on artificially developed underground water according to the legal relations of land ownership

※ Besides the above mentioned laws, there are approximately 10 laws, which are directly or indirectly related to the clean underground water storage in Korea

■ Major legal issues that need to be reflected in current ASR governance system
① Legal relationship concerning the management, use, distribution and disposition of underground water and its ownership are somewhat unclear;
② 'Water-source protection zone' pursuant to the 「Water Supply and Waterworks Installation Act」 can impose unnecessary restrictions on the development and use of clean underground water storage;
③ Current water quality standards pursuant to the 「Underground Water Act」, 「Mange. Of Drinking Water Act」 and 「Water Supply and Waterworks Installation Act」 are thought to be somewhat excessive or unsuitable for the business and service of clean water storage; and
④ Overemphasis of public character and concern of underground water resources can act as a fatal constraint on the development and use of clean underground water storage.

■ Current legal system modification and improvement direction in consideration of ASR in Korea

Legal Issues	Relevant Laws	Modification / Improvement
Poorly defined water right and legal ownership	• 「Civil Law」 • 「Underground Water Act」 • 「Mange. of Drinking Water Act」	• Define water right, • Legally separate the land ownership and water right of underground water
Water source protection zone' Restrictions	• 「Water Supply and Waterworks Installation Act」 and	Exclude the application of water source protection zone
Water Quality Standards Control	• 「Underground Water Act」 • 「Mange. Of Drinking Water Act」 • 「Water Supply and Waterworks Installation Act」	• Properly mitigate or adjust the water quality standards in the context of project viability • Excessive quality limits may harm the viability of the project
Publicity of water and lack of recognition on the ASR Concept	• 「Underground Water Act」 • 「Mange. Of Drinking Water Act」 • 「Water Supply and Waterworks Installation Act」	• Define the scope of the artificially developed underground water resources • Consideration of economics of ASR project to exclude the publicity of underground water resource

Conclusions

▶ In Korea, some laws including management of drinking water act, water supply and waterworks installation act, underground water act and civil act, where the last two acts are peculiar ones not easily found in other countries, are existent for regulating the development and use of clean underground water storage.
▶ Initially, four major issues in need of modification and improvement of current legal system to accommodate ASR project are extracted and discussed.
▶ Commercial and economic considerations required for the proliferation of ASR project need to be considered and reflected into a unified legal framework in Korea

Induced Bank Infiltration Pilot Project: Water Quality Improvement and Consequencesof River and Lake Reactions within the Aquifer

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KEYWORDS
Bank infiltration . Hydrochemistry . Alluvial aquifer . Groundwater/surface water relations

ABSTRACT
Induced Bank infiltration (BI) is a method that has long been known but still new and not being practiced in Malaysia. At present, the conventional river water treatment for water supply is using chemicals to reduce several contaminants due to pollution. However, chemicalsapplication in drinking water during water treatment could give longterm effects to the health of consumers. BI isnatural process of surface water seeping from the bank or bed of a river to the groundwater production wellsthrough the natural filtration (aquifer) to treating river water. Higher frequency of pollution to rivers in Malaysia could affect the drinking water resources. This paper focuses on field investigation with various types of field data used to determine the potential benefits of BI (geophysical and isotope) and the removal or degradation of contaminations is a combination of physicochemical and biological processes aspects, including the chemistry and quality of BI waterand consequences of the river and lake reactions within the aquifer to evaluate effectiveness of BI method. Physicochemical and microbiological parameters of the local surface water bodies and groundwater were analysed before and during water abstraction. Abstracted water during pumping test at duration of 0.5, 24,48 and 72 hours was carried outwith different distance between the river and the test well, is about 18m for DW2 and 35m for the DW1 respectively. The river water was filtered through a 13 m thick gravelly sand for DW2 and 16 m thick silty sand for DW1.In this result of well placement with different distance provided important information needed to ensured meeting adequate soil retention times and result of water analysis shown that the performances of BI with significant decreased in turbidity, nitrate, aluminium, arsenic sulphate and calcium in BI which were very high in the river. Microorganism counting (*E. coli*, total coliform, *Cryptosporidium* and *Giardia*) confirmed that the microorganism counts were significantly reduced during the passage in BI which is capable to achieve more than 99.9 % removal of *E. coli*, total coliform and *Giardia*.It is shown that, there are very much interest on the effectiveness of BI method for the sustainability of water management in the Langat Basin due to the high water demand in the area

PART A: SITE CHARACTERISTICS-HYDROLOGY, HYDROGEOLOGY, GEOPHYSICS FEATURES

Establishment of the Bank Infiltration site
- Geophysical Investigation
- Construction of Monitoring Wells and Test Wells
- Sieve Analysis for Aquifer Material
- Pumping test
- Stable Isotope study to identify interaction between surface and groundwater
- Defining the localized flow pattern via colloidal borescope tests
- Definition of a regional flow pattern via water level contour

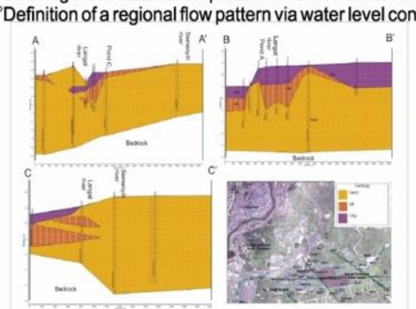
Fig 2. The schematic hydrogeological cross section A-A',B-B' and C-C' is illistrating the aquifer and Bank Infiltration system in Jenderam Hilir

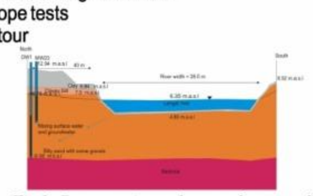
Fig 3. Cross-sections of across the test well DW1 site

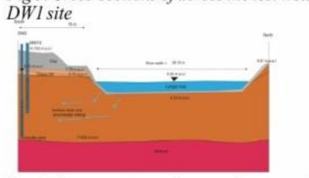
Fig 4. Cross-sections of across the test well DW2 site

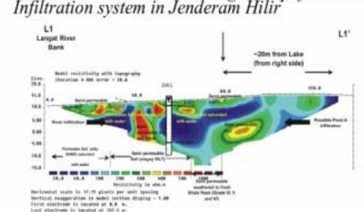
Fig 5. The 2-D image profile for the survey line L1-L1' at the site

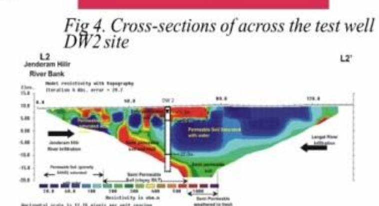
Fig 6. The 2-D image profile for the survey line L2-L2' at the site

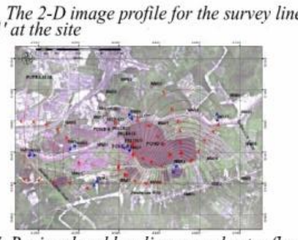
Fig 7. Regional and localize groundwater flow direction at the study site

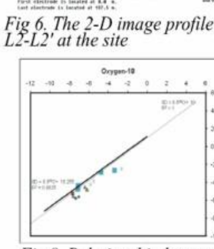
Fig 8. Relationship between $\delta^{18}O$ vs $\delta^{2}H$ for the BI in study area

CONCLUSION
A two-year study was conducted to determine the possibility of implementing the BI system to support the high water demand and cost of water treatments encountered by existing conventional water treatment plants that serve highly populated urban areas. The main issue reported by the poster is on the sustainable management of surface and groundwater. This study essentially explores the possibility of the use of BI to source the polluted surface water in conjunction with groundwater. Three major factors were considered for evaluation, namely, (a) investigation on the contribution of surface water through BI, (b) input of local groundwater, and (c) water quality characteristics of the water supply. The efficiency of BI depends on local conditions such as the hydrology and hydrogeology of the site, the geochemistry of water (from both the river and the aquifer), the geochemistry of microbial populations, and associated metabolic activity. Thus, field investigation with various types of field data used is important to determine the potential and expected efficiency of the BI process. Although the practice of BI has been used in Europe for more than a century, the current understanding of the processes and mechanisms behind this technique remain very empirical. Moreover, its use in tropical countries is almost nonexistent. The use of BI in tropical countries can be promising by studying various types of geophysical data, sieve (particle size) analysis, pumping test data, isotope analysis, colloidal borescope data (to determine the local direction of flow at the well), and water quality data. The issue on removal processes related to water chemistry to explain the filtration effect on water quality in the long term remains in the preliminary stage because the water samples analyzed were only based on a 72-hour (maximum) pumping test. A substantial removal/reduction of contamination and microorganisms during percolation was observed through subsurface systems.

STUDY AREA
The study area is located in the southwest state of Selangor within the Langat Basin, Peninsula Malaysia and extends between latitude 2° 53' 28.56" N and 2° 53' 39.75" N and longitude 101° 42' 03.78" E and 101° 44' 14.58"E, and covers an area of 10 km². The nearest town to the study area is Dengkil, which is located near Putrajaya (the administrative capital of Malaysia) and Kuala Lumpur International Airport (KLIA). Three major tributaries, namely, the main Langat River, Semenyih River, and Jenderam Hilir River, drain the study area. The Langat River Basin is an important water supply source in the Klang Valley. Langat and Semenyih are two primary dams that store water from the Langat River Basin. Eight water treatment plants are found along the Langat River Basin. Since the last 20 years, several occasions where water intakes and treatment plants have been closed because of serious river pollution have occurred. The closure of water intakes and water treatment plants has affected the water supply and economic activities of industries and other sectors. The bedrock in the mountainous area includes Permian igneous rocks and Pre-Devonian schist and phyllite of the Hawthornden Formation. Hawthornden Formation rocks are highly deformed and have undergone two phases of deformation. The predominant rocks in the foothills include Permo-Carboniferous meta-sandstone, quartzite, slates, phyllites and quartz schist of Kenny Hill Formation. In general, these sediments grade downward from clay to gravel, and are deposited in fluvial and shallow marine environments. Coarse to very-coarse sandy gravel of the Simpang Formation (Palaeocene to Pliocene) at the base of the Quaternary strata is considered to be the primary aquifer of the Langat Basin. Typically, the aquifer near the foothills has a thickness of several metres, and varies from about 50 m to more than 100 m further toward the coast. The geology of the Sepang and Kuala Langat District is characterized by the Kenny Hill Formation, Schist Hawthorden, granite, and alluvium. The Kenny Hill Formation, Hawthorden, and granite have a series of faults. The geology of the study area consists of phyllite, schists, slate and sandstone layers, which alternate with the Kenny Hill Formation with some conglomerates overlain by alluvium consisting of sand, gravel, clay, and silt.

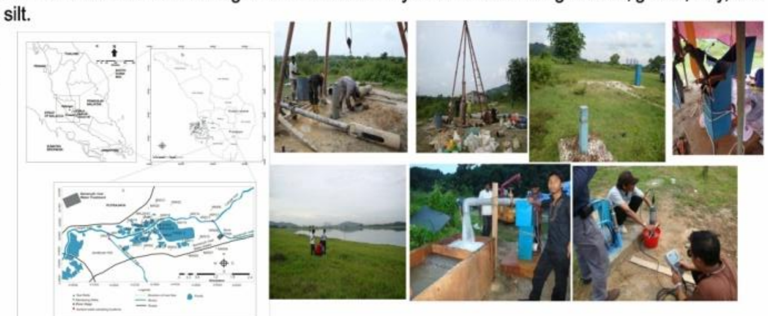
Fig 1. Location of study area and details of the study area including the locations of the Langat river,Semenyih river, monitoring wells and pumping wells

PART B: MICROBIOLOGICAL AND PHYSICOCHEMICAL IMPACT ON GROUNDWATER QUALITY
Water Sampling and analysis
- Physical and Chemical parameter
- Microorganism Counting

Table 1. Water quality during pumping test (abstraction), for period of 0.5, 24, 48, and 72 h and percentage removals of chemicals at DW1 and DW2 wells and Drinking Water Standard, Department of Standard Malaysia (DSM), (2010)

Parameter	unit	Water Quality During Pumping Test For DW1: Langat river upstream	Downstream	DW1 hours 0.5	24	48	72	Percentage Removals	Water Quality During Pumping Test For DW2: Langat River upstream	Downstream	DW2 hours 0.5	24	48	72	Percentage Removals	Drinking Water Standard (2010)
pH		6.6	7	8.1	6.3	6.3	6.9	0	6.3	6.7	7.1	5.26	5.26	5.27	0	6.5-9.0
Colour	H.U.	5	5	5	5	5	5	0	5	5	5	3.5	5.6	8	0	15
Turbidity	N.T.U	187	699	71	60	61	11	98	52	128	14	57	61	60	82	5
Conductivity	µS/cm	4	102	101	101	135	161	0	161	94	211	141	135	130	0	-
SiO_2	mg/l	16	3	8.1	5.4	14.9	7.2	55	7.7	22	6.2	14.2	14.9	13.8	37.27	-
Tot. Solid	mg/l	308	104	108	120	99	98	68.18	206	370	140	92	99	84	77.29	-
Diss. Solid	mg/l	98	16	36	60	86	68	30.61	38	54	120	90	86	83	5.68	1000
HCO_3	mg/l	104	38	51	23	39	66	36.54	41	23	99	38	39	39	4.87	-
Cl	mg/l	24	6	7	7	1.5	0.5	98	11	7	7	1.6	1.5	0.8	93	250
SO_4	mg/l	9	5	3	2	1.89	1.5	83.33	15	10	6	2.61	1.89	3.8	74.66	250
NO_3	mg/l	1	0.01	0.01	0.02	0.46	0.01	98.94	0.03	0.011	0.015	1.12	0.46	0.75	0	10
NO_3	mg/l	16	8.1	2.1	0.6	0.6	0.4	97	16	9.1	1	0.007	0.009	0.009	99.9	10
F	mg/l	<0.5	<0.5	0.5	<0.5	0.2	<0.5	0	<0.5	<0.5	<0.5	0.2	0.2	0.15	0	0.4-0.6
P	mg/l	0	0.02	0.88	0.06	0.04	0.81	0	0.79	0.81	0.76	0.05	0.04	0.05	0	-
NH_4	mg/l	<0.5	<0.5	0.5	0.5	0.5	0.5	0	<0.5	<0.5	<0.5	0.71	0.86	0.86	0	1.5
Al	mg/l	1.2	0.7	0.1	0.2	0.65	0.1	92	2.5	11	<0.1	0.63	0.65	0.78	93	0.2
As	mg/l	0	<0.01	0.09	0.02	0.012	0.02	40	0.03	0.01	0.06	0.016	0.012	0.018	40	0.01
Ca	mg/l	16	9.5	8.4	10	11.9	13	18.75	24	11	32	11.3	11.9	12.63	47.37	-
Fe	mg/l	2.7	3.8	20	10	9.93	9.45	0	3.4	7.9	15	7.93	8.93	8.74	0	0.3
K	mg/l	4.5	3.8	3.6	6	3.48	5.4	0	4.6	4.8	8.3	3.37	3.48	3.68	0	-
Mg	mg/l	1.1	0.8	4	5.1	3.11	5.6	0	1.4	1.5	3	3.1	3.11	3.3	0	150
Mn	mg/l	0.2	3	3.5	0.9	0.95	1.2	0	<0.1	0.2	0.8	0.59	0.62	0.65	0	0.1
Na	mg/l	10	6.4	3.4	4.6	3.01	5.4	46	9.5	5.4	3.8	2.88	2.94	3.12	67.35	200
Zn	mg/l	<0.1	<0.1	0.1	<0.1	0.07	0.1	0	<0.1	<0.1	<0.1	0.06	0.07	0.04	0	3
Cd	mg/l	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	0.003
Co	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01	0	1
Cr	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	<0.01	<1	<0.01	<0.03	<0.03	<0.03	0	0.05
Cu	mg/l	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01	0	<0.1	<0.1	<0.1	<0.01	<0.01	<0.01	0	1

Table 2. Occurrence of Cryptosporidium and Giardia in river water (SW) and test wells (DW) sample in Jenderam Hilir, Dengkil, Selangor and Occurrence of total coliform and E. coli in river water and groundwater (DW) samples in Jenderam Hilir, Dengkil taken in 2010 - 2011

Station No	Sampling Site	Date collected	Sampled volume (liter)	Concentrated volume (ml)	Parasitological Analysis: Giardia cysts/l	Cryptosporidium cysts/l
SW1	Langat river	20/4/2010	20	20	2.9	0
SW2	Langat River	20/4/2010	20	20	0.1	0
DW2	Test well	20/4/2010	20	20	0	0

Samples	Bacteria Analysis: Total Coliform	E. Coli	Sampling No	Total Coliform (MPN/100 ml)	E. Coli (MPN/100 ml)
Langat River	>2420 MPN/100 ml, [illegible]	[illegible] MPN/100 ml, [illegible]	Langat river	[illegible]	[illegible]
			24 hours	<1.0	<1.0
DW1	<1.0 MPN/100 ml, [illegible]	<1.0 MPN/100 ml, [illegible]	48 hours	<1.0	<1.0
			72 hours	<1.0	<1.0
DW2	<1.0 MPN/100 ml, [illegible]	<1.0 MPN/100 ml, [illegible]			

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MAR to MAR-ket

DISSEMINATION AND TECHNOLOGY TRANSFER CRITERIA APPLIED TO MANAGED AQUIFER RECHARGE. A STRATEGIC PROPOSITION AND EXAMPLES TO TRANSFER THESE TECHNIQUES TO INDUSTRY

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ABSTRACT

The main aim of Mar to MAR-ket is to plan a strategy to bring hydrogeology and MAR to the industry, taking notice of the importance of recharged aquifers for future industry advance in a broad range of branches. This line of action is inserted within the framework of DINA-Mar and MAR-SOLutions projects

PLANNED METHODOLOGY

Industry must be aware that much of their future is linked to groundwater

AWARENESS BY ADAPTED DISSEMINATION TECHNIQUES

Water efficiency linked to a bigger productivity and savings
- Permanence and sustainability guarantee
- Lower "Blue print"

MAR-SOLutions´ sequential actions in related industries

First stages:

1. Agro-industry
2. Waste water treatment plants dealers
3. Desalinations agents
4. Bottled companies
5. Golf courses
6. Public Administration branches
7. MAR & SPAs (Sallus Per Aquam)

Market analysis on the potential exploitation of the achieved technological solutions

MAR-SOLutions project

Demo sites

- *Demo sites to show* the suitability of MAR technique
- Sequential actions involving, firstly, related industrial sectors of high visibility
- Technological solutions (wp13)
- Hydro-economic modelling (combines factors hydro (geo) logical, structural, institutional and economic to simulate the evolution of the value of water in space and time)
- 21 partners, 8 countries, 3 years, budget about 11 € M
- Specific action Group (AG):

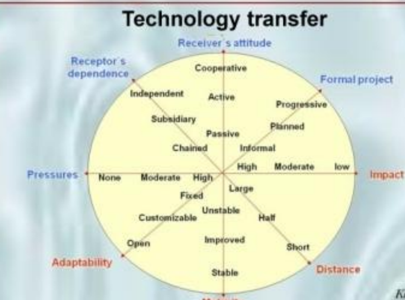
Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought

STRATEGY

- To consider dissemination as a spin-out process from development groups to diffusion circles.
- To employ technology transfer techniques (e.g. diagnosis and technological resources management).
- To prepare a list of materials and activities for different target groups.
- To let the procces be open and adapt it to each country s culture and idiosyncrasies.

Scheme of an action plan that combines general and particular information with the derivative strategies

Technology transfer



Overall representation of the high complexity of a technology transfer project

Technological resources management

	Essential	Suitable	Assistant
Dominated	T1 (key)		T6 (key)
Known	T2 (basic)	T5 (key)	Technologic diagnosis
Unknown		T4 (basic) T3 (emergent)	T7 (emergent)

Relative importance of the technology — Level of absorption in the company

Map illustrating the management of technology resources foccused to target groups (seven different technologies)

$$K = d \cdot e^2 \cdot T^3$$

Strategic objectives: Process

Dissemination circles (6 groups)

Strategic objectives: *D&TT MATRIX*

SOME EXAMPLES FOR ACTIVITIES AND MATERIALS IN THIS TARGET UP TO NOW

CONCLUSIONS

Environmental education and technology transfer are very effective dissemination techniques in Hydrogeology and MAR.

Sharing technological solutions requires :
- High doses of "hidro-imagination". - Patience in the achievement of results - Innovative and participative mentality - *Demo sites*. Correctly executed works - Appropriate follow-up
- *Commitment & generosity*

-It is neccesary to make access to information easy to improve education and hydrogeologic knowledge among users, so as to facilitate their participation.

-The proposed strategy counts on a catalogue of activities and materials focused to target groups & open for future improvements. Each product is a planned process.

Saph Pani – Clean Water

Investigation of organic micropollutants at bank filtration sites in India

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[1]Dresden University of Applied Sciences, Germany; [2]Technische Universität Dresden, Germany

Water pollution by organic micropollutants

Agriculture, municipal and industrial wastewater are sources of organic micropollutants (OMPs, e.g. pharmaceuticals, pesticides and corrosion inhibitors) in surface and ground water. Many OMPs can be removed from raw water for drinking by natural treatment such as bank filtration (BF). However, the time-lag from sampling until analyses in the lab can result in the degradation of OMPs in the aqueous phase e.g. during storage and transport. Thus the objectives of this study were to develop a mobile solid phase extraction (SPE) apparatus for subsequent analyses of the extracted solid-phases in the lab and to investigate the presence of OMPs at various BF sites in India using the new SPE apparatus (Figs. 1, 2 & 3).

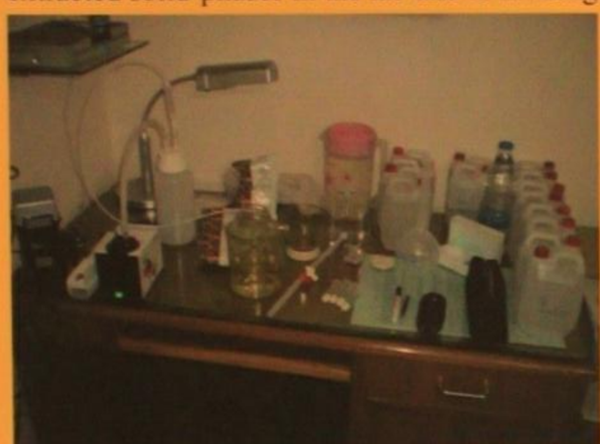

Fig. 1: Mobile extraction unit (in operation in a hotel-room)

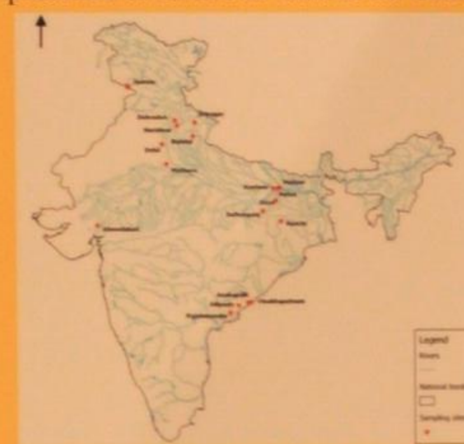

Fig. 2: Location of the sampling sites in India

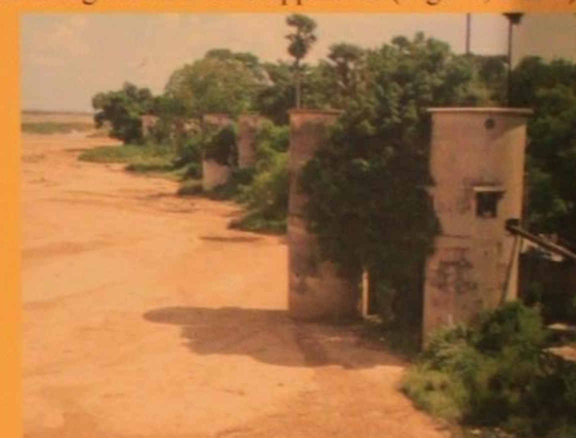

Fig. 3: BF site in Gaya by the Falgu river (south Bihar)

Mobile solid phase extraction

Seventyone water samples were analyzed for 31 OMPs from 18 sites (Fig. 2). The SPE was accomplished in India, within a few hours after sampling (Fig. 1). To extract the solid phase from the aqueous phase with a mobile unit, the extraction method had to be changed. The influence of these changes on the test results were analyzed with 3 pilot tests. The tests verified the influences of storage temperature, conditioning of the cartridges and integration of a clean-up step after the SPE (Figs. 4, 5 & 6).

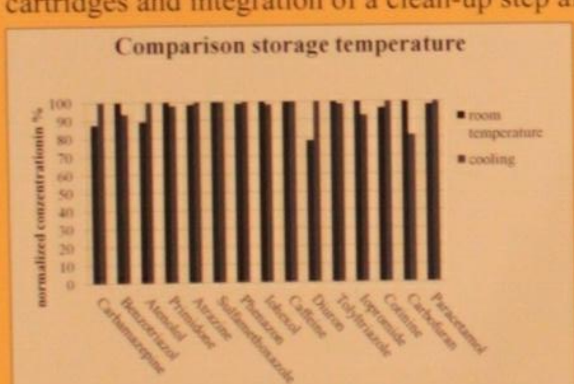

Fig. 4: Pilot test 1, the influence of the storage temperature

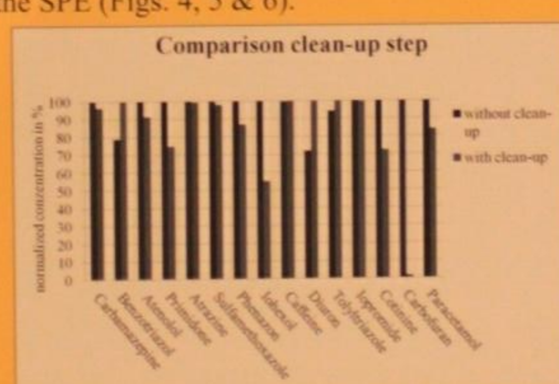

Fig. 5: Pilot test 2, the influence of the clean-up step

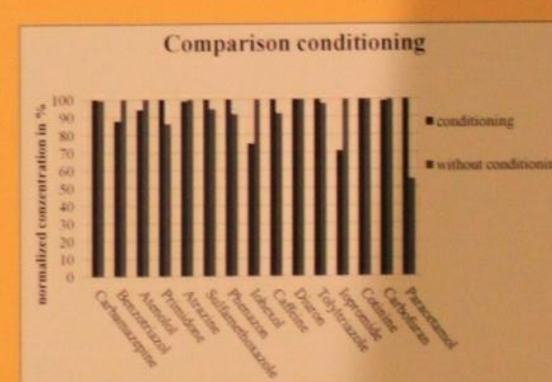

Fig. 6: Pilot test 3, the influence of the conditioning of the cartridges

Tab. 1: Removal of OMPs at selected sites in India (red: Concentration > 100 ng/l)

	Allipudy (Tandava river)	Ranchi (Ranchi lake)	Patna (Ganga river)	Mathura (Yamuna river)	Jammu (Tawi river)
OMPs detected in surface water	Caffeine Iopromide Paracetamol	Caffeine Carbamazepine Iopamidol Sulfamethoxazole Phenanzone Iohexol Diuron Tolyltriazole Iopromide	Caffeine Paracetamol	Caffeine Sulfamethoxazole	Caffeine Paracetamol Atrazine Sulfamethoxazole Iohexol Diuron Iopromide Cotinine Atenolol
OMPs detected in drinking water production well	Caffeine	Caffeine Carbamazepine Iopamidol Sulfamethoxazole Phenanzone Diuron Tolyltriazole	Caffeine	Caffeine Sulfamethoxazole	Caffeine Atrazine
Removal of OMPs [%]	Caffeine 85 Iopromide 100 Paracetamol 100	Caffeine 53 Carbamazepine 56 Iopamidol 94 Sulfatmethoxazole 92 Phenanzone 72 Iohexol 100 Diuron 89 Tolyltriazole 94 Iopromide 100	Caffeine 68 Paracetamol 95	Caffeine 94 Sulfamthoxazole 78	Caffeine 99 Paracetamol 100 Atrazine 99 Sulfamethoxazole100 Iohexol 100 Diuron 100 Iopromide 100 Cotinine 100 Atenolol 100

Results & conclusions

- The mobile solid phase extraction unit is a suitable method to prepare water samples in the field to analyze OMPs
- The influences of the changes in extraction method on test results are very low for most OMPs (Figs. 4, 5 & 6)
- Carbofuran is not detectable after a clean-up step (Fig. 5)
- Some OMPs are detectable in wells at many sites (Tab. 1)
- Caffeine, Paracetamol, Diuron, Sulfamethoxazole and Carbamazepine were found mainly in surface water and also in some wells (Tab. 1)
- The presence of caffeine in all wells is an indication of the impact of domestic wastewater (Tab. 1)
- Bank filtration lowers and in some cases completely removes OMPs from surface water due to degradation, sorption and dilution processes (Tab.1)

Acknowledgements

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- Faculties of Mechanical Engineering / Process Engineering and Civil Engineering/Architecture (Water Sciences) at the HTW Dresden
- National Institute of Hydrology Roorkee and its regional centres in Kakinada, Patna and Jammu
- Department of Civil Engineering (Environmental Engineering) at the Indian Institute of Technology Roorkee
- D.A.V. Post-Graduate College Dehradun
- Riverbank Filtration Cell of Uttarakhand State Water Supply and Sewerage Organisation - Uttarakhand Jal Sansthan

TECHNISCHE UNIVERSITÄT DRESDEN

HOCHSCHULE FÜR TECHNIK UND WIRTSCHAFT DRESDEN

A New Passage to India

A methodological concept for the development of potential bank filtration sites in India

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Motivation

Bank filtration (BF) is gaining awareness as a sustainable alternative and supplement to the direct abstraction of surface water for drinking in urban and rural India (Figs. 1 & 2). However, interactions with Indian water supply organisations have revealed the need for a scientifically based methodology to systematically select, investigate and evaluate potential BF sites. Such a methodology will serve as a tool to enable the development of new full-scale BF systems in India and to address the imminent threat to BF sites from monsoon floods (Fig. 3).

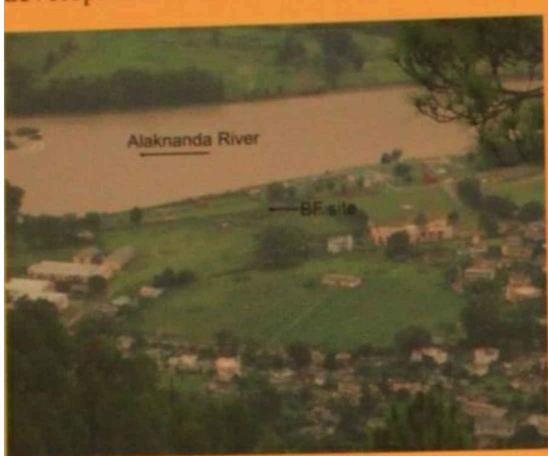


Fig. 1: Location of new BF site under development in Srinagar in monsoon (August) 2011 (Photo: Ebermann)

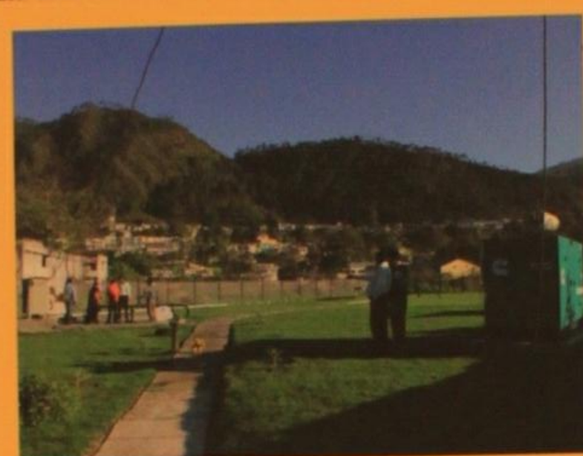


Fig. 2: Production well (left), control-panel (extreme left) and generator of BF site in Srinagar in March 2013 (Photo: Voltz)

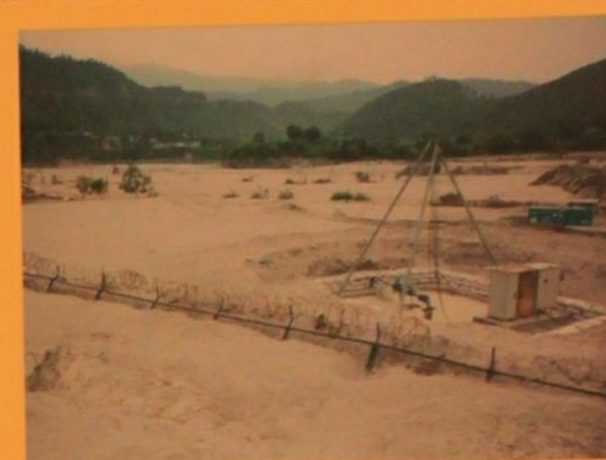


Fig. 3: Deposition of ~1.5 m sand at BF site in Srinagar after extreme flood in June 2013 (Photo: Sandhu)

Methodological concept

The methodological concept is based on hydrogeological investigations and data evaluation (Fig. 5 & Tab. 1) conducted for water supply systems at Haridwar and Patna. Thereafter, the investigation stages 1 to 4 (Fig. 5) were applied to construct (in 2010) and develop four new sites in Srinagar, Agastmuni, Karnaprayag and Satpuli (Fig. 4). The concept has now been modified to include a risk assessment (Fig. 6).

Fig.4: Locations investigated in India for BF (modified from Sandhu et al. 2011)

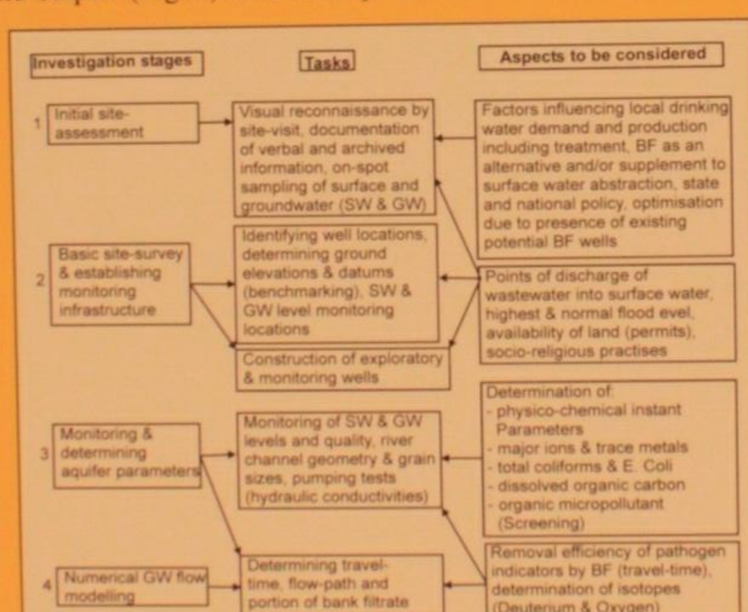


Fig. 5: Methodology to investigate Haridwar and Srinagar for BF

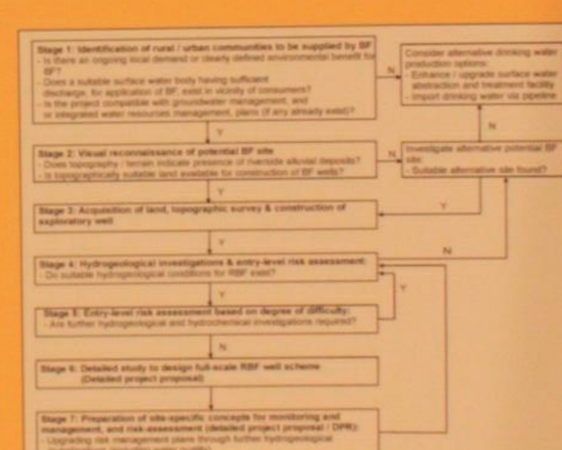


Fig. 6: Modification of the concept to include a risk assessment (after Bartak et al. 2013)

Results

Tab. 1: Summary of results methodology (in Fig. 5)

Parameters	Haridwar	Patna	Srinagar
Production capacity [m³/day] (# of wells)	>43,000 (22)	>3,500 (6)	>4,000 (6)
Aquifer thickness [m]	17	>90	21
Hydraulic conductivity of aquifer [m/s]	1.2×10^{-4} – 4.7×10^{-4}	1.4×10^{-3} – 5.6×10^{-4}	7.7×10^{-5} – 4.0×10^{-3}
Travel-time of bank filtrate	2 – >100 days	ND	~2 years
Mean TOC concentration in well-water [mg/L]	1.0 (n = 23)	2.5 (n = 11)	1.2 (n = 3)
Log_{10} removal of Total Coliforms	2.5 – 4.7	2.3 – 4.4	2.8
Log_{10} removal of E. coli	3.5 – 4.4	ND	>3.4
ND: not determined			

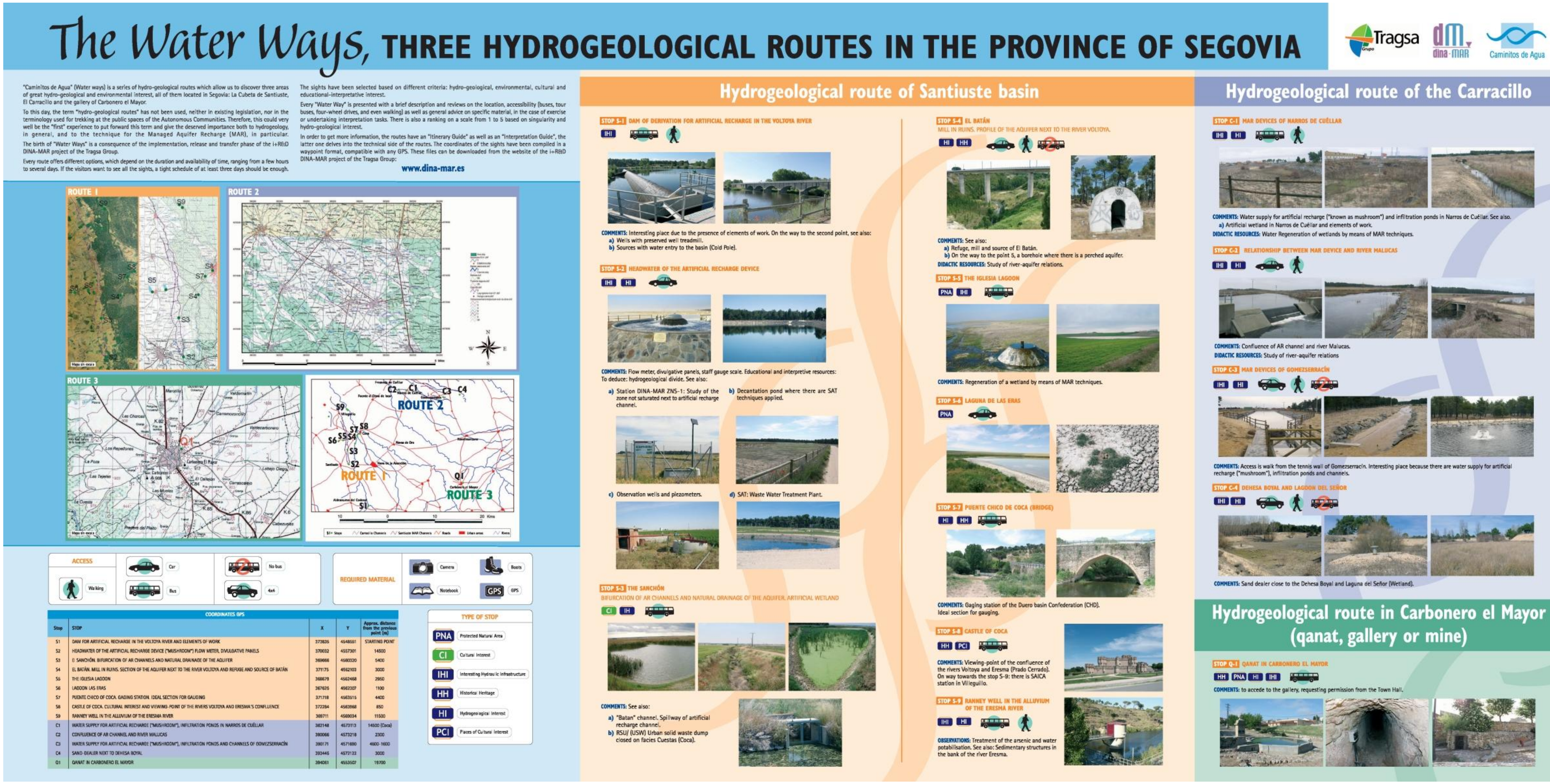
A summary of some of the main parameters indicates that suitable conditions for BF exist at the investigated sites (Tab. 1). Furthermore, all other water quality parameters were within the limits for drinking water (Indian Standard), except high nitrate in BF well-water in Srinagar.

Main conclusions for the application of the methodology for the investigation of potential BF sites are: 1) Limitations of access for well drilling equipment in mountainous areas; 2) aquifer thickness in hills is limited, thus use of horizontal collector-pipes can be an alternative to vertical wells; 3) the extreme flood of June 2013 in Uttarakhand underlined the importance of constructing flood proof wells, an assessment of the deposition of sediment and preventing bank erosion; 4) contamination from land-side groundwater is usually a threat for BF sites downstream of habitations, the source of which can be traced by including an analyses of organic micropollutants, 5) presence of confining clay extending beneath the riverbed in the lower courses of the Ganga and its tributaries can be a limiting factor for BF.

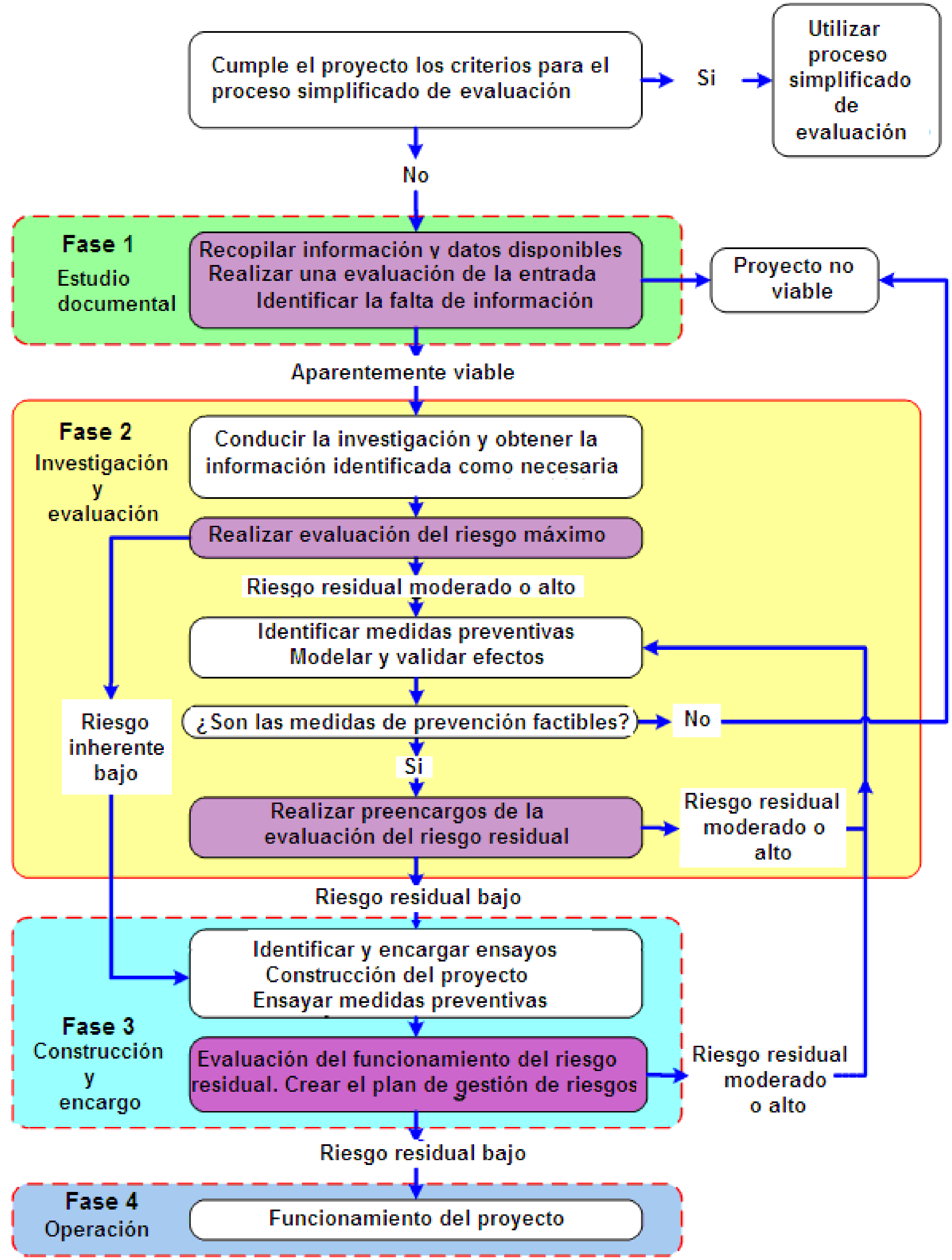
HOCHSCHULE FÜR TECHNIK UND WIRTSCHAFT DRESDEN UNIVERSITY OF APPLIED SCIENCES

Acknowledgement

Co-funding of the Saph Pani project by the European Commission within the 7th Framework Programme under Grant agreement number: 282911 is kindly acknowledged

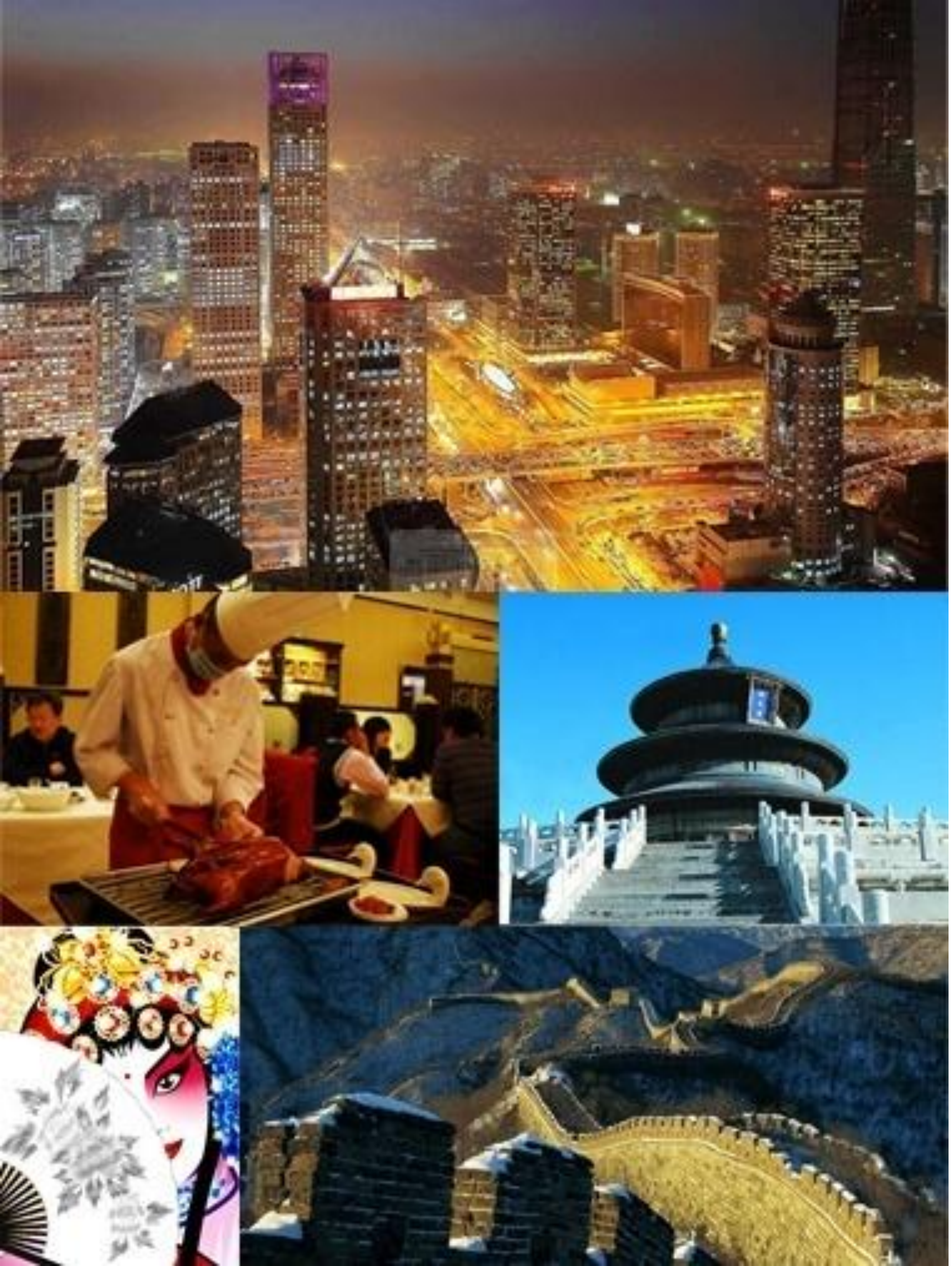

The Water Ways, THREE HYDROGEOLOGICAL ROUTES IN THE PROVINCE OF SEGOVIA
Tragsa
dina-MAR
Caminitos de Agua
"Caminitos de Agua" (Water ways) is a series of hydro-geological routes which allow us to discover three areas of great hydro-geological and environmental interest, all of them located in Segovia: La Cubeta de Santiuste, El Carracillo and the gallery of Carbonero el Mayor.
To this day, the term "hydro-geological routes" has not been used, neither in existing legislation, nor in the terminology used for trekking at the public spaces of the Autonomous Communities. Therefore, this could very well be the "first" experience to put forward this term and give the deserved importance both to hydrogeology, in general, and to the technique for the Managed Aquifer Recharge (MAR), in particular.
The birth of "Water Ways" is a consequence of the implementation, release and transfer phase of the i+R&D DINA-MAR project of the Tragsa Group.
Every route offers different options, which depend on the duration and availability of time, ranging from a few hours to several days. If the visitors want to see all the sights, a tight schedule of at least three days should be enough.
The sights have been selected based on different criteria: hydro-geological, environmental, cultural and educational-interpretative interest.
Every "Water Way" is presented with a brief description and reviews on the location, accessibility (buses, tour buses, four-wheel drives, and even walking) as well as general advice on specific material, in the case of exercise or undertaking interpretation tasks. There is also a ranking on a scale from 1 to 5 based on singularity and hydro-geological interest.
In order to get more information, the routes have an "Itinerary Guide" as well as an "Interpretation Guide", the latter one delves into the technical side of the routes. The coordinates of the sights have been compiled in a waypoint format, compatible with any GPS. These files can be downloaded from the website of the i+R&D DINA-MAR project of the Tragsa Group:
www.dina-mar.es
ROUTE 1
ROUTE 2
ROUTE 3
ACCESS
Walking
Car
Bus
No bus
4x4
REQUIRED MATERIAL
Camera
Notebook
Boots
GPS
COORDINATES GPS
Stop | STOP | X | Y | Approx. distance from the previous point (m)
S1 | DAM FOR ARTIFICIAL RECHARGE IN THE VOLTOYA RIVER AND ELEMENTS OF WORK | 373835 | 4548551 | STARTING POINT
S2 | HEADWATER OF THE ARTIFICIAL RECHARGE DEVICE ("MUSHROOM") FLOW METER, DIVULGATIVE PANELS | 370032 | 4557301 | 14500
S3 | EL SANCHÓN. BIFURCATION OF AR CHANNELS AND NATURAL DRAINAGE OF THE AQUIFER | 369686 | 4560320 | 5400
S4 | EL BATÁN. MILL IN RUINS. SECTION OF THE AQUIFER NEXT TO THE RIVER VOLTOYA AND REFUGE AND SOURCE OF BATÁN | 371175 | 4562103 | 3000
S5 | THE IGLESIA LAGOON | 368679 | 4562468 | 2950
S6 | LAGOON LAS ERAS | 367625 | 4562307 | 1100
S7 | PUENTE CHICO OF COCA. GAGING STATION. IDEAL SECTION FOR GAUGING | 371718 | 4563515 | 4400
S8 | CASTLE OF COCA. CULTURAL INTEREST AND VIEWING-POINT OF THE RIVERS VOLTOYA AND ERESMA'S CONFLUENCE | 372284 | 4563968 | 850
S9 | RANNEY WELL IN THE ALLUVIUM OF THE ERESMA RIVER | 368711 | 4568034 | 11500
C1 | WATER SUPPLY FOR ARTIFICIAL RECHARGE ("MUSHROOM"), INFILTRATION PONDS IN NARROS DE CUÉLLAR | 382148 | 4573113 | 14500 (Coca)
C2 | CONFLUENCE OF AR CHANNEL AND RIVER MALUCAS | 380066 | 4573218 | 2300
C3 | WATER SUPPLY FOR ARTIFICIAL RECHARGE ("MUSHROOM"), INFILTRATION PONDS AND CHANNELS OF GOMEZSERRACÍN | 390171 | 4571680 | 4600-1600
C4 | SAND-DEALER NEXT TO DEHESA BOYAL | 393446 | 4572122 | 3000
Q1 | QANAT IN CARBONERO EL MAYOR | 394061 | 4553507 | 19700
TYPE OF STOP
PNA Protected Natural Area
CI Cultural Interest
IHI Interesting Hydraulic Infrastructure
HH Historical Heritage
HI Hydrogeological Interest
PCI Places of Cultural Interest
Hydrogeological route of Santiuste basin
Hydrogeological route of the Carracillo
Hydrogeological route in Carbonero el Mayor (qanat, gallery or mine)

Risk assessment



MAR Risk assessment, CSIRO. Modified from DINA-MAR

Notes



Notes

8TH INTERNATIONAL SYMPOSIUM ON MANAGEMENT OF AQUIFER RECHARGE, ISMAR-8, POSTERS. BEIJING, CHINA.

8º SIMPOSIO INTERNACIONAL DE GESTIÓN DE LA RECARGA DE ACUÍFEROS ISMAR-8, POSTERS. PEKÍN, CHINA.

P-ISMAR 8

Managed Aquifer Recharge:
Meeting the Water Resource Challenge