Innovative use of technology and management for sustainable development of water infrastructure in under-serviced regions

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Abstract

Globalization, urbanization and climate change are major driving factors in global mandates aimed at improving national and local government capabilities, environmental awareness and increasing energy efficiency. These confines have contributed to encourage sustainability in both policy and implementation, particularly to new development practices. Typically, urban growth areas did not always coincide with the availability of water, energy or environmental consideration. In conjunction with the international focus on climate change, a large emphasis has thus been placed on innovative technologies that are environmentally friendly and sustainable with low operation and maintenance demands. Many large European countries such as Germany and Poland have invested significantly in research and development of green technology and innovative uses thereof, leading to niche areas within the environmental technology market. As such, a regional initiative implemented in water scarce South Africa, which involves accelerating water services and infrastructure to vulnerable areas, has been identified as a basis for regional and international cooperation in knowledge sharing and technology transfer within the relevant environmental sectors. Specifically, this work assesses technological options to create sustainable water and energy infrastructure in developing regions. Case studies are discussed, highlighting international cooperation in developing and marketing innovative technology for sustainable implementation. A comparative regional overview of green technology experiences and the attendant policies in Germany and Poland will be presented in correlation with actual implementation projects and related policies in South Africa.

Key words: urbanization, green technology, water and sanitation infrastructure, sustainable development.
JEL Classification: (O30, O33)

1 Introduction

As a consequence of globalization, the gradual integration of regional economies, cultures and societies have inevitably led to rapid urbanization. In some developing countries this has also led to the formation of megacities with a large uncontrolled influx of people from the rural areas to the urban or peri-urban interface. Together with a dependence on cheap fossil fuels these have become major drivers in climate change and other environmental concerns. Urbanization and climate change have been recognized by a large number of international organizations (United Nations, European Union, OECD, World Bank), scientific bodies (IPCC, Millennium Ecosystem Assessment, IGBP, IHDP), business organizations, national and local governments, as well as the international and local mass media as a critical problem for the present and future of societies globally [1]. This influx of people, industries and pollution place a particularly large burden on existing water, sanitation and energy infrastructure [2].

Since water is closely related to, food, ecosystems, biodiversity, resources, energy, and health, water cycle changes due to global warming could directly and indirectly cause serious problems that affect the world's economy and population [3]. Aggravating global water problems caused by population fluctuation, population concentration in urban areas, and lifestyle changes is climate change, and together they may cause problems directly linked to the slowdown in economic growth in both industrialized and developing countries leading to disputes and conflicts over water [4]. National, regional and local water sectors have been rapidly expanding with new entrants, services, products and technology — particularly in urban water activities. These sectors are usually knowledge-based, innovative and service-orientated, aiming to actively contribute to sustainable development. Recognition of the consequences of climate change, particularly the change in rainfall patterns, has shifted the paradigm for water management, focusing on private sector participation, sustainable infrastructure and technological innovation [5].

In the water scarce southern Africa region, there is a demand for innovative, sustainable solutions and management of scarce water resources. Here a highly variable climate, together with a country's growing economy and dependence on primary resources, will assure continued expansion and significance of this sector within developing countries [2]. To counteract water problems caused by changes in the water environment that occur along with global climate change, it is important to locally establish water utilization and management plans that take into account long- to mid-term water demand and supply balance based on highly accurate water cycle forecasts. At the same time, it is necessary to develop technologies that mitigate and adapt to water problems and to effectively incorporate the technologies into municipalities. Lessons learned from other transitional democracies in Europe (such as Germany and Poland), particularly from their environmental sector comprising engineering, technology and manufacturing firms; water infrastructure construction companies; water distribution entities; can be beneficial to developing countries like South Africa, helping it 'leapfrog' certain development issues while improving both industrial competitiveness and environmental sustainability..

This paper discusses trends in regional cooperation linked to the water and sanitation sector and reviews some examples of technological innovation and multi-national ventures. Implementation case studies (water and sanitation projects) in the rural Eastern Cape region of South Africa will be discussed based on sustainable technology ventures. Global trends in infrastructure management and private sector participation in service delivery will also be detailed within the context of a developing country like South Africa.

2 Innovations in Technology and Management

2.1 Background

Nearly 80% of the Southern African population rely on surface water as the main source of water. In the Southern African development Community (SADC) the urban population has more than doubled in the past thirty years [6] and it estimated to surpass the 180 million mark by 2025 [4]. Consequently fresh water abstractions are projected to increase resulting in many member countries falling into the water stress category. Water demand management (WDM) in said areas will increase in importance and will also impact on trans-national rivers which many are dependent on. Figure 1 illustrates both the current and projected global and African situation with respect to water and sanitation. This relatively high percentage of the population that is without proper water supply services indicates that many of the people still utilize untreated surface water for domestic purposes.

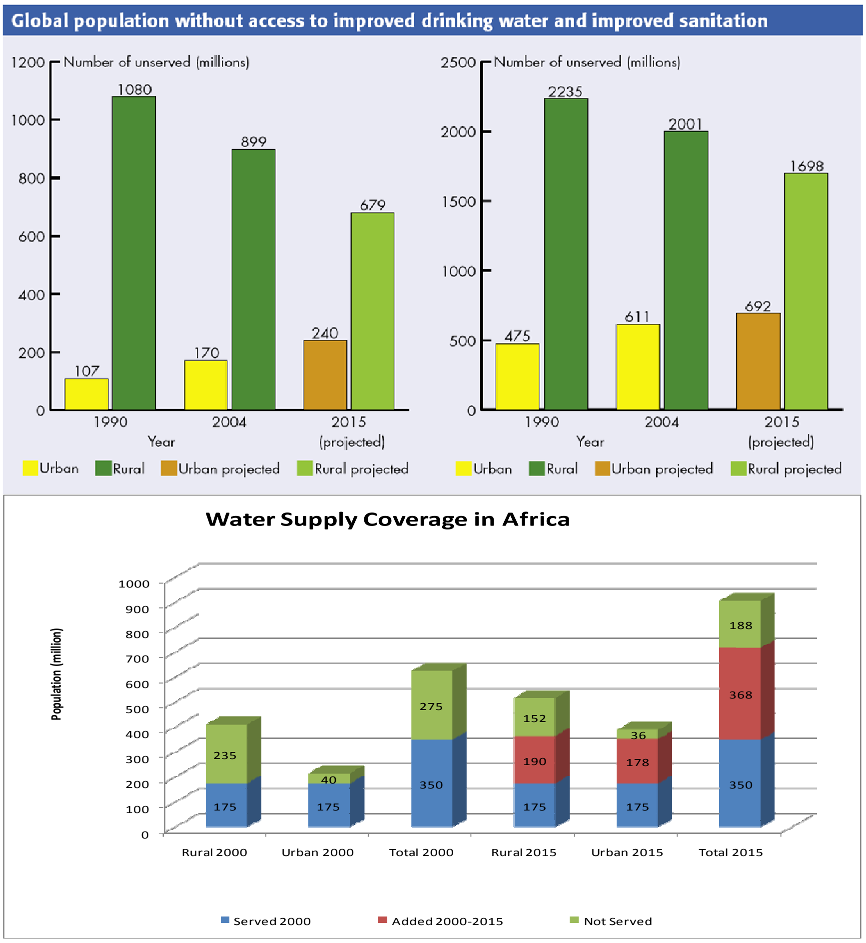

Figure 1: Global water and sanitation situation [2] (top) and water supply coverage in Africa (bottom).

Most of these people are rural villagers, located where reticulated water systems are impractical and rely on State intervention for improved water supply. In rural areas, pollution from human settlements lacking appropriate sanitary infrastructure, partially treated or untreated wastewater, leachates from refuse dumps and from land-use activities such as agriculture are the major pollution sources of the surface water. Additionally, the incidence and prevalence of water-borne pathogens are subject to geographical factors. Most of the pathogens are distributed world-wide, but outbreaks of some diseases, for instance, cholera, shigellosis, and typhoid tend to be regional.

In the European Union (EU), urbanization and urban population density is on the increase where urban size and congestion cause the demands on urban infrastructure and complexity to increase. This has a knock-on effect on the requirements of infrastructure to meet economic demands, heath and safety needs, where it is viewed as unacceptable to have have roads, drinking water, sewage, electricity and waste-discharge systems to fail. The (re) development of urban infrastructure now includes management and technological tools to fulfill the necessary demands, and lessons learned can be transferred to developing regions.

2.1.1 Urban trends and green technology in the EU

In the short term emerging, multi-cultural democracies like South Africa can learn a lot from transitional societies like Poland and Germany. Poland and the former East Germany for example, have undergone major decentralization in their planning politics since the end of the industry intensive communist era. Misdirected spatial planning policies such as location of coal mines close to ecological corridors have resulted in environmental problems [7], particularly in the black triangle region (Polish, German Czech borderland). A major change from this name to the current green triangle region was due to the significant improvement of the quality of the natural environment due to a European Union funded program to clean up coal burning power plants and monitor air quality [8]. This PHARE CBC program was a huge step towards engaging trans-boundary partners to solve environmental and landscape issues. The success of the initiative and hence the spatial development policy depended largely on the cooperation of local and regional authorities rather than other policy areas [7]. Surface water recylcling is effective in Germany with grey water treatment and recycling companies (Pontos, Gmbh) and government ministries (BMBF) encouraging green technology initiatives both locally and abroad (communal water house concept in Jansenville, South Africa).

Urbanization has however created stress on urban infrastructure and services. Poland has experienced a dramatic increase in urbanization with 61.8% of the total population found in urban areas compared to 42.5% in 1950 [9]. In Germany, unification actually reduced the population density, due largely to the sparsely populated GDR which saw little of the suburbanization seen in West Germany. This has resulted in a greater contrast between urban and rural areas in the new Länder than in the West.

2.1.2 Examples of Regional Cooperation

The EU has significant economic ties with developing countries such as Brazil and Malaysia, particularly in relation to transport fuels driving the EU mandate to increase the biodiesel component in transportation fuels to 10% by 2020. The EU is a large importer of first generation biofuels, which are too costly from both an economic and environmental perspective to produce within the EU, shifting the environmental burden rather to developing countries [10]. Nevertheless, international cooperation also allows for the exchange of scientific and technological expertise as demonstrated by the 40 year partnership between Germany and Brazil. One such example is the ECOGERMA environmental technology fair, held from 12-15 March 2009 in São Paulo and was jointly opened by the German Federal Minister of Education and Research and the Brazilian Minister of Science and Technology. Until now, more than 90 percent of drinking water in the federal district has come from the Rio Descoberto dam, 25 km from Brasília, and from the Rio Paranoá. Partners within the Helmholtz Centre for Environmental Research (UFZ) launched a German-Brazilian project International Water Research Alliance Saxony (IWAS) in the over-populated and infrastructure stressed federal district of Brasília, the capital of Brazil. The aim was to develop system solutions for the various water problems in five model regions of the world: Latin America, Eastern Europe, Central Asia, South-East Asia and the Middle East, involving regional and international partners from research and industry.

Science and technology cooperation with Africa has also been very high on the political agenda throughout 2008, following the launch of the EU-Africa Strategic Partnership at Lisbon in December 2007. The African Union (AU) Commission has worked, with input from European Commission services, to prepare a 'book' containing 19 Lighthouse Projects to implement the 8th Partnership on Science, Information Society and Space. The Communication on a strategic European framework for international S&T cooperation states that research cooperation with developing countries should be aligned with development cooperation policies and the Millennium Development Goals. In the case of Africa, it calls for a concerted EU and Member States effort on the implementation of the Joint Africa-EU Strategic Partnership and in particular on Science, Information Society and Space [11]. Collaborative projects involving EU funding, national line departments and science councils (such as the CSIR) are described in more detail in section 2.2.3 of this paper.

2.1.3 Scope for Innovative Water Interventions

Environmental sustainability and infrastructure design requires financial sustainability. It is widely accepted that municipalities (at all levels) and developing countries in particular cannot rely solely on philanthropic or even public resources. Technological solutions should be financially sustainable, low maintenance, environmentally compatible and be within the skills and capacity of the local workforce, before they can be scaled up and replicated to achieve large-scale impact. A major challenge with sustainable technology ventures is decoupling improvements in well-being and economic development from the unsustainable use of natural resources [12]. Leapfrogging (a theory in which developing countries may accelerate development by skipping, inferior, less efficient, more expensive/polluting technologies and industries and move directly to more advanced ones) can offer opportunities to access a more sustainable development path. Ventures in developing countries can leap to more sustainable modes of production and consumption without having to pass through stages with unsustainable resources use, such as the renewable energy production (solar, wind, hydro-power, geo-thermal, second and third generation biofuel) [13]. Incentives also exist for richer developed countries to invest in such initiatives, as much of this technology (such as photo-voltaics) is expensive, even by first world standards and have a longer lead time than polluting fossil based alternatives. Three perspectives related to the analysis of a sustainable technology venture is summarized in Figure 2.

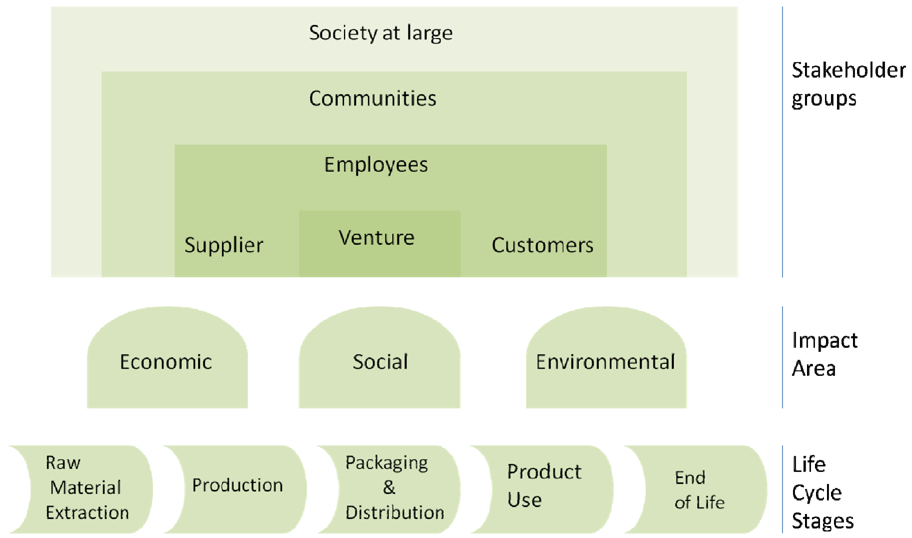

Figure 2: Generalised perspectives of analyzing a sustainable technology venture (modified from [12]).

The global perception of water is slowly (but realistically) changing from a natural resource to a commodity. As with any other scarcity, global water shortages can also create investment opportunities. A list of some of the more well known indexes designed to track various water-related investment opportunities follow:

- Palisades Water Index - This index was designed to track the performance of companies involved in the global water industry, including pump and filter manufacturers, water utilities and irrigation equipment manufacturers. The index was set at 1000 as of December 31, 2003. It closed at 1351.08 on December 30, 2005.

- Dow Jones U.S. Water Index - Composed of approximately 23 stocks, this barometer climbed from 500 to 800 over the 12 months ending December 31, 2005.
- ISE-B&S Water Index - Launched in January 2006, this index represents water distribution, water filtration, flow technology and other companies that specialize in water-related solutions. It contains 20 stocks.
- S&P 1500 Water Utilities Index - A sub-sector of the Standard & Poor's 1500 Utilities Index, composed of just two companies, American States Water and Aqua America (NYSE: WTR). In 2005, the S&P 1500 Water Utilities Index rose in excess of 45% .
- The Bloomberg World Water Index and the MSCI World Water Index provide a look at the water industry from an international perspective. There are also a variety of utility indexes that include some water stocks [14].

2.2 Implementation case studies in South Africa

Some of the key features that distinguish the South African water and sanitation sector from other countries are the following:

- The existence of an important institutional tier between the national and local government in the form of Water Boards;
- Strong linkages between water supply and sanitation and water resources management through these Water Boards;
- A strong government commitment to high service standards and to high levels of investment subsidies to achieve those standards;
- A policy of free basic water and sanitation;
- Relatively stable and successful private sector participation in water supply;
- A strong water industry with a track record in innovation.

Project implementation and case studies were carried out in the impoverished and under-serviced Eastern Cape region of South Africa. Much of the ground work was achieved via excellent support from the highly efficient Amatole District Municipality (ADM). A community type distribution and location of some of the municipalities consulted during the case studies is illustrated in Figure 3.

2.2.1 Integrated Development Planning

The South African system of Integrated Development Planning (IDP) is a process by which municipalities prepare 5-year strategic plans that are reviewed annually in consultation with communities and stakeholders. These plans seek to promote integration by balancing social, economic and ecological pillars of sustainability without compromising the institutional capacity required in the implementation, and by coordinating actions across sectors and spheres of government. In terms of the methodology outlined in the IDP Guide Pack, each municipality is required to prepare a ´sector plan´, which is similar to existing water services development plans (WSDP) as part of the water integration phase. The WSDP would require the following:

- Inclusion of the results of the analysis phase of the existing situation related to service backlogs and priorities.
- Water sector guidelines and strategies
- Consolidated outputs, targets, locations, time schedules of water and sanitation projects as well as any other projects which impact upon water projects and services.

The requirement for Water Sector Plans from each Local municipality, as part of this IDP process facilitates integration of local municipality water sector issues into the District Municipality WSDP (Figure 4).

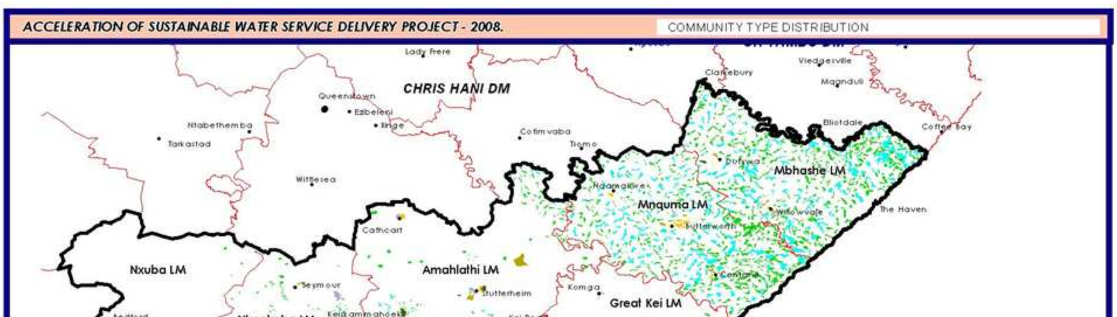

Figure 3: Community type distribution in the selected municipalities in the Eastern Cape Province.

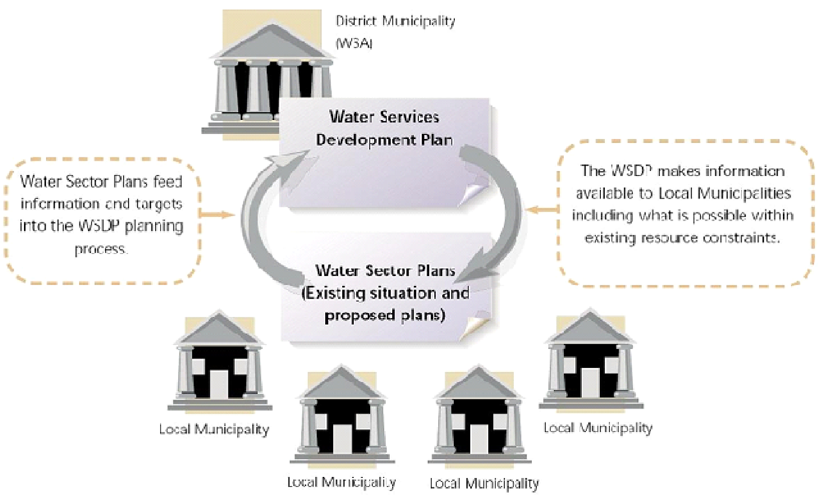

Figure 4: Integration of local municipality water sector plans into the District Municipality WSDP.

2.2.2 Tariffs and privatization

Water tariff structure is also very important and determines the consumer behavior in response to water consumption and service delivery. In South Africa, this is a contentious issue, as it is linked to the loosely worded political promise of free essential services. Water tariffs are nevertheless easy to structure in urban and even peri-urban areas, but are not a factor for consideration in deep rural areas. According to Mara [15], a study of urban and peri-urban water supply tariffs revealed that an urban Water Service Authority (WSA) could charge three groups of customers having different levels of service:

- Non-poor households with metered multiple-tap in-house supplies,
- Poor households with unmetered yard taps, and,
- Poor households in unmetered standpipe cooperatives.

In South Africa, municipal infrastructure investments were financed from the following sources in 2002/2003 [5]:

- 24% through municipal and provincial grants (each 12%);
- 15% through loans;
- 42% through internal cash generation; and
- 19% through other sources.

The larger municipalities rely more on loans and on internal cash generation, while the smaller ones depend more on grants and other sources of funding. All municipalities receive a constitutionally mandated share of national tax revenues as an unconditional recurrent grant, called "equitable share". The structure is designed to benefit poorer municipalities. There is also an additional Municipal Infrastructure Grant (MIG) administered by the Department of Provincial and Local Government and a Capacity Building Grant. The MIG programme is aimed at providing all South Africans with at least a basic level of service by the year 2013 through the provision of grant finance to cover the capital cost of basic infrastructure for the poor.

In high population density mega-cities such as Johannesberg, pre-paid meters were introduced, including the largest township Soweto and in other cities as part of management contracts with private operators. These meters, which cut off water supply above the 6 m^3 monthly limit if no payment is made, predictably sparked violent protests in poor neighbourhoods. In Johannesburg they were maintained even after the management contract expired. In April 2008 the South African High Court found this practice unconstitutional, and wrote that denying the poor access to adequate water "is to deny them the rights to health and to lead a dignified lifestyle." It was further stated that "25 liters per person per day is insufficient for the residents of Phiri", and ordered the city to provide free basic water in the amount of 50 liters per person per day with the option of an ordinary credit-metered water supply (instead of pre-paid) for more use.

With respect to public service delivery, there are numerous debates concerning the question of private sector participation in water and sanitation services. These differences are positioned within the broader ideological arguments concerning the appropriate role of the state and the private sector in fulfilling economic development and equity objectives amongst both rich and poor countries alike [16]. Nevertheless, since the 1980s private sector involvement in public service delivery has grown in both developing and industrialized nations, although not nearly as significant compared to services such as power, transportation and communications. By the end of 2000, at least 93 countries had privatized at least some of their water and waste water services through leases, concessions, BOT-type agreements and or divestiture [17].

Most privatization ventures appear to work best in industrialized countries. The cancellation of high-profile concession agreements in cities such as Buenos Aires, Jakarta and Manila [16], has encouraged opposition civic and advocacy groups leading to the decline of privatization in the water and sanitation sector in developing countries. These are also some of the arguments against increasing private sector participation or privatization of the water and sanitation sector in South Africa.

2.2.3 Innovative Water Technology

A large number of municipalities in the sparsely populated Eastern Cape province of South Africa are located in semi-arid regions, outside of the municipal reticulation system. Local rivers usually dry up during the dry-season and are therefore water stressed, so people rely largely on groundwater and rainwater harvesting for personal water needs. Infamous as one of the most corrupt and inefficient provinces in the country, even municipalities in the water secure eastern coastal regions have isolated problems, related to water borne diseases such as cholera, rather than droughts. This region was therefore an ideal test site for innovative technologies and sustainable ventures aimed at recycling and reuse of water in arid regions, while focusing more on low cost, effective water treatment in rural, poorly serviced coastal regions.

In consultation with the Amatole District Municipality (which was identified as the most efficient and capable municipality in the province) the following problems were identified:

- Immediate assistance with improving water quality with the view of guaranteeing access to safe drinking water.
- Technological assessment of innovative, sustainable water treatment devices or alternative sources of drinking water.
- Education and water safety awareness in the community
- Identification and monitoring of ground water sources.

Traditionally villagers have been using historical paths to their water source, in the case of a river or dam. The rationale behind treating water at the source, allows villagers to maintain their usual access paths, but now the water they access will be treated at the site and safe drinking water can then be carried away for cooking and drinking purposes. Domestic and household water use for washing and animals can be supplied by alternative sources such as rainwater harvesting or directly from the source (no treatment). The 'sweat' component ensures that people use the treated water efficiently (drinking and cooking) and responsibly.

This concept was taken further by the Ikwezi local municipality (via the Department of Science and Technology, German Ministry for Education and Research and the CSIR) with the design and construction of a communal water house in the impoverished arid town of Jansenville. Realistically, every peri-urban water treatment unit will experience maintenance problems at some point. In conjunction with an integrated borehole management plan, point of use ceramic water treatment units will be investigated as a contingency plan when the CWS is undergoing maintenance. Prototype household filter units are being designed and tested at the CSIR.

The energy input has been based on the solar driven pump, used in a communal water house initiative (Figure 5). The tanks can be made of clear poly(ethylene) and are therefore also capable of being sterilised using the sun's UV irradiation. Local commercially available Solar Water Pump Kits include the following hardware - solar panels, solar pole mounting frame (pole excluded),pump master control box with on/off switch, base plate, pipe couplings, nipple, non-return valve, ski-rope, electric cable, HDPE piping and submersible pump. Technology in the form of equipment and expertise was transferred from German partners via a research based SA-German Agreement. The German companies involved used this CWH implementation project as an opportunity to get a foothold in the African market with their technology and products, while the SA municipality benefitted as an end-user.

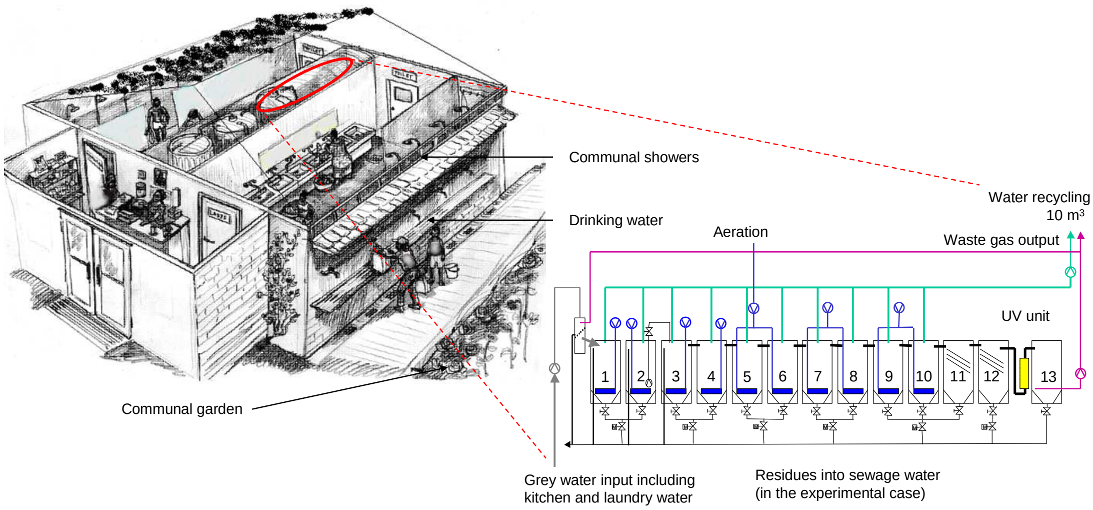

Figure 5: Communal water house and the attendant water treatment and recycling technology. Inset 1: Pontos Gmbh (Berlin) technology used for water treatment and recycling.

2.2.4 Sustainable sanitation technology

Due to the lack of sufficient budgets and personnel, municipalities have resorted to low-standard substitutes for the proper removal of water-born wastes, such as Ventilated Improved Pit (VIP) toilets, and chemical-based toilets rather than flush toilets. These types of toilets present two major problems. First, VIP and chemical based toilets in fact, do not involve waterborne solutions to the problem of human waste, though the 1994 *White Paper* established the importance of water in transporting human wastes from the home. VIP toilets are pit latrines which first allow the urine to dry, leaving the human waste to dry and decompose [18]. However in practise this does not work very effectively (at least in the Eastern Cape that is). Extensive social studies at the CSIR have identified vandalism and inadequate education as the reason for the failure of both VIPs in South Africa. People, who migrate to the urban areas, are usually poor, uneducated and frustrated by the lack of service delivery, forming an electorate that is often manipulated by local politicians. The promise of free basic services and the provision thereof in neighbouring suburbs drives people to vandalise VIPs thus increasing the burden on already strained municipalities.

Additionally, VIP latrines and chemical toilets do not carry waste away from the site, there remains the risk of disease spreading throughout the community and by seepage into the environment, particularly into the groundwater, thus polluting water sources. Therefore, although the 1994 White Paper emphasized a need for water-based solution to sanitation and the need for a clean removal of waste, municipal response is minimal in its security against health risk and low pollution standards. Therefore, there is a gap between policy and implementation, showing a need for stronger legislation and enforcement mechanisms not only in pollution, but in sanitation standards [2]. A sustainable alternative has been driven via the CSIR/DST accelerated sanitation program which advocates urine diversion toilets (UIDs) as a sustainable alternative to VIPs (Fig. 6).

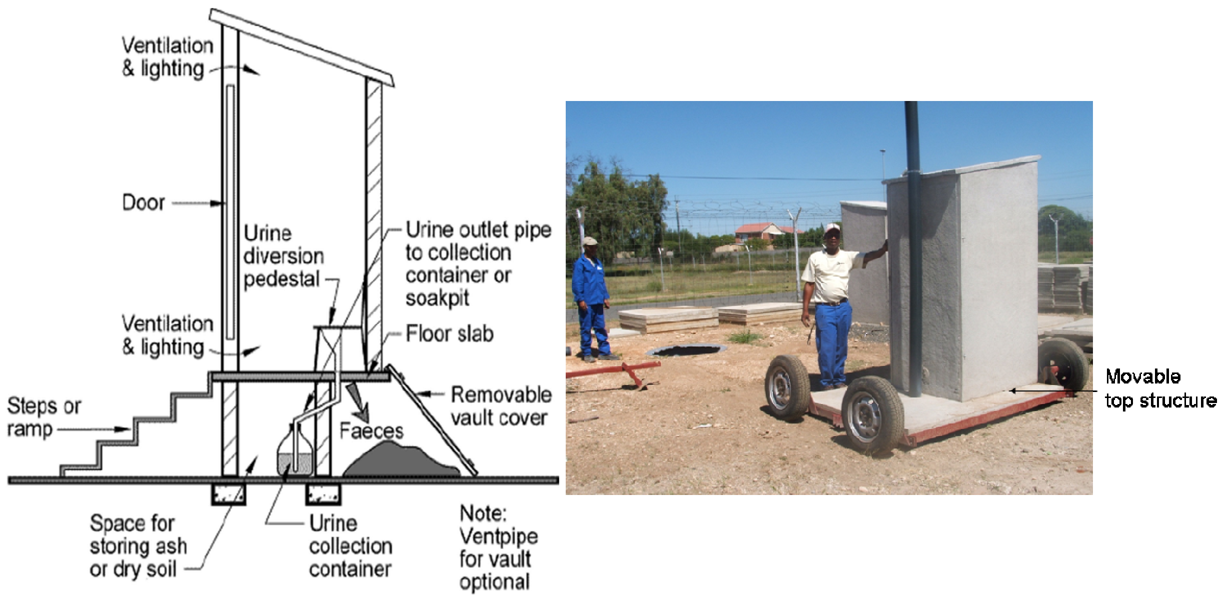

Figure 6: The Urine diversion alternative with movable top structures.

Community awareness campaigns and education initiatives started in 2008 and construction of movable UIDs has started in the Amatole DM. The UIDs (also linked to the CWH technology described in the previous section) require and provide for complete separation of the liquid and solid waste. The collected urine is diluted and used as fertilizer together. Solid waste is allowed to dehydrate naturally and is also used as fertilizer, thus completing the phosphorus cycle in the attendant environment. However collected human waste with a high moisture content will increase the kill time required to eliminate pathogens by dehydration. UIDs are made of poly(ethylene) in South Africa, thousands of these UID toilets have been rolled out under the trade name Enviro Loo (Enviro Options Australia Ltd).

3 Conclusion

Water treatment in small LMs should be simple, effective and reliable. Sustainability of the venture is determined largely by the financial sustainability of the municipality and, local capacity and buy-in of the stakeholders. If surface water is to be treated then multiple stage low-cost filtration, coupled with a chlorination option is the ideal option. For groundwater use, a simple hydro-geological survey is required and baseline tests to ensure that abstraction occurs from an uncontaminated and protected aquifer, so that treatment is not required. Water tariff structures in Southern Africa, are important as they determine what consumers pay for their water and how this price changes with the amount consumed. From a planning and policy point of view, lessons learnt from the transitional democracies in Europe, could be applied holistically to MDG goals and bottlenecks in South Africa. Private sector participation in the sector should be encouraged, rather than aggressively opposed. Viewing water as a commodity and drawing from proven examples in industrialised countries could play a vital role in accommodating such partnerships and bringing in further investors.

The sanitation problem in the Eastern Cape is critical and could serve as an early warning of what could happen in wealthier provinces and municipalities in the future. The RDP agenda and government policy, particularly with respect to sanitation is unsustainable and at odds with implementation on the ground. This has led to the conclusion that there is a serious gap between sustainability policy and provision of household water and sanitation. The use of proven, sustainable technological interventions in both the urban and rural environment is best achieved via cooperation with relevant experts and officials both locally and regionally. It is important to ensure that during the initial project planning stages, all the necessary stakeholders and actors be consulted and included in the discussion process. This also serves to assess who the interested and motivated parties are and to identify national, regional and local project managers. Furthermore, this can also help in identifying the best options for project implementation and planning, formulation of the main aims of the process, technology development and trouble shooting.

The CWH sustainable technology intervention aims to achieve the following:

Water infrastructure benefits:

- Reduce the water amount needed by 2-3 times at the same level of services
- 2-3 times people served by the same amount of water
- 2-3 times prolonged life time of boreholes
- Reduced capacities of connections with lower operation and maintenance requirements

Social benefits:

- Reduced transport of large water amounts to the households
- Washing efficiency by reduced washing agent costs
- Improved education for water house users via communication centre
- Job creation for water house construction and maintenance

Environmental benefits:

- Use of organic fertilizer in private gardens
- Generally reduced environmental impacts
- Lower input of washing agents into environment
- Use of solar energy instead of fossil fuels
- Environmental awareness improved
- Production of organic fertilizer in compost toilets

Acknowledgements

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