CHALLENGES AND POSSIBLE SOLUTIONS FOR WATER RESOURCES MANAGEMENT IN THE 21st CENTURY

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INTRODUCTION

Drought in Ethiopia, national conflicts over the Middle East waters, floods along the Yangze river in China, floods and droughts in alternate years in India, riots over irrigation water in the Punjab, cholera in Peru, subsidence in Mexico City, groundwater pollution in Western Europe, industrial effluents in the Volga and arsenic pollution in the state of West Bengal and in different corners of the world water-related problems take different shapes, mirroring the looming water crisis, which will undoubtedly increase in magnitude during the 21st century.

Because the world is facing extraordinary tough decisions about the finite extent of all its natural resources, the only way is to establish policy is through objective and transparent methods that everyone accepts. This technical meeting, which is pioneering these methods, may have repercussions on other environmental policy areas such as climate change, air quality, biodiversity, etc.

The World Health Organization reports that for the first time ever, the majority of the world's population lives in a city, and this proportion continues to grow with projections of 70 percent by 2050. Currently, around half of all urban dwellers live in cities with populations between 100,000 and 500,000 people, and almost 10 percent of urban dwellers live in megacities, which are defined by UN HABITAT as a city with a population of more than 10 million.

As cities around the world experience this exploding growth, the need to ensure they can expand sustainably, operate efficiently and maintain a high quality of life for residents becomes even greater than it is today. This is where smart cities come into the picture. The term "smart cities" is trending amongst governments, urban planners and even the private sector to address the projected demands of cities in the future. Making cities smarter to support growth is emerging as a key area of focus for governments and the private sector alike. A recent estimate of the investment going to be made in the near future on the smart cities initiative is around $108 billion, especially for the smart city infrastructure, such as smart meters and grids, energy-efficient buildings and data analytics.

This keynote address mainly deals with key issues dealing with major water and environmental challenges, namely, raising awareness, data/information shortage, integration, and the management of environmental resources. We all have specific interests on water and environmental issues and possible solution methods specifically smart water management and a brief accounting of these points are discussed in this paper.

Global Perspective on Water and Environment

Before concentrating on water related problems in India, let us have a look at the global situation. The Second World Water Forum in The Hague in March 2000, the largest freshwater conference ever, showed it very clearly to the world public: Water will be one of the **central**

issues of the 21st **century** of this globe and the life of billions of people will depend on the wise management of this resource. During the Forum, the International Water Management Institute published a study on the world water situation in **2025**. Some of the statements of this study may be quoted here:

*"Nearly one-third of the population of developing countries in 2025, some **2.7 billion** people, will live in regions of **severe water scarcity**. They will have to reduce the amount of water used in irrigation and transfer it to the domestic, industrial and environmental sector" (IWMI 2000).*

In **India**, some 460 million people and in **China** more than 500 million people will live in regions that will face **absolute water scarcity**.

Groundwater reserves will be increasingly **depleted** in large areas of the world. In some instances this will threaten the food security of entire nations, such as India. This will certainly lead to major problems in food security and excess to save water.

Groundwater contamination by human interference, e.g. by industrial effluents, agricultural pollution or domestic sewage water intrusion is another world wide problem, which asks for urgent counteractions.

The world's **primary water supply** will need to increase **by 41%** to meet the needs of all sectors in a sustainable way in 2025. This increase in water demand is largely due to the increase in the **world population**, which is estimated to increase to some 80 million people every year, at least up to 2015. This means **another India for the world to feed every decade** (Falkenmark 1998)**!**

Another problem which faces mainly the Developing World is the phenomenon of **urbanization**: "Safe water and sanitation close to the home for everyone" as demanded by the Mar del Plata Action Plan, seems to remain a dream when acknowledging that in 2025 nearly **4 billion people** will live in urban areas – and the process is most dramatic in countries with relatively few resources (GWP 2000). **Seawater intrusion** in coastal aquifers due to overdrafting is another urgent problem in most tropical and subtropical countries alike. This anthropogenic problem accelerates in some areas the already existing natural problem of **poor groundwater quality**, e.g. of high **salinity**. In Tunisia, 26% of surface water, 90% of water pumped from shallow and 80% from deep aquifers have a salinity of more than 1.5 g per litre. There are many other water related problems, like frequent floods, soil salinization, acid rain etc. which are encountered worldwide. This is clearly stated in the statement of World Water Commission as follows:

"Every human being, now and in the future, should have enough clean water, appropriate sanitation and enough food and energy at reasonable cost. Providing adequate water to meet these basic needs must be done in a manner that works in harmony with nature."

World Water Commission, quoted from GWP 2000

This is the **global water challenge** and it is well known (theoretically), how to reach this goal, how to solve or least to alleviate the above mentioned problems: " Mobilizing the political will to act", "Making water governance effective", "Generating Water Wisdom", "Tackling urgent water priorities", or "Investing for a secure water future" (GWP 2000).

Among the "**urgent water priorities**", which have to be tackled, some should be mentioned here:

- Increasing productivity of water consumed in agriculture,
- More water storage in reservoirs or underground,
- Better water recycling/reuse practices: "Use each drop of water four times!"
- Reduction in water distribution losses in cities as well as in large irrigation systems
- Regulating groundwater extraction
- Conservation of Available Water
- Effective waste water treatment, less water pollution etc.

The '**Dublin Principles'** shall be the guidelines, among them the highly debated one: "Water shall be regarded as an **economic good**". Will we ever meet the "global water challenge" as mentioned above? Why do the problems persist, in spite of so many declarations, so many 'Visions' and 'Frameworks for Actions'? What are the **underlying causes?.** At least for the Developing World, we can identify some reasons why the situation worsens:

- Pauperisation,
- Lack of social structures,
- Lack of education and training, awareness
- Marked oriented production on a global scale ("Globalisation") with missing or at least insufficient enforcement of environmental laws, etc.

(At least the latter point is also true for many countries in the Industrialized World.)

It is clearly evident that there will be hardly any change to the better during the first decades of the 21st century in this respect, unless the **global economic order** is adjusted. A purely profit-oriented global society will neither go for "sustainable development", nor solve the problems of lower income classes nor of the Developing World in general. There is not only the need for a change in water related paradigms, but a general thinking-over, what paradigms we should accept, what goals we should set. There is **no alternative** than to give a larger share of the global profits to the poor and to the Developing World, allowing them a more stable economic, social and environmentally friendly development (Loucks 1994).

Water and Environmental problems in India

"Our vision is that in two or three decades there will be sufficient, save, clean and healthy water for nature and people living in stable societies in the region". This **statement should be the 'motto' for the management of Water for the 21st Century**. There is definitely a long way to go to reach this goal: **drinking water supply** and **waste water management** are very unsatisfactory in rural areas of many states, where they use **low quality** water resources, such as shallow wells. One reason for the low quality of water in biological terms is the so called "**utility gap"**, which means the percentage of population connected to the water supply minus that of connected to sewerage. This "utility gap" is large in many countries. This situation leads to increase pollution of surface and sub-surface waters and health risks. To tackle this precarious situation on water quality, an **anti-pollution programme that includes the following aspects needs to be implemented**:

- Enforcement of environmental laws and regulations
- Harmonization of laws and regulations within the European Union and beyond

- Development of the knowledge base required by actors (= legislators, regulators, industry, local authorities, public health bodies, consumer organizations etc).
- Knowledge of the state and evolution of the resources in quantitative and qualitative terms
- Understanding of the nature of pollution within water supply systems
- Understanding of the impact of the pollution on human health and the environment
- Research on socio-economic aspects of the fight against pollution with the purpose of understanding better the system of interaction linking different players and developing new approaches for combating pollution
- Improving waste water treatment quantitatively and qualitatively, addressing also the specific socio-technological and economic constrains on operators in suburban and rural areas.

Prevention of pollution diffusion by:

"On site" treatment of effluents e.g. pre-treatment before disposal in public sewers

- Treatment in accordance with the specific re-use /re-cycling
- Rehabilitation of contaminated soils, sediments and aquifers
- Implementation of cropping techniques appropriate for preventing or limiting this diffusion of pesticides and fertilisers to nearby aquifers.

Most of the water bodies in the country (surface water and groundwater bodies) receive excessive amounts of untreated or insufficiently treated municipal waste water.

- Pre-treatment of **industrial effluent** is often insufficient for biological treatment processes in treatment plants; industry accounts for a significant part of the discharge of polluting substances into inland waters in the region.
- Both the **agro-food** and pulp and paper industries discharge substantial amounts of oxygen- consuming, nutrient-rich and slowly degradable substances.
- The production of **synthetic chemicals and emerging contaminants** brings new and more exotic types of production wastes. and waste water treatment installations typically suffer from insufficiency, overloading and poor operation and maintenance.
- **Agricultural activities** contribute substantially to the overall nutrient load in surface and in groundwater. **Eutrophication** of rivers, inland and coastal waters is one of the major problems. The problems created by agricultural production include ammonia volatilisation, nutrient leaching, discharge of farm wastes.

Past strategies of water supply development have generally been based on the development of supply by improving abstraction techniques and exploitation of new "primary" sources (European Commission 1996). Needed are strategies for rationalisation of **demand** through

1. **Use of "secondary" sources**, mainly **re-use /recycling** of waste water or drainage water (Prinz 1999a). Re-use and recycling of water as well in industry as in agriculture is needed.
2. **Reduction of consumption of water** as well in private as in industry or in irrigation. To encourage the various categories of water users to save water, economic, fiscal and statutory instruments have to be designed and applied. In industry, water

can be conserved through finding alternatives to water for cooling, solvent precipitation medium, or by development of better water equipment and management methodologies. In agriculture, water can be conserved either by improved irrigation scheduling (better instrumentation, information and control systems) or by using irrigation methods with a higher water efficiency (sprinkler, drip irrigation).

3. **Minimization of losses:** The losses in **public supply** and in irrigation networks are about **15-30%** of the total water extracted. Therefore, the strong need exists to minimize those losses by (1) leak detection, (2) leak repair and (3) by leak prevention, e.g. by using material which is less subject to corrosion and mechanical fatigue. Adequate pricing policies or subsidies should therefore guarantee sufficient clean water supply **to all sectors of the society**.

For the development and **diversification** of the supply sources the following actions have to be taken:

1. Exploitation of presently under- or unexploited water resources, e.g.
   - Collecting rain / runoff for use as domestic water of for agriculture
   - Collecting runoff for artificial recharge of aquifers, taking into account the potential environment impact
   - Exploiting the karstic aquifers found in many of the Mediterranean coutries, evaluating the impact of such exploitation on the local and regional hydrological equilibrium.
2. Extended application of the **desalinisation technology** with particular attention being paid to the use of renewable energy technologies (e.g. photovoltaic cells).

Future climate change will have strong impact on the hydrologic , especially in areas already characterised by water scarcity. Additionally to impacts on availability of water, extremes and fluctuations may become larger and seasonal distribution of precipitation and / or runoff may alter negatively. Increased **temperatures** will increase the demand of crops as well as of vegetation in regard to water and irrigation will be necessary in areas where it was less needed before. Higher average temperatures will result in higher evaporation rates from reservoirs and additionally stronger winds / storms are expected. As climate change is (to a large extend) caused by anthropogenic actions, e.g. burning of fossil fuels, **counteractions** to reduce the release of relevant trace gases are a necessity.

Extreme **floods** are not only caused by the coincidence of unusual natural factors, but also influenced by land use changes, narrowing of the river bed e.g. by constructions in the flood plain, etc. It is therefore extremely important to look for **organisational and institutional structures** for national as well as international **river basin management**. The establishment of **river basin authorities** is therefore an essential part of the flood management. There is no doubt that water resources management in quality and quantity is possible only within a watershed and therefore this regulation is overdue. The importance of flood protection as one of the major elements of watershed planning is exemplified by the fact, that 85% of all civil protection measures taken by states are concerned with flooding.

Specific actions to avoid extreme events like floods and sudden or exceptional pollution are:

- Improving the capacity to forecast the occurrence (incl. likely amplitude , extent, impact)
- Improving of the knowledge about the causes of "natural" catastrophes

- Establishment of preventive practices (e.g. in the framework of land management)
- Development of management tools to interact rapidly and efficiently
- Development of emergency systems e.g. for supplying water to affected populations.

The principles of Integrated Water Resources Management (IWRM) should be the cornerstones of any implementation strategy in the Indian water sector.

The IWRM principles focus on :

- **Integration**
  - of water quality and quantity management
  - of groundwater and surface water management
  - of freshwater and coastal zone management
  - of water supply and sanitation planning
  - of upstream and downstream demands in regard to water quantity and quality
  - of physical, economical and social aspects of water resources management
- E**cosystem management** in recognizing all values of biodiversity and the integrity of ecosystems
- **Communication** between main actors in water resources management, including water consumers, water specialists, interest groups, etc.
- **Capacity building** by training of professional skills, raising public awareness, etc.,
- **Public participation** in decision making, based on access to water-related information.

SMART CITIES AND SMART WATER

Smart cities encompass six important sectors that need to work in unison to achieve a common goal of making a city more livable, sustainable and efficient for its residents (Fig.1). These sectors are smart energy, smart integration, smart public services, smart mobility, smart buildings, and smart water.

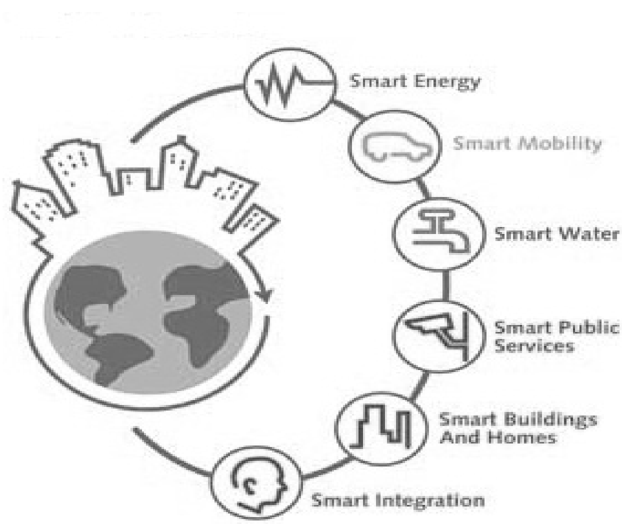

Fig. 1 Conceptual Model for the Smart City

Building smart cities upon the six sectors is crucial for sustainable global growth, but the financial, logistical and political challenges are enormous. The conversations about growth of smart cities have historically been dominated by large IT companies that focus on analyzing "big data" taking a top-down, software-centric approach. However, when it comes to the modernization of hundred-year-old systems like water distribution or the power grid, advanced software and networking capabilities are rarely broad enough in scope to make the necessary impact. Conversely, a bottom-up approach to smart city development is based on the belief that the rapid migration to cities will tax municipal infrastructures beyond their breaking points. The cities that succeed in transitioning to "smart" operations will be those that improve their critical systems and infrastructure at a fundamental level as well as integrate their systems through advanced technology. Lastly, smart cities will apply advanced monitoring and analytics to continuously measure and improve performance.

One of a city's most important pieces of critical infrastructure is its water system. With populations in cities growing, it is inevitable that water consumption will grow as well. The term "smart water" points to water and wastewater infrastructure that ensures this precious resource - and the energy used to transport it - is managed effectively. A smart water system is designed to gather meaningful and actionable data about the flow, pressure and distribution of a city's water. Further, it is critical that that the consumption and forecasting of water use is accurate.

A city's water distribution and management system must be sound and viable in the long term to maintain its growth and should be equipped with the capacity to be monitored and networked with other critical systems to obtain more sophisticated and granular information on how they are performing and affecting each other. Additional efficiencies are gained when departments are able to share relevant, actionable information. One example is that the watershed management team can automatically share storm water modeling information which indicates probable flooding zones and times based on predictive precipitation intelligence. The transportation department can then reroute traffic accordingly and pre-emptively alert the population using mass notification.

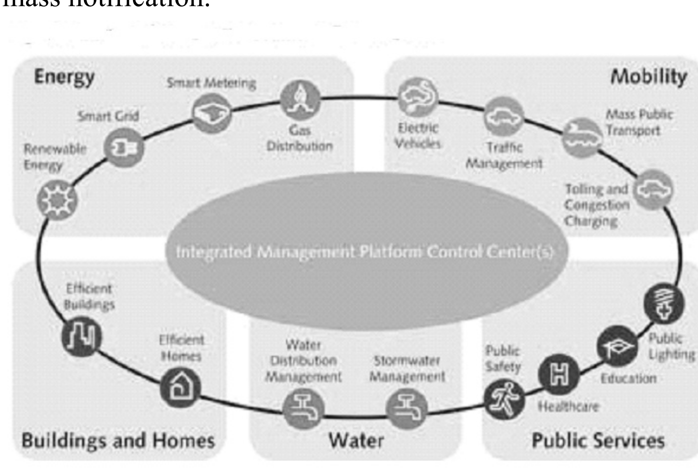

Fig. 2 Integrated Management Platform Control

Water systems are often overlooked yet are critical components of energy management in smart cities, typically comprising 50 percent of a city's total energy spend. Energy is the largest controllable cost in water/wastewater operations, yet optimizing treatment plants and distribution networks has often been overlooked as a source of freeing up operating funds by cash-strapped municipalities. Once facilities are optimized and designed to gather meaningful and actionable data, municipal leaders can make better and faster decisions about their operations, which can result in up to 30 percent energy savings and up to 15 percent reduction of water losses.

Water loss management is becoming increasingly important as supplies are stressed by population growth or water scarcity. Many regions are experiencing record droughts, and others are depleting aquifers faster than they are being replenished. Incorporating smart water technologies allows water providers to minimize non-revenue water (NRW) by finding leaks quickly and even predicatively using real-time SCADA data and comparing that to model network simulations. Reducing NRW also allows municipalities to recover costs incurred in treatment and pumping - this can be significant. A medium-sized city with 100 million gallons per day of produced water that loses 25 percent (not an unusual amount) is incurring over $13 million per year in non-recoverable labor, chemical and energy expenses.

Final Remarks

"Every human being, now and in the future, should have enough clean water, appropriate sanitation and enough food and energy at reasonable cost... "

This 'vision' will never become true, but we should act in India in solidarity with the billions of people of the world whose 'basic needs' are by far not met, - and we should do it "in harmony with nature."

Water in India is a precious, an endangered and often a problem-causing resource. Water is in many places in **short supply** and an increasing standard of living is normally paralleled by an increase in water demand. Additional stress will arise from anthropogenic climate change. The application and adjustment of the various means of **supply and demand management** plus adoption of "smart water" technology are great challenges for the future.

Water is all over the country endangered by **pollution** - either by insufficiently or even totally untreated waste water from private households and industry or by agro-chemicals. Not only **pollution control** based on information, legislation, enforcement of legislation and peoples' participation challenges us, but the **integrated planning of water quantity and quality**, too.

Many states in India face **chronic water deficits** and suffer frequently from **droughts**. Strategies for demand reduction include the better land use management, diversification of the water supply sources, rainwater harvesting, artificial recharge of aquifers, exploiting of karstic aquifers and desalinisation. Climate change aggravates the problem. The challenges are manifold; strategic planning, financial assistance for implementation of preventive measures and promotion of innovative technologies are some of the needed measures.

Floods and excess water pose frequently severe problems to the people affected as well as to governments; special problems are encountered in some 'Transformation Countries' due to the breakdown of drainage systems. The need for appropriate preventive measures, e.g. on the sector of land use planning, restoration of wetlands and floodplains, is unquestioned. Water is largely a shared resource and thus a wide variety of actions is involved in its management; their decisions frequently have inter-basin or even trans-regional impacts.

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