Alternative concept for water supply to satisfy basic needs in fast growing megacities

R. AZZAM[1], C. POST[2] & K. BAIER[3]

[1] Department of Engineering Geology and Hydrogeology (azzam@lih.rwth-aachen.de)
[2] Department of Engineering Geology and Hydrogeology (cpost@lih.rwth-aachen.de)
[3] Department of Engineering Geology and Hydrogeology (baier@lih.rwth-aachen.de)

Abstract: Migrants from rural areas live mainly in peri-urban areas with insufficient infrastructure and difficult living conditions. Improvement of these circumstances begins with provision of a basic supply of water for drinking and domestic use in sufficient quality and quantity, as well as to prevent spread water related diseases. The installation of an appropriate distribution network can takes a long time and be expensive. However, the lack of access to potable and domestic water and adequate infrastructure facilities and sanitation need to be quickly overcome. In these peri-urban areas access to water supply is difficult; people spend more money to obtain water from non-authorized dealers than the people in adjacent districts with a well-established infrastructure. In an area where increasing population causes water deficit, the water distribution network is often inadequate and unreliable. Where present, the sanitation systems and water supply pipes are often in a poor condition (development of encrustation, weed growth, or blocked by stones). The absence of an adequate water management system results in worsening conditions of water resource distribution, mainly due to illegal connections and tapping into the resource supply system.

The overexploitation and deterioration of aquifers highlights the need for water conservation, water recharge and reuse depending on the regional water balance. Suitable methods of treatment and reuse depending on local water quality standards must be applied in a sustainable way. Within the scope of these problems an alternative concept for fresh water supply has been developed that considers the relevant macro-factors and can be considered as a major part of a sustainable and integrated water management concept. The concept envisages the construction of local self-sustaining "waterhouses". Such a facility could supply a peri-urban area with water for drinking and domestic use as well as water treatment using mechanical, biological and electrolytic methods. The energy needed for this process could be produced from organic waste material (biogas) and other renewable energies (for example solar energy).

Résumé: Les migrants qui viennent des régions ruraux ne vivent pas dans des secteurs urbanisés mais la plupart du temps dans des secteurs, dans l'infrastructure est insuffisante et les conditions de vivre sont très difficiles. L'amélioration de ces circonstances commence par le besoin de base d'approvisionnement en eau potable et pour l'usage domestique dans une qualité et quantité suffisantes, aussi bien que la prévention des maladies reliées par l´eau. L'établissement d'un réseau de distribution approprié prend beaucoup de temps et est très coûteux. Cependant, ce manque d'accès en eau, puis le manque d'infrastructures et d'hygiènes proportionnées exige une action très vite avec des mesures correspondantes. Dans ces colonies informelles l´approvisionnement en eau est assez peu commun, les gens doivent dépenser plus d'argent pour obtenir du l´eau des revendeurs non autorisés que les personnes dans les zones avec une infrastructure bien établie. Dans un secteur où la croissance de la population cause un déficit de l'eau, les réseaux de distributions de l'eau sont souvent insatisfaisant ensuite il manque de fiabilité. Dans beaucoup de cas, les systèmes d'hygiènes et les conduites d´eau sont en mauvais état (développement de l'encroûtement, de la croissance de mauvaise herbe, blocage par des pierres). L'absence d´un système de gestion proportionné pour l'eau cause un état de détérioration de la ressource d'eau, principalement en raison des raccordements et des gemmes illégaux sur la ressource.

Devant l'over-exploitation et ainsi que la détérioration des couches aquifères demande la mise en relief de la conservation de l'eau et la réutilisation selon l'équilibre de l'eau dans la région. Chaque possibilité de traitement et de réutilisation selon des normes nécessaires de qualité de l'eau doit être lancée et réalisée d'une manière durable et soutenable. Vu la dimension de ces problèmes on a développé un concept alternatif pour l'approvisionnement en eau qui considère les macro-facteurs appropriés et peut être considérée comme majeure partie d'une conception durable et intégrée de la gestion de l'eau.

Le concept envisage la construction de local auto- fournissant 'maisons d´eau'. Ces équipements puissent accomplir l'approvisionnement pour une banlieue entière avec de l'eau potable et l'usage domestique ainsi bien que le traitement de l'eau par des méthodes mécaniques, biologiques et électrolytiques. L'énergie exigée pour ce processus pourrait être produite à partir des déchets organiques (biogas) et également à partir d'autres énergies renouvelables (par exemple énergie solaire).

Keywords: fresh water, groundwater contamination, infrastructure, megacities, water quality, water resources

INTRODUCTION

Informal settlements or peri-urban areas play a key role in the sustainable development of megacities. Migrants from rural areas live in peri-urban areas characterized by insufficient infrastructure and difficult living conditions.

The improvement of these facilities starts with provision of basic needs such as the supply of water for drinking and domestic use in sufficient quality and quantity as well as for prevention of water related diseases. The establishment of a water supply distribution network can takes a long time and be expensive. However, lack of access to potable and domestic water and lack of adequate infrastructure facilities and sanitation need to be overcome without delay. In many densely populated countries, up to 20% of the total population live in megacities and it is these groups that suffer these adverse conditions.

In all peri-urban areas, where there is inadequate water supply, people have to spend relatively more money to get their water from non authorized dealers than people in well established districts. The reasons for this inequitable and non-effective water supply system have been well analysed. Under a water deficit situation for the increasing population, the water distribution network is often inadequate regarding water leakage and reliability. Problems also occur due to intermittent water supply, costs for alternative supply and contamination of water supply pipes. In many cases the sanitations systems and water supply pipes are in poor condition (development of encrustation, weed growth, blocked by stones), leading to contamination of fresh water at points of leakage. The absence of effective water management worsens the scarcity of the water resource, due to undetected illegal connections and tappings. The effects of aquifer overexploitation and deterioration emphasis the need for water conservation, water recharge and reuse depending on regional water supply patterns. Water treatment and reuse to necessary water quality standards should be achieved in a sustainable way.

Within the scope of the problems identified, an alternative concept for fresh water supply has been developed as part of sustainable and integrated water management. This concept envisages the construction of local self-sustaining “waterhouses”. These facilities would provide a peri-urban area with sufficient water for drinking and domestic use as well as waste water treatment by using mechanical, biological and electrolytic methods. The energy required for the process could be produced using organic waste material (biogas) and renewable energies (from example solar energy).

Megacities - an introduction

The third millennium will be characterised by vast urbanisation and huge megacities. Estimates suggest that by the year 2025, 85% of the population of the industrialised countries and 55% of the population of the third world will be living in urban environments (Feldbauer & Parnreiter 2001). So for the first time in the history of man more people will be living in megacities than in rural areas. The process of urbanisation will most likely continue in the industrialised nations, although the extreme growth dynamics have already began to decline in the megacities of the north during the middle of the 20th century. In contrast, the cities of the third world are currently undergoing expansion. On the whole, the number of megacities worldwide continues to increase. As shown in Figure 1, today there are 39 megacities worldwide of which 28 are located in third world countries.

An important characteristic of the megacity, other than population density, is that of “functional primacy”. This includes: high concentrations of administrative, economic, social, cultural and scientific functions; and resultant power and decision structures (Bronger 1984). The “functional primacy” of a third world megacity is limited to national level.

Due to their “functional primacy” the megacities are attractive, becoming centres of migration. The huge attraction of the third world megacities is justified by the hope for a better life by the rural population. In the 1990s the growth of the urban population in developing countries was calculated to be up to 160 000 persons per day. Although migration to the megacities of the third world is gradually declining, population increases in the megacities is mainly due to natural population growth. This implies that even if there was a radical decrease in migration from rural areas the increase of urban population would continue. The growth of these megacities is difficult to control, indicates future problems for these cities, to be discussed in the following section.

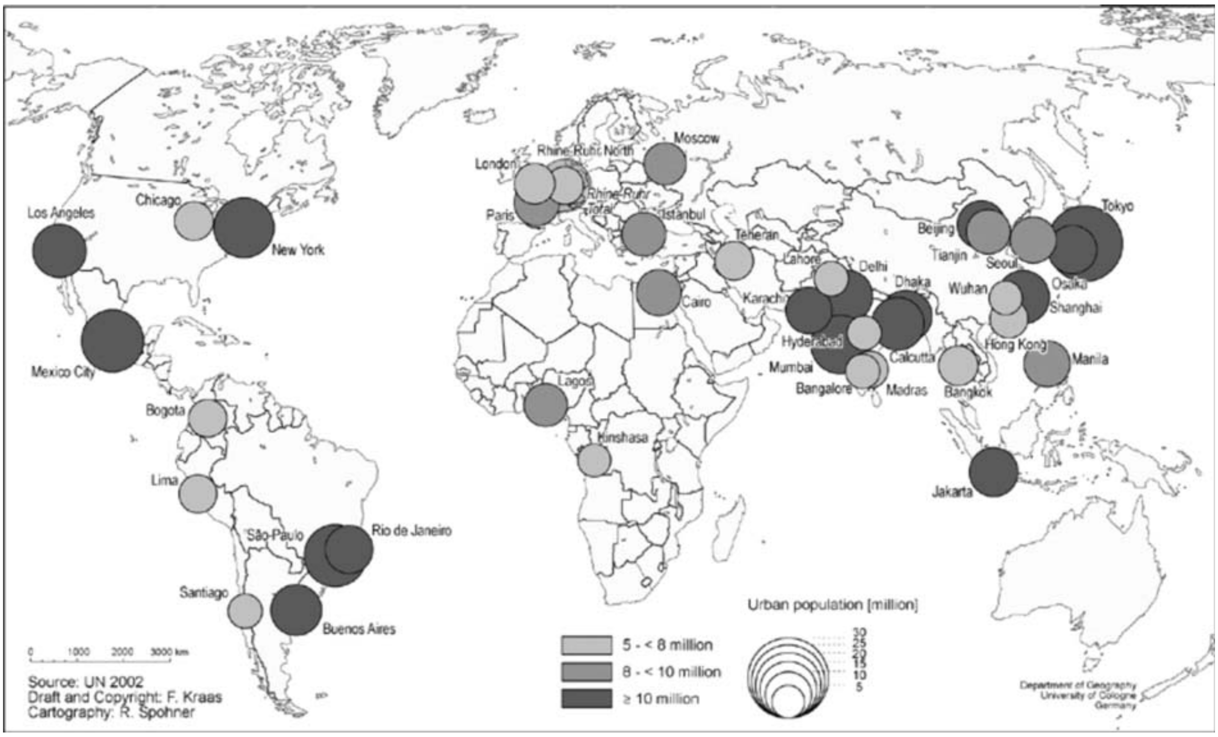

Figure 1. Allocation of megacities; Source: (Kraas 2003)

Megacities face future problems both in first and third world countries. The main issues are structural, ecological and socio-economical problems (see Figure 2). The problems in the megacities of the third world are increased through lack of financial and economic resources and are thus more difficult to solve. Nevertheless, many of these problems are also experienced by megacities in first world countries.

As shown in Figure 2 the problems of megacities are complex and interconnected, implying that it is difficult to solve these challenges individually. It is thus more important to recognise connections and to develop solutions. Due to the diverse cultural, social and economic preconditions of the different regions in which megacities are located, solutions have to be modified to fit the regional circumstances.

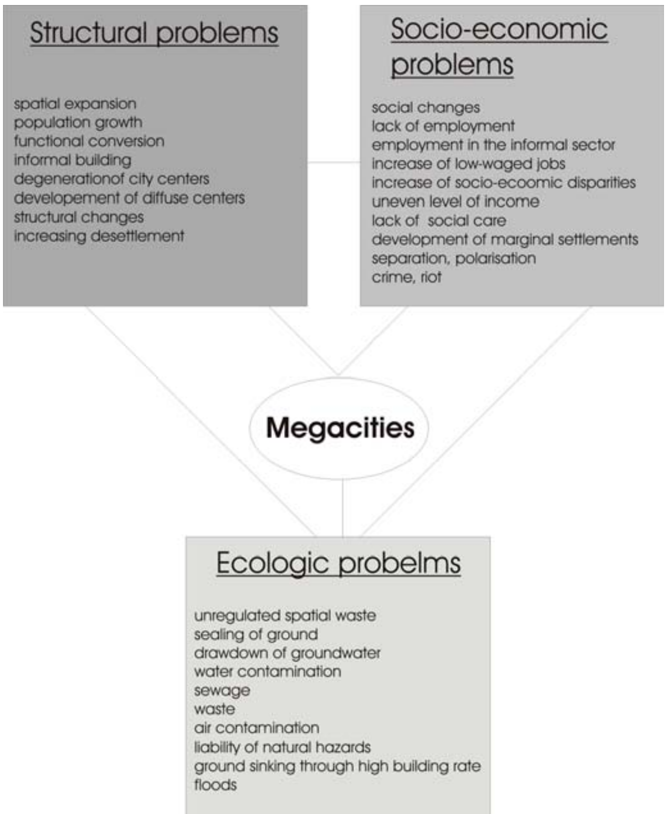

Figure 2. Problems of megacities

One of the main problems of megacities is the socio-economic disparitie. Within the megacities, the social and economic polarisation is seen in the most extreme form. Here socio-economic extremes collide in direct spatial concentration. Although this phenomenon is seen in European and American megacities, in the megacities of the third world the disparities in the developing countries are more obvious due to the total lack of social security and economic power. A result in the latter the extensive development of slums and favelas on the outskirts of the cities. In most of the third world megacities up to 50% of their populations live in such quarters. Reversing this process is almost impossible due to limited capital and lacking urban planning. This results in an ongoing marginalisation of large parts of these populations.

Structural problems of megacities are often characterised by lack of land use planning and regulation. This often results in growth beyond national and civic control. This often causes unregulated expansion and a large increase in informal building that leads to a the coexistence of diverse forms of utilisation, such as agricultural, industrial utilisation and housing. As a result of this unregulated development, problems such as waste land, industrial emissions and ecological problems frequently occur with megacities often suffering serious infrastructural, ecologic and congestion problems.

In summary the megacities in the third world are facing a major dilemma - how to supply the population with water in adequate quality and quantity. The quality of water supply for large parts of the population is a severe problem for many megacities. The water supply to peri-urban populations, the disposal of sewage and the dewatering of large areas covered by buildings are challenges for which no clear solutions have been found. The systems that have been developed in the megacities of the first world countries are not sustainable for the challenges implied in the megacities of developing countries. Attempts are bound to fail due to the enormous technical dimensions and the total lack of financial potential. How is the infrastructure of cities that grow by the size of Frankfurt every year going to manage this development? The European and American infrastructure systems are far too expensive to establish globally. Due to the ongoing growth of these cities the water problem is going to increase, not only for the environment surrounding these cities, but also for the urban population itself (Graw & Maggio 2001).

URBANISATION PROCESSES AND EFFECTS OF GROWING CITIES ON GROUNDWATER:

Regardless of which use or user, urbanisation drastically affects local aquifer systems in terms both of quantity and quality. If the catchment of the aquifer in question underlies the city, there are various aspects of usage:

The aquifer

- is beneath the use of surface water the source of water supply;
- acts as a receptor for solid waste and for the disposal of waste water;
- contains the urban engineering infrastructure (pipelines, tunnels and foundations) and
- serves as a source of building material.

The first two of these functions directly affect the underlying groundwater system. In urban area's water quality problems often span multipoint source contamination, which causes microbial contamination from on-site sanitation. The poor rate of sanitation coverage worldwide leads to increased entry of pathogens into the groundwater in particular in the fast growing peri-urban areas of megacities (Morris et al. 2003).

Using groundwater provides a buffer against adverse conditions, whether climatic (droughts) or induced by human activities (overdraft, pollution events) and reduces pressure on conventional freshwater supply sources; many large cities rely on surface water for supply purposes. Not using groundwater may lead to flooding and damage to underground structures (e.g. underground railway systems, basements, underground parking areas) (Vázquez-Suné et al. 2005). Hydrologists believed that cities reduced the amount of recharge to the underlying groundwater through impermeabilisation of the surface. They now accept that the infrastructure for water supply and storm drainage generates large amounts of recharge through leaks. A lot of water is imported into most cities for supply, distributed through underground pipes and collected again in sewers and septic tanks. The leaks from these pipe networks often provide substantial recharge (Lerner 2002). This persists in the quasi laminar entry of differently polluted seepage water into the groundwater system.

Quantity problems resulting from increased demand can lead to over-abstraction - which in turn leads to wells drying- up, conflict between users or in some circumstances intrusion of saline water or the flooding of underground structures. A falling water table can cause physical damage to buildings and underground services as a result of land settlement and subsidence; whereas a rising water table, caused by an increasing infiltration rate, can damage building and foundations because of the hydrostatic uplift and possible chemical attacks to concrete and other building materials.

To overcome the adverse effects of change in the underlying water table, master plans and management strategies need to be implemented to control the underground water balance of cities to avoid further damage.

MANAGEMENT STRATEGIES

Environmental problems today are complex, requiring a wide spectrum of solutions. Interdisciplinary approaches allow assessment at different concurrent levels, allowing integration of site-specific aspects. Water use master plans have to be developed which take technical, financial and political constrains into account. In India for instance, agriculture interests have frustrated reforms on power pricing and groundwater regulations that are economically and environmentally "rational" (Morris et al. 2003). Technical and scientific specialists, who understand aquifer systems, water balances and water quantities from precipitation, storage, recharge and consumption, are requested to include economic and social aspects in their considerations. Awareness from users and participation from stakeholders and decision makers are just as important as any form of water treatment or reuse. Nevertheless, the legal framework has to define water conservation and protection methods including

- Pumping permits;
- Definition of allowed uses;
- Delineation of protection areas;
- Identification of polluters and
- Monitoring.

Monitoring of water quality and water levels in an aquifer is the basis of groundwater resource management (Jörgensen 2000). The precondition of all measurements is an understanding of the flow system and the baseline of water quality before identifying emerging problems such as over abstraction or water pollution. Any implementation of management strategies is sensitive to the status of the country and the characteristics of the city source of water supply (Vázquez-Suné et al. 2005).

These management strategies only make sense, if there is public or municipal distribution of fresh water. In most megacities, with the expansion of informal settlements due to population growth, there is no connection to the municipal water supply and the sewerage network. In such circumstances, any management master plan would fail, because the people have no choice even to decide if they want to participate and behave in an environmental friendly way. They have to satisfy their elementary needs no matter if there is any contamination due to on-site sanitation or lowering the water table due to tapping the municipal pipelines. In these circumstances, a short term solution is proposed and presented in the following section. A long-term concept should be provided to solve the problems that are described in Figure 3 concerning the water supply in fast growing cities. The first step of any strategy is to make potable water available for slum dwellers and establish sanitation facilities in the peri-urban areas using waterhouses.

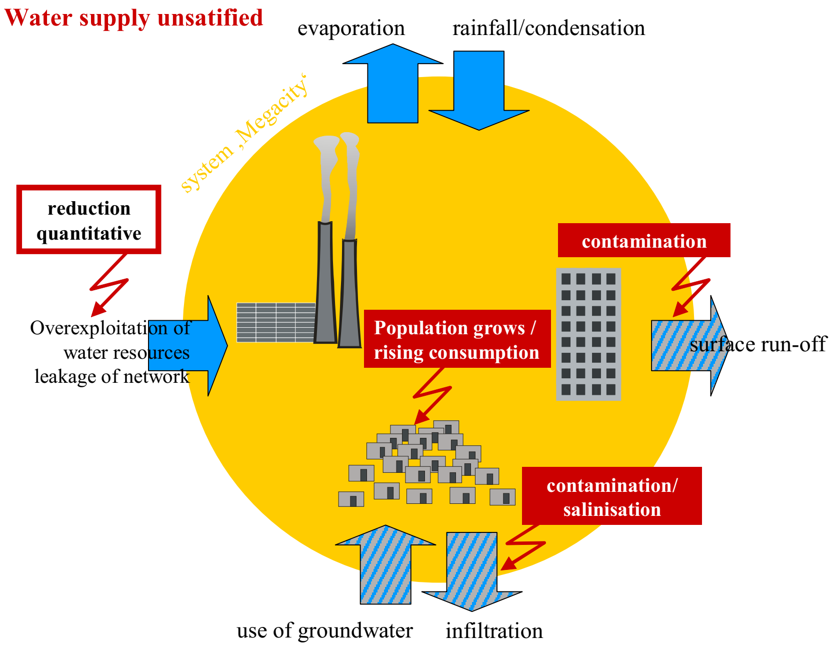

Figure 3. Unsatisfied water supply

SUSTAINABILITY IN URBAN GROUNDWATER MANAGEMENT IN CONSIDERATION TO SATISFY BASIC NEEDS FOR WATER SUPPLY

To provide a basic supply of good quality water and in sufficient quantity for large parts of the population in the rapidly growing megacities of the third world, small scale, integrated, decentralised supply and disposal systems need to be established using defined water management concepts. Such a small scale supply and disposal system is described here. In local areas a water supply system for inhabitants could be provided using a "waterhouse".

The primary idea of the "waterhouse" is derived from the several centuries old bagnio or bath houses in the Greek or Arabian culture (Cisterns, Hamams). Issues of sanitation or personal hygiene were centrally organised and provided for the community within an acceptable distance to everyone of the district. The bath houses were also places for conversation and exchange and they therefore fulfilled an additional social need of the population.

The "waterhouse" in a modern sense serves the same way, but is adapted to local conditions to fulfil primary social needs such as the allocation of potable water, water for sanitation and laundry to local people, that migrate to the megacities. It is just one extra step to ensure sustainability by treating the waste water or give the possibility to reuse less polluted water within a cycle. In a "waterhouse" (Figure 4) potable water, sanitary facilities for personal hygiene and laundry facilities can be provided.

The functionality of the "waterhouse" cycle serves the intention to make water available for that part of the population not connected to a municipal network. The supply of potable water in such districts cannot wait for the municipal administration to install water supply or sewerage systems. Basic needs have to be satisfied, which means making potable water, water for personal hygiene and water for washing available. To enable sustainable development in the peri-urban areas of fast growing cities, the water resources have to be used carefully and any possible method of water conservation to be taken into account, using suitable methods of reuse and treatment to supply quality sensitive uses.

The water cycle of the concept starts at the "waterhouse" itself, which offers areas for personal hygiene, places for laundry and water cocks for tapping potable water. The "waterhouse" is equipped with a well, because complete recycling of used water is actually not yet possible. The first two applications produce waste water that must be treated for secondary use. Initial treatment includes the mechanical separation into liquid and solid phases and then biological treatment to prepare the anaerobic decomposition of the produced sludge. At this point of the water cycle it is possible to add external waste water. In the next stage a water pipe system can then be planned and installed to supply individual dwellings from the "waterhouse". If the water treatment facilities are not fully utilised, additional waste water from outside can be treated at the facility. This offers the advantage of minimising any misuse of waste water through spillage on the ground, which causes contamination of the groundwater. The accumulation of the bacterial activity takes place in the bioreactor to produce biogas. This gas can be supplemented by solar power to serve as energy sources for the treatment of potable water. The "waterhouse" and the drinking water treatment facility can then be run with this energy. To reduce the concentration of pathogens and other contaminants in the waste water, several methods of treatment are possible (solar distillation, membrane separation, extraction, etc.) depending on local conditions e.g. the concentration of heavy metal, faecal coli forms, other inorganic substances or the capacity of the available energy.

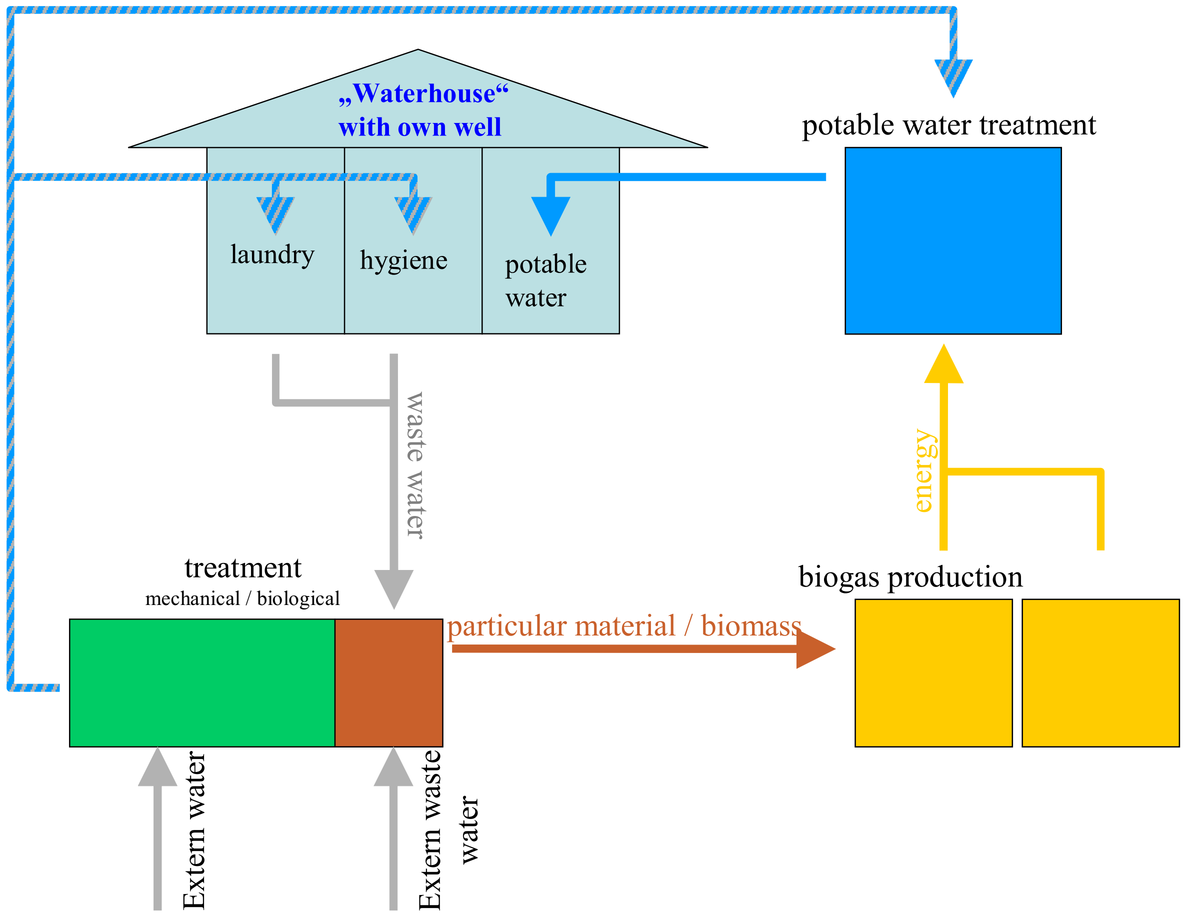

Figure 4. Waterhouse; own concept

This concept requires the calculation of size and type of the treatment devices, dependant on environmental conditions for the "waterhouse" to operate successfully. Another point to consider when planning a "waterhouse" is cultural difference.

Within such a concept the three aspects of sustainability can be achieved. Ecologically, the efficient use of scarce water resources can be increased and the emission of pollutants reduced. Economically, jobs are created, operational costs can be optimised and an economic pricing system established. In a social context the living standards of the affected people can be improved and conflicts about water reduced. As in Figure 5, there are many benefits to be obtained by installing a small scale supply and disposal water system.

SUMMARY

This paper discusses the problems of water supply in rapidly growing megacities in order to achieve a sustainable solution. The described concept of a "waterhouse" provides an ecological, economical and social approach, which aims to quickly improve the often drastic water deficit situation in peri-urban areas and informal settlements. The prospect of overexploitation and thus deterioration of aquifers in the megacities emphasises the need for water conservation, water recharge and reuse based on regional water supply conditions. In this context the "waterhouse" concept is presented to integrate use of waste water treatment methods like mechanical/biological treatment and the application of solar distillation and electrolytic methods depending on hydrological and hydrochemical conditions. Different methods are used to optimise reuse and conservation of scarce water resources; these are integrated in a self-sustaining treatment cycle operated by the dwellers themselves. Employment in the community is generated by the need to maintain the "waterhouse". The community are made aware of the need to conserve water and prevent water pollution. The intention of the "waterhouse" is to make potable water immediately available at an economically viable price for the unconnected parts of the megacity, but is not meant to replace the responsibility of the municipal administration to provide water and sanitation facilities to their population. Such infrastructure problems need time to implement but basic needs have to be satisfied without delay.

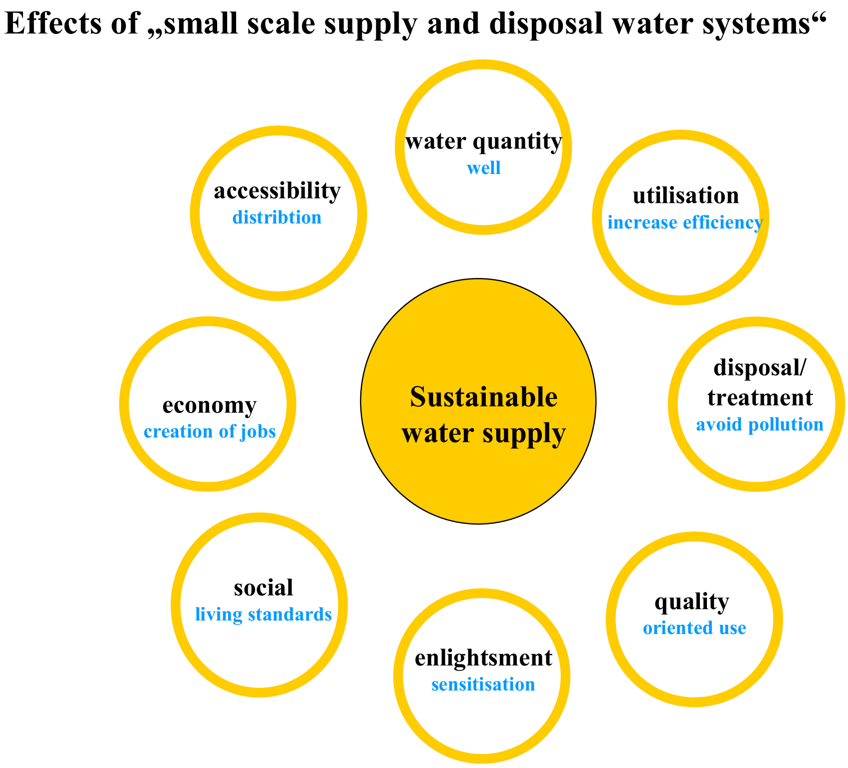

Figure 5. Positive effects

REFERENCES

BRONGER, D. 1984. Metropolisierung als Entwicklungsproblem in Ländern der Dritten Welt. *Geographische Zeitschrift*, **72**, 138-158.

FELDBAUER, P. & PARNREITER, C. 2001. Einleitung: Megastädte – Weltstädte – Global Cities. *In: Mega-Cities. HUSA, K., PLIZ & E., STACHER, I. Die Metropolen des Südens zwischen Globalisierung und Fragmentierung. Historische Sozialkunde, 12, Frankfurt a.M., Wien*, 9-20.

GRAW K.-U. & MAGGIO, E. 2001. Wasserver- und Abwasserentsorgung von Megastädten – eine Aufgabe desneuen Jahrtausends. *Bauingenieur (VDI),* **76**, 26-29.

JÖRGENSEN, S.E. 2000: Management and conservation of water resources in urban areas. *Urban Environmental Management, UNEP*, 32-35.

KRAAS, F. 2003. Megacities as Global Risk Areas. *PGM Zeitschrift für Geo- und Umweltwissenschaften*, **4**, 6-15.

LERNER, D.N. 2002: Identifying and quantifying urban recharge: a review. *Hydrogeology Journal*, **10**, 143-152.

MORRIS, B.L., LAWRENCE, A.R., CHILTON, P.J.C., ADAMS, B., CALOW, R.C., & KLINCK, B.A., 2003. *Groundwater and its susceptibility to degradation: a global assesment of the problem and options for management.* Early Warning and Assesment Report Series, RS.03-3. United Nations Environment Programme, Nairobi, Kenya

VÁZQUEZ-SUNÉ, E, SÁNCHEZ-VILA, X. & CARRERA, J. 2005: Introductory review of specific factors influencing urban groundwater, an emerging branch of hydrogeology, with reference to Barcelona, Spain. *Hydrogeology Journal*, **13**, 522-533.