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Pro-poor sanitation technologies

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Abstract

It is estimated that at least two billion people have inadequate sanitation. The current situation in water and sanitation services for millions of peri-urban residents is starkly anti-poor and represents a major challenge for the 21st century. By virtue of its cost and water requirements, we would argue that conventional sewerage is an implicitly anti-poor technology. This paper summarises low-cost sanitation technologies that have been developed by engineers from around the world, and seeks to provide evidence that there is such a thing as a pro-poor technology. We argue that simplified sewerage is often the only sanitation technology that is technically feasible and economically appropriate for low income, high-density urban areas. Simplified sewerage will only truly be a pro-poor technology if issues such as lack of investment in sanitation, insufficient cost recovery for sanitation services, conservative technical standards favoured over innovation, low-cost technologies perceived as second class provision, the nature of peri-urban settlements, and lack of engagement with users, are addressed. So often, peri-urban sanitation schemes fail to exist, fail to be sustainable, or fail to be pro-poor. The challenge is for engineers, social scientists and other professionals to work together to make pro-poor sanitation a reality and interdisciplinarity the norm.

Keywords: Sanitation; Sewerage; Simplified; Low cost; Pro-poor; Peri-urban

1. Introduction

Over two million people, most of them children, die each year from diseases associated with lack of access to safe drinking water, inadequate sanitation and poor hygiene (WHO and UNICEF, 2000). The number of deaths is equivalent to a terrorist attack *every day* on the scale of the '9/11' attack on the World Trade Centre in New York in 2001. At the closing plenary session of the Water and Poverty Theme of the Third World Water Forum in Kyoto in March 2003, the president of the Asian Development Bank, referring to the outbreak of war in Iraq, said "We should not, however, forget the reality of people in slum and rural communities in many parts of the world who wage a daily war at their level to obtain enough fresh water to give hope to their families" (ADB, 2003).

While there has historically been much emphasis on water quality, it has been shown by numerous epidemiological studies that water quantity, sanitation and hygiene education are just as important, if not more important, in reducing diarrhoeal and other water-related diseases (Esrey et al., 1991). It is estimated that at least one billion people lack access to safe water, while over two billion people have inadequate sanitation (WHO and UNICEF, 2000). The United Nations Millennium Declaration adopted in September 2000 was a statement from the world's governments and international agencies that they are committed to a number of Millennium Development Goals. One of these goals is to halve the number of people without adequate water supplies and sanitation by the end of 2015.

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The twin phenomena of rapid population growth and rapid urbanisation (really, peri-urbanisation) have ignited an urban demographic explosion in developing countries (Black and Sutila, 1994). Most of the current growth of cities in developing countries is concentrated in peri-urban areas, which are low income, high-density, and often informal or illegal settlements. Narrow streets and irregular layouts are typical, and they are often located on the worst urban lands (rocky, hilly, unstable, flood-prone and on the outskirts of cities). The installation and operation of any sanitation system can be difficult in these circumstances.

The peri-urban areas generally receive disproportionately inadequate sanitation and other services, while better off residents in the formal sectors of cities receive reasonable levels of service often at subsidised rates. The current situation in water and sanitation services for millions of peri-urban residents is therefore extremely anti-poor and represents a major challenge for the 21st century.

Human waste is the major cause of disease transmission. Slum dwellers are often surrounded by human excreta in open drains and streets. In high-density peri-urban settlements the potential spread of diseases amongst the population is much greater, and therefore the importance of adequate sanitation even more crucial than in rural areas.

This paper summarises low-cost sanitation technologies that have been developed by engineers from around the world, and seeks to provide evidence that there is such a thing as a pro-poor technology. Several low-cost on-site sanitation technologies are outlined in Section 2. While these can be highly appropriate in low-density settlements, the focus of most of the discussion in this paper and Special Issue is on high-density urban areas, where sewerage is usually more appropriate. Conventional sewerage is therefore a consideration, but we would argue that by virtue of its cost and water requirements, it is an implicitly anti-poor technology. We argue in Section 3 that simplified sewerage is often the only sanitation technology that is technically feasible and economically appropriate for low income, high-density peri-urban areas. In an appeal to interdisciplinarity, Section 4 highlights several reasons why peri-urban sanitation schemes fail to exist, fail to be sustainable, or fail to be pro-poor; and challenges engineers, social scientists and other professionals to work together to overcome them.

2. On-site sanitation technologies

On-site sanitation technologies such as pit latrines and pour-flush toilets are often the cheapest and most appropriate form of sanitation in rural areas and in urban areas with low-population densities and low incomes. On-site sanitation technologies can provide the same health benefits and user convenience as cistern-flushed toilets and conventional sewerage (Kalbermatten et al., 1982).

Box 1. What are simple pit latrines, VIP latrines and pour-flush toilets?[1]

A simple pit latrine consists of a seat or squatting hole over a pit, in which the human waste collects. A ventilated improved pit (VIP) latrine has the addition of a screened vent pipe which extends from the pit to eliminate odours and flies. A pour-flush toilet is similar to a cistern-flush toilet but with a shallower U-bend so that the toilet can be flushed by manually pouring a small amount (2–3 l) of water into the toilet pan. For on-site disposal, the toilet is connected to a pit. For all these toilet types, the pit is normally designed so that liquids disperse into the surrounding soil, while the solids accumulate and decompose over time, and can be safely removed after a few years for disposal or re-use on agricultural land.

In peri-urban areas, the ground conditions often make on-site sanitation infeasible, with poor drainage and risk of contaminating drinking water sources. High population densities result in a high liquid load, and lack of space for pits, making sewerage the better option. In Indonesia for example, regulations classify areas with over 250 people per hectare as densely populated and prohibit on-site sanitation (Fang, 1999). Even in peri-urban areas with relatively low-density populations, uncontrolled urbanisation can rapidly make them high density.

3. Simplified sewerage

Conventional sewerage has been a standard method of removing human waste from the urban living environment in developed countries since the 19th century. It is also considered by many engineers and planners as the only sanitation technology for developing country cities but, by virtue of its cost and water requirements, we would argue that it is unaffordable and inappropriate for low-income communities. To work effectively, the system requires a reliable multiple-tap in-house water supply. Poor peri-urban users are most unlikely to have access to, or be able to afford, this high level of water supply, let alone afford to pay for the construction and maintenance of the sewerage system itself. Conventional sewerage is simply not an option for low-income urban communities. Simplified sewerage is a lower cost alternative that is particularly appropriate for high-density settlements.

[1] Described in detail by Mara (1996).

Box 2. What is simplified sewerage?[2]

Sewerage is a network of pipes that takes domestic sewage away to be treated or disposed of elsewhere. For conventional sewerage, conservative values of minimum pipe diameters, gradients and depths have accrued in codes of design practice over the last hundred years or so. In simplified sewerage (also known as condominial sewerage in some cases), the conservative design codes are relaxed in order to reduce the pipe diameters, gradients and depths, while maintaining sound physical design principles.

The wastewater volume per household assumed in design can be reduced significantly where it is evident that households have limited water supply. Even so, in a high-density area, the resulting sewage flows are high. Even in the highest parts of the network where the flow is intermittent, solids are gradually moved along the pipes each time there is a flush of flow. This transport process is more efficient in smaller diameter pipes.

Vitrified clay or PVC pipes can be used, with simple joints and minimal leakage. Simple pipe junctions and cleanout and inspection units are used in place of manholes. The simplified sewer network is very flexible, with pipes often laid inside a housing block, in the front garden, or under the pavement, rather than in the centre of the road as with conventional sewerage. This results in considerably less disruption to existing structures, and cost savings in excavation, backfill materials and pipe quality. Since simplified sewer networks are flexible in layout, they are appropriate for existing yet dynamic unplanned peri-urban settlements, and equally appropriate for new housing estates with more regular layouts.

3.1. Relative cost of simplified sewerage

Average construction costs of sanitation technologies are given in Table 1. These values can vary widely and should be treated with caution. Costs are always site specific depending on topography, housing layout, customer choice, materials used and population density. However, on-site sanitation and simplified sewerage are invariably cheaper than conventional sewerage. The construction cost of conventional sewerage in northeast Brazil was reported to be US$1500 per household (Watson, 1995), and the projected cost of conventional sewerage for a rural sanitation project in Jordan in 1997 was US$2200 per household (Bakir, 2001). The cost of installing simplified sewerage in 1984 to Christy Nagar, Pakistan, was reported to be only US$45 per household, including household pour-flush toilets, fittings, sewers and a basic level of sewage treatment (Watson, 1995). In Colombo, Sri Lanka, similar services were provided for US$60 per household, while in early trials in Natal, northeast Brazil, total capital costs were US$325 per household (Sinnatamby, 1990); operation and maintenance costs in this area were US$0.21 per household per month (Watson, 1995).

Table 1
Cost of sanitation technologies

	Construction cost (US$)[a]
Simple pit latrine	26–60
VIP latrine	50–57
Pour-flush toilet	50–91
Conventional sewerage	120–160
Simplified sewerage	52–112

[a] Average for Africa, Asia, Latin America and the Caribbean, 1990–2000 (WHO and UNICEF, 2000).

For peri-urban areas, economies of scale can make simplified sewerage cheaper than even on-site sanitation technologies. Research in Natal, northeast Brazil, found that simplified sewerage was cheaper than on-site systems (in terms of total annual costs per household) at population densities greater than ~160 people per hectare (Sinnatamby, 1983).

Box 3. Brazil – the home of simplified sewerage

Simplified sewerage is most widely used in Brazil, where it was first developed by José Carlos de Melo, consultant to CAERN (the water and sewerage company of the state of Rio Grande do Norte) and Professor Cicero Onofre de Andrade Neto of the Federal University of Rio Grande do Norte. It was field-tested in the low-income areas of Rocas and Santos Reis in Natal in the early 1980s. CAESB, the water and sewerage company of Brasília, started implementing simplified sewerage in poor areas in 1991 and it now considers simplified sewerage as its standard solution for rich and poor areas alike. It currently has over 1200 km of simplified sewers. In a survey of simplified sewerage systems in seven Brazilian cities, around half of the systems performed as well as conventional sewerage, but cost between a third and a quarter of the price (Watson, 1995). Where community consultation was sufficient, connection rates observed were 95 to 98 percent of the intended beneficiary populations.

Simplified sewerage is now common elsewhere in Latin America (e.g., Colombia, Peru and Bolivia; Bakalian et al., 1994).

[2] Described in detail by Mara (1996).

3.2. Community participation

A key feature we have found in some of the most successful simplified sewerage systems has been community participation, at all stages. The local sewerage authority has engaged with residents from the start regarding the choice of system. Householders can be responsible for unblocking the length of sewer laid in their own plots. Simplified sewerage can be introduced gradually to a community block by block, such that a relatively small number of householders need to be on board initially for a demonstration project, and others can join once they can see that the system has proved to be successful. Low cost and community involvement help to ensure, even in low-income settlements, that a high proportion of households are connected to the system. The community based approach to sanitation has been shown to be effective on a large scale, for example in Brazil (Katakura and Bakalian, 1998), Indonesia (Banes et al., 1996), and Pakistan (Sinnatamby, 1990).

Box 4. The Orangi Pilot Project

Simplified sewerage was introduced to Pakistan in 1984 in Christy Nagar, in Orangi, the largest squatter settlement in Karachi, and in Pakistan (Watson, 1995). Thanks to flexible layout options, the system reached customers living in high density irregular settlements that have historically been excluded from sanitation services. Five years after construction, the system was reported to be still working well. The project was extended across Orangi, and eventually became the NGO Orangi Pilot Project (OPP). It mobilised extensive community involvement to extend simplified sewerage to some 750,000 poor people (Sinnatamby, 1990). The OPP helped fifteen percent of residents to build their sewers, while a further 25 percent learnt from their neighbours to build sewers for themselves, demonstrating the incremental growth of people's demands as the benefits of the sanitation technology were realised. The programme has since been replicated in 49 other settlements in Karachi and in eight other cities in Pakistan by local NGOs, community-based organisations (CBOs) and local governments. The OPP approach has also become very influential in policy circles internationally.

Simplified sewerage is becoming increasingly common across Asia (Tayler, 1996).

In other cases, the choice of technology, level of service and tariff has been set by the regulator, but the system can still benefit from community involvement. Aguas del Illimani's 1997 takeover of the water and sewerage services for La Paz and El Alto in Bolivia is discussed in detail by other papers in this Special Issue (e.g., Laurie and Crespo). The company chose to implement simplified sewerage as a more affordable option than conventional sewerage and have encouraged uptake by offering US$50 reductions of the US$180 connection fees in exchange for labour during construction (Komives, 2001). Where communities provide labour for simplified sewerage, laying small diameter pipes at fairly flat gradients requires good quality construction materials and careful construction techniques, so proper training and supervision is required.

4. Barriers to pro-poor sanitation technologies

Simplified sewerage has proved to be a successful pro-poor sanitation technology in many cases throughout the world. However, we regret that the technology is not fully exploited, and some 2.4 billion poor people still live without adequate sanitation. Time after time, peri-urban sanitation schemes fail to exist, fail to be sustainable, or fail to be pro-poor. While other papers in this Special Issue address wider issues relevant to the pro-poor water debate, such as globalisation and privatisation, in the following sections we discuss some of the barriers specific to pro-poor sanitation that we believe engineers in particular should recognise and can contribute to overcoming.

4.1. Lack of investment in sanitation

Despite the huge impact of lack of sanitation on the world population, sanitation is often given low priority at international, state and local levels.

Total investment in Africa, Asia, Latin America and the Caribbean in water supply was estimated over 1990–2000 at US$12.6 billions per year, whereas the estimate for sanitation was only US$3.1 billions per year (WHO and UNICEF, 2000). Sanitation projects are often less favoured by politicians than high-prestige projects such as airports and dams. For the same reasons, within the sanitation sector, high-cost conventional sewerage is often favoured over low-cost sanitation. Despite evidence to the contrary, the perceived benefits of sanitation are thought to provide a low return on investment compared to water projects.

In large urban areas, it is generally accepted that the incremental cost of collecting and treating sewage is 1.5–3 times the incremental cost of treating and supplying water (TWUWS, 1996). Similarly, on-site sanitation such as pit latrines typically cost double the water supply equivalent such as a public standpost (Cairncross, 1992). Yet, out of eleven World Bank-funded (US$4–240 million) water and sanitation projects in Asia and Africa from 1983 to 1993 (reviewed by Fang, 1999), eight of them devoted less than ten per cent of the total investment to sanitation.

At the local level, for households with little or no income and poor living conditions, sanitation is likely to be lower in priority than the need for food, water and shelter. For communities that are willing and able to pay for sanitation systems in the long term, it is often difficult to obtain the initial capital required without access to suitable banking institutions. However, there are micro-credit schemes or micro-finance initiatives (MFIs) which offer small loans to the very poor without prohibitively high rates of interest. They have tended to support small-scale enterprise, but are increasingly used for housing improvements, including sanitation provision. Saywell (not dated) noted micro-credit schemes used for sanitation over the 1990s in Lesotho, Honduras, Indonesia, Ghana, South Africa, India and Pakistan.

Engineers in particular can play a role in designing low-cost sanitation technologies, and working in a truly interdisciplinary way with social scientists and other professionals in order to maximise the success rate of sanitation programmes. In addition, engineers and engineering academics should take advantage of the dissemination and lobbying skills of other professionals to best promote the view, from community to international level, that investment in pro-poor sanitation is 'value for money'.

4.2. Insufficient cost recovery for sanitation services

In 2002, the UN Committee on Economic, Social and Cultural Rights adopted a new right to water, which entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water, without discrimination and equally for men and women. While we acknowledge that the UN statement is highly significant and long overdue, we suggest that it is counterproductive to interpret it as meaning "water services should be free". More than half of the countries in Africa, Asia, Latin America and the Caribbean charge an urban water tariff that is less than the unit cost of production of the water, and sewerage tariffs are even lower (WHO and UNICEF, 2000). The fact that tariffs do not cover the full cost of services frequently causes existing services to be unsustainable, because of lack of money for essential maintenance, and prevents investment in extension of services to the poor.

A simplified sewerage project in South Africa was started in 1999 by Durban Metro Water in partnership with Lyonnaise des Eaux. The project began well, with bathrooms and sewers provided to a new housing area with predominantly poor black residents. However, further uptake by residents was stalled by election promises that water would be free for all, which the residents took to mean that connection charges should be waived. This created a deadlock with required political intervention (Brocklehurst, 2001).

The urban poor are numerous and often willing to pay for basic services including sanitation, provided the services are worth paying for (Whittington et al., 1992). Indeed the urban poor may be viewed as a large, growing and mainly untapped market. Cairncross (1992) reported that low-income groups typically spend 2–3% of their income on sanitation, although their willingness to pay is clearly influenced by their current sanitation situation. Notwithstanding their willingness to pay, the actual incomes of the urban poor are by definition modest. Consequently, if services are to be extended to the poor, costs are to be recovered and subsidies reduced or even eliminated, the technologies employed must be inexpensive, the tariffs affordable, and initial connection fees not prohibitive.

Financing plans, subsidized interest rates and micro-credit offered by Aguas del Illimani and NGOs have helped simplified sewerage services in La Paz and El Alto to be extended to the poor (Komives, 2001).

4.3. Conservative technical standards favoured over innovation

Many engineers and politicians stick to established technical standards and lack engineering insight and innovation. Design codes for conventional sewerage stipulate minimum pipe diameters, gradients and depths that are unnecessarily conservative and expensive. A few innovative Brazilian engineers introduced simplified sewerage using smaller pipe diameters, gradients and depths, and proved it to be a viable alternative; it has now been successfully adopted into mainstream Brazilian sanitary engineering design codes. In Bolivia, the regulator approved the transgression of traditional sewerage standards to allow a pilot project of simplified sewerage to 10,000 households (Komives, 2001). In 2003, the Bolivian Institute for Technical Norms and Standards followed in the footsteps of the Brazilians, approving new technical standards and by-laws for the design and construction of low-cost sewerage systems.

For the Durban Metro Water simplified sewerage project in South Africa (Brocklehurst, 2001), the participants knew that for the project to proceed, they would have to transgress the law. Simplified sewers did not comply with the National Building Regulations, but Durban Metro Water and its partner Lyonnaise des Eaux accepted the risks for this pilot project. For such pro-poor sanitation technologies to be more widely adopted across South Africa, changes in the law or national building and sewerage codes need to be instigated.

We fear that many other countries may be slower to benefit from this pro-poor technology due to the reluctance of conservative-minded professionals to depart from established practice.

4.4. Low-cost technologies perceived as second class provision

Low-cost options are often viewed by lobbyists, who influence users, as second class, in that the poor deserve the same standards as provided for the affluent and developed countries. Engineers, planners and lobbyists have therefore traditionally been well-meaning proponents of conventional sewerage, but its expense is far beyond the reach of the poor.

In post-apartheid South Africa, conventional sewerage is the norm for historically white areas and formal townships, so there are expectations that this should be extended to informal settlements, despite its cost and the resulting pressure on water supplies (Beall et al., 2000). Political imperatives and popular expectations can prevent the most appropriate technology from being used. According to Bakir (2001), centralised and conventional wastewater systems are the preferred choice of planners and decision-makers in the Middle East and North Africa (MENA), despite the high cost and water scarcity in the region. This is a major constraint to expanding sanitation coverage, and we support Bakir's call for a paradigm shift towards decentralised systems and technologies such as on-site sanitation and low-cost sewerage.

Pro-poor sanitation technologies do not need to be either second class or anti-rich. Simplified sewerage, for example, can be a cost-effective and desirable option even for the affluent, and has been installed in affluent areas such as Lago Sul in Brasília (Mara, 2002), rural New Hampshire, USA (Watson, 1995), and in Europe (e.g., Greece; Alexiou et al., 1996). Even wealthy residents appreciate cost savings and, for the service providers, using lower cost technologies to serve affluent areas can allow more funds to be directed to extending services to the poor.

4.5. Dynamic and illegal settlements

Due to the high density and dynamic nature of informal settlements, mapping required for sewerage can be a challenge. A short design period is prudent given the uncertainties of future land use patterns. This approach also reduces the initial capital requirements for the system and reduces the maintenance difficulties associated with low flows.

To discourage illegal settlements, governments may stipulate that water and sewerage connections can only be provided for households with registered legal title to their land. Aguas del Illimani was subject to this restriction by Bolivian regulations, and found this to be in direct conflict with their contractual requirements to extend services to all areas (Komives, 2001). Where plots of land are owned by the householders, sewers laid in freehold land can present problems for sanitation authorities in future when land changes hands. In a simplified sewerage project in South Africa, this potential problem was overlooked in the interests of getting a pilot project off the ground (Brocklehurst, 2001).

4.6. Lack of engagement with users

Many municipal authorities and their professional representatives have little understanding of the needs and wishes of the poor communities under their jurisdiction. If peri-urban settlements are viewed as illegal, there is no responsibility to provide and residents are not consulted. The poor are often not respected as clients deserving a service or a choice. If residents are not consulted or given choices, and there is inadequate education or hygiene promotion, there will be little incentive on the part of users to pay for, use or maintain sanitation facilities.

Despite significant successes, some simplified sewerage systems in Brazil suffered from low-connection rates, poorly constructed networks and inadequate operation and maintenance (Watson, 1995). The unsatisfactory performance was attributable to the same problems that plague conventional systems: lax construction practices and inadequate or inappropriate efforts to involve customers in project planning and implementation. In cases where customers were not fully informed how to use or maintain their systems, connection rates were less than 40 percent of the intended beneficiary population.

The community approach may appear difficult to reconcile with classical project management techniques. For simplified sewerage schemes, senior management may find a gradualist block by block approach difficult to reconcile with fixed objectives and timetables. Engineers may be even more reluctant to deal with low-income communities than to deal with low-cost technologies. Professional engineers often have little experience of community work, so negotiations with the community are best undertaken by a multidisciplinary team. Negotiations may be lengthy, but neglecting the opinions of the community has proved to be a false economy (Watson, 1995). Local knowledge is required to ensure understanding of cultural norms, which can require particular sensitivity regarding toilet practices. Maintaining good relationships between sanitation providers and the community after a system has been implemented is also important, particularly in areas with a high turnover of residents. Sanitation systems have worked well when authorities, engineers and users have been able to learn how to interact productively.

While user participation has proved to be useful in sanitation schemes and resulted in health and lifestyle benefits to poor communities, Beall et al. (2000) make a pertinent point about the inequity of user participation: Little or no participation is expected of wealthy people in the planning, implementation or maintenance of their services, while the poor often have to rely almost entirely on their own resources and initiatives.

5. Conclusions

Pro-poor sanitation technologies offer an opportunity for adequate sanitation services to be extended to the greatest number of people. Sanitation can improve the health and quality of life of individuals, and eventually improve the standard of living of communities and economic productivity of nations.

Engineers have developed a technology with the potential to provide sanitation for the world's urban poor. Simplified sewerage is one of the most important advances ever made in sanitation. It will often be the only technically feasible and economically appropriate sanitation option available for low-income, high-density urban areas. It can provide an equivalent level of service and health benefits as conventional sewerage, and should not be viewed as a second class option.

However, simplified sewerage will only truly be a pro-poor technology if issues such as lack of investment in sanitation, insufficient cost recovery for sanitation services, conservative technical standards favoured over innovation, low-cost technologies perceived as second class provision, the nature of peri-urban settlements, and lack of engagement with users, are addressed.

Examples of simplified sewerage schemes given in this paper have illustrated that innovation and the challenging of convention have been at the forefront of both the development of the technology itself and in the tackling of some of these issues. The challenge for engineers, social scientists and other professionals is to work together, through dialogue, ideas exchange, and engagement with the poor, to make pro-poor sanitation a reality, and interdisciplinarity the norm.

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