# SESSION 3

## *Sanitation Options for Low Income Urban Areas: Technical Options and Financial Arrangements*

*Duncan Mara*
Professor of Civil Engineering, University of Leeds

## *Co-Paper: Semicentralised Supply and Treatment Systems – Integrated Solutions for Fast Growing Urban Areas*

*Peter Cornel / Susanne Bieker*
Technische Universität Darmstadt, Department of Civil Engineering and Geodesy

## *Annex: From No Basic Sanitation to Condominial Sewerage – The Example of El Alto (Bolivia)*

*Alain Mathys*
Suez Environnement, Paris

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## Acronyms

| | |
|---|---|
| MDG | Millenium Development Goals |
| AISA | Aguas del Illimani |
| BMBF | Federal Ministry of Education and Research |
| BOD | Biological Oxygen Demand |
| CAERN | Companhia de Águas e Esgotos do Rio Grande do Norte |
| DC | Developing Country |
| GoB | Government of Bolivia |
| ha | Hectare |
| IBNORCA | Bolivian Institute for Technical Norms and Standards |
| IC | Industrialised Country |
| LAC | Loan Approval Committee |
| MDG | Millennium Development Goals |
| NGO | Non-Governmental Organization |
| PF | Poor flush |
| SPARC | Society for the Promotion of Area Resource Centres |
| STC | Supply and Treatment Centre |
| TDS | Total Dissolved Solids |
| UN | United Nations |
| UNICEF | United Nations International Children's Emergency Fund |
| USIT | Urban Sanitation Improvement Team |
| VIP | Ventilated Improved Pit |
| WB-WSP-LAC | World Bank Water and Sanitation Program of Latin American Countries |
| WHO | World Health Organization |

## Abstract

Two trends characterise the current world population development: absolute population growth and rapid urbanization. Rapid urbanization, taking place in Asia, Latin America and Africa, puts major pressure on the affected regions. While most of this growth is expected to occur in low-income areas, today's development of e.g. Asian countries is stamped by a combination of urbanization with high rates of economic growth. A conventional centralised infrastructure of supply, treatment and disposal of water cannot cope with the new challenges arising from these incomparably high growth rates. New approaches are therefore required for ecological, socio-cultural and economical reasons, and – at least partially – they do exist.

In the main paper Professor Duncan Mara makes a distinction between on-site and off-site sanitation and high density and lower density population areas. In high-density areas (> 160 – 200 inhabitants / ha), he sees three viable options: simplified sewerage, low-cost combined sewerage and community-managed sanitation blocks. In lower density areas, pit latrines, vault latrines, biogas latrines and pour-flush toilets are technically well established solutions. Emptying the pits when they are full often turns out to be highly problematic in practice and it needs to be addressed specifically. Community participation is crucial for the viability of any options. Cooperative approaches can reduce costs and increase the utility's financial viability. Access to well embedded micro-finance is important to facilitate household-level investment. Similarly, if service providers have access to long term funding, and if the purchasing power is on a certain level, central systems become affordable for low income areas.

In the co-paper Professor Peter Cornel presents the vision of a semicentralised approach focusing on integrated water supply and treatment structures for wastewater and waste at neighbourhood level. He argues that a shift from centralised to semicentralised supply and treatment systems will minimise the severe discrepancy between rapid urban growth and the provision of supply and treatment infrastructure. The semi-centralised approach offers great flexibility in implementation, energy self-sufficient operation, as well as enormous saving potentials in water demands through intra-urban water reuse. Even for higher income areas, the approach has advantages when compared to centralised sectored solutions.

In the annex Alain Mathys deals with affordable access to improved sanitation services for households located in low-income peri-urban areas and slums. In 1998, the water operator in charge of the water and sanitation services of the municipalities of La Paz and El Alto (Bolivia) started the construction of condominial sewerage systems in low-income areas of the city of El Alto. Prior to the project, 70% of the inhabitants relied on outdoor faeces disposal. With 60% of the population below the poverty line, most houses were not equipped with toilets and other sanitary facilities. The overall result of the project was definitely positive and it demonstrated that reaching universal coverage in water and sanitation even in very poor communities is possible. A sustainable approach has to combine appropriate engineering design, community participation, promotion of sanitation and hygiene education and micro-credit.

# Main Paper: Sanitation in Low-income Urban Areas: Technical Options and Financial Arrangements

Duncan Mara[1]

## 1. Introduction

The world's population is increasing almost exponentially at present, but almost all population growth over the next 40 years is expected to occur in urban areas in developing countries, as shown in Figure 1. We can expect most of this growth to be in low-income areas, and therefore sanitation solutions have to be appropriate for these areas, whether they are slum areas or not • with "appropriate" here meaning socioculturally acceptable, financially affordable and institutionally feasible.

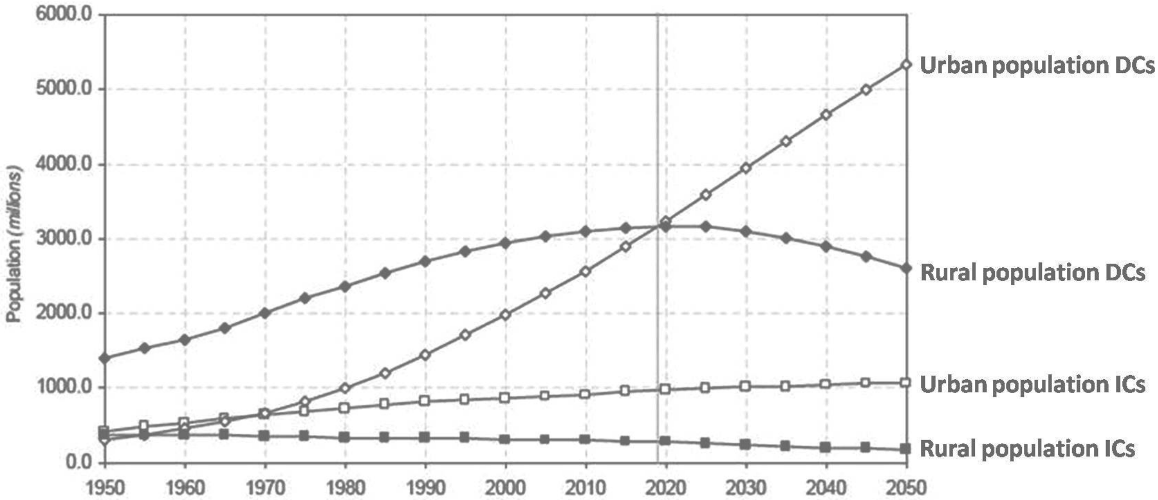


**Figure 1. World population 1950• 2050**

**DCs: developing countries; ICs: industrialised countries**

*Source:* United Nations Department of Economic and Social Affairs, Population Division (2008).

A highly practical approach to sanitation technology selection has to be taken. It is therefore useful to consider two broad types of sanitation system and two broad population-density classifications. These are:

- on-site sanitation, and
- off-site sanitation.

and:

- high-density areas, and
- lower-density areas

[1] School of Civil Engineering, University of Leeds, Leeds LS2 9JT, UK (email: d.d.mara@leeds.ac.uk)

### 1.1. On-site and off-site sanitation systems

On-site sanitation systems are those in which the excreta, toilet-flush water (if any), and greywater are disposed of into the ground within the plot area if individual household-level sanitation is provided, or within or adjacent to the area in which the community lives if communal facilities are provided. Off-site systems are those in which the excreta, toilet-flush water and greywater are piped away from the households, ideally to a wastewater treatment works and subsequent use of the treated wastewater in aquaculture and/or agriculture.

On-site systems include the following:

- ventilated improved pit (VIP) latrines, which may have single pits or alternating twin pits,
- urine-diverting alternating twin-vault ventilated improved vault latrines (also called eThekwini latrines),
- pour-flush (PF) toilets, which may also have single pits or alternating twin pits,
- biogas toilets, and possibly also
- ecological sanitation systems.

Off-site systems include:

- simplified sewerage (also called condominial sewerage), and
- low-cost combined sewerage.

Further distinction may be made between individual-household sanitation systems and communal (but, as detailed in section 2 below, preferably community-managed) sanitation facilities; the latter may be on-site or off-site systems. Commonly there is also an institutional distinction: the local water and sewerage agency is generally responsible for simplified and low-cost combined sewerage but not for on-site systems, which are normally the responsibility of the users under the oversight of the environmental health department (or equivalent) of the local council • see the Background Paper for Session 4 of this Symposium.

For descriptions of all these systems see ‘Further Reading’ below.

### 1.2. High-density and lower-density areas

This distinction is useful because it was found in northeast Brazil in the early 1980s that simplified sewerage became cheaper than on-site sanitation above a population density of ~160 persons per ha.[2] In South Africa the corresponding figure is ~200 persons per ha.[3] The term “lower-density areas” is therefore used here to refer to urban areas where at least one on-site sanitation system is cheaper than simplified sewerage.

## 2. Sanitation Options in High Density Areas

In high-density areas there are three options: simplified sewerage, low-cost combined sewerage and community-managed sanitation blocks.

### 2.1. Simplified sewerage

Simplified or ‘condominial’ sewerage was developed in northeast Brazil in the early 1980s to serve high-density periurban areas. Essentially the very conservative design codes for conventional sewerage were relaxed in order to reduce the sewer diameter, minimum

[2] Sinnatamby, 1986
[3] J. Bhagwan, Water Research Commission, Pretoria, personal communication, 2007

gradient and depth, while maintaining rigorous hydraulic design principles • in fact simplified sewerage is more rigorously designed than conventional sewerage.[4]

The minimum sewer diameter used in simplified sewerage is 100 mm and, for a minimum tractive tension of 1 kN/m$^2$ (which ensures self-cleansing of the sewer), the minimum sewer gradient is 1 in 200 (i.e., 5‰), and the sewer is commonly laid in-block to reduce the length of house connections. A 100-mm diameter sewer laid at this gradient can serve ~200 households of five persons with a water consumption of 100 litres per person per day. Cost comparisons between conventional and simplified sewerage in Brazil, India and South Africa have shown that the cost of simplified sewerage is ~35•50% of that of conventional sewerage.

Community participation in the design of simplified sewerage schemes is essential for success.[5] Sewerage agencies that fail to engage effectively with their low-income customers simply ensure the failure of their schemes.[6]

### *2.2. Low-cost combined sewerage*

In low-income areas subject to regular flooding low-cost combined sewerage is often less expensive than simplified sewerage and separate stormwater drainage.[7] The design basis adopted in the state of Rio de Janeiro in Brazil is as follows: (a) the drainage area should not exceed 12 km$^2$ (see also the co-paper on semi-centralised solutions); (b) the design stormwater flow is that resulting from the local 10-year flood; and (c) the minimum sewer diameter is 400 mm. The sewer gradient is determined for the peak daily wastewater flow in the dry season and the sewer diameter selected to carry the 10-year storm flow.

### *2.3. Community-managed sanitation blocks*

In high-density low-income urban areas, including slum areas, often the only viable sanitation system is community-managed sanitation blocks of the type promoted by SPARC, the Society for the Promotion of Area Resource Centres, an Indian NGO (www.sparcindia.org). These sanitation blocks are designed, built, owned and managed by the communities they serve: they are for the use of the community members, who pay for its upkeep[8] • they are in no sense public facilities, although a community may allow casual use on payment of a per-use fee. These sanitation blocks, which commonly have a piped water supply, are better designed and managed than conventional government-funded and contractor-built communal toilet blocks without community participation and they cost less. In Bangladesh, there is positive experience with community-managed sanitation blocks comprising a loan component.[9] This model of community-designed, built and managed sanitation blocks is easily adaptable to other sociocultural settings • for example, it has been successfully applied in Kibera slum in Nairobi. Generally help from a local NGO is required initially to catalyze community activity and to interact, on behalf of the community, with and seek financial support from the local city or town council.

[4] Mara et al., 2001; Melo, 2005
[5] de Andrade Neto, 1999; see also the El Alto example in the annex
[6] Watson, 1995
[7] Guimarães and de Souza, 2004
[8] Burra et al., 2003
[9] Khandaker, 2004

# 3. Sanitation Options in Lower Density Areas

## 3.1. Pit latrines, vault latrines, biogas latrines and pour-flush toilets

These options are technically well established (see 'Further Reading' below). Which one is the most appropriate in any given situation is best determined with the beneficiary community. Emptying the pits when they are full is often in practice highly problematic and pit emptying needs to be addressed fully at the sanitation option selection stage. Generally it requires regulatory and institutional arrangements including payment procedures. One important factor is to reduce the cost for proper sludge removal and disposal and treatment (e.g. a sufficient number of acceptance points reducing transport costs).

## 3.2. Ecological sanitation

While it is true that 'EcoSan' solutions offer in principle sound advantages from the reuse of the nutrients (principally nitrogen and phosphorus) in human excreta, costs are currently very high and, to quote Otterpohl,[10] ecological solutions "are not really ready for large-scale application, except in rural areas." In urban settings, the cost for organising transport and reuse generally exceed the value of nutrients • the recent abandonment of the EcoSan systems in the 'EcoTown' of Erdos in China provides good evidence for this view.

## 3.3. Keys to successful programmes and projects

The Lesotho Low-cost Urban Sanitation Programme, which started in 1980 and was based on VIP latrines, serves as a very good example of a successful project. Its keys to success were as follows:[11]

- an affordable and acceptable latrine design;
- minimal direct grants or subsidies to householders;
- all latrine construction done by the private sector;
- a comprehensive programme of latrine promotion and hygiene education;
- integration of the project into existing government structures; and
- strong coordination in policy and planning between different departments promoting improved sanitation.

# 4. Proven Solutions

## 4.1. Water and Sanitation Cooperatives

Supplying water supply and sanitation services to groups of households is simpler and much cheaper than to individual households.[12] Groups of households form cooperatives, and the local utility bills the cooperative, rather than individual member-households. The cooperatives may be:

- community-managed water-and-sanitation block cooperatives;
- standpipe cooperatives with either individual simplified-sewerage connections or individual on-site sanitation systems;

[10] 2008
[11] Blackett, 1994
[12] Melo, 2005; Mara and Alabaster, 2008

- yard-tap cooperatives with either individual simplified-sewerage connections or individual on-site sanitation systems; or
- multiple-tap in-house cooperatives with individual simplified-sewerage connections (this option is for non-poor households).

The type of cooperative is chosen by the community in conjunction with the local utility. The sewerage service would be a simple surcharge on the water fee.

### *4.2. Microcredit: VIP latrines in Meseru, Lesotho*

Householders in Maseru receiving VIP latrines as part of the Lesotho Low-cost Urban Sanitation Programme obtained a loan from the parastatal Lesotho Bank which was repaid in 20 instalments over 24 months at the bank's normal rate of interest • no payments were to be made in December and January as householders had Christmas expenses and school fees to pay. The loan was obtained from a bank rather than from the government as people knew that the government was relatively inefficient at collecting loan repayments. In the event loan repayments were high and defaulting households were mostly the non-poor who thought they could reasonably escape payments. The whole process was very well organised (see Box 1 on page 5) and it clearly lends itself to replication elsewhere. The proportion of poorest urban population that did not benefit from the loan programme and could not afford the VIP construction was limited to roughly 10%.[13]

HOW TO GET CREDIT FOR YOUR VIP

"If you do not have the funds to build a VIP now, then you can apply to USIT[1] for a loan from Lesotho Bank. This is what you have to do:

1. Go to your nearest USIT office and ask for a full explanation of the Loan Scheme and the various options available.
2. With USIT assistance, complete the Loan Application Form. You can choose to repay your loan over any period of up to 20 months. Interest will be charges at the normal Lesotho Bank rates on the loan. In exceptional circumstances, repayment of the loan could be negotiated for a longer period.
3. You will then be called for an interview by the Loan Approval Committee (LAC). They need to check that you are over 18, that you can produce a site ownership certificate and that you are likely to meet your monthly repayments. Before you can receive for the loan you will have to collect 120 blocks and sand for the substructure. You must also dig your own pit.
4. When you have collected the materials, you will have to sign an "Acknowledgement of Debt" agreement and commit your collateral against the loan amount. You should then pay the M 10.00 registration fee.[2] This fee covers the cost of paperwork, flyscreen, roof screws and a few small items. You will then be given a "loan number".
5. USIT will help you find a trained builder and give you a purchase order for the remaining materials and the builder's fee.
6. After you collect the materials yourself from the suppliers, the builder can start building. A USIT Technical Officer will check that it is built correctly. When it is finished, you will have to sign a completion certificate, stating that you are satisfied with the VIP – before the builder is paid.
7. When the invoices have all been paid, USIT will set up the loan with Lesotho Bank. You will be given a Loan Repayment Card to take with you to the Bank. The repayment should be made on or before the first day of every month.
8. If you have any financial problems and cannot make a repayment, talk to USIT community staff about it and USIT will try to help you. Remember, if you repay in less than 20 months, you will pay less money in interest."

*Notes:* [1] Urban Sanitation Improvement Team; [2] M10 = approx. US$3.50.

**Box 1: Sanitation Financing • The Lesotho VIP Latrine Loan Scheme**

[13] Wsp, 2002

### *4.3. Long term loans: Simplified sewerage in northeast Brazil*

In the early 1980s the cost of simplified sewerage in low-income areas of Natal in the northeastern Brazilian state of Rio Grande do Norte was US$ 350 per household.[14] CAERN, the state water and sewerage company, borrowed money for a simplified-sewerage project from the then Banco Nacional de Habitação (now the Caixa Econômica Federal) and determined it could repay the loan over 30 years by surcharging the monthly water bill by only 40% (rather than the 100% surcharge used for conventional sewerage) • thus no subsidies were required and the schemes were self-financing. In January 2008 the surcharge was 35% and the monthly payment equivalent to ~1.7% of the local minimum monthly wage,[15] thus clearly demonstrating the affordability of the system.

This is a very pertinent example as it can be straightforwardly applied to any local sewerage agency and any local or non-local development bank in areas where the general purchasing power is sufficient to pay for such cost-efficient services.

## 5. Conclusions and Recommendations

- Well-tested, socioculturally acceptable, financially affordable and institutionally feasible sanitation options for low-income urban areas are currently available for use at scale (e.g. Lesotho, India, Bangladesh, Brazil).
- Financing institutions should ensure that during programme design, all relevant sanitation options have been considered. This requires that in the selection process of consultants the experience with relevant sanitation options and with participatory planning processes is one of the selection criteria.
- In very low income high density areas the affordable service level might be limited to community managed sanitation blocks. Financing mechanisms can facilitate the access of communities to better facilities through the provision of medium term loans.
- Water supply and sanitation cooperatives can achieve substantial cost reductions.
- Successful micro-financing models are available and replicable for on-site sanitation. They are most effective in combination with a well organised private sector offering good low cost technical options. Programme support should look at both loan facilities offered by micro-finance institutions and qualification of private sector artisans.
- Simplified sewerage becomes affordable for poorer households, if the implementing institution can rely on long term loans (e.g. 30 years). Financing institutions should contribute to overcome the lack of long term credit facilities in countries with poor overall economic performance (e.g. Sub-Saharan Africa).

[14] Sinnatamby,1986
[15] Mara, 2008

# Co-Paper: Semicentralised Supply and Treatment Systems – Integrated Infrastructure Solutions for Fast Growing Urban Areas

P. Cornel, S. Bieker[16]

## 1. Challenges of Fast Growing Urban Regions

Worldwide, rapid urban growth has tremendous effects on the infrastructure of supply, disposal and treatment of water, wastewater and solid waste. The environment is put under serious strain by deficient or missing wastewater- and waste treatment plants. Not only does this situation cause worldwide environmental damage, it also causes inadequate access to water and sanitation for the growing urban population and, in connection, results in aggravating health problems. As stated by WHO/UNICEF in 2000, “one-sixth (1.1 billion people) of the world’s population is without access to improved water supply and two-fifths (2.4 billion people) lack access to improved sanitation. The majority of those affected live in Asia and Africa. Fewer than one-half of all Asians have access to improved sanitation.” As regards sanitation in China, for instance, it can be predicted that problems related to an insufficient water supply and treatment will increase in the next couple of years.[17] At the global level, the situation regarding water supply has especially worsened in urban areas: “Unlike urban and rural sanitation and rural water supply, for which the percentage coverage has increased, the percentage coverage for urban water supply appears to have decreased over the 1990s.”[18] It has been widely acknowledged that there is a close link between water supply and sanitation, human health and development in general. This puts the improvement of access to water and sanitation high on the global development agenda.[19]

### *1.1. New infrastructure solutions needed to cope with urban growth*

To improve the access to water and sanitation, two main objectives are to be pursued. First the environment must be protected from pollution, secondly the wastage and overexploitation of resources have to be reduced to a minimum. Today this has been recognised worldwide. In particular the formulation of the Millennium Development Goals (MDG) reflects the increased awareness of this necessity. In the context of Goal 7 (“Ensure environmental sustainability”), of specific relevance are Target 9, to “reverse the loss of environmental resources”, and Target 10, to “halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation”. Among the recommendations formulated to achieve these targets the identification of new water sources, such as rainwater and reclaimed wastewater[20] is vital. With regards to densely populated and fast growing urban areas, this inevitably requires intra-urban water reuse. The applicability of specific technologies to this end has to be assessed context-related manner. In addition to the ecological aspects of water reuse there are strong economical arguments for reclaiming water. The increasing water demand while natural resources (groundwater, surface water) remain fixed inevitably leads to scarcity in highly condensed urban regions. Rising prices for the purification of tap water from alternative resources (like seawater by desalination) are the direct outcome. They can only be prevented through a massive

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[16] Technische Universität Darmstadt, Department of Civil Enigneering and Geodesy, Intstiute IWAR, Persenstr. 13, 64289 Darmstadt, Germandy (E-mail: p.cornel@iwar.tu-darmstadt.de)
[17] Wilderer et al., 2003
[18] WHO/ UNICEF, 2000
[19] Lenton et al., 2005
[20] UN, 2008; Lenton et al., 2005

reduction of the amount of water needed by reusing main fractions. This will additionally save energy for transport and conditioning.

However, it is obvious that this objective is barely realisable with the conventional centralised supply and disposal systems, as they were implemented in industrialised countries in the 20th century. Centralised treatment units can treat the sewage of millions of urban residents – but only if the grid system necessary is comprehensive and regularly maintained and the population to be supplied with infrastructure is more or less steady. Yet the urban reality of developing countries is characterised by a population increasing by some dozen up to several hundred people a day.[21] Shanghai for example grows by 32 people per hour,[22] resulting in an additional 280,000 inhabitants per year, or more than 2 Million more people. This occurs within a typical time frame of 7 to 10 years from the planning, financing and building of sanitation infrastructure like sewers and centralised treatment plants. One of the main features of centralised supply and disposal systems is the poor flexibility in associated facilities, which makes an appropriate standard of supply and disposal economically almost impossible in growth-periods. The treatment capacity of technical units has to be much higher than the actual individual demand. Furthermore centralised systems have a high and long-term capital commitment, because of their vast grid network. Because of the obvious shortcomings of centralised pipe and sewerage systems, alternative solutions have been discussed worldwide. One of them involves decentralised sanitation systems treating waste waters on-site at the household level. These might be appropriate within areas characterised by low population densities but not within densely populated urban areas because of the limited availability of space for on-site treatment facilities. On the other hand, household-based solutions such as compost toilets, household-based urine-separation and rainwater collection treatment have already been proposed as possible solutions. These systems give valuable information. In urban areas with high population densities, however, problematic aspects such as (monitoring) quality standards and surveillance, hygiene, maintenance and performance put in doubt a widespread use of household-based solutions as stand-alone solutions.

Another challenge predominantly surfacing in fast growing developing countries is the rising amount of sewage sludge, a result of increasing treatment capacities. At the same time, fast growing urban areas have to focus on increasing amounts of residual waste. For both challenges there suitable and reliable solutions are missing, especially in urban regions with high population densities and therefore lacking space.

To overcome the shortcomings of centralised systems on the one hand, and of household-based decentralised systems on the other, a semicentralised approach will be developed. But semicentralised doesn't only indicate the size of a system. A simple shift from sectored centralised to semicentralised supply and treatment systems, from industrialised countries to fast growing urban regions in newly industrialised and developing countries, does not appear to be appropriate. Intra-urban water reuse fosters relatively compact structures, avoiding substantial transports of wastewater out of the city borders for treatment and of the service water back into the city for reuse. For this reason, the shift from traditional centralised systems towards semicentralised solutions is a decision in favour of integrative planning and proceeding of technical infrastructure as well as material and energy flows.

### *1.2. The Semicentralised Approach – supply and treatment on district level*

The implementation of innovative semicentralised supply and treatment systems will minimise the grave discrepancy between the rapid urban growth and the provision of reliable and sustainable supply and treatment infrastructure systems. Intra-urban recycling,

[21] Shanghai Statistical Bureau, 2007
[22] Burdett & Rohde, 2007

especially the reuse of water and the recovery of energy from waste and sludge are an advantage of compact systems, which avoid long-distance transports of wastewater, waste and sludge and foster a close-by treatment of domestic material flows.

**Semicentralised systems – integrated treatment technologies**

In contrast to conventional city-wide systems, semicentralised supply and disposal systems do not comprise entire cities, but work in smaller district units (cp. figure 1).

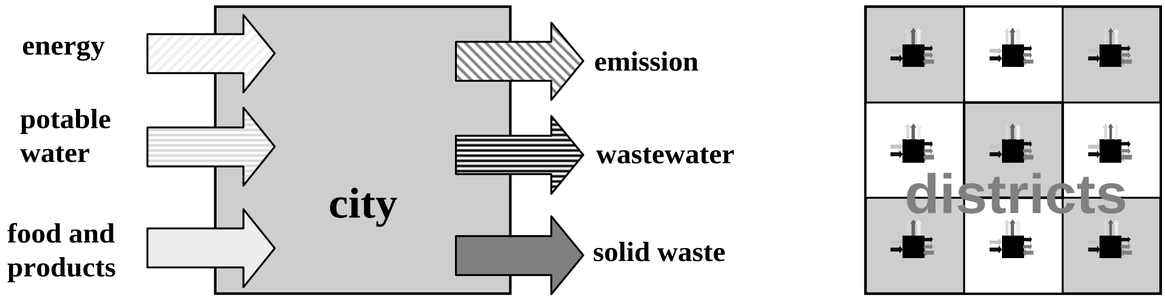


**Figure 1 Centralised (left) vs. semicentralised (right) supply and treatment systems (Weber et al. 2007)**

Semicentralised supply and treatment systems therefore offer the opportunity of integrated treatment facilities for water, wastewater and residual waste. They provide service water for intra-urban use, e.g. for toilet flushing or irrigation of public greens, for the entire district of a city.[23] As figure 2 shows, each district operates its own Semicentralised Supply and Treatment Centre (STC). The combined treatment in STC includes the implementation of new technical solutions and treatment methods to optimise mass and energy flows for instance by the co-fermentation of organic waste and wastewater sludge.

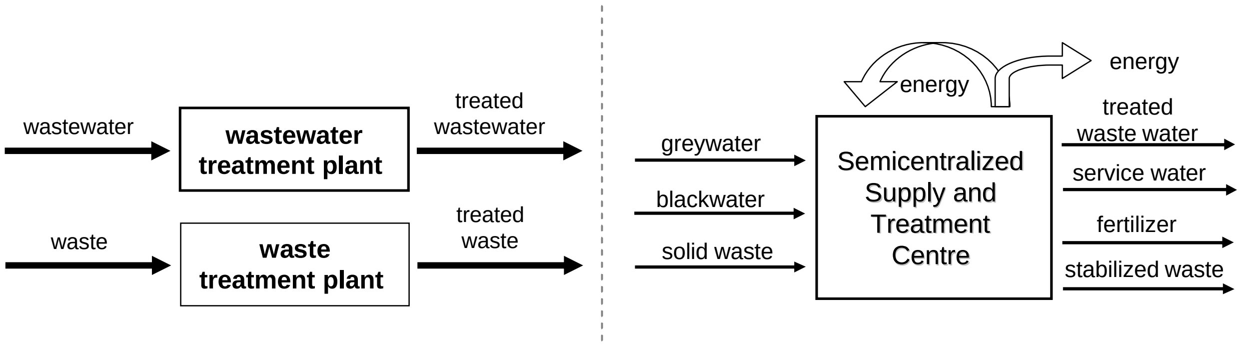


**Figure 2 Comparison of sectored centralised (left) and integrated semicentralised (right) material flows in supply and treatment systems**

To minimise the distance between the households (source of greywater and blackwater as well as consumer of service water) and the treatment location of the water flows, the STC has to be located close to urban housing areas. The contiguity of housing and treatment units requires a compact STC design due to high land costs and development pressure. Therefore compact treatment methods are of particular interest. In addition, emissions (such as odour and noise or air pollution) need to be reduced to a minimum. These requirements are best met by enclosed solutions.

[23] Böhm et al. 2006

The residential reuse of water and the integrated treatment of solid waste and sewage sludge are key elements of the integrated semicentralised concept and consequently of enclosed solutions. A determination of specific treatment technologies is not intended – the choice has to take the specific circumstances into consideration.

The treatment of tap water for producing high quality potable water is an option which is not included in the subsequent energy balance.

**Scale and flexibility**

As indicated above, the overall aim of semicentralised supply and treatment systems is to contribute to improve techniques. At the same time it guarantees flexibility. This is based on the assumption that the conflicting pillars of sustainability, economic, social and ecologic interests can only be balanced in an integrated and condition-adapted system. Integration concerns the utilization and optimization of interfaces between different supply and disposal sectors, such as solid waste, water and wastewater, through the recycling of materials. Therefore the system has to be adaptable to the specific situation of a given context. This in turn can only be achieved by a flexible supply and treatment system. Hence, semicentralised supply and treatment systems must be flexible in implementation.

A further central issue concerning the design of a semicentralised supply and disposal systems is the scaling. In accordance with the concept of adaptation to specific contexts, the actual size of the population supplied by one unit has to be assessed from case to case, but is to be guided by the principle "as small as possible as big as necessary", coping with the ambivalence of sustainability with regards to economic as well as social and ecologic interests. The comparison of different scales, starting from about 10,000 up to more than 200,000 capita suggested the recommendation of a best suitable scale (according to ecological, sociocultural and economical reasons) of 50,000 up to 200,000 capita in a fully integrated semicentralised supply and disposal system.[24] Latest research provides the evidence that this scale is also recommendable if the system is not fully integrated, i.e. not comprising all four material flows (water purification, greywater treatment, blackwater treatment, integrated sludge and waste treatment), but any case-adapted integrated solution.[25]

Furthermore, supply and treatment are carried out by qualified personnel, thus assuring maximum reliability in achieving high quality standards, the control of material flows, and above all hygiene in water distribution and water reuse. In addition to these advantages, planning and design are much more reliable as it comprises smaller and manageable frames in time and space as well as economical advantages.[26]

## *2.* Advantages of the semicentralised approach

In comparison to conventional (sectored) centralised supply and treatment systems integrated semicentralised solutions offer a range of advantages, like:

- Water savings - *e.g. 30-40% by non-potable intra-urban reuse for toilet flushing;*
- Energy self-sufficiency – *to operate independently and reducing operational costs;*
- Minimised carbon footprint – *by using resources from wastewater and solid waste;*
- Decreased capital commitment – *by adjusted, modular and flexible growth;*
- Reduced operation costs – *by minimising the energy bill;*

[24] BMBF, 2006
[25] Bieker 2009, *to be published*
[26] cp. Paragraph Capital commitment and planning certainty

- Higher flexibility and therefore higher planning certainty.

These will be outlined below.

### *2.1. Water savings and energy self-sufficiency*

To illustrate the saving potentials in energy matters, the sectored centralised approach needs to be analyzed in more detail. Figure 3 shows a scheme of conventional treatment in fast growing urban regions in China, using the example of the city of Qingdao. The fresh water demand ranges at about 109 L/(C d) and the needed waste treatment amount is of about 1 kg/(C d).[27]

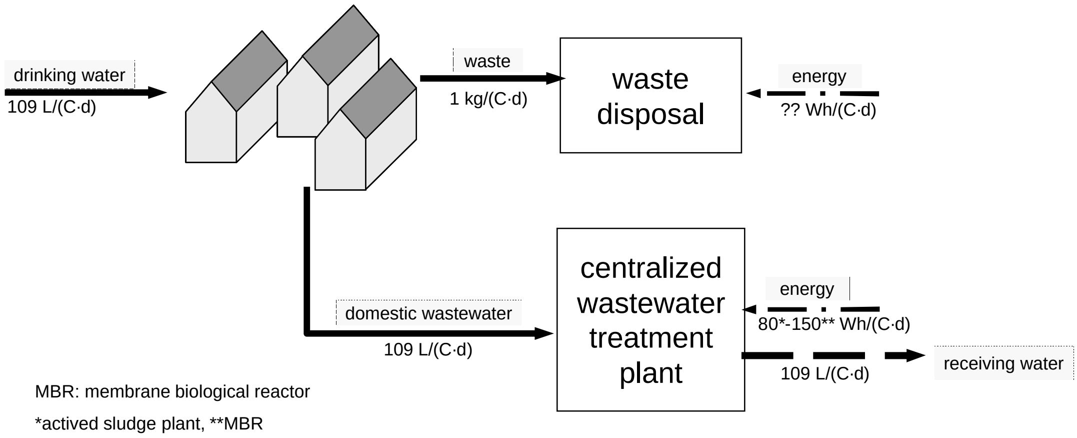


**Figure 3 Material and energy flow in a conventional centralised system – the case of Qingdao, P.R. China [Cornel et al. 2007]**

In comparison, the integrated semicentralised approach, visualizing the example of the city of Qingdao (cp. figure 4), can achieve large reduction rates: In a first step toilet flushing is operated with service water gained from greywater (in this case: greywater 'light' – gained from washing machines and bathing), which can save more than 40% of the needed tap water. Higher water reduction rates can be achieved by treating the whole amount of the arising greywater (greywater 'light' plus hand wash basins and kitchens). The flexibility of the semicentralised approach allows an application-optimised operation, also in terms of service water.

[27] Bi, 2004

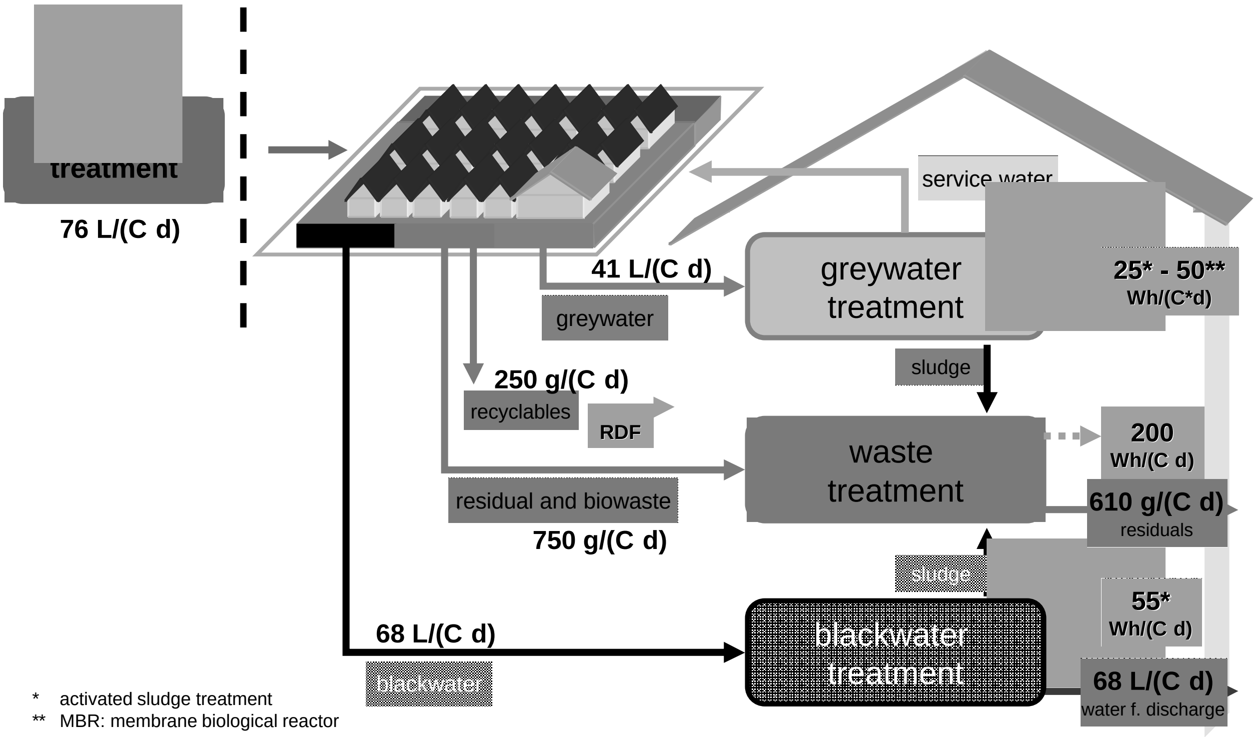


**Figure 4 Material and energy flows in an integrated semicentralised supply and treatment system (scenario greywater 'light' reuse) – the case of Qingdao, P.R. China**

The treated greywater for non-potable use in private households has to meet high quality standards. The example of China shows the quality level required: according to GB/T 18920-2002, water quality standard for urban miscellaneous water consumption, water for toilet flushing has to fulfil the following requirements as for example (extract):

- TDS • 1,500 mg/L
- $BOD_5$ • 10 mg/L
- $NH_4$-N • 10 mg/L
- anionic surfactants • 1 mg/L
- coli form • 3/L[28]

The integration of sludge and waste treatment leads to an increase of the overall system efficiency and a decrease of the amount of residues to be disposed. At the same time the sludge gets stabilised and a solution is provided for the currently severely deficient situation of the treatment of wastewater sludge.[29] The biogas obtained from the integrated anaerobic treatment of sludge and waste is (under biogas-optimised treatment conditions) energetically sufficient to provide for the STC's electric energy demand and even to produce a surplus for additional purposes. An energy self-sufficient operation of the integrated semicentralised supply and disposal systems is therefore possible.

Some figures as they result from a feasibility study: There's a system demand of 25 up to 50 Wh/(C d) for the greywater treatment, according to the chosen treatment method. Additionally around 55 Wh/(C d) are needed for blackwater treatment. The example of Qingdao excludes potable water purification on a semicentralised scale for statutory reasons; therefore the potable water purification is not part of the energy balance. The conversion of

[28] GB/T 18920-2002
[29] cp. openPR, 2008; Bfai, 2008

biogas into electricity generates about 300 Wh/(C d). Approximately 100 Wh/(C d) are needed for solid waste treatment, so there is a surplus of 200 Wh/(C d). Deducing the system needs for greywater and blackwater treatment, an energy surplus of 95 to 120 Wh/(C d) is to be reflected in the energy budget. Although the surplus might be further reduced in practice it seems at least to be sufficient for pumping waste water and distributing service water.

Concurrently, the energy production from waste and sludge improves the carbon footprint of the STC. The energy is (nearly exclusively) gained from organic material, the wastewater treatment sludge as well as bio waste and residuals. By using the biogas out of this sludge and waste, not only is the energy bill reduced to a minimum, also the $CO_2$-balance of the whole system is significantly improved. Ongoing research will clarify the greenhouse gas balance further.

Another advantage of the integrated semicentralised approach is the proximity between consumers and treatment facilities. This allows for short sewer and pipe systems and can reduce water losses to a minimum. It also permits to separate municipal wastewater from industrial wastewater, resulting in a convenient water reuse. Treated wastewater can be profitably launched for domestic use as toilet flushing or intra-urban irrigation, because long transport distances between use and treatment are avoided. At the same time, close-by waste treatment facilities minimise transport routes and optimise the recycling of resources according to energy recovery.

Furthermore, the temperature of the separated greywater provides potentials in heat-recovery, which can be easily employed in nearby settlement structures, e.g. for heating processes. If appropriate applications for thermal use exist, additional heat can be received from the conversion of biogas into electricity. Depending on the system configuration, up to 1.5 times as much of the amount of the gained electricity can be achieved.

### *2.2. Capital commitment and planning certainty*

Semicentralised systems focus on small and compact units, avoiding large distances between housing and treatment plants – with economic saving potentials and without any lack of comfort. In earlier times, odour, noise and hygienic aspects have been sound reasons to locate waste and wastewater treatment units far away from housing and other sensitive uses. Modern treatment techniques and methods, on the other hand, enable close-by treatment with the opportunity to save massive resources even without any changes in the habits of water use.

One essential consequence of the proximity between the accruing and the treatment location is the massive reduction in grid scale. Considering that 70% - 80% of the capital costs of a wastewater system result from the sewer lines,[30] any reduction in grid distances and diameters leads to enormous saving potentials. Moreover, shorter distances induce lower investment needs and operation costs for water transport and pumping.

In addition, planning and operation are much more reliable than in conventional centralised systems, as the integrated semicentralised system consists of smaller and better manageable frames in time and space. One line of argument regarding the reliability of planning is as follows. Realizing a centralised system for several 100,000 or even million people is a planning risk. What happens, if the development scenarios fail because of unforeseen circumstances such as worldwide economic turbulences or simply false forecasts as those put forward in East Germany in the last decade of the past century? Investments in far too large sewer system and treatment facilities are not only an economical disaster but also pose technical challenges. These are corrosion in the sewers induced by anaerobic

[30] cp. Günthert, 2001

degradation due to low flow velocities and the operation of the treatment facilities far below the designed capacity. As far as semicentralised systems of some 10,000 properties are concerned, the planning scenarios offer a very different reliability, even in new development areas. Within three to five years the planned scales of integrated semicentralised supply and disposal systems can operate fully loaded.[31] And even if those development scenarios failed, the economic casualties would be incomparably lower than for centralised systems. This additional flexibility offers a huge advantage in spatial planning and spatial development in general. Further potential may lie in the standardisation of planning and construction processes of integrated semicentralised systems. Ascertained reductions in planning and realisation through off-the-peg solutions are conceivable, but are still under advanced investigation.

Finally, semicentralised scales are much less vulnerable in terms of external influences. Even in case of complete system failures as a result of natural disasters like floods or earthquakes, the impacts to civil life are not comparable in terms of affected properties. For the same reason semicentralised supply and disposal systems would be of no interest as potential targets for terrorism, because the effects would be strictly limited as contrasted with centralised systems of several 100,000 connected residents.

**Implementation strategies for Semicentralised systems**

Although the overall recommendation of the scale of integrated semicentralised supply and treatment systems focuses on 50,000 up to 100,000 inhabitants served, smaller units can also be realistic. Current research and data from a feasibility study in a coastal city of China gives reasons to believe that the higher investment costs of semicentralised systems are going to pay off after a period of 15 to 20 years, because of the substantially lower operation costs of semicentralised solutions resulting from closed water and energy loops within the system. If these prospects will be confirmed, the above mentioned argumentation in terms of flexibility and planning certainty of integrated semicentralised supply and treatment systems will be corroborated even further.

Further studies are focusing on the partial integration of some material flows to enhance the adaptability of the semicentralised supply and treatment system even more.[32] As considered in a first step at the case of Qingdao, a fully-integrated approach (potable water, greywater, blackwater, sludge and solid waste) need not be the best adapted one – and therefore different grades of integration will be considered. First results suggest that economic advantages can be achieved in less integrated solutions, too.

**Obstacles and further Challenges**

- *Governance*
  Since the administration for water supply, sanitation, wastewater treatment and solid waste disposal is quite often separated, the integrated approach is likely to encounter resistance.
  Furthermore, innovative new approaches necessarily have fewer references. Administrations are not known for being innovative and open to new ideas.

- *Cost and fees*
  Reuse water has to be cheaper than fresh water for the customer. As long as drinking water is subsidised, the user will prefer freshwater. Thus the fees have to reflect the true costs for both freshwater and reuse water. Energy intensities might serve as an indicator. As an example the desalination of seawater might require around 3,5 to 4 kWh/m³, and long distance transport might need an even higher energy input, the energy intensity of high quality non-potable reuse water is below 1 kWh/m³.

[31] cp. Bieker, 2009, *to be published*
[32] cp. Bieker, 2009

- *Funding and Financing*
  Financing institutions rather like to finance few large projects compared to a large number of small units. Furthermore they tend to be conservative in requiring large numbers of references.
- *Public Acceptance*
  All users and stakeholders have to be educated and convinced, especially to reusing water. Reliable technical design and professional operation are basic elements for convincing consumers, but public awareness and participation might be as important as technical issues. Singapore's Newater provides an example of perfect public relations in the context of water reuse.

## 3. Conclusions

New development areas in fast growing urban areas are facing new challenges in infrastructure and resource matters. The employed case study is based on the city of Qingdao, China. But the mentioned challenges are not only Chinese. They occur in fast growing urban regions worldwide. The integrated semicentralised approach offers flexible solutions to cope with the new needs and to develop case-adapted solutions, wherever certain thresholds of population density are topped. In this range, semicentralised supply and disposal systems open a wide scope of possibilities in resource management, especially reducing the fresh water demand of new urban areas – besides any changes in behaviour (there lie further potentials, which are not part of this study). Furthermore, semicentralised supply and disposal systems offer energy self-sufficient operation and even delivery of surplus energy while integrating solid waste and sewage sludge treatment.

# Annex: From No Basic Sanitation to Condominial Sewerage – The Example of El Alto (Bolivia)

Alain Mathys[33]

## 1. The Sanitation Challenge in Developing Countries

Affordable access to improved sanitation services in developing countries is an issue for many households located in low-income peri-urban areas and slums. Sustainable sanitation is a concept that has been discussed by many experts and institutions. There is a common agreement that a sustainable sanitation system should be economically viable, socially acceptable, and technically and institutionally appropriate, and should also protect the environment and the natural resources.[34]

Infrastructure development and its effective operation and maintenance are key elements to allow urban population to have a permanent access to sanitation services. The responsibilities to make this happen are shared by several institutions: national and local governments, financing institutions, research centres, the civil society and the water and sanitation services providers. Among these stakeholders, water utilities have a pivotal role to play in ensuring the development of sanitation infrastructure to the underserved areas. They have the responsibility and the ability to develop and implement large-scale sanitation projects and to ensure sustainable operation and maintenance of infrastructure and reliable customer services. Their role is not only technical and operational but they also have to understand community demand and its ability to pay in order to ensure the economic viability and the social acceptability of the systems to be built and operated.

In developing countries, local conditions (less developed economies, strong urban growth and irregular settlements) require the development of cost-effective sanitation solutions significantly different to the ones implemented in industrialised countries and adapted to local demand. Access to sewerage and on-site sanitation remains a big issue in the majority of large cities. Pilot projects have tested various technical options but few cities have been able to implement such projects at large scale. The development of sanitation services is complex and, as for water supply, involves technology innovation and differentiation, education and marketing, investment and subsidies.

## 2. Condominial Sewerage Approach

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[33] Suez Environnement, Pari, France (email: alain.mathys@suez-env.com)
[34] Sustainable Sanitation Alliance at www.susana.org

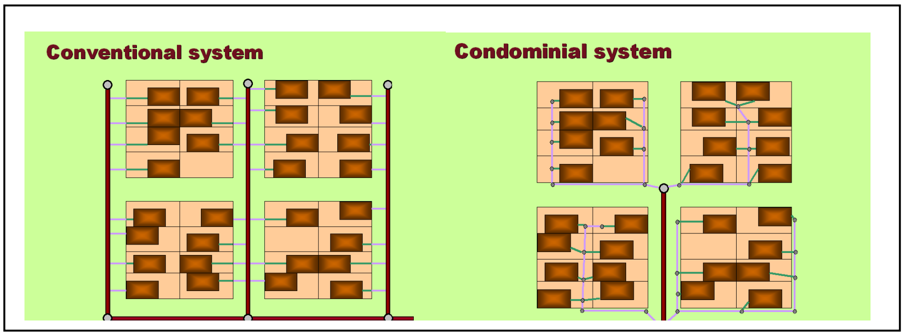


**Figure 1: Conventional and condominial networks**

In Latin America and particularly in Brazil, service providers have been involved for more than 20 years in the development and management of condominial water and sanitation networks, in response to the rapid development of peri-urban neighbourhoods. The term condominial refers to a group of housing that is considered as a housing unit, similar to an apartment building except that a condominium is physically horizontal and institutionally informal (see figure 1).

Condominial networks are based on two fundamental principles:

- technical optimisation of the collection system in order to reduce investment costs
- participation of the population in the construction and maintenance of the system.

## 3. Urban Development Challenges in El Alto

In 1997, the city of El Alto had a population of 600,000 inhabitants, the majority belonging to the Aymara ethnic group. This city faced many challenges: considered as the highest city in the world (elevation between 4,000 and 4,150 meters above sea level), it has a cold climate (ranging between + 15° C and – 5° C). It suffered an accelerated growth process generated in the 80's by internal migration. El Alto had an annual growth rate of 9.2%, one of the highest ratios in America. Initially a small suburb of La Paz, the city increased in size very rapidly and encountered the usual challenges of rapid urbanization in a low income country. As far as basic services are concerned, the rapid growth has generated an important coverage deficit, particularly for sanitation (30% sewerage coverage, 52% water coverage). The vast majority of houses in El Alto are quite simple, even precarious made of adobe (sun-dried mud brick) and are not equipped with toilets and other sanitary facilities.

El Alto is dominated by the informal economy. Seventy percent of the employed population works in family-run businesses – they are street vendors or artisans. Moreover, about 60% of the population lives under the poverty line. The average monthly household income is US$120, while the cost for a conventional sewerage connection is US$276.

Cultural characteristics also contributed to the project being critical. The religious beliefs of the Aymara people preclude certain forms of modern hygiene. For example, latrines and septic tanks would be regarded as unacceptable to many because they involve the burial of faeces in the ground, something that is considered sacrilegious to their deity Mother Earth, the Pachamama goddess.

Water consumption is low; on average just under six cubic meters per household per month (or about 40 litres per capita per day). The largely rural origins of the population and the cold temperature make many people reluctant to adapt to modern urban lifestyle in particular regarding personal hygiene. People are accustomed to obtaining their water directly from nature, and disposing their faeces outdoors.

All of these characteristics combined to make El Alto a unique location and raised a number of technical and social issues for the expansion of water and sanitation services. This prompted the water utility to conduct in-depth socio-economic and anthropological studies and to develop partnership with local associations and authorities in order to better understand the specific characteristics of community demand for water and wastewater services. As far as sanitation was concerned, on-site sanitation such as latrines and septic tanks was not a solution, since the religious beliefs of the Aymara people regarded them as unacceptable.

The high fee to be paid for a connection to sewer network would prohibit many household to connect to modern sanitation system and the low water consumption would create concerns for the efficient functioning of the sewers. This prompted a search for ways of reducing the cost of providing sewerage to low income households, and led the Bolivian authorities and the water utility to consider the potential use of the condominial sewerage approach.

## 4. The Concession Contract for Water and Sanitation Services of La Paz and El Alto (Bolivia)

In 1997, a private consortium led by Suez Environment under the name Aguas del Illimani (AISA) took over a 30-year-concession contract to provide water and sewerage services to La Paz and El Alto cities in Bolivia (altogether 1.6 million inhabitants). Contract was awarded to AISA through an international tender led by the Bolivian Government. The tender was structured through a precise definition of objectives to be reached, both in terms of levels of service as well as in terms of service expansion, which was the major goal sought by the Bolivian Government.

For this reason, the award criterion selected for the tender was the number of new water and sewerage connections that the bidders would offer for the first five years of the contract. After it took over in August 1997, AISA focused on delivering the objectives and results agreed upon through the contract for the first 5-year plan, i.e.:

- improving water supply service coverage to reach 100 % in La Paz and 82 % in El Alto (within the service area).
- improving sanitation service coverage to reach 83 % in La Paz and 41 % in El Alto (within the service area). For El Alto, this would mean achieving 38,000 new sewerage connections in five years.

## 5. The El Alto Pilot Project

In 1998, Aguas del Illimani, in charge of the water and sanitation services of the municipalities of La Paz and El Alto (Bolivia) started the construction of condominial sewerage systems in low-income areas of the city of El Alto (average income per household: 120 US$/month) in response to the low sanitation coverage (around 30%). Between 1998 and 2002, close to 5,000 households or 25,000 inhabitants were connected to condominial sewers. The innovative characteristics of the El Alto Pilot Project were based in the engineering design, the community participation, the promotion of sanitation and hygiene education, and a micro-credit facility offered to household to finance their in-house sanitation facilities.

*Engineering design*: the wastewater collection network is divided into two parts (see fig. 2): the main collector (public) that corresponds to the secondary network in a conventional sewerage network and the condominial branches running within housing units in the most convenient locations (in the front yards, back yards or under the sidewalks). Pipes diameters, length, and excavation depth of the network are reduced. This innovative design allows savings in equipment and construction costs that can go over 50% compared to conventional sewers.

*Community participation*: the second innovative element of the condominial system is the participation of the community in the design, construction and maintenance of the system. This implies to develop a narrower relationship between the service provider and the customers than with conventional approach. Community participation allows further reduction costs of construction and maintenance.

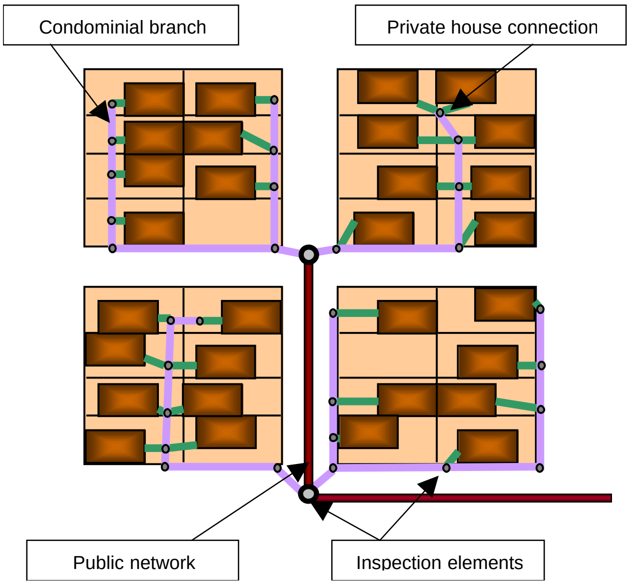


**Figure 2: Schematic diagram of a condominial system. Housing units are connected to the public network by a single connection**

*Promotion of sanitation and hygiene education:* At the start of the project in El Alto, very few families had got any form of sanitation equipment in the project areas. Hygiene education and technical support were provided by the water company's team specially trained in community participation techniques to the communities and help them constructing their own bathrooms.

*Micro-credit:* A micro-credit facility was included in the project to help poor families pay for the material required to construct a bathroom. Overall, 25% of households applied for credit. However most of the inhabitants chose to rely on their own savings or to borrow money from close relatives to finance these equipments.

The El Alto Pilot Project was conceived as a joint venture between the Government of Bolivia (GoB), the private concessionaire Aguas del Illimani (AISA), the World Bank Water and Sanitation Program of Latin American Countries (WB-WSP-LAC), and the Swedish International Development Agency.

- The GoB agreed to relax its technical standard which would legally preclude the use of the condominial approach.
- With the endorsement of the regulatory agency, AISA agreed to use the condominial approach to meet a proportion of its expansion targets in El Alto.
- The role of WB-WSP-LAC was to facilitate the transfer of this alternative technology for low cost water and sewerage system from Brazil to Bolivia. WB-WSP-LAC has supported the institutionalisation process towards the modification of the technical standards for replicating the model at a large scale.
- The Swedish International Development Cooperation Agency financed the research and training activities required to transfer and adapt the condominial system to Bolivia.

During the El Alto Pilot Project implementation, 2,500 households were connected to condominial sewers distributed in 7 neighbourhoods. Some of them were not connected to the water network and AISA initiated the implementation of water networks and household connections in parallel to the development of the El Alto Pilot Project.

Different methodological approaches demonstrated that the Pilot Project's impact was as significant as expected. A census data survey (1,700 lots), and two random sample surveys were performed: one of the surveys to compare a conventional system neighbourhood with one simultaneous condominial system neighbourhood (76 lots versus 87 lots); and, the other to compare the situation before and after the condominial system (134 lots). The results were as shown in table 1.

**Table 1: Results of the evaluation and impact survey of the El Alto Pilot Project**

| Parameters | Condominial system (census survey) | Conventional system (random sample survey) | Pre-condominial system (random sample survey) |
|---|---|---|---|
| Connections | 98% | 66% | 0 % |
| Bathroom equipment | 74% | 30% | 35% (with water network)<br>8% (without water network) |
| Water consumption | 7.4 $m^3$ | 5 – 6 $m^3$ | 5.0 – 6.3 $m^3$ |
| Hygiene habits | % of households with outdoor faeces disposal decreased from 70% to 20% | | |
| Satisfaction with condominial sewerage | 83% of households were satisfied with the system | | |

As to connections, there was a higher level of households' sewerage connections in the condominial system than in the conventional one. In relation to bathroom installation, there was a higher proportion of bathrooms built in the condominial system. It is worth mentioning that before the implementation of the condominial system, among those that had water network, 35% had their bathrooms installed, while among those neighbourhoods that did not have water networks, only an 8% had bathrooms installed.

As regards water consumption, it was possible to verify a greater water use compared to the conventional system and also to the situation before the condominial sewerage (a statistically significant difference). As to hygiene habits, there was a substantial improvement, such as the elimination of water consumption from dangerous sources, and the reduction of households that practiced outdoors excreta disposal.

Through a financial study it was possible to demonstrate that there was a 20 to 30% saving when using contractors, and a 40 to 50% saving when using community labour. Savings in the cost of materials arose as a result of the shorter length and narrower diameter of the pipes; savings in labour effort resulted from the shorter and shallower trenches that can be used in the condominial case while savings in labour costs arose from community participation.

Today there are about 5,000 connections of condominial sewerage in El Alto and La Paz. The project also had a significant positive impact on urbanization, such as an increased population density, street lightning and road pavement.

Thanks to the El Alto Pilot Project validation in November 2001, the governing board of the Bolivian Institute for Technical Norms and Standards, IBNORCA, approved new technical standards for the design and construction of sewerage systems and wastewater treatment plants. This new set of standards will support condominial system replication on a large scale in Bolivia.

The success of the El Alto Pilot Project has encouraged other countries like Peru, Ecuador and Paraguay to initiate projects to test this alternative in their own contexts. The peculiar cultural, geographical and social circumstances of El Alto make it an extreme test for the condominial approach in the sense that the factors which limited the benefits of the condominial system in Bolivia might not necessarily be present to the same degree in other contexts.

The Pilot Project's results have demonstrated that it is possible to reach universal coverage in water and sanitation, whatever the developing community level is, provided that there is: common vision of the actors involved, community participation, efficiency of the operator, and availability of financial mechanisms.

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1• 2-page descriptions of ventilated improved pit latrines, urine-diverting ventilated improved vault latrines, pour-flush toilets, biogas toilets, greywater systems, simplified sewerage, low-cost combined sewerage, and community-managed sanitation blocks, with links to additional information.
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