United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme of UNESCO

The General Water Authority, Libyan Arab Jamahiriya

Sahel and Sahara Observatory

Managing Shared Aquifer Resources in Africa

Co-organized by
The General Water Authority
Libyan Arab Jamahiriya

UNESCO-IHP
and **Sahel and Sahara Observatory**

Tripoli 25– 27 May 2008

THIRD INTERNATIONAL CONFERENCE

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme of UNESCO

The General Water Authority, Libyan Arab Jamahiriya

Sahel and Sahara Observatory

Third International Conference on

Managing Shared Aquifer Resources in Africa

Tripoli, Libya, 25-27 May 2008

Book of Abstracts

Objectives and Scope of the Conference

The Conference will provide a valuable input to the seventh phase of the UNESCO IHP and will contribute to the current debate on transboundary aquifers management. The outcomes of the conference could provide beneficial information for some of the related activities to be organized by international organizations during the next years.

Amongst these are the debate on transboundary aquifers in Africa that takes place at the Stockholm Water Week and the upcoming Seminar in August 2008, the 5th World Water Forum (WWF) sessions on Transboundary Waters and the UN World Water Day on 22 March 2009, the theme of which will be "Transboundary Waters".

The conference will provide an overview about **what we know about transboundary aquifers in Africa** (session 1) and the activities initiated by the UNESCO ISARM Project in Africa. It will provide the opportunity to expand the existing network of experts and make proposals for new sub-regional activities.

The conference will serve as a platform to debate and evaluate the **Management of Transboundary Aquifers** up to the present (session 2). It will consider experiences related to the existing scientific knowledge, assessment methodologies, management constraints, data availability, monitoring systems, environmental impacts and criteria for non-renewable water resources.

Several international and regional organizations are evaluating the real possibility to achieve the management of surface and groundwater resources as following the indications provided by the IWRM approach. At the latest Stockholm Water Week one of the seminars discussed if and how groundwater can be considered as an integral part of transboundary river/lake basin management in Africa. Can existing institutions or river basins commissions jointly manage international river basins and transboundary aquifer resources under the present conditions? The question is still open. The conference will try to contribute to this debate.

"**Looking into the Future: What options do we have?**" will be the guiding question in session 3, evaluating options for the future of Transboundary Aquifer Management considering Institutional and Legal Aspects, Governance and Policy Guidance as well as Economic Aspects and Financial Instruments.

Session 4 of the conference will provide information on the Global Environment Facility's International Waters Learning Exchange and Resource Network (GEF – IW:LEARN) and case studies conducted in this framework. The Transboundary Diagnostic Analysis (TDA) methodology will be presented and possibilities how it could be adopted to groundwater resources will be discussed.

During a **Round Table Discussion** on the **Role of the UNESCO Category 2 Regional Center on Shared Aquifer Resources Management in Africa** the participants are invited to provide inputs and debate on the mission of the Center, future cooperation with existing institutions and a **Plan of Action for Shared Aquifer Resources Management in Africa**. The results of the debate will be compiled by a drafting group and presented and discussed at the last plenary session of the conference.

The output of this conference will be compiled and sent as "**Message from Tripoli III**" to the 5th World Water Forum 2009 in Istanbul.

Translation will be provided English-French and French-English.

Conference Programme

		Day 1	Day 2	Day 3		
	24 May	25 May	26 May	27 May	28-29 May	30 May
08:00 - 09:00	Arrival of Delegates and Registration	**Registration**			Field Trip	Departure of Delegates
09:00 - 09:30		**Opening Ceremony**	**Session 2:** *Management of Transboundary Aquifers: How have we been doing?*	**Session 4:** *GEF-IW:LEARN*		
09:30 - 10:00						
10:00 - 10:30						
10:30 - 11:00		*Coffee Break*	*Coffee Break*	*Coffee Break*		
11:00 - 11:30		**Opening Speeches**	**Session 2 (contin.)**	Opening Ceremony RCSARM		
11:30 - 12:00				**Round Table Discussion**: *The Role of UNESCO Category 2 Centre (RCSARM)*		
12:00 - 12:30			**Round Table**			
12:30 - 13:00		*Lunch Break*	*Lunch Break*	*Lunch Break*		
13:00 - 13:30						
13:30 - 14:00						
14:00 - 14:30		**Session 1:** *What do we know about Transboundary Aquifers in Africa?*	**Session 3:** *Looking into the Future: What Options do we have?*	Acceptance of the Conference Statement		
14:30 - 15:00						
15:00 - 15:30						
15:30 - 16:00				**Plenary Session/Round Table**		
16:00 - 16:30						
16:30 - 17:00		*Coffee Break*	*Coffee Break*			
17:00 - 17:30		**Session 1 (contin.)**	**Session 3 (contin.)**	**Closing**		
17:30 - 18:00						
18:00 - 18:30		**Round Table**	**Round Table**			
after 18:30			Work of Drafting Group			

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SESSION 2

Management of Transboundary Aquifers: How have we been doing?

SESSION 3

Looking into the Future: What options do we have?

SESSION 4
GEF-IW:Learn

ROUND TABLE DISCUSSION
the role of the UNESCO Category 2 Regional Centre on Shared Aquifer Resources Management in Africa (Tripoli, Libya)

POSTER PRESENTATIONS

Opening ceremony

Transboundary Aquifer Resources Management
General Overview and Objectives of the Conference

Omar Salem
General Water Authority (Libya)

In arid and semi arid regions, groundwater is either the main or only available source of water supply and may occur in transboundary aquifers that require joint management for their sustainable development.

Libya shares several aquifer systems with neighboring countries, namely the Gefara Aquifer with Tunisia, the North Sahara Aquifer System with Algeria and Tunisia, and the Nubian Sandstone Aquifer System with Egypt, Sudan and Chad. Coordination among water authorities in these countries developed into agreements for conducting joint studies and monitoring programmes under permanent institutions such as the Joint Commission for the Study and Development of the Nubian Aquifer System which was established in Tripoli in 1989 between Libya and Egypt and joined at a later stage by Sudan and Chad, and the Coordination Unit between Libya, Algeria and Tunisia for the joint management of the North Sahara Aquifer System which was approved in 2002.

Libya has requested the International Hydrological Programme (IHP) Council to establish a regional centre under the auspices of UNESCO devoted for shared aquifers in Africa and the Arab region, aiming at providing training facilities to African experts and organizing seminars and meetings to facilitate the sharing of knowledge among African countries. The Centre will also enhance technical and scientific cooperation at regional and international levels. In 27/12/2007, a protocol for the establishment of the Centre was signed in Tripoli between the Director General of UNESCO and the Secretary of Agriculture of Libya. The Centre is now officially established and the following period will be totally dedicated for the nomination of administrators, securing working budget, and preparing work plans. The current Conference is expected to assist in the efforts already taken in this direction.

The third International Conference on Managing Shared Aquifer Resources in Africa (Tripoli III) is the result of several meetings between the General Water Authority of Libya (GWA), UNESCO and Sahel and Sahara Observatory (OSS). The Conference comes as an implementation of the Sirte Declaration of the African Union extraordinary summit on agriculture and water (Sirte 2004) which calls for:

- Strengthening centers of excellence and /or networks and their establishment for crops, animals, forestry, fisheries, water and environmental management
- Encouraging bilateral agreements on shared water management

The Conference, throughout its technical sessions, will review experiences on existing scientific knowledge, leading to the establishment of a plan of action for shared aquifer systems resources management in Africa.

The road to Tripoli III: what was discovered on the way, and where to next?

Shammy Puri
IAH Chair of the TARM Commission and Co-coordinator of the ISARM Programme

The IIIrd Conference in 2008, to be held I Tripoli, on the subject of Africa's shared-transboundary aquifers management is a celebration of the many achievements since the first such conference held in 2000. Since then, significant developments have taken place not only in Africa, but also in other parts of the World, where the ISRAM Programme has been active. This presentation will trace the background to the initial scientific conceptualisation of the issue, highlight that it was at the sequential Tripoli Meetings that an international group Experts first gave support to the consideration of regional aquifer systems in a holistic manner, many of which transcend international boundaries and then also developed the first continent wide inventory for Africa. Concurrently, the scientific developments in the Americas, the Balkans, Easter Mediterranean region, and in Asia have given a sound foundation to the understanding of the science and to the gaps in policy, both at the national level and at the international level. The latter has resulted in the development of Draft Articles on the Use of Transboundary aquifers, which may well become an important international legal instrument in the near future. The presentation will also give a perspective on the 'way ahead', especially in the context of the new Regional Centre on Shared Aquifers Resources in Africa. The establishment of such a centre with support from international organisations will meet the future needs of young scientists from Africa, in addressing their shared visions, and will fill the capacity gaps that currently are a constraint to bringing the science into policy.

Management of Transboundary Aquifer Systems: a world wide challenge, a need for concertation

Didier Pennequin
Water Director, BRGM

Eight to ten million km^3 of groundwater are supposed to constitute about 98 to 99% of the world's soft water stocks (in comparison all surface water systems together represent less than 1%), of which only a small part (a few % of renewable water, 10 Md. m^3 ?) can practically be used. Today Man withdraws from the earth's sub-surface 200 times more water than petroleum. Most of the groundwater abstraction is used for human needs (to cover more than 50% of the needs), agriculture (a large part) and industry. Groundwater plays a major role in the world water economy and contributes for a large part in the food security. Almost all countries use groundwater; for some of them, including in Africa, this is the basic (and sometimes the only) water resource.

However, although globally plentiful, groundwater availability and water needs do not always coincide in many parts of the world. Moreover, stresses on groundwater are important in many places, both in terms of quantity and quality, and they are likely to increase in the future with the climatic and the global changes.

To cope with this situation and this trend, it is mandatory to enhance sustainable development, management and protection of the water resources. This is needed to fulfil present-day needs and to preserve the socio-economic activities in many areas, but even more so, to ensure availability of the resources and well being for future generations. This is the core idea of the European Water Framework Directive which recommends management of the water resources at the basin scale, including in the cases of transboundary water resources which are numerous in all continents, including in Africa. This implies that integrated water resources must be achieved, meaning that it must involve all physical and environmental parameters, including both surface and groundwater whenever it is needed, but also all socio-economical factors to ensure sustainability. In the case of many countries, cultural aspects must often be added to this list.

Sustainable water resource management is therefore not an easy concept to apply when the water resource lies entirely within one country, or within one socio-economico-political system. However, it is even more difficult in the cases of transboundary water resources, and particularly when it includes groundwater systems which are not readily visible to the populations. In these cases, the challenge is great, but not insurmountable.

Solutions for integrated and sustainable transboundary water resource management and protection, and particularly when large aquifer systems are at stake, involve (1) gathering the necessary knowledge about the water resource and its overlying socio-economic context, and (2) building efficient management and decision support tools which will help to first understand the water resource system, and next to allow for the water resource's manager to do his job correctly on the basis of sound information. However, this is clearly not enough: there is also a need for (1) having a strong political will and support to collaborate toward a common objective (based on the shared water resource concept), (2) adequate institutional structures to organize and perpetuate the efforts and (3) the necessary laws and regulations to set up the framework.

New dimensions in studying shared aquifers in Africa

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OSS Advisor in water resources
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In attempts to optimize the future development of a trans-boundary basin, certain types of approaches, should be sought preferentially, both by institutions dealing with trans-boundary water resources and by national water authorities themselves.

A consideration of the Case Studies and other trans-boundary water resources has shown that several factors with potential contributions to the optimal future development of trans- boundary basins are of frequent importance, but have received insufficient attention from most researchers of which seismic events inducing hydrological changes has not received sufficient attention although many parts of African continent are located at the intersection of two seismically active tectonic belts. Moreover, the proper management of transboundary aquifers in Africa should consider all factors in hand in an attempt to promote a "basin awareness" by working to increase and exchange knowledge on these units (geological, hydro geological and geophysical as well as improvement of models, etc.), creation of effective joint structures in the face of still poorly mastered resource management. The programme of joint Management of Shared Water Resources seeks to achieve the realization of in-depth studies of the risk zones exemplified herein by the seismic risk and /or events impacted on the clear decline in the groundwater level after the earthquake, a situation which will renders groundwater levels deduced from any model invalid.

Now researchers have established a more subtle effect for shaking of aquifer materials by seismic waves--it increases the permeability of rock to groundwater and other fluids.

Seismic events inducing –hydrological changes is a new dimension that should be sought preferentially in studying shared aquifers in Africa and though it represents a modest step, it can help in the improvement of water management structure and in the development of new techniques.

The integration of water management and the resolving of conflicts can usually be achieved by a combination of institutional, and technical of which new approaches such as the consideration of seismic events should be sought preferentially.

Impact of climate change on transboundary aquifers and adaptation measures

Richard Taylor[1] and Alice Aureli[2]
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2) UNESCO Division of Water Sciences, 1 rue Miollis, 75732 Paris Cedex 15 France

Intensification of the global hydrological system brought about by climate change is predicted to accentuate current inequities in the distribution of precipitation. Over the next century, sub-tropical regions in Africa (Sudo-Sahelian Africa, southern Africa) as well as the 'Horn of Africa' are expected to experience a reduction in precipitation and fewer rainfall events whereas the humid tropics are predicted to feature an increase in precipitation involving fewer but more intense rainfall events. Considerable uncertainty exists regarding the impacts of these hydrological changes on groundwater resources due, in part, to more variable recharge regimes and increased groundwater withdrawals. The latter are expected to result from increased domestic demand due to population growth and increased irrigation as a result of reduced soil moisture and prolonged dry periods in semi-arid regions as well as increased evaporation under warmer air temperatures in arid regions. In humid regions, more frequent heavy rainfall events may increase the risk of groundwater contamination by pathogenic microorganisms through enhanced flushing of inadequately contained faecal wastes. For coastal aquifers, sea-level rise decreases the depth of the freshwater-seawater interface yet there is substantial uncertainty in the magnitude of sea-level rise over the 21st century. Its impacts on groundwater availability will depend, furthermore, upon not only the height of the water table above sea level but also employed abstraction regimes. All of these uncertainties in the impacts of climate change on groundwater resources combined with intrinsic limitations in our knowledge of the extent and properties (storage, flow) of aquifers pose immense challenges to equitable sharing of transboundary groundwater.

The impacts of climate change on the management of transboundary aquifers have yet to receive formal consideration in international fora on climate change (e.g. IPCC) and transboundary aquifers (e.g. ISARM). In Africa and around the globe, equitable sharing of groundwater from transboundary aquifers will require quantitative groundwater management strategies that consider the dynamic and transient nature of groundwater availability and demand as a result of climate change. How each region addresses this challenge remains an open, but critical, question. UNESCO-IHP's global programme, GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change), promotes sustainable management of groundwater in the face of climate change and linked human impacts through information exchanges and technical guidance by regional networks of experts who coordinate thematic working groups around representative case studies. Working under the umbrella of AMCOW, a similar model might usefully be considered for a coordinated African initiative on the management of transboundary aquifers under conditions of climate change. Supported by governments from countries primarily responsible for climate change, the initiative could be implemented through the newly established African Groundwater Commission and feature regional working groups that also engage in inter-regional dialogue around shared management challenges and uncertainties (e.g. aquifer environments, development scenarios). Case studies could be drawn from existing initiatives (GRAPHIC, ISARM) and the upcoming Groundwater & Climate in Africa conference in Kampala (June 2008). Such a strategic, continent-wide platform could strengthen institutional capacities and facilitate cooperation and the exchange of information. This model would, furthermore, encourage efficient, sustainable support from African water ministries and the donor community as well as the development of clear and complementary strategies to mitigate and adapt to the impacts of development and climate change

Challenges to Transboundary Aquifer Management in the SADC region

Philip Beetlestone, Phera Ramoeli
SADC Water Division, Gaborone, Botswana

The Southern African Development Community (SADC) within its Regional Strategic Action Plan on Integrated Water Resources Development and Management (1998) developed and adopted a regional Groundwater Management Programme (GMP, 1999) to focus on the exchange of information, research and training, monitoring, mapping, characterisation and management of transboundary groundwater resources. The overall objective of the GMP is to promote the sustainable development of groundwater resources at a regional level, incorporating research, assessment, exploitation and protection, particularly related to drought management and to integrate groundwater issues in the joint management of International River Basins. The GMP consists of 10 priority Projects within a framework of regional co-operation and development. Since 2002, SADC has begun to implement projects within the GMP. This presentation follows up on a previous presentation at ISARM in Tripoli 2002 and highlights the progress and challenges to transboundary aquifer management in SADC during the execution of its GMP.

SESSION 1

What do we know about Transboundary Aquifers in Africa?

Main achievements in the management of transboundary aquifers in Africa and relevance for national policy

Bo Appelgren
Senior UNESCO Consultant

The groundwaters in Africa, most of which is located within transboundary aquifer systems, represent a current and potential future strategic supply for social and economic use. The size of the transboundary aquifer systems vary over a wide range, from small local border aquifers to sub-regional systems with extensions of more than 3 million km^2, and with a corresponding water balance, with renewable and non-renewable flow and storage resources and water quality conditions and level of utilization, ecological flows and in- and outflows to neighboring water systems. The systems include alluvial, sedimentary, volcanic, limestone and basement aquifers and range from shallow water table aquifers related to surface water courses to deeper confined aquifers with limited recharge that are unrelated and interact with surface-water flow systems only occasionally. The African coastal aquifers (e.g. in the Mediterranean and the Gulf of Guinea) are characterized by important very substantial discharges into common coastal and marine water bodies and also transboundary in a perspective of regional water use and development with rapid urbanization and population concentrations and mega-cities in the rapidly growing, socio-economically important coastal zone. With the increased pressures, the coastal zone is becoming water scarce, polluted and vulnerable to seawater intrusion and negative impacts of climate change and sea level rise and the management of the coastal aquifers is emerging as a priority development and sustainability concern.

Implementation of transboundary aquifer management is ultimately referred to policy interventions and investments at the domestic and local level. In a regional perspective, the set-up for transboundary aquifer management in Africa is characterized by the number of multi- and bilateral interactions, with individual aquifers shared by up to six or more countries, and on the other hand African individual countries sharing up to six seven or more regional aquifers. It is argued that, as a complement and alternative to repetitive parallel bilateral and basin arrangements, it would be more cost-effective to provide guidance and support for harmonized policies and coordinated and consistent country action under a region-wide transboundary aquifer management program.

The African and the sub-regional water sectors are development and action oriented evolving in a direction of regional cooperation and common harmonized approaches, based on IWRM and focused on operational targets for drinking water supply for alleviation of poverty, and enhanced water productivity for improved growth, food security and well distributed welfare over the region. The priority is to mobilize the common natural resources in the region and secure technology and funding in local and external partnerships.

Within the envision of: "Africa as a region, where shared aquifers are jointly managed to satisfy local/ national/ regional water requirements to attain sustainable development" proceeding from the resolutions and outcomes of the two previous Tripoli International Groundwater conferences and workshops: Tripoli I: International Conference on «Regional Aquifer Systems in Arid Zones – Managing non-renewable resources», November 1999, and Tripoli II: International Workshop

on 'Managing Shared Aquifer Resources in Africa', June 2002, the main achievements in transboundary aquifer management in Africa, and the relevance for national policy and intervention for action in the African countries are reviewed and assessed.

The overview includes major regional institutional initiatives and resolutions, recent inventories, surveys and mapping of transboundary African aquifer systems, and the sub-regional initiatives and programs under the ISARM program together with African aquifer case studies, projects and references and compared with parallel ISARM programs in other regions and assessed for relevance with current global initiatives including the ongoing UN-ILC project on the Law on Transboundary Aquifers. The overview is concluded with a discussion proposal for an integrated regional program for well focused, effective and timely action to address, enable and drive transboundary aquifer management at regional and domestic level.

Transboundary Groundwater Management in the River Basin Organisations of SADC

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Possible unsustainable exploitation or pollution of shared groundwater resources by more than one country make it extremely important to take pre-emptive, appropriate measures to avoid possible future conflicts. This can be achieved when the respective countries cooperate by jointly locating and investigating groundwater environments that are of a transboundary nature. Measures can be agreed upon to manage the aquifer on a joint basis to obtain the maximum benefits for each of the countries without jeopardizing the integrity of the aquifer to the detriment of future beneficial use by any one of these involved.

Within the Southern African Development Community (SADC) the extent to which the principles for the management of surface water resources can be applied or adjusted to suit transboundary groundwater resource management have not received the required attention. The existence of transboundary aquifers in the SADC region has not been investigated comprehensively. Without prior knowledge about the extent and properties of the transboundary aquifers it is difficult to put the necessary appropriate management structures in place.

An ISARM SADC initiative, organized by UNESCO, commenced in March 2007 and it was realized that the number of transboundary aquifers (TBAs) thus far identified are not exhaustive and many new TBAs were identified. A Tri-State meeting between Botswana, Namibia and South Africa followed this meeting in July 2007 where it was decided to commence with the first combined investigation of the Karoo Basin TBA underlying the Kalahari in SW Namibia as well as bordering Botswana and South Africa. The main objective is to gather sufficient information in order to address legal, social, economic and ecological aspects in the area.

In order to best manage the aquifer its extent and properties must fully be understood. Only then can the best management strategy be designed and the needs of the three countries in this Karoo Basin area be optimally addressed. The wider purpose of the study is to propose possible ways of implementing better transboundary aquifer management within SADC.

Les aquifères transfrontaliers du circum-Sahara et les changements climatiques : améliorer la compréhension des enjeux

Charles Baubion, Ahmed Mamou
Observatoire du Sahara et du Sahel

Avant d'explorer spécifiquement le cas des aquifères transfrontaliers circum-sahariens, il est nécessaire de préciser les multiples relations, impacts directs et indirects entre les eaux souterraines de façon générale et les changements climatiques en Afrique.

L'impact le plus direct du changement climatique sur les eaux souterraines concerne la recharge des aquifères. L'accroissement de la variabilité des précipitations, leur diminution, leur augmentation, ainsi que le changement de leur répartition spatiale et temporelle affecteront directement la recharge des aquifères. C'est aussi l'augmentation des phénomènes climatiques extrêmes et en particulier des inondations qui pourra participer à augmenter la recharge. A contrario, la recharge sera réduite en général par l'augmentation de l'évapotranspiration liée à celle des températures. Et en outre, l'évolution probable de la végétation dans les zones de recharge perturbera les processus d'infiltration des eaux dans le système sol-plante et donc à nouveau la recharge (IPCC, 2007)[1].

D'autre part, l'impact du changement climatique sur les débits des fleuves et rivières ou le niveau des lacs modifiera aussi la piézométrie des aquifères à travers le lien entre les eaux de surface et les eaux souterraines. Lorsque les connexions et les échanges hydrauliques entre les systèmes de surface et souterrains sont productifs et la recharge faible, les évolutions du niveau des fleuves et rivières peuvent influencer par ailleurs bien plus la piézométrie des aquifères que les variations de la recharge.

De façon plus indirecte, mais pas forcément moindre, le changement climatique affectera directement la demande en eau qui sera amenée à s'accroître significativement, et concernera tout autant les aquifères que les eaux de surface. Certes l'augmentation de la demande ne sera pas liée uniquement au changement climatique, qui est à mettre en regard de l'augmentation démographique, entre autre. Néanmoins, l'augmentation des températures renforcera les besoins en eau des plantes dans les zones irriguées et donc les prélèvements sur les eaux souterraines. L'accroissement de la variabilité climatique, qui entraînera une variabilité plus forte de la disponibilité des ressources en eau de surface renforcera en particulier la pression sur les eaux souterraines. Toujours en ce qui concerne la demande, l'impact des changements climatiques sur les migrations accentuera les phénomènes d'exode rural vers les villes, renforçant dés lors la demande urbaine en eau, et donc les prélèvements dans les aquifères qui fournissent l'eau potable de la majorité des villes d'Afrique.

En ce qui concerne la qualité des eaux souterraines, le risque d'augmentation du niveau des mers pourra avoir un certain impact sur l'intrusion des eaux salées des mers au sein des aquifères côtiers, surtout si elle se conjugue avec une augmentation des prélèvements et les rabattements piézométrique que celle-ci entraînerait. Et l'accroissement de l'évapotranspiration dans les régions arides et semi-arides augmentera les risques de salinisation des sols puis des nappes phréatiques. C'est aussi l'infiltration des eaux stagnantes suite aux inondations accrues, projetées en Afrique de l'Ouest par exemple, qui pourront affecter la qualité des eaux souterraines.

Ces multiples relations entre eaux souterraines et changements climatiques nous montrent ainsi clairement que les aquifères seront affectés par les changements climatiques en Afrique et dans le monde.

1. Inter Governmental Panel on Climate Change, 4th assessment report, Chapter 3

Si l'on projette tous ces impacts potentiels du changement climatique sur les aquifères transfrontaliers du circum-Sahara[2] , force est de constater que les impacts directs du changement climatique sur ces aquifères seront globalement limités : ils sont pour l'essentiel de grands systèmes aquifères fossiles, offrant pour l'essentiel des eaux non-renouvelables, leur recharge étant extrêmement faible comparée à leurs réserves, qui sont, elles, très importantes (OSS-UNESCO, 2006)[3].

Les principaux impacts directs du changement climatique sur les aquifères transfrontaliers du circum-Sahara seront donc de deux ordres :

- les impacts liés à l'augmentation du niveau des mers en ce qui concerne les aquifères côtiers (Djeffara tuniso-libyenne, Système Aquifère du Sénégalo-Mauritanien) et les risques de salinisation afférents
- les impacts sur les systèmes hydriques de surface, tels que les perturbations des débits des fleuves et du niveau d'eau des lacs, dans le cas où les aquifères sont liés à ces eaux de surface (Système Aquifère d'Iullemeden avec le fleuve Niger, système Aquifère du Lac Tchad). Mais dans ces cas précis, au vu des divergences entre les résultats des modèles climatiques dans la frange sahélo-soudanaise - certains prévoient une augmentation des précipitations, d'autres une diminution (IPCC, 2007) -, il est encore difficile de prévoir quels seront ces impacts. Quoiqu'il en soit, une augmentation de la variabilité climatique et de l'occurrence des phénomènes extrêmes comme les sécheresses et les inondations est fort probable, ce qui aurait un impact important sur les eaux de surface, ainsi que sur les eaux souterraines qui y sont liées. Toutefois les nappes pourront aussi jouer un rôle tampon encore plus important qu'aujourd'hui, soutenant les débits des fleuves en période de sécheresse et se rechargeant de façon plus importante lors des inondations.

Enfin, en ce qui concerne les grands aquifères du Nord du Sahara (Système Aquifère du Sahara Septentrional, Bassin du Murzuk), caractérisés à la fois par une faible recharge et un lien très limité avec les eaux de surface, ceux ci seront finalement peu affecté directement par le changement climatique.

C'est donc principalement à travers l'augmentation de la demande en eau, impact indirect du changement climatique, que les aquifères transfrontaliers du circum-Sahara seront fortement sollicités. Il apparaît ainsi, que ces ressources en eau, souterraines, transfrontalières, et finalement peu visibles, pourront, à travers le changement climatique, démontrer clairement leur aspect stratégique. Le stock d'eau qu'ils conservent devra être protégé et géré de façon rationnelle et concertée entre les pays qui les partagent afin d'utiliser au mieux ce stock stratégique et ses caractéristiques uniques pour s'adapter au changement climatique : ressource disponible à toute saison, soutien des étiages… A cet effet, il convient d'accélérer fortement l'amélioration des connaissances dont on dispose sur ces ressources encore trop faiblement étudiées. De même, il s'agira de conduire des recherches précises sur le changement climatique et son impact sur les ressources en eau, de façon à informer les stratégies d'adaptation au changement climatique et de préciser le rôle que peuvent jouer ces aquifères transfrontaliers dans de telles stratégies. Mais attention, pomper l'eau des aquifères profonds coûte cher en énergie, il ne s'agirait pas ainsi d'augmenter la facture de CO_2 de la planète…

2. Dans le circum-Sahara, la grande majorité des eaux souterraines circulent au sein de grands systèmes transfrontaliers, sur lesquels l'OSS mène études et projets de coopération entre les pays qui les partagent.

3. Ressources en eau et gestion des aquifères transfrontaliers d'Afrique du Nord et du Sahel, OSS-UNESCO, 2006

Groundwater Resources Evaluation of Agades Province, Niger (Iglalen-Tegeden-Igorar)

Salem M. Rashrash[1], Nabila A. Altwibi[2]
1. Alfateh University, Department of geological Engineering, Tripoli - Libya
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The purpose of this study is to evaluate the groundwater resources of Iullemmeden basin in Niger which extends over more than 1000 km from north to south and over 800 km east - west. This hydrogeological basin is one of the most important basins in Central Africa shared by many countries. The Republic of Niger is one of the under development African countries, and suffering from droughts and changing in the weather in the last decade.

The study area is located within Agades Region in the western central part of the Republic of Niger. The study area covers three locations, Iglalen, Tegedenadrar and Igorar sites which are targeted by the pilot agriculture project conducted by Libyan government to help the Niger people. This study is based on hydrogeological and geological data gathered from 13 exploration and production wells in the three mentioned locations.

The results of the study showed that there is a continuous aquifer extending under all the study area of good quality water. The transmissivity values ranges from 1.04×10^{-3} to 6.0×10^{-3} m^2/s, based on pumping test data analyses.

A preliminary hydrogeological model has been constructed for this area using the hydrogeological parameters and water requirement needed to irrigate the pilot project in the three sites. The model results show that the aquifer can produce the water requirement with a maximum predicted drawdown after 50 years of 63m in Iglalen , 48 m in Tegedenadrar and 24m in Igorar site.

A comparative study of groundwater chemistry and dynamics within the shared aquifer of the Lake Chad Basin (Kadzell and Bornu regions, Niger and Nigeria)

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The large (500,000 km^2) unconfined Quaternary aquifer of the Lake Chad Basin is shared by four countries in central Africa (Cameroon, Chad, Niger and Nigeria). For most of the 25 millions inhabitants of this semiarid basin, groundwater represents the only perennial fresh water resource available. Numerous studies have been achieved since the 1960s, mostly dedicated to the characterization of the aquifer storage at large scales. At a finer scale, processes of groundwater recharge and mechanisms of salinization remain poorly known. However, a good knowledge of these processes is required to simulate the water resources variation and the impact of the rapid environmental changes (land clearing, global warming) on their dynamics.

The Bornu (Nigeria) and Kadzell (Niger) plains are separated by the Komadugu Yobe (KY) River, which flows northeast to the Lake Chad (Fig. 1). They both have in their centers a large natural piezometric depression, up to 40 m deep (PNUD/CBLT, 1970). The proposed explanation is an upward flux in their center by evapotranspiration whereas the Lake and the KY River maintain high hydraulic potentials by infiltration along the edges; lateral fluxes toward the centers are very limited due to the low horizontal permeability.

The main goal of our study was first to test this hypothesis, using environmental tracers (stable isotopes, trace elements and major ions), and second to estimate, by numerical modelling and radio-isotopes, a possible time scale evaluation for groundwater response to an abrupt change in environmental conditions. Piezometric data were obtained from various published reports and additional measurements performed from 2004 to 2006. Groundwater samples were obtained in large diameter wells or boreholes, for the same period, in collaboration with local authorities.

Carbon-14 (12 analyses) and tritium (10 analyses) data confirm that the center of both depressions correspond

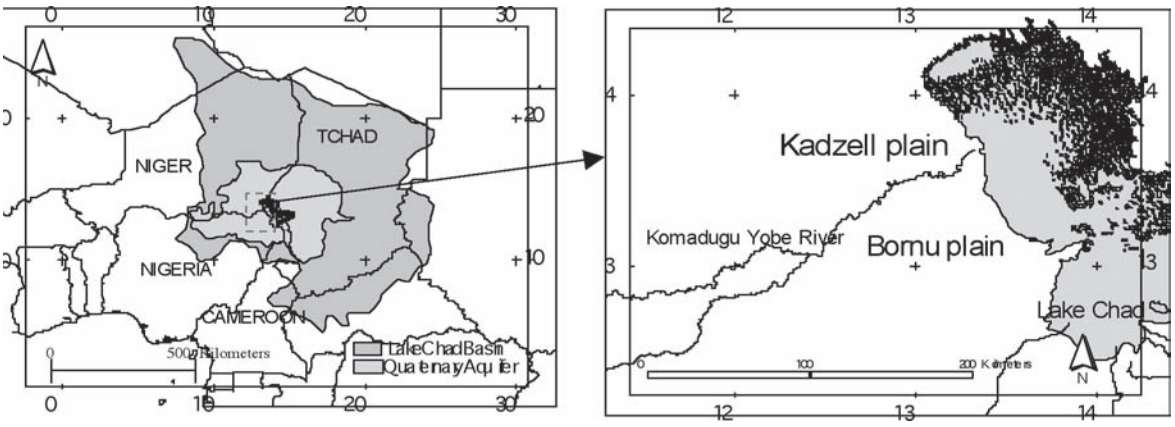

Fig.1 Location of the study area

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to a minimum renewal rate. Tritium contents show values below the detection threshold (< 1.0 TU) except near the Lake and the KY River where higher contents are observed. Carbon-14 data are also consistently lower in the center with a minimum observed in the Bornu depression (17 pmC). Although water - rock interactions are likely to occur within the aquifer (as shown by Sr isotopic values), C-14 data interpreted in terms of "groundwater age" point out the Holocene period for recharge of oldest groundwater. This result is consistent with lower values of $^{18}O/D\text{-}H_2O$ in the center of the plains, a consequence of groundwater recharge under a cooler and/or more humid climate.

Major ions (including Cl) and trace elements (Li, Br, B and Sr) data were used to further constrain recharge processes. The influence of River and Lake water on groundwater chemistry is obvious along the KY floodplain on both sides of the river, and near the Lake shore; within a few kilometers, mixing with older groundwater occurs, characterized by higher chloride contents and lower Li/Cl ratios.

Environmental tracers are therefore useful to track flowpath and assess first estimates of time scales to be taken into account for groundwater modelling.

For water resources management issues, the following conclusions should be highlighted:

(1) a symmetrical pattern of recharge and discharge processes occurs on both sides of the Niger and Nigerian border (KY River)
(2) Shared surface waters (from both Lake Chad and KY River) contribute significantly to groundwater recharge
(3) Although similar processes appear in Niger and Nigeria, differences exist in hydrodynamics (water table depth) and geochemical parameters (C-14 content, electrical conductivity and major ions concentration)

These conclusions confirm that sharing experience is of mutual benefit for long term management of water resources in the Lake Chad Basin. For scientific objectives, comparing two symmetric aquifers helps in deciphering local characteristics from general patterns.

Transboundary Aquifer Management and Climate Change Programmes: The Experiences of the Nile Basin Programme

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Groundwater plays a significant role in surface water systems but this role has not been adequately considered in most transboundary river basin management initiatives, including the Nile Basin. Groundwater maintains baseflow to streams and water levels in many wetlands, which are critical for providing refuge to fauna and maintaining biodiversity. Information about the role of groundwater, in particular its contribution to water balances in lakes, rivers, and wetlands is very crucial for instituting water resource management strategies. Recent studies in the Nile Basin show that many swamps may in fact be fed by groundwater and that in some sections of the basin around Lake Victoria, there are significant interaction between transboundary surface water and groundwater resources. Furthermore, groundwater levels in monitoring wells constructed in an alluvial aquifer and surface water levels in Lake Victoria respond in a similar manner to climate variability and change. The above findings call for management of groundwater resources as part of transboundary river basin management whether the aquifers are transboundary or not.

The state of understanding on groundwater flow and solute transport between Ethio-Djibouti and Ethio-Kenyan boundaries along the East African Rift

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Uplifting, volcanism and concurrent rifting in the Eastern Africa resulted in a complex topographic, climatic and hydrologic setting. The topography is charactersied by narrow depression bounded by highlands in both sides. This topographic setup in turn control the monsoon moisture re-distribution once the moisture originating from Indian or Atlantic Ocean reaches the region. As the result the rift floor is characterized by arid to semi arid climate and the plateau by relatively humid climate.

The interaction between volcanism, tectonic activities, and uplifting also resulted in aquifer compartmentalization, discontinuous groundwater flow, lower groundwater storage and complex groundwater flow pattern. High salinity, high fluoride, above average content of trace elements in groundwaters observed in the East African rift is the result of volcanism and climate.

Because of scarcity and seasonality in the availability of fresh surface water resources groundwater is the principal source of groundwater in the region. The availability and quality of groundwater in the rift floor however depends on groundwater flow connection between the highlands bordering the rift where recharge takes place and the rift floor aquifers. Tectonic configuration along the plateau rift transects in the region is the principal control on groundwater flow continuity between the plateaus and the rift. In the rift floor the groundwater flow lines are parallel to the axis of the rift favoring transboundry groundwater flow between Ethiopia and Kenya and Ethiopia and Djibouti. New evidences show that regional groundwater flow cross the Ethio Kenyan border following the Magado Fault belt confined in the Bulbul Basalts although such evidence of transboundry groundwater flow is not clearly documented along the Ethio Djibouti border.

Regardless of the transboundry nature of aquifers in the Ethio Kenyan and Ethio Djibouti borders or elsewhere between the political boundaries between countries of East Africa cut by the rift, the volume of groundwater shared by the countries is low. This is because of the discontinuous nature of groundwater flow paths, low storage capacity of volcanic aquifers and emergence of groundwater resources within the rift floor prior to reaching the shared political boundaries. Regardless of the relatively limited volume of transboundry groundwater flow the East African countries form a complex ecological niche. The ecology of the rift floor in this countries (Djibouti, Ethiopia, Kenya, Tanzania and Uganda) is highly groundwater dependent. For example the major part of the water budget of the East African Rift lakes is groundwater dependent (reference). Groundwater is the major pathway for solute and nutrient path ways in the wetlands and lakes of the rift valley. For example fresh eutrophic lakes with no surface water flows are the result of solute loss to groundwater. Despite the minimal volume of groundwater shared by the countries sharing the rift valley, the rift valley of these countries share one thing in common. That is their rift ecosystem dependent on groundwater resources. Groundwater exploitation in one country may have an impact on ecosystem of the country near by calling for a common vision for ecosystem based groundwater management in the rifts.

In addition to the aquifers the countries share and the similarity and interdependence of ecosystems of the rift floors, the countries crossed by the rift share common methodological challenges in understanding and managing their groundwater resources. These is because volcanic aquifers are complex by nature and physical groundwater modeling has limitations, geochemical methodologies is investigating the resources is also challenged. Therefore there is a need in these countries to share their understanding of groundwater flow and best practices and methodologies in exploiting and managing the resources judiciously.

By reviewing the methodological challenges the East African Countries face in managing their groundwater resources, this work presents one cases study on groundwater flow investigation along the Ethio-Kenyan boundary and one case study on groundwater flow between the Ethiopian Highlands and Djibouti. This work also presents cases studies on the role of groundwater in rift ecosystem. This work emphasizes the need of common management of groundwater resources despite the relatively minimum volume of groundwater flow along the political boundaries of the East African countries.

An integrated hydrological, geochemical and hydrogeological investigation in Borena lowlands of Ethiopia bordering the Ethio-Kenyan boundary demonstrate that the two countries share groundwater emerging from the highlands of Borena and flowing through the extensive Ririba fault zone running NS between Kenya and Ethiopia. The groundwater flow is confined in the Bulbul basalt of high transitivity and good groundwater quality (TDS <1500 mg/L). In the Ethiopian Djibouti transect the major groundwater originating from the Ethiopian highlands in the Blue Nile plateau is recycled mainly in alluvial grabens bordering the rift. Geochemical and isotope hydrological evidence show the major portion of groundwater circulating in the rift floor bordering Djibouti and Ethiopia originate from recharge taking place in the Awash flood plain.

Delineation of the shared Groundwater Bodies in Egypt using the European WFD Approach - a step toward formulating the African WFD

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Since 1998 many National and International Institutions promoted intensive studies in regard to Shared Aquifer (SA) characterization.

As pioneer organization UNESCO lunched ISARM project, which improved the existing scientific knowledge, provided a comprehensive assessment of SA, and formulated common principals for SA resources management. Based on the significant global inventory; UNESCO introduced about forty SA systems In Africa among them eleven located in Nile Basin Riparian Countries, for it joint and sustainable management is essential to maintain human and environmental needs.

This encouraged the GEF IW program to propose and lunch four Medium Sized project in North and North East Africa at the last five years to develop framework for the sustainable management and use of the SA includes Illemeden, Northwestern Sahara, Nubian and River Nile Aquifer Systems through the formulation of a Transboundary Diagnostic Analysis (TDA) followed by a Strategic Action Program (SAP) to ensure inter regional comparability. These projects will expand and consolidate the technical and scientific knowledge of the shared aquifer systems.

Looking for the European experience in the field of the SA management we found that EU established Water Framework Directive (WFD 2000/60/EC) includes a comprehensive regulatory framework for the protection of groundwater, which follows the same stepwise approach as for surface waters namely characterization phase, monitoring programs, design programs of measures in the context of the Transboundary river basin management planning and compliances to good status objectives by the end of 2015. All EU member state has to harmonize their national legislation, groundwater units and standard with that described in the WFD guidance documents. First step of the WFD implementation is localizing and outlining of the water bodies in the country and their initial characterization. The groundwater body is the management unit under the WFD that is necessary for the subdivision of large geographical areas of aquifer in order for them to be effectively managed.

In this paper the author introduce the Egyptian experience in delineation of twenty nine groundwater bodies in a horizontal and in vertical manner based on the Egyptian hydrogeological mapping program; established since 1988 and according the EU guidance documents. Following those criteria a distinction between single porous groundwater bodies and groups' groundwater bodies as well as shallow groundwater bodies and deep groundwater bodies has been made. The following delimitation criteria as size, geological and hydrogeological homogeneity, groundwater chemistry, the existing national monitoring network, utilization, economic importance and risk potential have to be taken in to account. With respect to the different geological strata one must distinguish between porous, fractured and carbonate karstic types of aquifer.

Delineation of such detailed and homogenous groundwater bodies will precise the technical and scientific knowledge of the shared aquifer systems in Africa.

The approach followed in delineation, characterization of the groundwater bodies and to overcome obstacles due to lack of measured hydrogeological parameters and uneven distribution of the population density, can be applied at any other country in the region.

One of the most important items at the action plan is the Formulation of specific expert group for delineation, characterization and mapping of the shared groundwater bodies; under the Regional Centre for Shred Aquifer Resources Management in Tripoli. This task group will review the EU WFD Guidance documents and prepare draft African WFD to support both African Union and African Ministerial Council on water.

The hydrogeochemical characteristics of coastal aquifers in the West Coast of Africa: A review

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The coastal aquifer of West Africa cut across several countries including Cameroon, Nigeria, Benin, Togo, Ghana, Cote d'voire and Senegal. The present study was therefore designed to use available hydrochemical data to assess the regional groundwater quality and determine the processes controlling groundwater chemistry of the coastal aquifer in Nigeria, Benin and Senegal. The data showed that of the 139 data considered, about 10%, 85% and 55% of total dissolved solids (TDS), chloride and nitrate respectively, was higher than the World Health Organisation (WHO) maximum admissible values of 1000mg/l (TDS), 250mg/l (Cl) and 10mg/l (THC). This suggests contamination of the groundwater by natural and anthropogenic sources. Specifically, seawater encroachment is a major problem in Nigeria and Senegal with maximum TDS/Cl concentration of 5017mg/l/2300mg/l and 6190mg/l/3195mg/l respectively. Secondly, anthropogenic pollution constitutes a problem in Benin with maximum NO_3 concentration of 144mg/l; and Senegal with a maximum NO_3 concentration of 436.4mg/l. The standard deviation of the data is wide indicating several processes including seawater mixing and ion exchange control the water chemistry. On the basis of cumulative probability curves for Cl and NO_3, the groundwater is grouped into four classes as follows: Class I-Cl<88mg/l and NO_3<70mg/l is poor in Cl and NO_3 suggesting no problem with seawater and anthropogenic pollution. 62.20% of the total no. of samples belongs to this class. Class II- Cl>88mg/l and NO_3<70mg/l is rich in Cl and poor NO_3 indicating problem with seawater and no problem with nitrate an indicative of anthropogenic pollution. 23.00% of the samples belong to this class. Class III which has 5.80% of the samples is characterized by Cl<88mg/l and NO_3>70mg/l which, is poor in Cl and rich NO_3 indicating no problem with seawater but has problem with nitrate. Class IV with 8.60% of the samples has Cl>88mg/l and NO_3>70mg/l is rich in Cl and NO_3 indicating problem with seawater and nitrate. The seawater water (SMI) mixing index was applied to evaluate the level of seawater mixing with groundwater. The data showed that the classes I and II waters have SMI<1.00, while classes III and IV have SMI>1.00. The implication of these results to the management of the coastal aquifers is discussed in this article.

Assessment of renewal rate in the shared Djeffara coastal aquifer by isotopic investigation

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Estimation of groundwater recharge in arid and semi-arid areas is difficult due to the low amount and variability of recharge. A multitracer approach investigation based on a linear mixing model for oxygen-18 and a "well-mixed" reservoir model for C-14 activities allows direct investigation of relatively long-term renewal rates of an aquifer. The recharge process of the three layered Djeffara system, was investigated using isotopic approach. This study investigates the whole basin of the Djeffara from the Gabès in Tunisia to Jebel Nefousa in Libya. Over this basin, recharge is highly heterogeneous with different origins, from rainfall to fossil water through interconnection between underlying Continental Intercalaire aquifer mainly through geological features (faults) but as well as by vertical leakage. Recent recharge mainly occurs in the Libyan basin through water-bearing formations outcrops. Heterogeneity of the recharge is reflected through the wide variation of oxygen-18 content of the groundwater. The carbon-14 activities range for most of the groundwater falls between 0 and 100 pmc showing pre and post-aerial thermonuclear test recharge. A well-mixed reservoir model has been applied to estimate renewal rates taking in account recent and fossil contribution to input water signature. This model gives relatively low renewal rate for the area. Using carbon-14, mean annual rates of groundwater renewal range from 2.3 to 0.004 ‰ but with relatively significant differences for each layer of the Djeffara system indicating different recharge mechanisms.

Keywords: Groundwater; Recharge; Isotopes; Semi-arid environment; Djeffara; Tunisia, Libya

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Etude du système aquifère de la Djeffara tuniso-libyenne

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Le système aquifère de la Djeffara, localisé dans la plaine côtière tuniso-libyenne, renferme une ressource dont l'exploitation a connu une intense évolution au cours des trente dernières années. Cette étude tente de proposer une vision homogène et coordonnée d'un même et unique système ; elle répond ensuite au besoin de définir des politiques d'exploitation des ressources en eau ; en prédire les impacts sur le court et le long terme ; préciser et aider à gérer les risques et évaluer leurs conséquences.

L'analyse de l'ensemble des informations géologiques a permis de définir trois aquifères majeurs :

a) l'aquifère supérieur, constant sur toute la région et renfermant des eaux de qualité médiocre dans les zones frontalières ;
b) l'aquifère inférieur, contenu dans les couches triasiques perméables ;
c) l'aquifère intermédiaire, qui regroupe un certain nombre de formations perméables autour des sables Miocènes.

La lame d'eau moyenne annuelle précipitée sur la région de 177 mm et le volume précipité sur le domaine de la Djeffara s'établit à 8,5.109 m^3/an soit un flux équivalent à 270 m^3/s. En admettant des coefficients d'infiltration directe de 2 à 3%, l'apport par recharge directe aux affleurements perméables utiles serait de l'ordre de 200 Mm^3/an. L'infiltration des crues d'Oueds s'établirait à près de 90 Mm^3/an, soit, en première analyse, 50% des ruissellements totaux.

Par ailleurs, l'apport estimé du Continental Intercalaire Saharien représente le triple du débit initial des sources de la Djeffara et presque autant que l'exploitation totale actuelle de la nappe intermédiaire en Tunisie. C'est dire l'importance que revêt l'impact de sa connaissance et de son évolution dans le temps sur celle de toute la nappe de la Djeffara.

Cette plaine se distingue d'ores et déjà par un niveau d'alerte prononcé : en 40 ans, les prélèvements y sont passés de 200 Millions m^3 en 1960 à près de 1 Milliard m^3 en 2000. Il en est résulté d'importants rabattements (parfois supérieurs à 50 m) dans les zones côtières où se trouve concentrée l'exploitation, notamment dans la région de Tripoli où de dangereuses intrusions salines ont été constatées.

Sur la base de l'information collectée et analysée avec l'aide des spécialistes des deux pays (Libye et Tunisie), un modèle hydrodynamique a été conçu et élaboré en vue de simuler le comportement du système aquifère et de faire des prévisions sur son comportement à moyen terme (50 ans).

Le calage du modèle est conduit sur la période 1950-2000. Il donne un bilan des entrées de 594 Mm3 en 1950 et de 1365 Mm^3 en 2000, soulignant ainsi le net déséquilibre qu'a subi entre temps, ce système aquifère. Le modèle a permis de reconstituer cette modification du régime des écoulements et de la salinité des eaux, et d'aider à rechercher les moyens de minimiser cette nuisance. Il a également permis d'anticiper, de façon satisfaisante, le comportement des différentes nappes de la Djeffara en termes de rabattements.

Le bilan hydraulique du système fait ressortir l'importance de l'infiltration (330 Mm^3/an) et de pressentir l'importance que l'on doit accorder à l'étude de

la recharge naturelle ainsi qu'à l'estimation des apports latéraux souterrains en provenance du Système Aquifère du Sahara Septentrional (260 Mm^3 en 1950, passant à 200 Mm^3 en 2000). On notera que « l'intrusion marine » est prend de l'importance dans ce bilan, et commence à être sensible dans la région de Tripoli (34 Mm^3/an) et représente un risque majeur pour la détérioration de la qualité de l'eau.

Le transport de sel a été simulé en régimes permanent et transitoire. Le régime hydrodynamique correspondant est celui obtenu par calage du modèle d'écoulement. Le modèle de transfert de sels traduit les échanges d'eau de différentes qualités entre les diverses entités hydrogéologiques et avec leur environnement, selon une représentation globale des salinités et une modélisation pseudo-tridimensionnelle des transferts de sels conforme au schéma hydrodynamique.

Des simulations prévisionnelles ont été réalisées, qui prédisent les impacts de l'exploitation actuelle et future des aquifères de la Djeffara, en termes de rabattements supplémentaires des niveaux, et de modifications de la qualité des eaux qui pourraient en résulter. Elles ont orienté les deux pays concernés vers les zones les plus propices au développement de l'exploitation et celles qu'il y a lieu de considérer comme zones à risque.

Groundwater losses by evaporation in the Nubian Sandstone and the Paleozoic aquifers in Libya and Egypt: earth observation, field experiments and numerical modelling

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This study summarizes results of two investigations (Menenti, 1984; Menenti *et al*., 1989) on the groundwater losses by evaporation in the Sahara. Both studies relied on a combination of field experiments, satellite observations and numerical modelling. Occurrence of groundwater at the surface or at shallow depths is widespread in the deserts of North Africa. These areas are fed by the major aquifers in this region, where the water bearing formations store mainly fossil groundwater. These aquifers release water through these discharge areas (playas) at a quasi-steady rate and the yearly evaporation adds up to a very considerable water resource that is being lost at present, irrespective of whatever strategy has been adopted about groundwater exploitation.

Specifically, two aquifer systems were studied:

a) The Paleozoic (Cambro-Ordovician) and Mesozoic (Cretaceous) aquifers in the Fezzan region in Libya; where groundwater development in the Al Jufrah and Wadi Ash Shati areas is significant and where playas in the Wadi Ash Shati depression.are extensive. This aquifer system is undergoing natural depletion since the Makalian pluvial 11000 years ago.
b) The Nubian sandstone aquifer in the Western Desert of Egypt where groundwater resources are very significant and development of agriculture in the oases of the Western Desert has been pursued by the Government of Egypt since the 70-s.

The two studies reviewed here relied on the evaluation of the land surface energy balance to estimate the amount of evaporation. This approach entails determing how much radiant energy is absorbed at the land surface and how much is being dissipated by heating the soil and the air. By imposing closure of the land surface energy balance, the rate of energy consumed by the liquid to vapour phase transition (latent heat) is determined. The latent heat is equivalent to the mass of water evaporated.

The land surface energy balance in the playas of Fezzan was studied by field experiments in 1978 and 1979, and in the Western Desert from 1986 through 1988. Concurrent airborne and satellite data collected by multi-spectral imaging radiometers were acquired to determine the land surface albedo and surface temperature. Parameterizations of radiative and convective flux densities were developed (SEBAL, Bastiaanssen, 1995) and used to estimate the latent heat flux density, i.e. the rate of evaporation, as a function of land surface albedo and temperature.

The airborne and satellite radiometric data allowed to extend the findings of the field experiments to the entire area where groundwater evaporation occurs and the total yearly amount of groundwater evaporation was obtained for both the Wadi Ash Shati depression and the playas in the Western Desert of Egypt.

The total yearly evaporation lost from the aquifers West Libya was estimated at 8.5 10^8 m^3yr^{-1} and at 2.4 10^9 m^3yr^{-1} for the Nubian Sandstone Aquifer System in the Western Desert of Egypt.

In both cases the consistency of these results with groundwater flow in these aquifers was evaluated using numerical models. In the case of the Western Desert of Egypt, the model study showed that the

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SEBAL estimations of evaporation were consistent with the calculated groundwater flow of 2.1 10^9 m^3yr^{-1} (FEMSAT model) and 2.3 10^9 m^3yr^{-1} (TRIWACO model) using observed pressure heads and large values for the saturated hydraulic conductivity of the water bearing formations, K_{sat}. Such large, but still consistent with aquifer properties, values, ranging from 300 to 600 cm d_1, could be physically explained by the low water viscosity at temperatures of 60°C to 70°C which prevails in deep aquifers (>4000 m).

In conclusion, these studies point out the very significant amount of fossil groundwater that is being lost at a near constant rate, because of a hydrological process that can only be slowed down by attaining lower hydraulic head through groundwater exploitation.

SESSION 2

Management of Transboundary Aquifers: How have we been doing?

Management of urban-coastal aquifers: the case of Dakar (Senegal)

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The rapid increase of urban population in the region of Dakar, with the consequent increase of informal suburban settlements, has become a source of concern for water supply, needs, and quality control. Approximately 80% of water resources in the region come from groundwater reservoirs, which are strongly affected by the impact exerted by uncontrolled waste deposal and lack of policies for septic tank and sanitary measures. As groundwater quality is decreasing, is important to discriminate the different sources of pollution and a strong policy of groundwater management is required in order to avoid further pollution and health diseases for urban and suburban population.

This work has focused mainly on the identification of the origin of groundwater pollution based on a survey on 26 piezometers and wells, conducted in march 2006.

Analyses were performed on both major and trace elements as well as the stable isotopic signature of water molecules and dissolved compounds. Isotopic signals, together with concentration levels of elements in groundwater, give information on the origin and the migration of pollutants in the studied systems.

Nitrates concentrations in almost all stations exceeded the drinking water limits and were associated with microbiological pollutants, while the sea water intrusion represented the major issue in the rapid decline of groundwater quality. Furthermore, the analysis of the stable isotopes of dissolved nitrates allowed for the identification of urban sewage and fertilizers as a major source of contamination, defining also the distribution of their impacts. The occurrence of denitrification processes, although limited, suggested the potential for auto-purification of the contaminated water, if the source of the pollution were forced to cease.

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Apport de la modélisation dans la gestion concertée des aquifères transfrontaliers : cas du SASS et du SAI

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Le développement des modèles hydrogéologiques a conduit à des avancées significatives dans la gestion des ressources en eau. Leur utilisation pour appréhender le fonctionnement hydraulique des systèmes aquifères est en plein essor et devient indispensable, notamment dans la perspective d'une réflexion sur le développement durable et l'application des principes de la GIRE (Gestion Intégrée des Ressources en Eau).

L'expérience de l'OSS dans ce domaine, acquis dans le cadre des projets menés sur les aquifères transfrontaliers du Système Aquifère du Sahara Septentrional (partagé par l'Algérie, la Libye et la Tunisie) et du Système Aquifère d'Iullemeden (partagé par le Mali, le Niger et le Nigeria), a permis de dynamiser l'utilisation de l'outil de modélisation pour la gestion rationnelle et concertée des ressources en eau souterraines transfrontalières partagées. En effet, cette modélisation, en tant que démarche scientifique, contribue à concevoir l'entité hydrogéologique dans son ensemble et à traduire le comportement du système aquifère dans ses limites naturelles avec une meilleure appréciation des risques et impacts qui menacent la ressource.

La modélisation réalisée dans le cadre de ces deux projets avait essentiellement pour objectif l'actualisation des connaissances et la mise en place d'un programme de gestion rationnelle, concertée entre les pays. Cette activité s'est révélée d'une importance première car au delà de la réalisation des objectifs initialement fixés, notamment la quantification de la ressource exploitable, elle a permis d'identifier des aspects qui n'avaient pas été considérés initialement, de comprendre les imperfections des modèles conceptuels et de vérifier les hypothèses formulées. En effet, en plus de la bonne restitution des mesures, dans les limites des ordres de grandeurs acceptables, les modèles ont permis de borner certains problèmes (exploitation dans le SAI, hydrodynamique de l'exutoire tunisien du SASS).

Des exemples édifiants dans le cadre de nos travaux sont donnés par les modèles du SASS et du SAI qui, en réalisant leurs objectifs, ont conduit à identifier de nouveaux aspects instructifs :

- la configuration de l'exutoire tunisien du SASS a été reconsidérée au cours du calage du modèle, ce qui a permis de mieux comprendre son fonctionnement hydraulique.
- les simulations exploratoires ont permis d'identifier des réserves (potentialités) importantes dans le bassin occidental du SASS (zone non exploitée), non soupçonnées initialement, dont la mobilisation pourrait être une alternative pour soulager d'autres zones très sollicitées.
- Les hypothèses formulées sur l'exploitation des nappes du SAI ont permis d'aboutir à des résultats pertinents, notamment les baisses relativement fortes du niveau d'eau dans certaines localités

Les interactions entre interrogations, informations et modèles ont conduit à une meilleure connaissance, caractérisation, compréhension et quantification des phénomènes modélisés. Ces modèles ont aussi permis de faire des prédictions pour les pays concernés et servent ainsi d'outils d'aide à la décision.

Des actions adéquates ont été menées pour le bassin aquifère du SASS, puis dupliquées et adaptées pour le SAI, à savoir le développement d'une conscience de bassin par :

- la mise en place d'une structure de concertation
- la mise au point d'une approche méthodologique

Cette duplication / adaptation a amené les pays se partageant le SAI à : fixer des orientations pour définir un programme de concertation, faire le bilan des connaissances, définir les contraintes actuelles et, enfin mener une réflexion sur un programme de sensibilisation des décideurs et de la population.

En définitive, l'activité de modélisation entreprise dans le cadre des projets de l'OSS met en place un cadre de concertation entre les différents acteurs (OSS et représentants des pays). Elle permet aux administrations nationales responsables des ressources en eau de s'approprier d'un outil de gestion et de suivi de l'utilisation de la ressource. En ce sens, elle intègre le contexte de la GIRE, traitant les problèmes sur une échelle intersectorielle.

Gestion conjointe du système aquifère côtier partagé du Golfe de Guinée : point des activités et perspectives dans la mise en place du projet MSP/FEM

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En Afrique de l'Ouest, pendant la dernière décennie les aquifères des bassins sédimentaires côtiers ont été détériorés, en raison de la faible gestion globale des eaux souterraines. Pour faire face à ces menaces, l'UNESCO a initié un projet intitulé : Gestion conjointe du système aquifère côtier du Golfe de Guinée. L'objectif de cet article est de faire le point sur les étapes dans la mise en place du projet. Dans le cadre de l'exécution du PDF A, une Analyse Diagnostique Transfrontalière (ADT) préliminaire a d'abord été menée et ensuite, à travers des actions concertées, le projet a été finalisé et soumis au financement du FEM dans un format PIF (Project Identification Form). L'ADT préliminaire a révélé que la principale menace est la pollution des eaux souterraines due à la mauvaise utilisation des terres causant ainsi la dégradation de l'écosystème côtier. La chaîne d'analyse causale de ces menaces a permis d'identifier les causes profondes dont l'une est le manque de gestion concertée de ces aquifères partagés. Ainsi, pour créer les conditions de la gestion conjointe de ces aquifères côtiers transfrontaliers, une des cinq composantes du projet est axée sur l'établissement d'un cadre légal de coopération et des mécanismes institutionnels. Une deuxième composante, porte sur la mise en place d'une Base de Données Régionales et d'un Système d'Echange d'Informations (BDR&SEI) du Système Aquifère Côtier du Golfe de Guinée (SACGG). La structure de la base de données régionale devant permettre de gérer ces aquifères de manière conjointe a donc été définie. Le projet vient d'être approuvé par le FEM et son coût total s'élève à 2.065 000 $ US. La prochaine activité va consister à présenter le projet dans un format beaucoup plus détaillé afin de permettre le décaissement des fonds par le FEM.

Mots Clés : Aquifères côtiers, Golfe de Guinée, Analyse Diagnostique Transfrontalière, Base de Données Régionales et Système d'Echange d'Informations, Pollution des eaux souterraines.

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Joint management of the shared coastal aquifer system of Gulf of Guinea: activities and outlook in the project MSP/GEF implementation

In West Africa, during the last decade the aquifers of the coastal sedimentary basins were deteriorated, because of the total weak management of groundwater. To face these threats, UNESCO initiated a project entitled: Joint management of coastal aquifer system of the Gulf of Guinea. The objective of this article is to give a progress report on the stages in the installation of the project. Within the framework of the execution of PDFA, a preliminary Transboundary Diagnostic Analysis (TDA) was initially carried out and then, through joint actions, the project was finalized and subjected to the financing of GEF in a PIF format (Project Identification Form). Preliminary TDA revealed that principal threat is groundwater pollution due to the misuse of land thus causing coastal ecosystem degradation. Causal chain analysis of these threats made it possible to identify major causes of which one is the lack of joint management of shared aquifers. Causal chain analysis of these threats made it possible to identify major causes of which one is the lack of joint management of shared coastal aquifers. It is to create the conditions of the joint management of these aquifers that the framework of the project made of five components; the accent was put on the means of concerted management in two components. Thus, to create the conditions of the joint management of these shared coastal aquifers, one of the five components of the project is axed on the establishment of a legal framework of cooperation and institutional mechanisms. A second component, relates to the installation of a Regional DataBase and Information Exchange System (RDB&IES) of the Coastal Aquifer System of the Gulf of Guinea (CASGG). Thus, the structure of the regional data base having to make it possible to manage these aquifers in a joint way was defined. The project has been just approved by GEF and its total cost amounts to 2.065 000 $ US. The next activity will consist in presenting the project in a format much more detailed in order to allow the withdrawal of the funds by GEF.

Key words: Coastal aquifers, Gulf of Guinea, Transboundary Diagnostic Analysis, Regional Database and Information Exchange System, groundwater pollution.

Metadata catalogues as a base of the Shared Water Information Systems for shared water resources management

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Whatever for groundwater as for surface water, the access to update and complete information concerning the status and the evolution of the water resources and its uses is a major stake as regards transboundary or local water policy: whether it concern regulatory actions, planning, risk management or informing the public, the administrators of the water resource need to regularly avail themselves of reliable, up-dated and pertinent information.

Thus, it is yet established that the sound governance of water issues supposes the organization of efficient information systems in order to meet the expectations of the deciders and other main information users.

In opposition to centralized information systems where information is concentrate in a unique point, the distributed and shared water information systems present various interests:

- Integration of the various levels: Whereas public action concerns, in the highest degree, the national territory, and sometimes that of local authorities, water issues are global and concern, in most cases, a simultaneous combination of various levels of action: local, basin, regional, national, international, etc
- Integration of the various data producers in relation with the various topic to deal with for a real Integrated water resource management
- Possibility to let and to manage the data at the most appropriate level, as close as possible of data producer, in order to involve and to have a better participation of the various actors, and to always have access to the last updated version made available

Once organized the principles of partnership between the various institutions and actors to be involved, one of the fist step for the establishment of these shared water information systems is to identify the main information expected by the final users and then, on base of this need analysis, to identify and analyze the quality of the data and information already existing at the level of the various institutions.

Metadata catalogues are particularly useful at this stage. Indeed, these highly capable tools enable each partner to do the following via Internet:

- Input and then consult metadata from a variety of existing information sources depending on access rights set by each metadata producer ;
- Identify data available locally, nationally and internationally, based on geographical criteria or using key words;
- Download data depending on access rights set by data producers.

More other they allow to promote, to share and to regularly update via Internet, the results of the various inventory of existing available water related data source regularly realized by the water related projects.

Water related metadata catalogue were tested with success during the "Feasibility study on the development of a regional water observation mechanism in the Mediterranean".

This metadata catalogue is presently under development at Mediterranean level within a EWMIS project aiming to prepare, in coordination with

the EEA, a "Mediterranean information mechanism on water" which is compatible with the "Water Information System for Europe" - WISE. The metadata collection process will be open to any organization providing water related data.

On the other hand, the International Office for Water is also presently supporting the "Convention on the Protection and Use of Transboundary Watercourses and International Lakes of the UNECE" in the establishment of a metadata database (other appellation of a metadata catalogue) for the EECCA countries, this in coordination with the Euro-med catalogues previously mentioned.

Couldn't we envisage studying the interest of such tools to support transboundary African water resource management?

Gestion intégrée des resources en eau dans les bassins transfontaliers. Bassin côtier Senegalo-Mauritanien

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NAPPE DU TRARZA / CHAMP CAPTANT D'IDINI POUR L'ALIMENTATION EN EAU POTABLE DE LA VILLE DE NOUAKCHOTT / MAURITANIE

La maîtrise et la sauvegarde des ressources en eau passent obligatoirement par une gestion coordonnée et intégrée des ressources en eau. En effet, la plupart des grandes villes dans l'Afrique du nord de l'Ouest sont tributaires des eaux des bassins hydrologiques ou hydrogéologiques partagés.

La présente intervention, est relative aux ressources en eau partagée entre la Mauritanie et le Sénégal et en particulière le comportement des ressources en eau observés suite à l'exploitation du champ captant d'Idini et les conditions climatiques du bassin en général.

En Mauritanie, la plupart des ses grandes villes, plus qu'ailleurs sont tributaires des eaux souterraines pour l'ensemble de leurs besoins en eau.

L'étude et le suivi de ces ressources sont plus qu'ailleurs un facteur essentiel et déterminent pour s'assurer de leur développement futur.

Les aquifères les plus sollicités sont du Continental terminal et entièrement localisés dans le bassin sénégalo-mauritanien localement appelé bassin du Trarza du nom de la région administrative la plus occupée par cet aquifère.

A l'implantation de la capitale Nouakchott, en 1958 l'état des connaissances de ces aquifères ne permettait pas d'envisageait une exploitation intensive pour assurer les besoins essentiels de la jeune capitale.

C'est ainsi qu'il a été adopté dans un premier temps d'assurer les besoins essentiels de la que la capitale par une usine de dessalement d'eau de mer.

Au début des années 1970 sur la base d'études plus approfondies, la possibilité d'alimenter Nouakchott à partir des eaux souterraines n'est plus un doute et grâce à la coopération chinoise a débuté par dix huit (18) forages implantés dans le petit campement du nom d'Inini située à 55 km de la capitale. Une nouvelle ère pour l'exploitation des eaux souterraines à une échelle jamais connue au paravent en Mauritanie a commencé.

Depuis lors, la ville ne cesse de grandir non seulement par la croissance démographique normale et le développement du tissu industriel, mais surtout par l'exode massif consécutif aux graves sécheresses successives qu'à connue toute l'Afrique soudano sahélienne des années 70 et 80.

De 18 forages à l'origine à 34 forages actuellement, pour une production respective de 25.000m^3 à 60.000 m^3 par jour, l'exploitation de l'aquifère ne doit plus être la affaire des producteur mais surtout des spécialistes.

C'est ainsi qu'un réseau piézométrique est mis en place depuis quelques années et suivi de manière permanente et régulière, pour mieux connaitre le comportement de l'aquifère en vue des dispositions techniques et efficaces à prendre pour assurer l'alimentation en eau permanente de la capitale.

Au de là des forages destinés à l'alimentation de la ville de Nouakchott, des centaines d'autres forages et puits privés ou collectifs exploitent le même aquifère sur l'ensemble du bassin.

Après quelques années de collecte de données et au regard du rôle des grands ouvrages hydrauliques (barrage de Manantali en amont et celui de Diama en aval) construits sur le fleuve Sénégal, principale source probable de réalimentation des aquifères du bassin, nous voudrions présenter dans cette note, sur base des données, des rapports et des hypothèses des études antérieures, les premières conclusions sur le comportement du bassin et plus particulièrement du champ captant de Idini :

- quantité et qualité de la ressource en eau ;
- échange eau de surface – eau souterraine;
- bilan de la ressource ;
- scénarios de gestion intégrée.

Mots clés : gestion intégrée, bassin côtier, ressources en eau, Mauritanie, Sénégal, nappe du Trarza, champ captant Idini, Barrage, Forages, Puits.

Groundwater resources management in a region suffering severe natural and anthropic constraints: the Lake Chad basin

Ngounou Ngatcha Benjamin[1], Laignel Benoît[2], Mudry Jacques[3] and Genthon Pierre[4]

The Lake Chad basin is located at the southern limits of the Sahara Desert. The lake is shared by four countries: the Niger in the northwest, Chad in the east, Nigeria in the southwest and Cameroon in the south. Groundwater resources of the lake Chad basin play a major role in the water economy of the four countries. Over the past 30 to 40 years, climate variability has led to strong pressure on ressources: the water supply situation is therefore fragile in several lake Chad basin countries. The region suffers from irregular and insufficient rainfall, poor soils and high temperatures (45 °C). Because of the large variations of yearly rainfall values, the groundwater and surface water level varies consistently across the years. The lake Chad has no outlets and has a high water loss from evaporation (2250 mm). The growing population is putting increased pressure on groundwater resources.

The purpose of this paper is to draw together experience of application of groundwater resources management in semi-arid region in order to provide guidance and examples of good practice in a sustainable manner without sacrificing the possible prosperity of future generation. The main objectives for managing groundwater resources are as follow: reducing pollution; preventing and setting conflicts of use; promoting joint management of aquifer water resources shared among several territorial entities; integrating the management of groundwater and surface water on the basis of proper recognition of the links between aquifer systems and hydrographic basin; review and update the river basin management plan and the programme of measures to take into account any change of circumstances; exchanges of experience and particularly relevant and targeted cooperation throughout the world.

Key word: Lake Chad Basin, groundwater resource management, transboundary aquifers, climate variability, anthropic constraint.

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Analysis of ASAR WS and MERIS FR Data for large scale water and vegetation monitoring in the Iullemeden aquifer west African Sahel Zone

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This paper presents results and products achieved within the AQUIFER project and from applying a remote sensing approach for regional scale water and vegetation monitoring in the Sahel. The Sahel is the transition zone between Sahara desert and an area where in the presence of rainfall agriculture is possible. This area is characterized by important interaction between climate variability and socio-economic key factors like agriculture and water resources. Water resources from dams or groundwater are used in the drought for irrigation, but individual water bodies may dry out completely and large areas are only cultivated during the rainy season. The natural vegetation adapts to the annual cycle of rainfall with a slight temporal delay. The physiognomy of the vegetation zones changes from contracted vegetation in the Sahara to tree, shrub or grass savannas in the Sahel. During the long drought a huge part of the natural vegetation withers. Bald trees and bushes show no photosynthetic activity until the next rainfall. A sparse tree density together with intensive pasturing results in an increased soil erosion in the whole region. The present study is focussing on surface water and vegetation monitoring over parts of Niger, Nigeria and Mali, three countries sharing the common Iullemeden Aquifer System. It is one information layer amongst others in the frame of the AQUIFER project with the overall aim to support transboundary groundwater management. The groundwater of the Iullemeden Aquifer System (IAS) is composed by two major aquifers: the cretaceous Continental Intercalaire and the tertiary and quaternary Continental Terminal. This Aquifer system is affected by progressive over-extraction, water quality degradation human induced pollution, associated with soil degradation, and the impacts of variability and climatic change.

The specific vegetation and the open surface water bodies in these arid regions are good indicators for environmental change. In many parts of the Sahel there are no continuous ground truth measurements available to allow statements about the extension of vegetation and open water bodies. Earth Observation data may provide the only approach to detect and analyse long-term changes and it allows to monitor the negative impacts of human activities and climatic change of the available water resources in this area. This study demonstrates the performance and suitability of ENVISAT MERIS and ASAR-WS data for this purpose. The application of radar capabilities to detect the moisture content and optical information for the phenological state monitoring of the vegetation was aspired. Land cover classification maps were generated using a rule based (object oriented) classification approach. Two different groups of classification types were divided. The first group consists of land cover and land cover change products of four different times within one growth period. The second group consists of pre-classification change product, focused on seasonal dynamics. Additionally, the changes between the four different dates as well as the seasonal vegetation and water dynamics have been analysed.

Keywords: Synergy, ASAR, MERIS, Water and Vegetation Monitoring, Iullemeden Aquifer System, Sahel.

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Transboundary Aquifers Management/Modelling as Management Tool

M. Elfleet

In regions, where groundwater is the principal source of fresh water, the problem of over-abstraction can lead to particular problems – where levels in unconfined aquifers effectively fall, loss of formation pressure in confined aquifers, changing boundary conditions and the potential intrusion of saline water into the aquifer resulting in abstracted water being contaminated by salt water.

In order to develop and understand the impact of strategies for the sustainable exploitation of available water resources in transboundary aquifers, a means of predicting the response of the aquifer to the different demands placed on it is needed. The most obvious approach is to develop a computer based simulation tool which attempt to encapsulate the fundamental equations which govern the flow of water in the aquifer.

This paper presents a case study that uses modelling techniques to forecast unconfined aquifer's response to planned abstraction operations.

SESSION 3

Looking into the Future: What options do we have?

Trends and developments in the legal and institutional dimension of shared groundwater management

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Transboundary (shared) groundwater has been emancipated from transboundary surface water in the treatment it has received by the international community of sovereign States and by legal specialists. Where relevant, State practice has, as evidenced by treaties, agreements and non-binding pronouncements, increasingly zeroed in on the specifics of transboundary groundwater resources development and protection, and has laid down the rules of behaviour for States in their management of this increasingly critical resource. Transboundary groundwater-specific international customary rules are also emerging, largely as a result of the on-going work of the UN International Law Commission. This paper will illustrate relevant State practice while indicating emerging international custom in the matter, and thereafter tease out emerging trends and the issues ahead.

Conceptualizing Cooperation on Africa's Transboundary Aquifer Systems

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In 2007, the German Ministry for Economic Cooperation and Development (BMZ) commissioned the German Development Institute (GDI) to develop a conceptual approach for cooperation on Africa's transboundary aquifer systems (TBA). This was due to the growing awareness in German development policy that groundwater might be a crucial resource for assuring water security and reducing poverty in Africa. Transboundary groundwater management was identified as a particular important topic because of the large number of about 40 TBAs. By this time, these waters are only partially used and seldom managed by riparian states in a collaborative way. The research aimed at identifying overarching principles that can describe a pathway towards improved their management.

The project built on the analysis of five case studies from different African regions, namely the Lake Chad Aquifer System, Kilimanjaro Mountain Aquifer, Stampriet Artesian Basin, North-West Sahara Aquifer System and Nubian Sandstone Aquifer System. These case studies which were effected in close collaboration with local and international experts, revealed that transboundary effects from intense usage are already perceived in the Northern African TBAs by their riparians. In sub-Saharan Africa, effects from intense usage (which is definitely happening, e. g. in Chad (Lake Chad Aquifer) and Namibia (Stampriet)) are still limited to local level what allows for the first conclusion that transboundary groundwater management in sub-Saharan Africa is largely about managing potential effects. Such effects might include a lowing of groundwater tables or changes in groundwater quality that effect its utilization potential. It is to say that the lack of perception of transboundary effects might also be related to a lack of understanding of the systems' hydrogeological features.

The project assumes that (potential) effects to the resources will lead to (potential) cooperation problems, i.e. that these effects can only be avoided or limited by collaborative action of riparian states. Collaborative action is however, impeded by some attributes of TBAs:

- **Externalities**: Due to the complexity of hydro-geological systems, the actual effects of groundwater exploitation might be difficult to relate to the actual causes. This sets incentives for unilateral behaviour of riparian states (race to the bottom).
- **Time lag and Irreversibility**: Once effects to an aquifer are perceived, it might be too late to reverse or remedy them. This calls for precautionary management which is traditionally hard to implement.
- **Information asymmetry**: Costs of monitoring and data management can lay heavy burdens on riparian states. This leads to an advantage for better-off riparians as they know better about the natural system. Governance structures need to counterbalance such financial imbalances.
- **Uncertainty and data needs**: As long as TBAs are not understood as complex and linked systems, there is no incentive for riparian states to gather for cooperation. With regard to the low level of available data on African TBAs, this constitutes a major problem for collaborative management.

Additionally, cooperation problems are often hard to solve as they usually require a re-organisation of use patterns and thus losses for at least one party. Such re-organisation is only achievable if this party is convinced that it gains in the long run, e. g. in form of long-term water security. The definition of costs of non-cooperation (CNC) is thus a crucial element for improved collaboration between riparian states. Unfortunately these CNC are usually hard to figure out as they might be distributed

over long time ranges or involve particular groups of society (e. g. ethnic minorities) which are not valued in domestic policies.

It seems obvious that the establishment of trustful relations between riparian states is a favouring, although no sine qua non condition for cooperation on transboundary groundwater. International development partners might play an important role in working out realistic CNC and communicating these among riparian states.

The research project identified stages of cooperation from separate to joint management which exhibit levels of increasing complexity. (Fig. 1) Joint management might touch on strategic interests and political domains that are perceived in many countries as matters of sovereignty. Nevertheless, it constitutes the only appropriate way for assuring long term sustainable use of transboundary groundwater resources in Africa.

Stage of cooperation	**Levels of increasing complexity**
Establishment of a cross-border forum to develop an information basis, to coordinate national research activities, and to establish a monitoring network	Less contentious
Geological surveys and exchange of information on national use patterns	Touches on strategic interests
Identification of sources of actual and potential threats to transboundary groundwater resources	Touches on strategic interests
Developing use scenarios, including a pre assessment of transboundary impacts	Requires cost / benefit distribution
Decisions regarding common objectives and joint activities to be implemented on national levels	Touches on sovereignty; restrictions on use may conflict with property rights

Source: Scheumann / Herrfahrdt-Paehle 2008:32

Fig.1
Stages of transboundary groundwater cooperation

Transboundary aquifer management is about people

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Groundwater is an extremely important natural resource. It serves vital and economic interests of a large part of the world's population and it plays an important role in sustaining nature and the environment. Groundwater tends to be dynamically interconnected over large distances, through the pores or fissures of aquifers. As a effect, a person abstracting groundwater from a well – or having any other local interaction with the aquifer – in principle modifies groundwater conditions for his neighbours and even for people living at more remote locations within the aquifer's sphere of influence. In economic terms, the impact caused is called an externality – one of the grounds for groundwater resources management interventions. Transboundary aquifers are likely to produce externalities across international or other administrative boundaries. Managing groundwater resources of such aquifers is difficult, even more difficult than groundwater resources management within one single jurisdiction.

First of all, groundwater users have been confronted over the last decades with a gradually more complex world. New voiceless groundwater users have been identified: ecosystems and future generations. Globalisation and increasing pressures on the groundwater systems resulted in the need for taking an increasingly wider geographical context into consideration.

Secondly, one has to be aware that interdependencies, perceptions and scales play an important role in water resources management. Recognizing the interdependencies in the socio-economic domain, the natural domain and the institutional domain helps developing correct perceptions of what is going on and choosing an appropriate scale and effective measures for action.

Finally, how to trigger real transboundary aquifer management action? Four factors seem crucial: awareness, motivation, institutional framework and operational means. Evidently, people start being involved only after they have become aware of the presence of one or more relevant transboundary aquifers. Motivation for action will depend on the results of a transboundary aquifer diagnostic analysis. Further steps require some kind of organisation with a mandate and access to legal or regulatory instruments. To make all these steps possible, an appropriate budget is indispensible, as well as political and public support.

Legal Framework for Sharing Transboundary Ground Water Resources in Regions of Africa

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Water scarcity and its plentitude in spatial distribution by the hand of nature created a paradox for the living conditions of the people around the world. Yet water as a source and resource for sustaining life on earth is such a perennial problem that can hardly be addressed in simple manner because some solutions are not visible on the site while sighting a solution does not necessarily make the problem slighter. Complicated legal issues cropping up surrounding the groundwater reserve and sharing it on fair, equitable and sustainable basis have far reaching implications for the administration of environmental and human rights law. As demand for water increases, water shortages are becoming more common in some areas of the world. In places with water scarcity, such as in a desert, it made sense in the past to have small bodies of governance with strict rules for the inhabitants. Freedom, it appears, is greater where water is most available. Human rights are therefore protected and enjoyed more meaningfully by the people with access to water. Dispute involving sharing water resources are politically sensitive and rarely is it resolved by legal mechanism although legal procedure is often resorted to under the prevailing legal framework. Dispute involving sharing surface water is a visible matter whereas groundwater resource can be contexualised only in the backdrop of scientific principles based on proven data and analytical research output.

More than 2 billion people rely on aquifer for their drinking water supply, irrigation needs and drawing livelihood from ecosystem. Use of ground water for Irrigation need covers 40% in India and 70% in Libya and Algeria. While excessive exploitation can make water table to go down, contamination can be a bad dream for it is not only expensive to clean up but in some cases remediation may not be possible at all. The key to resolve the world's water crisis may lay hidden underground. Thus, nearly half the world's population already depends on groundwater that is pumped from the pore spaces of rock formations, known as aquifers, which lie hidden below the Earth's surface. These formations can span thousands of kilometres and contain enough water to satisfy all of humanity's demands for many decades provided a rational mechanism is devised.

Ground water resources are increasingly being viewed with great possibility in playing a key role in poverty eradication or alleviation as well as sustainable growth in Africa. Ground water is the most reliable and affordable source of potable water and most efficient source for irrigation. The ongoing inventory of aquifers indicates that 60 trans-boundary aquifers are shared by riparian states many of them are located in arid and water short region. About 24 transboundary river basin in Africa, institutional mechanisms are in place (www.bgr.bund.de./EN/Themen/Wasser).

Several hundred metres deep with some of the purest water in the world to grasp the dimensions of the Nubian Sandstone Aquifer, for example, which lies under the desert sand of Libya, Egypt, Chad and Sudan is a boon waiting to be harvested.

Under English common law, water beneath the ground is absolute property of the landowner without regards to its effects on the neighbouring land owners (Bradford v. Pickles). This is known as Riparian rights inherent with the right of ownership of overlying land. A shift in favour of more logical legal rules emerged with enlightenment on the lateral contiguity of aquifers and development of the principles of prior rights known as Appropriative rights (first come, first served). Ground water also can be appropriated and diverted outside of ground water basins by cities, water districts, and other users whose lands do not overlie a ground water basin. In international law context, a State

may within its own territory, make use of groundwater as long as it causes no appreciable harm to another State. However, long term over pumping of ground water that exceeds natural or artificial replenishment has long been a concern. Over abstraction or over drafting a ground water supply is costly and may result in increased pumping, deepening or drilling new wells, poorer water quality; and reduced aquifer capacity.

Ground water lacks the natural self-cleansing abilities of streams and rivers. Under the aquifer's anaerobic conditions, the environment is relatively bacteria-free and the temperature fairly constant. The lack of turbulence in slowly moving ground water allows the transport of pollutants through the system as a «plume» rather than dispersing and diluting contaminants. With the introduction of new chemical compounds into the environment and major advances in detection technology, traces of unfiltered chemicals are discovered in wells worldwide. When ground water is pumped from a coastal aquifer faster than it can be replenished from surface sources, seawater intrudes and contaminates the aquifer.

In African context a *laissez faire* approach to the problem of groundwater abstraction rights is unlikely to serve the general purpose and common interest of the people living in the same region as they share commonalty and contiguity of ground water resources. Shared aquifers are a major bone of contention in arid regions of North Africa and the middle-east. The issue of West Bank groundwater between Israel and the Palestinians is one of the thorny eruptions remaining for settlement. The nature of aridity or semi-aridity characterises the climate and hydrology of the region, hence undisturbed access to water is essential for continued survival. Added to the problem, political tensions among the concerned riparians aggravate the water disputes.

Groundwater is of high social, economic, environmental and strategic importance. It represents about 97% of the freshwater resources available on earth, excluding the water locked in the polar ice. Aquifers, among them numerous transboundary ones, are coming under growing pressure from over-abstraction and pollution, which seriously threaten their sustainability. Up to now international law has paid very little attention to ground water issues than to surface water. Slowly but surely, however, a body of rules dealing with this vital resource is emerging that indicates a trend towards more comprehensive international regulation. Knowledge is percolating through many layers of scientific discussion since the inception of Darcy's law (Darcy's law is a generalised relationship for flow in porous media. It shows the volumetric flow rate is a function of the flow area, elevation, fluid pressure and proportionality constant).

There is an urgent need to make use of the ushering knowledge paradigm to demystify the value of ground water and its relationship to surface water. Moreover, there is a need to inject hydro-geologic concepts and understanding into legal and political discourse and to embark on the development of sound, science-based laws and policies. The present study will explore and analyse some appropriate models for development of clear, logical, and appropriate norms of State conduct by highlighting two issues relating to the question of excessive abstraction either up-gradient or down-gradient across the international frontier which can diminish the groundwater resources in the neighbouring country and inadequacy of protection measures in an up-gradient country which can lead to contamination of valuable groundwater resources in down-gradient country pointing to the integration of modern technology into a legal strategy within a workable model framework.

Transboundary Aquifers in Argentina (South America), cooperation for protection and governance

Ofelia C Tujchneider[1,2], Marta del C Paris[1], Marcela A Perez[1] & Mónica P[1]

South America is a region of the world with a wide variety of water resources, there are very important superficial basins – most of them shared by several countries – and also large transboundary aquifers. In the past, the attention was directed to study and understanding the superficial basins whereas fewer efforts were devoted to groundwater resources. Although for surface water bodies there is a great experience on treaties and other legal agreements providing rules of good governance among the riparian countries, there is no such experience on groundwater resources.

By the ISARM Programme, an international network for transboundary aquifer resource management, supported by UNESCO´s IHP, in co-operation with IAH, FAO, OAS, UNESCWA/OSS, seven transboundary aquifers were preliminary identified in Argentina. Most of them were recognized in agreement with the scientists of the sharing countries. The identification of transboundary aquifer systems requires a multidisciplinary approach and the generation, processing and analysis of thematic data and information, such as geology, hydrogeology, geological structure, hydrogeochemisty, hydrodynamics, hydraulic parameters, climatic information, biodiversity, legal and socio-economical aspects, and so on. All of these factors should be interpreted and accepted by the sharing countries to agree on the geometry, boundaries and characteristics of the shared aquifer. The appropriate methodological procedures and framework for this activity was offered by the UNESCO/OAS ISARM America Programme. The Programme is a local initiative launched by UNESCO/International Hydrological Programme (UNESCO-PHI) with the Organization of American States (OAS), during the International Hydrogeologists Association (IAH) and Latin American Association of Groundwater for Development (ALHSUD) at the Mar del Plata Congress (Argentina, 2002). The main objectives of this Programme are: 1) reaching better scientific, environmental, legal and institutional knowledge on transboundary groundwater; 2) collecting information to create the Americas Transboundary Aquifers Inventory; 3) selecting prioritary study cases to implement pilot projects.

In the Argentine inventory, two important transboundary aquifer systems had been identified previously to the launching of ISARM America: the Guaraní Aquifer System (SAG) (Montaño *et al*., 1998; Silva Busso, 1999) and the Yrendá Toba Tarijeño Aquifer System (SAYTT). The other five:

called Litoral Cretácico, Salto-Salto Chico, El Cóndor and Puneños aquifer systems are the result of the Programme mentioned above. According with the different climatic characteristics of the country and the shortage of surface water resources, groundwater and particularly transboundary aquifer systems, acquire strategic interest in the socio-economical development for Argentina. Nevertheless the lack of control in their exploitation and land use control could produce the eventual deterioration of their quality or/and quantity. So, the great and main challenge for all the South American

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countries will be the selection of appropriate models of institutional organization to manage and protected the transboundary water resources. Independently of the diversity of the possible institutional models, it must take into account the real richness of fresh water and the need of agreement and cooperation between countries. This involves a the great responsibility for the environmental sustainability and an equitable and efficient manage that must be solved on the basis of system (natural and social) knowledge, the develop of legal instruments, capacity building strategies, control and protect policies to avoid conflicts, strengthen the institutions, raise awareness, improve the water governability, reduce poverty and achieve the Millennium Goals.

Fig.1
Transboundary Aquifer Systems in Argentina.

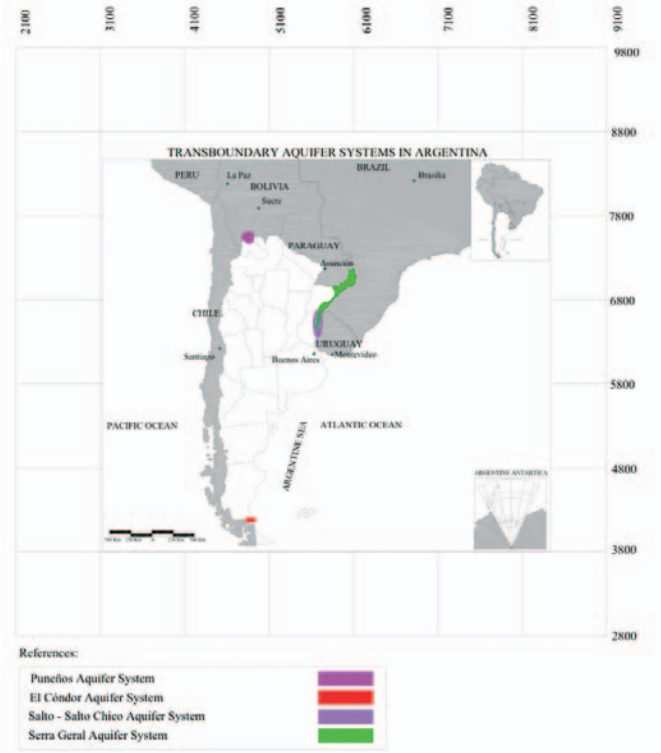

Fig.2
Transboundary Aquifer Systems in Argentina.

Benefit Sharing Framework in Transboundary River Basins: The Case of the Nile

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Evidence of global water crisis is widespread. Currently, one-third of the world's 6 billion people have no access to sanitation and one billion are without access to clean water. The UN believes that over the next two decades the average supply of water per person worldwide will drop by a third. Although 60 percent of the African continent is covered by transboundary river basins, about one-third of its population (300 million people) is experiencing increasing water scarcity. It is projected that by 2025 half of African countries will experience water stress and the sharing of shared water resources will play a significant role in inter-state relations amidst a combination of burgeoning population and recurrent drought/famine in some parts of the continent.

Benefits in use of transboundary rivers such as the Nile are multiple and interacting. These benefits include political cohesion, economic cooperation, environmental and natural resource protection and development, and social and cultural relations. It is high time for the aforementioned projects to identify the economic and social benefits that can be accrued from them and build principles and mechanisms by which benefits can be shared amongst the riparian states. The aim of the study is to highlight the concept of benefit sharing in transboundary river basins with special emphasis on the Nile.

The findings of the study indicated that benefit sharing in transboundary river basins should dovetail macro economics with micro livelihoods impact to identify potential benefits and costs. For transboundary rivers such as the Nile, attempts should be made to identify the typologies of benefits, aspects of benefit sharing, scenarios of benefit sharing, and the optimization/ maximization of benefits. With the better management of ecosystems cooperation can provide'benefits to the river'; with cooperative management of shared rivers benefits can be accrued 'from the river' (e.g. increased food production and power); with easing of tensions between riparian states costs 'because of the river' could be reduced; and with cooperation between riparian states leading to economic integration comes 'benefits beyond the river'. In terms of aspects of benefit sharing, issues related to benefit sharing for whom, by whom and because of whom need to be addressed. Similarly, scenarios of benefit sharing should be considered as phases or time perspectives by anchoring short-term works of strengthening the hitherto existing riparian links, medium-term tracking and improvement of in-country and transborder institutional arrangements for resource use and cooperation and long-term efforts on investment in basin-wide joint development and programs.

There is huge number of benefits in the Nile Basin that are potentially realizable. For instance, the implementation of watershed management in the Ethiopian highlands may lessen siltation and flooding in downstream Sudan and Egypt. By the same token, there could be economic benefits of electricity generation in DRC to the neighboring co-basin states of Rwanda, Burundi and Uganda. There are also benefits that are less tangible, which take a political direction. A good example for this could be the ease of travel between co-basin countries that can facilitate economic activities and social networking.

The challenge is not so much in identifying benefits but rather to put them in a realistic framework as funded and agreed upon by governments on a bilateral basis. Once this is done, the next important step would be to treatise the agreement so that it becomes part of the treaty. Efforts should hence be made to come up with the Nile Basin Benefit sharing Treaty rather than restricting ourselves to the Nile Basin Waters Agreement.

Further developments of ISARM in Africa : the legal and institutional focus area. Example from the Americas

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The ISARM project has identified five focus areas: scientific-hydrogeological scope, legal, socio-economic, environmental and institutional.

In the American continent, the development of the program has been undertaken by UNESCO in partnership with OAS. In its first phase, the program has focused on the common identification of transboundary aquifers by the national coordinators of more than twenty participating countries. The final result, about seventy transboundary aquifers, was presented at the V workshop in Montreal in September 2007. Following the recommendations of the national coordinators, the program entered into its second phase which was the study of the legal and institutional aspects of transboundary aquifers in the Americas. This paper aims at presenting the process followed, the results obtained, and will give some thoughts on analysis and recommendations. The paper will also give some suggestions for future and further developments of ISARM in Africa, considering existing regional cooperation, initiatives and agreements on transboundary waters, and their possible extension to transboundary aquifers.

A WEB-BASED INTERACTIVE DATABASE FOR SHARED AQUIFERS IN THE EURO-MEDITERRANEAN PARTNERSHIP REGION

J. GANOULIS[1] AND Y. AL-MOOJI[2]

As much as 80% of water resources in the Mediterranean region are shared between two or more countries. Shared aquifers are the most precious sources of water in the Euro-Mediterranean Partnersship countries (Morocco, Algeria, Tunisia, Libya -associate members, Egypt, Palestine, Jordan, Lebanon, Syria, and Turkey), known collectively as the MEDA region. Three regional commissions of the United Nations, namely the Economic and Social Commission of Western Asia (ESCWA), the Economic Commission of Africa (ECA) and the Economic Commission of Europe (ECE) in cooperation with the UNESCO International Hydrological Programme (IHP) have been implementing various activities aiming to improve the management of shared groundwater resources in the MEDA region.

The main purpose of this database is to put together existing reliable data / information on shared aquifers in the MEDA region and make them available and accessible for the use of member states. The database consists mainly of meta-data and it is WEB based and accessible through the Internet. The Google technology is used as background for the regional location of the shared aquifers.

Basic hydro-geological characteristics and also information on groundwater use and assessment in the present situation are provided. The interactive map allows the web user to take a tour in the region, zoom into selected aquifer locations and access basic information on hydrology, hydrogeology, water uses and policy, which can be used for a general understanding of the situation of any particular aquifer or aquifer system. Such information would be useful to decision makers, water professionals, educators, students and all interested citizens.

Key words: Sustainable shared aquifer resources management, cooperation, information exchange, databases, MEDA countries.

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Main achievements in the management of transboundary aquifers in Africa and relevance for national policy

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The aim of this paper is to analyse the inherently political nature of transboundary water management specifically focusing on transboundary aquifer management. While transboundary waters, at least to some extent, has been treated as a natural scientific issue it is argued that it is imperative to include an account of the political context in which decisions guiding the water management of a transboundary basin are taken. Some of the main conclusions drawn in the paper are;

First, water is linked to other political concerns. This is evidenced in the discussions on sanctioned discourses where concerns relating to history, national heritage etc. to a larger or lesser extent influence the water policy decisions.

Secondly, transboundary aquifers (as well as transboundary surface waters) seem to be a source of co-operation and that relates in part to the regime/institutional characteristics that evolve over time in different basins. However, to achieve improved co-operation with increased trust among the riparians donors and other actors need to keep in mind that a key aspect is that the evolvement of co-operation is a process which takes time and patience.

Thirdly, the co-operation that takes place shall be viewed through a hydro-hegemony perspective which helps understand the underlying power structures and the fact that what may seem like genuine co-operation is rather a "coercive" function.

Keywords: Conflict, Co-operation, Hydro-Hegemony, Sanctioned Discourse and Water Regimes.

Third International Conference
Managing Shared Aquifer Resources in Africa

Avdhesh K. Tyagi[1] and Abdelfatah Ali[2]

This paper concentrates on the groundwater issues of Libya and surrounding countries. Libya covers a large surface area of more than 1.5 million square kilometers. Libya shares it's borders with Egypt and Sudan in the east, Chad and Niger in the south, and Algeria and Tunisia in the west. In the north, it has more than 2,000 kilometer border on the Mediterranean Sea. These surrounding six countries share different groundwater basins with Libya.

The most important of these aquifers is the Nubian Sandstone Aquifer extending under Libya, Egypt, and Chad, whereas the Sahara basins share water resources with Tunisia and Algeria. In the north, Libya has over pumped groundwater, resulting in salt water intrusion into the groundwater aquifer. An optimized control of pumping is needed to retard the invasion of the fresh-salt water interface.

The Ogallala aquifer underlies the states of Nebraska, Kansas, Oklahoma, Texas, Colorado, and New Mexico like Libya and the surrounding countries. Modeling studies are performed by the U.S. Geological Survey, Oklahoma State University and other universities in the six states. In addition, the United States has many states such as New York, Florida, Alabama, Texas and California that are affected by the saltwater intrusion problem. There are similarities in the U.S. problems and those in Libya for aquifer management.

This paper is on concepts of groundwater modeling and optimization of groundwater pumping using operations research techniques. In order to grow crops, the water quality is equally important. Sometimes total dissolved solids between 1,000 to 3,000 milligrams per liter are found in aquifer, limiting its usage only for specific crops. Softwares will be suggested for use for groundwater flow and water quality modeling using constraints of pumping and water quality.

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SESSION 4

GEF-IW:Learn

Testing Regional Dialogue and Twinning Processes in Africa for Adaptive Learning in Transboundary Water Resources Governance

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Introduction

The GEF currently supports about a dozen African freshwater basin projects representing investments in the range of US$90 million. The Africa Governance Process project is testing regional dialogue and twinning for adaptive learning in transboundary water resources management and aims to assist African basins in effecting policy reforms to improve water governance and transition to needed investments. Through this project GEF is supporting the adoption and national ownership of transboundary water partnerships, the shift to "systems-thinking" approaches by integrating groundwater, lake systems and climate change considerations in shared basin planning and management, the strengthening of investment planning processes, as well as the exchange of experiences from African basins & GEF projects & partners – including this conference and the outcomes achieved this week here in Tripoli - that can inform global policy dialogues such as the World Water Forum (WWF) in 2009. At the broader development level, GEF IW projects are expected to contribute to the achievement of MDGs and of the Johannesburg Plan of Implementation in relation to Integrated Water Resource Management (IWRM) and reform in the water sector. In particular, the Africa Governance Process project will help ensure that successful experiences in benefit sharing are replicated, that legal reforms support investments and that intersectoral coordination supports poverty reduction efforts in sectors underpinned by the use of water resources. In order to support systematic reforms in transboundary water management and governance, the German government in cooperation with GEF, UNDP, and the World Bank support a process of experience sharing and dialogue (known as the Petersberg Process) and hosted a roundtable dialogue for African Transboundary basins near Bonn in late September, 2007. This high level Roundtable identified priorities determined by a wide range of African stakeholders including public institutions, regional transboundary basin organizations, civil society representatives and donors. The Africa Governance Process project and the experiences of the GEF international waters portfolio in Africa are integral parts of this process and will ensure the recommendations and priorities identified by the Petersberg Roundtable contribute to meetings such as this one and are taken a step further to inform the WWF in 2009. The United Nations University International Network on Water, Environment and Health is working with African Rift Lake basin commissions and North American Great Lakes commissions to jointly develop and test the use lake basin management indicators and to test twinning of great lakes systems. The project also aims to ensure that the water resources concerns of African countries are broadly informed by science, that policy reform is supported by tested benefit-sharing methodology and enacted through the engagement of regional organizations of parliamentarians in integrated water governance – including surface and groundwater as well as freshwater and marine linkages - and that the effectiveness of regional groundwater, lake and River Basin Organizations are enhanced. UNESCO-IHP is coordinating the mainstreaming of groundwater and climate considerations into transboundary water resources management (TWRM) under the umbrella of the GEF/UNDP Africa Governance Process project from 2007 through 2010.

Rationale

It is estimated that transboundary water systems cover 61% of Africa's landmass, that 77% of the African population lives in their basins and that they represent 93% of the available surface water in Africa. The distribution of water resources in the African continent is characterized on the one hand by great variability from the dry North to the South and from the Sahel in the West to the arid Horn region and on the other hand by tremendous interconnection through the 60 transboundary river basins covering over 63% of the continent's land area, some 700 lakes (15 of which are transboundary), and by vast and largely undeveloped transboundary groundwater aquifer systems. This is reflected in the extent of the GEF response through its extensive investment in African IW river, lake and groundwater (including coastal aquifers) – as well as land degradation, biodiversity and adaptation – projects.

Objectives

To increase African leaders and stakeholders' knowledge and political will for balancing sustainable uses of water resources at the transboundary and regional basin systems scales by institutionalizing systems-thinking and adaptive management feedback mechanisms, 3 mutually instructive objectives support the continent-wide GEF and other donor-funded transboundary water cooperation initiatives:

1. To facilitate implementation of partnerships, exchanges of experience, and learning on policy, legal and institutional reform for transboundary waters management through increased knowledge and capacity of decision-makers, legislators and public opinion-makers;
2. To enhance regional and national knowledge and capacity for the management and planning of shared water resource systems through the integration of groundwater dimensions, climate impacts and development of science and policy linkages for river basin and lake system management;
3. To strengthen investment planning processes in shared water resources management and infrastructure by sharing lessons on transition from donor support to self-sustaining regional water institutions and providing a basis for assessing optimal investments in support of benefit sharing discourse

Outcomes expected

The principles of engagement for all partners in the Africa Governance Process are: a) Ensuring that all activities benefit African countries, basins and organizations; b) Building on existing projects and initiatives, when they bring an added value to GEF projects and to the water governance process in Africa; c) Broadening the stakeholder base beyond the usual technicians, scientists and water experts – and to specifically include parliamentarians and media.

The project supports activities contributing to:

- Enhancing understanding and capacity of regional and national decision-makers, legislators and the media to influence governance and reform shared water resource planning and management;

- Informing deliberations at WWF 2009 with African TWRM experiences;
- Regional learning mechanisms institutionalized among African RBOs;
- Building capacity of key actors and institutions to mainstream groundwater considerations and climate change impacts in water resource management strategies and policies;
- Articulating African perspectives and priorities on (i) groundwater and climate change, (ii) Lakes management and governance and (iii) adding value to collaboration (and also brought to discussions at WWF);
- Agreed framework for collaboration on great lakes systems through enhanced science and policy linkages;
- Testing methodology for assessing benefit sharing options for investment;
- Catalyzing investment commitments at water system levels;
- Transferring lessons on transition from donor support to self-sustaining regional water institutions.

With the backing of the international community the project strives through partnership among GEF IW projects, AMCOW, AMCEN, NEPAD, Parliamentary organizations of the regional African communities, civil society organizations, media and scientists, to generate three key results:

a. Better understanding among national legislators and decision-makers of transboundary water issues and experiences - and that African experience will inform deliberations of the WWF in 2009;
b. "Water system" approaches and climate change considerations are better reflected in water resource planning and management
c. Effectiveness of transboundary water resources management institutions are enhanced through strengthened investment planning and financing.

Conclusion

The African nexus is clear: Growing pressure on water resources from population and economic growth and climate change is driving the need to engage stakeholders at multiple levels and across sectors in integrated, eco-system-based approaches as a foundation of sustainable development. This means confronting an increasingly urgent need to improve cooperation both within and between transboundary basin systems at a sub-regional and indeed continental scale to balance competing uses of water resources and share experiences.

On the issue of water scarcity, the 2006 Human Development Report concluded that it was a consequence of poor management and governance rather than one of absolute scarcity of the resource. The delivery of tangible benefits for African populations and the conservation of key ecosystems functions and services are threatened by (i) poor governance structures and the lack of translation of transboundary agreements into national legislation; (ii) theoretical understanding of benefit sharing which is not easily valued in terms of development impacts and (iii) the prospective of future climate change impacts which tend to reverse the tendency from cooperation to the protection of individual, national interests. As noted already by AMCOW and underscored in the Petersberg Africa Roundtable, while capacity remains weak in African water

governance institutions at all levels, the institutional architecture is largely in place, the Africa Water Vision provides a framework for priority actions, networking among African practitioners and policy-makers within and among transboundary basins is a proven means to share successful experience and learn from mistakes, benefit-sharing approaches can increase the benefits to all stakeholders within transboundary surface and groundwater systems and the role of groundwater and aquifers is expected to be developed as one of the keys to successful adaptation to the impacts of population pressure in the context of climate change in arid regions and in particular in Africa. The need for considerable information exchange and communication is crucial to forging new ways to manage Africa's shared freshwater resources as a network of hydrologically and socio-economically interconnected and transboundary hydrographic systems and to implement ecosystem-based governance as a means to guide investment, infrastructure and development planning from the regional to community scales necessary to meet Africa's development needs both in the context of climate change and without compromising future generations.

In closing it is my pleasure to welcome Andrea Merla who will now share with us some insight on the Transboundary Diagnostic Analysis (TDA) approach which has been developed under his tenure with the GEF and in particular why this is important in the context of ISARM and groundwater management in Africa, as well as to thank the GEF project managers who will then share some of the lessons and challenges from their experience in strengthening transboundary water cooperation in the Nubian, NW Sahara, and Iullemeden aquifer regions, and finally to thank one of our GWP partners who will address the significance of involving parliamentarians in TWRM – and to welcome and thank the participants in this session with whom we look forward to some fruitful discussion!

Groundwater Priorities in Africa – Five Years of GEF Experience

Andrea Merla
UNESCO Consultant

The arid and semi-arid regions of Africa have been since the early 2000's the focus of the groundwater portfolio of the Global Environment Facility, an independent financial organization that provides grants to developing countries for projects that benefit the global environment and promote sustainable livelihoods in local communities. The portfolio developed rapidly thanks to the scientific guidance provided by the ISARM program of UNESCO IHP, and to a partnership with UNEP, UNDP and the World Bank, the three core agencies of the GEF. It now embraces wide regions of Saharan and Sub-Saharan Africa addressing some of the world's largest transboundary aquifers: the Nubian, the NW Sahara, the Iullemenden among them. This first phase of GEF action was built upon UNESCO's pioneering work in the identification of transboundary aquifers systems, that has raised the awareness of states and of the local scientific communities on the shared nature of these fundamental resources. As we move towards a renewed and hopefully expanded effort of the GEF – UNESCO alliance on groundwater, it is the appropriate time to draw some general considerations from the experience gained during these first challenging years.

Among its many unique features, Africa is dominated by hydro-geological processes that develop almost exclusively at a large "continental" geographic and geologic scale. Meteoric water recharge occurs in huge amounts but largely limited to few "water towers" from where slowly, through geologic time, water infiltrates vast horizontally extended layered aquifers formed by permeable rocks in large sedimentary basins, little disturbed by tectonic movements. Because of this "continental" dimension, all these resources are of transboundary nature, and their sustainable use requires a regional, if not continental approach. The understanding of the key features of all major African groundwater resources, which is indispensable for their proper management, requires a regional appreciation of the hydro-geologic processes and a "large scale" vision. Likewise, their management schemes will necessarily have to move beyond narrow local or national contexts to reflect and take into account the regional and often transboundary nature of the processes involved. Possibly more than anywhere else, transboundary cooperation on groundwater issues is essential in Africa, to be achieved through various forms and mechanisms, moving from exchanges to consultation to joint management - from the regional level, like the Regional Centre for the Management of Shared Ground-water Resources recently established in Libya, to the transboundary aquifer level, like the mechanisms functioning for the NW Sahara Aquifer or the Nubian.

In Northern Africa, deep-seated groundwater resources are being actively and sometimes aggressively exploited. This tremendous development came about as a consequence of oil exploration, likewise similar situations in the Arabian Peninsula. Water mining from these largely "fossil" reservoirs poses both technical and sustainability issues, which need to be addressed in order to preserve to the extent possible the strategic importance of this vital resource. The experience being gained in the exploitation and management of these deep transboundary systems should be shared and progressively applied to the many deep but renewable groundwater systems that characterize the African sedimentary basins.

African groundwater resources sustain some of the world's largest and most valuable transboundary freshwater ecosystems, which traditionally provide livelihoods for populations in the hundred of thousands. This role is not always fully recognized. It is now more and more evident that groundwater, with its fluctuations in time and space, is critical for the existence of Saharan oasis and humid zones, for the survival during extended droughts of the inner deltas of the Niger or the Okavango, for the functioning of the Sudd swamps, and of many more wetlands and lakes of the continent. Lake Chad is a groundwater outcrop, its waters fluctuating, and even disappearing altogether, but never changing in salinity. This global patrimony of huge economic and biodiversity value is now at risk, not least because the fundamental importance of groundwater is not well understood. Excessive groundwater abstractions, lack of appreciation and disregard of surface water – groundwater interactions, and contamination are among the anthropogenic causes. Conjunctive surface and groundwater management is the only sustainable answer.

The imperative of climate change adaptation is presently at center stage worldwide. In Africa there is a growing sense of urgency, as land degradation progresses unstopped and enhanced by climatic fluctuations and extreme events. Groundwater, less dependent on climate, with a slow response to fluctuations, and almost ubiquitous, needs to play a strategic role in the climate adaptation arena. In many cases, it may make the difference. These key functions of groundwater have to be preserved, and enhanced through the use of new, innovative methods of recharge and exploitation, the full technical and economic assessment of deeper aquifers, the expansion of the resource base through the application of modern exploration technologies to new less endowed regions, and the recognition of its renewable and climate independent energy potential.

Le système aquifère du sahara septentrional: Exemple d'une gestion concertée d'une ressource partagée

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Le Système Aquifère du Sahara Septentrional (SASS), partagé par l'Algérie, la Libye et la Tunisie, renferme des réserves d'eau considérables, qui sont cependant peu renouvelables et ne sont pas exploitables en totalité. Au cours des trente dernières années, l'exploitation des eaux du SASS par forages est passée de 0,6 à 2,5 milliards de m3/an. En conséquence de cette multiplication non concertée des prélèvements, cette ressource se trouve aujourd'hui confrontée à de nombreux risques tels que la salinisation des eaux, la réduction de l'artésianisme, le tarissement des exutoires naturels, la baisse de la piézométrie ou les interférences entre pays …, ce qui menace lourdement à terme la durabilité du développement socio-économique engagé dans l'ensemble de la zone.

Face à ces enjeux, un processus de coopération entre les trois pays qui partagent les ressources en eaux du SASS est devenu indispensable. Tel a été le sens du projet SASS facilité et mis en œuvre par l'Observatoire du Sahara et du Sahel (OSS), conjointement avec les trois pays. Ce travail commun a axé son programme sur :

- La maîtrise des connaissances hydrauliques par le biais d'un modèle de gestion pour l'évaluation des ressources exploitables à l'horizon 2050 et l'identification des risques qui y sont liés.
- L'implémentation d'un système d'information commun avec une harmonisation des données facilitant ainsi l'échange et la mise à jour de la base de données commune.
- La sélection des réseaux communs de suivi de la ressource sur le double plan piézométrie et qualité
- La réalisation d'études relatives à la socio économie et aux impacts environnementaux en vue de consolider les résultats hydrauliques et formuler des recommandations à un développement qui préserve aussi bien la ressource en eau que celle des sols.
- La mise en place d'un mécanisme de concertation pour une gestion conjointe du bassin par les pays qui le partagent.

Cette communication a pour objectifs de décrire, d'une part les différentes étapes réalisées sur les plans technique et institutionnel pour asseoir une véritable coopération entre des pays partageant le même bassin,et d'autre part, le processus de passage du niveau technique au niveau politique pour assurer la mise en œuvre d'un développement commun,durable et concerté.

La gestion concertée des ressources en eau partagées du Système Aquifère saharo-sahélien d'Iullemeden (Afrique de l'Ouest)

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Au cours des trois dernières décennies, le Système Aquifère d'Iullemeden a fait l'objet, dans chacun des trois principaux pays de son domaine d'extension (Mali, Niger et Nigeria), de nombreuses études pour identifier, caractériser et mettre en exploitation les formations aquifères qui le composent. Ce Système aquifère appartient au grand bassin sédimentaire du Niger qui est encadré par les boucliers de la zone mobile panafricaine au nord et au sud, le bouclier du Man à l'ouest, la dorsale du Damergou à l'est qui matérialise la ligne de partage des eaux souterraines entre ce bassin et celui du lac Tchad. Il communique avec les aquifères du bassin de Taoudéni-Tanezrouft (Mali-Mauritanie-Algérie) par le graben de Gao à l'ouest. Dans sa partie occidentale, le Système aquifère est drainé par le fleuve Niger.

Le Système Aquifère d'Iullemeden est composé de deux importantes séries gréseuses aquifères : le Continental intercalaire (senso stricto) d'âge crétacé surmonté par le Continental Terminal d'âge tertiaire et quaternaire. Ces deux réservoirs aquifères sont séparés par des formations semi-perméables d'âge paléocènes et éocènes à travers lesquels ils communiquent. Des modèles conceptuels bidimensionnels hiérarchisés, ont permis d'illustrer les échanges hydrauliques existant entre ces deux principaux aquifères qui offrent des ressources en eaux souterraines considérables sur une superficie de 500.000 km^2.

Ces ressources en eau sont exposées à un environnement vulnérable et contraignant : 1) baisse de la pluviométrie de l'ordre de 20% à 30% depuis 1968-70 ; 2) ensablement du réseau hydrographique et installation des cordons dunaires notamment dans les aires de recharge. Par ailleurs, ces ressources en eau sont peu renouvelables et majoritairement anciennes avec toutefois des eaux récentes dans les zones de recharge. En effet, les eaux du Continental intercalaire ont révélé des teneurs en 14C variant entre 96%PCM dans l'extrême Nord où l'aquifère est à nappe libre, et 1%PCM au centre et au Sud de l'aquifère. Ces ressources sont soumises : 1) à la pression démographique (de l'ordre de 6 millions d'habitants en 1970, 15 millions en 2000, la population projetée atteindrait 30 millions d'habitants en 2025) ; et 2) à un accroissement sensible des prélèvements (50 millions de m^3 en 1970, 180 millions m^3 en 2004). Concomitamment, ces ressources en eau sont exposées à la pollution d'origines diverses et à la dégradation de leur qualité notamment par la présence de la Fluor- Apatite $Ca_5(PO_4)_3$ (OH, F, Cl) dans le Continental intercalaire.

C'est ainsi que trois risques majeurs ont été identifiés à travers la démarche ADT/PAS (Analyse Diagnostique Transfrontalière/Programme d'Action Stratégique) préconisée par le FEM pour les Eaux Internationales adaptée aux eaux souterraines transfrontalières du Système Aquifère d'Iullemeden. Cette analyse s'appuie sur une Base de données comptant 17.200 points d'eau couplée à un Système d'Information Géographique, qui ont permis d'élaborer le modèle hydrogéologique du système aquifère. Celui-ci a précisé entre autres, le bilan en eau, la dynamique des écoulements souterrains notamment la drainance entre les aquifères, et les impacts des prélèvements additionnels à l'horizon 2025. L'utilisation de la télédétection a aussi permis de localiser les aires de recharge.

En vue de prévenir et/ou atténuer les risques potentiels qui menacent leurs ressources en eau communes, le

Mali, le Niger et le Nigeria, convaincus que les efforts d'un seul pays ne sauraient maîtriser les conséquences de ces risques, conjuguent leurs efforts à travers une approche concertée pour atteindre les objectifs de développement. Ils ont ainsi adopté, dans ce cadre, la mise en place d'une structure de mécanisme de concertation permettant de mieux orienter les décisions de planification dans un esprit d'optimisation de l'usage de la ressource en eau.

Mots clés : Aquifères partagés, risques transfrontaliers, outils de gestion, mécanisme de concertation, gestion concertée, régions arides et semi-arides, Afrique de l'Ouest.

ROUND TABLE DISCUSSION

the role of the UNESCO Category 2 Regional Centre on Shared Aquifer Resources Management in Africa (Tripoli, Libya)

IGRAC AND ITS ACTIVITIES RELATED TO SHARED AQUIFER RESOURCES

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The International Groundwater Resources Centre (IGRAC) is a joint initiative of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Meteorological Organization (WMO). Generous financial support from the Netherlands Government enabled IGRAC to initiate its activities early 2003 and to develop them until today and beyond. The centre is hosted by the Netherlands Organization for Applied Science (TNO) at the premises of TNO Built Environment and Geosciences, Princetonlaan 8, Utrecht, The Netherlands.

Under the general objective of contributing to adequate development and management of the world's groundwater resources - in conjunction with surface water resources - the basic tasks adopted by IGRAC are the following:

- Enhancing world-wide knowledge on groundwater, by promoting groundwater-related information and experiences to be shared and by making this information widely available through centralised information storage/retrieval services and targeted dissemination.
- Contributing to the acquisition of more and better groundwater data, by means of guidelines and protocols for groundwater assessment and monitoring.
- Participating in international projects aiming to support adequate development and management of the world's groundwater resources.

These formulated tasks are the basis for IGRAC's programme of activities, developed in close consultation with the centre's main stakeholders.

A significant part of IGRAC's main activities is related to the subject 'Shared Aquifer Resources'. This includes – among others - contributing to regional inventories and related analysis of transboundary aquifers; developing and updating ISARM's global web portal and its regional components; developing a web-based information system for transboundary aquifers; contributing to correct incorporation of hydrogeological concepts in UNILC's draft Law on Transboundary Aquifers; participating in the preparation and implementation of international projects on transboundary aquifers and any other activities that contribute to the development and dissemination of related knowledge.

A quick look at the contents of the above-mentioned activities yields an impression of the world-wide development of ideas, approaches, knowledge and information on transboundary aquifer resources. It reveals not only what has been achieved, but also what is still missing – in terms of both scientific-methodological framework and geo-referenced information – and what is on schedule to eliminate such deficiencies. Above all, the emerging picture suggests that close and active co-operation between relevant stakeholders is a prerequisite for achieving progress on the subject of shared aquifer resources. There is an important role to play for many, including the new Regional Centre for Shared Aquifer Resources Management (RCSARM) at Tripoli.

The Quo Vadis Aquifer Initiative: Linking groundwater resources to human security

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The past decades have seen an increased exploitation and reliance on groundwater resources which has allowed many people to secure their livelihoods and for regions to develop agricultural production or their industry. Although groundwater resources are abundant on a global scale, they are, like all other freshwater resources, not homogenously distributed around the world. In many instances, groundwater resources are being overexploited, with withdrawal rates exceeding recharge rates and are polluted by anthropogenic activities such as industrial wastes, urban wastewater, land use changes, and/or agricultural pesticides and fertilisers. Unsustainable groundwater exploitation and the vulnerability of the resource itself to other anthropogenic activities either have direct consequences on populations (e.g. polluted drinking water, land subsidence in mega-cities), or represent a "creeping" threat that will materialise in the long run. Superimposed on this, climate change, by affecting the hydrologic cycle could make a difficult situation even worse in the future in some regions of the world. All these threats combine to put increasing pressures on the resource and this in turn threatens human security.

Human (in)security can be captured indirectly through vulnerability assessment of people or communities who rely on groundwater resources or who have no (or not yet) access to the resources. With this perspective, groundwater can be seen as having either a negative impact on people when the resource is degraded or it can also improve livelihoods when people who had no access to the resource gain that access. Capturing the linkages between groundwater resources and human security is thus a complex process and the United Nations University (UNU) and UNESCO-IHP have decided to cooperate on this topic by creating a research and capacity development umbrella programme called "Quo Vadis Aquifers" (QVA) that is now integrated in their respective work programmes. As the theme is complex, requires a multi-disciplinary approach and many aspects of the linkages between groundwater and human security should be addressed, the QVA programme will have various projects running under it.

The first such project is now in place and is a cooperation between four partners in Egypt, Vietnam and Iran I.R.; UNESCO-IHP; and two UNU Programmes (UNU-EHS – that coordinates this project, and UNU-INWEH). It is called Groundwater and Human Security – Case Studies (GWAHS-CS) and the overall objective of the project is to address the threats to human security and well-being currently posed by water scarcity and water quality degradation in developing countries and the role of groundwater management and protection in alleviating such threats. This research project will adapt and apply vulnerability assessment methods to determine the vulnerability of communities who face freshwater supply problems. In addition, socio-environmental indicators of vulnerability with respect to groundwater will be developed. Four case study areas were selected for the project research: one in Egypt (Wadi El Natroun which is located approximately 90 km south of Alexandria and 110 km North West of Cairo in the Western Desert); one in Iran I.R. (200 km southeast of Shiraz in the Gareh-Bygone Plain) and two in Vietnam (Tra Vinh Province in the Mekong Delta; and Binh Thuan Province in South Vietnam). The case studies represent a diversity of situations

with respect to the groundwater resource, climate, and human activities which will serve as a basis for reliable methodological developments. The results of this project (anticipated for the end of 2009) will then be used more globally in a follow-up phase and in other geographical and cultural settings.

POSTER PRESENTATIONS

New Dimensions in studying shared aquifers in Africa

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In attempts to optimize the future development of a trans-boundary basin, certain types of approaches, should be sought preferentially, both by institutions dealing with trans-boundary water resources and by national water authorities themselves.

A consideration of the Case Studies and other trans-boundary water resources has shown that several factors with potential contributions to the optimal future development of trans- boundary basins are of frequent importance, but have received insufficient attention from most researchers of which seismic events inducing hydrological changes has not received sufficient attention although many parts of African continent are located at the intersection of two seismically active tectonic belts. Moreover, the proper management of transboundary aquifers in Africa should consider all factors in hand in an attempt to promote a "basin awareness" by working to increase and exchange knowledge on these units (geological, hydro geological and geophysical as well as improvement of models, etc.), creation of effective joint structures in the face of still poorly mastered resource management.The programme of joint Management of Shared Water Resources seeks to achieve the realization of in-depth studies of the risk zones exemplified herein by the seismic risk and /or events impacted on the clear decline in the groundwater level after the earthquake, a situation which will renders groundwater levels deduced from any model invalid.

Now researchers have established a more subtle effect for shaking of aquifer materials by seismic waves--it increases the permeability of rock to groundwater and other fluids.

Seismic events inducing –hydrological changes is a new dimension that should be sought preferentially in studying shared aquifers in Africa and though it represents a modest step, it can help in the improvement of water management structure and in the development of new techniques.

The integration of water management and the resolving of conflicts can usually be achieved by a combination of institutional, and technical of which new approaches such as the consideration of seismic events should be sought preferentially.

Risque de pollution des ressources en eau souterraine dans la zone côtière congolaise : cas de Pointe-Noire

Albert Pandi[1], Guy Dieudonné Moukandi[2]

La région de Pointe-Noire est représentative des systèmes sédimentaires côtiers, qui est une agglomération densément peuplée où les problèmes de réduction de la quantité et de forte minéralisation des eaux souterraines sont identifiés. Ces ressources en eau souterraine sont sollicitées pour les besoins en eau potable, d'industrie et de sylviculture de façon exponentielle et incontrôlée depuis l'apparition massive des forages profonds (années 1997). Actuellement des entreprises et particuliers exploitent directement les nappes de l'aquifère de Pointe-Noire et les débits prélevés dépassent 88 848 $m^3.j^{-1}$ La deuxième ville de la République du Congo (600 000 habitants) est en train de connaître un très fort taux d'accroissement de sa population. Cette croissance fulgurante est accompagnée d'un développement urbain extensif qui a pour conséquence la consommation incontrôlée de l'espace. La croissance de cette agglomération se développe sous l'impulsion des activités pétrolière et portuaire. Elle constitue le poumon économique de la République du Congo où sont concentrées presque la quasi-totalité des industries (secteur bois, secteur mines : Potasse et Magnésium, hydrocarbures, boisson et eau minéral). Elle est aussi une région sylvicole où se développent des milliers des hectares de plantations d'eucalyptus. Aux activités industrielles développées chaque année, aggravent ainsi les problèmes d'alimentation en eau potable et en énergie, s'ajoute la pollution de l'air, des sols et des eaux par les rejets domestiques et industriels (hydrocarbures, effluents divers et autres) et par l'utilisation des sols (forêts d'eucalyptus). Le manque de suivi du réseau piézométrique et l'inexistence d'un modèle hydrogéologique fonctionnel de cet aquifère limite les possibilités de prévision du comportement des nappes, les exposants ainsi à un risque réel d'invasion par les eaux saumâtres.

De ce fait, on note une forte minéralisation dans la nappe profonde due à la baisse drastique du niveau de la nappe à quelques mètres (voire dizaine de mètre) de rabattement au cours de cette dernière décennie. La minéralisation des eaux, dans la zone de Pointe-Noire, est due à l'arrivée d'eau saumâtre. Celle-ci a été identifiée grâce aux campagnes de sonde de résistivité (Safege, 1990). Toutefois, une concentration en nitrates égale à 50 mg/l a été notée dans les eaux de puits domestiques issues de la nappe superficielle à Pointe Noire (Pandi et Mapangui 2002).

A l'échelle du bassin, l'évolution quantitative et qualitative des ressources en eau demeure une question entière à laquelle il faut impérativement apporter une réponse afin d'aider les organismes en charge de la gestion des ressources en eaux. Pour ce faire, une modélisation hydrogéologique 3D du système multicouche doit être conduite à l'aide des modèles appropriés. Mais préalablement la question du bilan hydrologique et plus précisément, la quantification du terme « infiltration » doit être regardé avec attention.

Le bassin sédimentaire de Pointe-Noire présente un système hydrogéologique à aquifère à multi couches qui sont comprise entre 10 et 400 m de profondeur à Pointe-Noire et 70 et 150 m à Pointe Indienne. Ces

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couches aquifères sont séparées par intercalations des matériaux très composites (calcaire marneux, grès consolidés, argile…) de la série argilo gréseuses rougeâtre du gréso-dolomitique. Les couches les plus exploitées sont la nappe phréatique et la nappe profonde n°1. La première est exploitée de façon artisanale par des puits traditionnels et la seconde industrielle par des forages profonds. Ce système d'aquifère s'alimente directement dans les plateaux de Hinda où existent les plantations d'eucalyptus, avec une réputation de la forte consommation en eau du sol. Les plantations d'eucalyptus pourraient entraîner la baisse d'alimentation de cet aquifère.

L'agglomération de Pointe-Noire compte plus de 77 forages repartis comme suit : 23 forages pour la SNDE (Société Nationale des Distribution d'Eau), avec pour débit d'exploitation 2.477 $m^3.h^{-1}$ soit 59.448 $m^3.j^{-1}$ et 54 forages privés (44 forages d'eau des grands consommateurs et 7 forages de petits consommateurs) pour un débit de 29.400 $m^3.j^{-1}$; soit au total la consommation dans l'agglomération de Pointe-Noire est de 88.848 $m^3.j^{-1}$; débit largement supérieur à l'usage prévisionnel. Le seuil donné par les études de Iwaco (1994) et de Safege (1990) est de 40.000 $m^3.j^{-1}$. Dépasser ce seuil il y aurait risque d'intrusion saline.

Si l'on ne peut pas optimiser le réservoir de cet aquifère, on s'attend à une catastrophe naturelle. D'ailleurs il est surprenant que rien ne soit signalé jusqu'à présent, ce n'est pas un miracle, mais tout simplement il se passe un problème de drainance très élevée qui alimente cette couche. Mais là n'est pas la solution, l'intrusion saline dans cet aquifère est signalée par les écoulements vertical et horizontal.

Le développement de l'exploitation minière et pétrolière pause déjà le problème d'approvisionnement en eau potable car la demande est accrue ; mais cette exploitation demande un pompage de 400 $m^3.j^{-1}$ par exemple pour l'exploitation de Magnésium. Si cela peut se faire dans cette zone, on assistera à une catastrophe naturelle qui se traduirait par une forte augmentation de la minéralisation qui les rendra ainsi impropres à la consommation ; on pourra même assister à l'assèchement des nappes. Le coût d'installation et d'exploitation des équipements de désalinisation des eaux rendrait hors de portée l'accès à l'eau potable aux usagers. Il est donc nécessaire de prévenir cette éventualité en engageant dès à présent une réflexion en vue de définir une stratégie de gestion rationnelle des ressources en eau de l'agglomération de Pointe-Noire. L'urgence de cette réflexion se justifie également par la nécessité de prendre en compte l'influence des variations climatiques sur l'équilibre hydrodynamique de l'interface eau douce/eau salée.

Il est urgent de réactualiser les données piézométriques existantes. Ceci nécessite un suivi régulier de la nappe de Pointe-Noire et donc de réhabiliter le réseau piézométrique de la ville. Le suivi régulier de la piézométrie fournira des données fiables pour le contrôle et la gestion des ressources en eau souterraine.

Groundwater flow system definition andits potential in transboundary and climate change issues

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The original focus of interest in early hydrogeological studies was the aquifer unit, as it is the physical media that stores and permits the transfer of groundwater from the rechargezonetothedischargezone,makinggroundwater available to boreholes for water extraction. Recently, the aquifer concept has been well complemented by flow system theory, where groundwater may be present in local, intermediate and regional flow systems. This implies that groundwater may travel from one aquifer unit to another aquifer unit (or more) located above or below the former. Understanding the geochemical behaviour of groundwater in its geological environment allows prevailing flow systems and existing natural or induced groundwater connection (between aquifer units) in any region to be proposed.

There is increasing evidence that climate is becoming more variable. However, there are still large uncertainties as to whether this may be attributable to global warming. Increasing climate variability may lead to an intensification of the components of the hydrological cycle. For some regions increases in magnitude and frequency of extreme events are already being observed. In addition there is a possibility that future extremes will be projected to be even more severe than those experienced to date. Climate change, as well as increases in climate variability, will increase the vulnerability of certain regions and communities to changes in hydrological responses. Foresighted management practices will be needed to help cope with, and adapt to, these changes. Climate variability and change have been identified as key drivers of ecosystem health, and the growth and spreading of water-related diseases; however, even without climate change, most developing countries will be confronted with serious water problems by the middle of the 21st century.

It has been recognized that adaptation to climate change requires different actions: i) science-based knowledge, ii) resilient development policies, iii) appropriate institutions and regulatory mechanisms, iv) adequate economic resources and instruments, v) international collective action, among others. With regard to the first action, groundwater flow systems and their chemical definition are paramount in the development of a sustainable groundwater extraction management strategy, which should be part of an integral water administration framework aimed at minimizing negative environmental impacts. Such impacts are expected to increase due to predicted future climatic conditions indicating an annual average precipitation decrease in most of the Mediterranean, northern Africa, northern Sahara, among others, an effect that is coupled with an increase in environmental temperature. The continuous expected increase in population and productive activities in those arid and semi-arid regions exercises an additional pressure on existing groundwater flow systems. When these regions are fractioned by administrative and political decisions, the definition of groundwater flow system becomes a significant issue.

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In a local groundwater flow system water takes months or years to travel between recharge and discharge zones, and a reduction in precipitation would reduce recharge and diminish stored water, therefore making local flows more vulnerable to climate change. Thus, there is a need to define local flows and to identify and enhance actions to protect them from contamination and from the danger of inefficient extraction that might be both uneconomical as well an environmental hazard.

In contrast to local flows, intermediate and regional flow systems might travel from one region, or country, into another, with their recharge processes usually taking place in a zone located far away from the discharge zone (naturally or by means of boreholes), and in addition to climate change issues, they need to be evaluated by means of an integrated approach to propose transboundary groundwater management. A definition of flow systems may be reached either through significant amounts of subsurface hydraulic-related data, which is usually scarce in developing countries, or from an integrated analysis of direct and indirect evidence that includes chemical, geological, soil, vegetation, isotopic, and hydraulic groundwater characterization.

The flow system definition may prove to be a valuable tool to define groundwater vulnerability to climate change at either village or city scale, as well as at a state or country level. They may assist in defining a suitable strategy to protect water sources associated with local flows, and the wise management of the flow systems with the lowest response to vulnerability to climate change (intermediate and regional flows) which are, however, central to transboundary groundwater issues.

Remote Sensing Applications for the Exploration of the Ntane Sandstone Transboundary Aquifer in Eastern Botswana and Zimbabwe

Max Karen

Conference Topic - Integrated Water Resource Management Applied to Transboundary Aquifers

Botswana is a semi arid country in Southern Africa, which is heavily reliant on groundwater. In the past 30 years major groundwater reservoirs have been identified within the Ntane Sandstone. The result of the exploration projects has led to the sandstone becoming a key component in the national water supply network.

The Ntane sandstone has been investigated all over Botswana, this has created a lot of data about the aquifer. In the North East of the country the Maitengwe groundwater exploration programme identified a major groundwater reservoir that has since been developed into a wellfield that now supplies 150,000 people in North East Botswana.

The Maitengwe project established important data about the aquifer including ways of targeting permeable zones, age difference of the water and variations in water quality. This data, which included remote sensing and both aerial and ground geophysics can be calibrated against the actual drilling results.

The ability to use remote sensing and geophysics calibrated against real borehole data enables this aquifer to be assessed more efficiently in other areas of Botswana and other SADC countries, this is particularly true of the Maitengwe area; this is because the Ntane sandstone in the Maintengwe area is in direct hydraulic continuity with the same aquifer in Zimbabwe where it is called the Forest sandstone, or more locally the Nyamandhlovu aquifer, it is therefore a transboundary aquifer. The Maitengwe area is part of the Nata Karoo sub basin which is close to the Tuli Karoo Sub basin, both areas are similar, therefore the possibility exists that data and knowledge can also be transferred and used to evaluate the aquifer in both basins.

The main objective of this paper is to highlight ways in which the aquifer can be evaluated in other countries based on decades of work in Botswana. In particular its aim is to try to highlight cost effective exploration techniques that are based on proven methods. The focus of the paper is the use of Landsat imagery in conjunction with aeromagnetic data, which will be used to highlight how structural controls on the aquifer can be identified before costly drilling programmes are started

Keywords: Ntane Sandstone, remote sensing, geophysics, transboundary aquifer.

Development of digital water well licensing system using new technologies for governance in El Kharga Oases–New Valley, Egypt

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In arid environments there are many groundwater bodies suffering of local groundwater overexploitation, groundwater lowering and quality deterioration due to the uncontrolled drilling of the production wells and poor well fields design.

The West Nile Delta groundwater body in North Egypt surviving of these problems, where the overall groundwater extraction surpass twice the groundwater potential, groundwater level lowered between 0.01 to 24 meter and the TDS increased, in the other hand 78% of the region territory still available groundwater potential and there are no sever groundwater deterioration problems.

Also at El Kharga Oases groundwater body located in the New Valley governorate the groundwater is the sole available water resources and it extracted from the unrenewable Nubian Sandstone Aquifer System, where the overall abstraction is slightly exceed the groundwater potential but only at 10% of the region territory; the groundwater units are overexploited by nine times the estimated groundwater potential, as the result of the poor well field design and inequitable well spreading crosswise the oases.

In this paper the author introduce a new digital licensing system put together many specific interactive static and dynamic layers using modern technologies of Geographical Information System (GIS), Global Positioning System (GPS) and numerical Groundwater Modeling System (GMS).

Initially to build the system we prepared five basic static layers, which reflect the general characteristics of the groundwater body; Topographic map or the digital elevation model, geographical map includes streams, surface water bodies and local administration units, boundary of the existing hydrogeological units, well location map and the generated GMS grid lie on top of the other layers using GIS techniques.

Then the Groundwater Body locally divided to even areas matching with the model grid named Groundwater Units that divided to similar smaller Elements, which include a certain number of the groundwater model Cells to link the basic maps with the GMS.

We used the well data and the groundwater information assembled and organized in the National Groundwater Information Center, which linked to the GIS and the GMS to produce series of aquifer interpretation (dynamic) layers and maps with different scales for the Groundwater Body till the smallest Element or Cell. These dynamic maps include Groundwater level map, distribution of TDS, thicknesses and extension of the different aquifers and abstraction distribution map.

In order to develop this interactive information system to fit the licensing processes we developed a macro program for data base software to take in the consideration the National Groundwater Legal Framework criteria and limitation and some important socio economic factors. Also we updated the GMS periodically with analytical sub routine and the recent well data to produce detailed dynamic specific reports or/and maps for certain groundwater area (cell, Element, Unit, Body). This specific report shows the total and

the available groundwater potential at this area, the characteristics of the nearest wells; includes the water level, discharge, water quality and optimum well design and also give major criteria and measures for requested well licensing or technical advice to move the requested well to appropriate place.

This Licensing System operated electronically by sending the well coordinates in UTM projection Via Email or SMS to the Groundwater Information Center located at the Research Institute for Groundwater to get the specific report for well license issue or renewal.

This licensing system is interactive realize the participation of all groundwater stockholders, investors, farmers, technicians, engineers, researchers, decision makers and politicians in the groundwater development and management process. It characterized by publicity and transparency and considered an efficient system for groundwater protection and a good step toward governance of the groundwater management in the arid and semi arid region for sustainable development.

Evaluation des ressources en eaux dans la région de Yaoundé (centre Cameroun): influcence des changements climatiques sur leur evolution

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Cette étude vise à la caractérisation (quantitative et qualitative) des ressources en eau dans le bassin versant du Mfoundi de la ville de Yaoundé, afin d'apprécier l'impact de la variabilité climatique.

Au niveau hydro climatique, les résultats des études montrent que les précipitations ont été dans l'ensemble moyennes (1547,2 mm). L'analyse des indices des précipitations permet de constater que la chronique 1927 à 2007 est marquée par une alternance des périodes excédentaires et déficitaires, sans aucun cycle régulier. Les périodes déficitaires, assez fréquentes, ont néanmoins entraîné une baisse significative des écoulements sur certains bassins versants. Le comportement de la nappe suit celui de la pluviométrie (vidange en saison sèche et recharge en saison de pluie). Les températures qu'en à elles ont plutôt augmentées.

Du point de vue bactériologique et physico-chimique, les résultats témoignent d'une dégradation significative des ressources en eau: concentrations en coliformes totaux et fécaux, en streptocoques fécaux, en aérobies sulfo réducteur comprise entre 10 et 500 000/l00ml d'eau ; matière en suspension (MES) comprise entre 5 et 107mg/l ; conductivité comprise entre 73 et 603 µS/cm ; Demande Biologique en oxygène (DBO5) comprise entre 16 et 48 mg/l et Demande chimique en Oxygène (DCO) comprise entre 43 et 81 mg/l. Le facteur prépondérant qui contrôle la qualité des ressources en eau dans le bassin du Mfoundi, reste l'anthropisation sous ses différentes formes (occupation anarchique des sols, rejets solide domestique et industrielles mal contrôlés, mauvais assainissement, augmentation de la population suivie des espaces occupées…. Ceci se traduit par les pollutions diverses observées sur les points d'eaux (puits, sources et cours d'eau) étudiés.

Mots clés : Yaoundé, ressources en eau, changement climatique, pollution, assainissement.

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Levels of cadmium, chromium and lead detected in a ground water source in Zaria, northern Nigeria

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The primary concern of scientists, managers and policy makers all over the world is not only on the depletion of ground water but also contamination. This contamination is caused by leaking of underground storage facilities; inferior design and construction of industrial waste ponds; and seepage from the deep well injection of hazardous wastes into underground geologic formations; and runoff carrying residues from food products, motor vehicles, road construction and buildings. A total of seventeen wells in seven settlements around Zaria, Northern Nigeria were investigated for nominal levels of Cadmium (Cd), Chromium (Cr) and Lead (Pb) using Atomic absorption spectrophotometer (AAS). Chromium was observed to have the highest mean concentration of 0.4882mg/L, while Lead had the least concentration of 0.0635mg/L. The concentration of Chromium was observed to be above acceptable levels for Total Daily Intake (TDI) while that of Cadmium and Lead were within acceptable TDI levels. It is established world over that an average of 25% of usable ground water is contaminated and in some areas as much as 75%. This is a cause for great concern as man and animals stand the risk of heavy metal poisoning. There is therefore the need to effectively manage and conserve groundwater.

Keywords: Ground water, wells, Cadmium, Chromium, Lead, Zaria, Nigeria.

Les prémisses d'une vision communautaire de la gestion des cours d'eau internationaux

Naoual Bennaçar

L'eau source de conflits entre États a toujours été foyer de discorde. Il est intéressant de rappeler que 145 traités portant sur des cours d'eau internationaux sont en vigueur[1]. Serait-ce le début d'une sagesse se profilant au travers d'un difficile apprentissage du partage de l'eau ? Une prise de conscience nécessaire pour qu'une révolution des mentalités et du droit international transforme l'approche destructrice que les hommes semblent faire prévaloir ?

La conscience qu'un partage pacifique de l'eau peut être une source précieuse de coopération entre les peuples éviterait bien des conflits latents ou à venir dans les rapports entre les différentes communautés. Car l'exploitation des nappes phréatiques et le contrôle des rivières peuvent provoquer des tensions et des conflits entre pays voisins et riverains. L'analyse des ressources hydriques dépasse le cadre national, et la problématique commence à recevoir l'attention nécessaire dans le système du droit international.

Une culture de l'eau dans les organisations internationales a vu le jour. Face aux réactions unilatéralistes de certains États dans l'appropriation de cours d'eau internationaux se construisent difficilement des théories de partage. Toutefois les obstacles à une approche prenant en compte la ressource dans sa globalité, semble peu à peu s'imposer (chapitre I). Une évolution paraît se dessiner pour enfin appréhender l'apprentissage difficile qu'est celui du partage de l'eau et reconnaître en l'eau non plus une ressource qui divise, mais une ressource naturelle qui, en étant partagée, peut aider à rapprocher des peuples et les États au-delà de leurs divergences (chapitre II).

En effet, la croissance démographique, les besoins différenciés mais en augmentation continue des pays industrialisés comme des pays en voie de développement, les aléas climatiques, qu'il s'agisse de sécheresses récurrentes, de pénuries chroniques ou d'inondations dévastatrices, exacerbent le caractère vital de l'eau, qui devient un enjeu économique majeur – et donc un enjeu de politique nationale ou internationale générateur de situations conflictuelles entre États.

Ces situations conflictuelles demeurent jusqu'à présent largement dominées par les rapports de force, qu'il s'agisse du Proche ou Moyen-Orient (Euphrate, Nil, Jourdain) ou d'autres parties du monde (Rio Grande, Gange, etc.). En dépit de timides avancées dans les concepts de partage des eaux, l'évolution prometteuse vers une approche intégrée constatée ces derniers décénnies ne dispense toutefois pas d'accélérer ce processus, si l'on attend du droit international de l'eau un appui décisif dans la résolution des conflits d'usage. Une harmonie entre les États sur le partage des eaux est nécessaire pour permettre enfin d'envisager l'eau en tant que Bien commun de l'humanité.

Chapitre I. Les obstacles à une vision communautaire de gestion de l'eau
Chapitre II. L'eau : Bien commun de l'humanité

1. WOLF et AMNER, cité par « The World Water Vision » in Proposition pour contribuer à la mise en œuvre de structures efficaces concernant la gestion des eaux partagées. Sur les 145 traités existant, 124 sont bilatéraux et 21 sont multilatéraux, 52 font suite à des litiges entre deux États, ou encore d'un désaccord entre deux États liés et un troisième (15), alors que 22 traités ne font mention d'aucun désaccord et que 47 ne le précisent pas. De nombreux traités ont été signés grâce à des compensations en espèce (46), en terrain (6) ou autre sans lien avec l'eau (10) et 83 se réfèrent uniquement à l'eau. En ce qui concerne leurs objectifs, 57 traités se rapportent à l'hydroélectricité, 53 à l'alimentation en eau, 9 aux usages industriels ou à la navigation, 6 à la pollution et 13 aux inondations. Enfin, 78 d'entre eux ont prévu des clauses pour les mesurer et 67 n'en ont pas. Beaucoup de ces traités, qui ont 20 à 50 ans, n'avaient que des objectifs limités, notamment résoudre une crise, et ne mettaient pas en place un organe permanent de concertation (ou ceux prévus n'ont pas fonctionné), (http://www.oieau.fr/forum2/resume_academie.htm)

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