

# **THE CONSERVATION OF DRINKING-WATER SUPPLIES: TECHNIQUES FOR LOW-INCOME SETTLEMENTS**

United Nations Centre for Human Settlements (Habitat)

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Nairobi 1989

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# FOREWORD

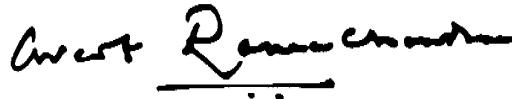
Globally, much progress has been made in increasing both access to and levels of water-supply service since the launching of the International Drinking Water Supply and Sanitation Decade (1981-1990). Much of this increased and improved service coverage has, however, only notably affected statistics in rural areas, and despite efforts in urban areas, service coverage has only managed to keep pace with increases in population in these centres. One of the reasons for this often is that the water available in urban areas is inequitably distributed, with middle- income and upper-income areas consuming much more water than is needed either for health reasons or for user convenience. Leakage losses from distribution systems are often very high. If high consumption can be reduced by the use of water-saving devices and if leakages can be reduced through leak-detection programmes, an increased proportion of existing water supplies can be made available to new areas, especially low-income settlements which house the unserved majority of populations in developing countries.

Interventions designed to redress the water-supply deficit during the Decade have focused on the commissioning of new facilities, and little, if any, effort has been made to identify and promote ways in which existing facilities might be used to provide improved service. The research efforts of the United Nations Centre for Human Settlements (Habitat) indicate that water conservation, through a number of measures, can contribute both to expanding and upgrading existing water-supply services. This document describes methods that are available for water conservation, with emphasis on simple and reliable techniques that are readily applicable in developing countries.

The report is the first of its kind addressing some of the issues of operation and maintenance of infrastructural facilities, and, as such, it is designed to draw attention to the long-neglected area of water conservation and to increase awareness of the role of conservation amongst decision-makers, engineers and planners. UNCHS (Habitat) expects to continue to provide detailed information on operating and maintenance issues in subsequent research publications and

additional reports produced under the joint World Bank/UNCHS (Habitat)/UNDP project (INT/86/006) - Support Programme For Urban Management - initiated in June 1987.

I hope the principles of water conservation defined herein will lead governments to pay attention to conserving water resources, as a fundamental strategy for improving urban supplies. I gratefully acknowledge the contribution of Professor Duncan Mara, University of Leeds (United Kingdom), to the preparation of this publication.

A handwritten signature in black ink, reading "Arcot Ramachandran". The signature is written in a cursive style. Below the signature, there is a horizontal line with two small dots centered underneath it.

**Dr. Arcot Ramachandran**  
Under-Secretary-General  
Executive Director

# INTRODUCTION

## A. Background

The cost of providing water supplies to urban centres has steadily increased over the years and will continue to increase, as nearby sources are exploited and it becomes essential to transport water from far afield or extract it from great depths. Despite concerted efforts to increase urban supplies over the past decade, most developing countries have only managed, at best, to keep pace with population increase. The majority of governmental responses to the problem of increasing urban water- supply coverage over this period has concentrated on the construction of new facilities.

The proportion of national budgets allocated to drinking- water supply amounts to between 1 and 6 per cent and has remained stable over the past decade, but, in the face of poor revenue generation and continually deteriorating facilities, increasing proportions of these funds are used to maintain and operate existing facilities. Consequently, funds for capital investments in the sector have primarily come from external sources which, in many countries, exceed 80 per cent of the total investment in new facilities. With their burden of debt, most governments are finding it increasingly difficult to justify and sustain current levels of borrowing, and radical shifts in policy are required to improve the efficiency and performance of the water sector.

Amongst the range of options available for maximizing returns from investment in water-supply facilities, one option, which has received little attention but, nonetheless, has great potential for improving and extending existing services, is the application of water-conservation techniques. Water supplies conserved through rational use and appropriate leak detection and repair programmes can increase substantially the quantity of water available for distribution and consumption. Although no quantitative assessment has been made of the benefits of water conservation, they are likely to be very significant indeed, as they can, in some cases, save as much as half the total quantity of water currently distributed.

Decision-makers and professionals concerned with supplying water to urban centres are often unaware of the role water conservation can play in extending and improving the use of existing facilities and optimizing future investments in water- supply and complementary sanitation facilities. Information regarding water-saving techniques has not been readily available, and, until recently, little effort was directed to initiating projects and programmes designed to promote conservation. However, there is a wide range of measures which can be implemented to conserve water supplies, and an overview of these measures is presented in this report.

## **B. The relevance of water conservation to low-income settlements**

In December 1986, the World Health Organization<sup>1</sup> estimated that, despite the considerable progress achieved during the first five years of the International Drinking Water Supply and Sanitation Decade (1981-1990), some 1.2 billion people were still without adequate water supplies and sanitation, and a further 500 million without adequate sanitation. Programmes for the conservation of drinking-water supplies might, at first, appear to be of little relevance to communities with inadequate or scarcely adequate water supplies. They are, however, very relevant, since conserved water can be used to improve the overall supply situation. This can be done, for example, by:

- (a) Reducing the amount of water lost through leakage in the distribution system, which may often be as high as 50 per cent of the water put into it;
- (b) Reducing the often excessively high level of water consumption in middle-income and upper-income communities, which can be readily achieved without sacrificing the high levels of user convenience favoured by these communities.

The achievement of these reductions has several benefits to the national economy, viz.:

- (a) Existing water supplies can be used to serve more people than before, especially those in low-income settlements, or to provide additional hours of service each day;
- (b) The requirement for large capital investments to exploit new and expensive water-supply sources can be deferred until some future date, thereby delaying the need to increase water tariffs;
- (c) On-site wastewater-disposal systems become feasible in a large number of middle-income and upper-income communities, thus obviating the need for expensive conventional sewerage systems.

The conservation of existing drinking-water supplies is, thus, not only relevant to the needs of low-income settlements, whose water supplies can thereby be improved, but also relevant to needs of middle-income and upper-income communities, since they will not have to pay for unnecessary capital works to expand the water-supply system and might also be able to avoid expensive sewerage charges.

## **C. Purpose and scope of the report**

This report is intended to increase awareness of the role water conservation can play in eking out existing water resources to meet the needs of unserved communities and improve current levels of urban service. However, fundamental adjustments to investment policies and programmes are essential if the benefits of water conservation are to be realized and the underlying concepts integrally addressed in all water-development efforts. Therefore, the report addresses senior decision-makers, engineers and planners engaged in the planning and provision of water supplies in



developing countries and is deliberately focused on presenting an overview of the benefits and techniques of water conservation. Although applicable to private water-supply development efforts, the report is specially designed to improve the performance of public water-distribution systems and to optimize related public investments.

The specific objective of this report is to review methods for conservation of drinking-water supplies in developing countries, especially those methods that are of relevance to the needs of low-income settlements. Chapter I introduces the methods that are available and illustrates the advantages of their adoption for developing countries. Appropriate methods for the reduction of excessively high domestic water consumption are described in chapter II, and leakage control is discussed in chapter III. Financial means for reducing water consumption are considered in chapter IV, and socio-political methods for water conservation - public education programmes and the development of appropriate legislation (building and plumbing codes) - are considered in chapter V. Case studies of water-conservation programmes in the United States of America and Mexico are given in chapter VI. Finally, chapter VII sets out possible national and international action to promote the conservation of existing water supplies.



# I. DOMESTIC WATER CONSERVATION IN DEVELOPING COUNTRIES

## A. Basic needs in water supply

Basic needs in domestic water supply can be met by the regular and reliable provision of between 30 and 50 litres per capita per day (lcd) of water of adequate quality for drinking, food preparation and personal and domestic hygiene.<sup>2</sup> Such a level of water consumption is considered adequate for the effective control of water-washed diseases.<sup>3</sup> In developing countries, a large proportion of the population is not supplied with the minimal quantity of water, and, as a result, water-washed diseases have a high incidence and are responsible for much morbidity and mortality, most notably in low-income settlements in both urban and rural areas.

Domestic water supplies in developing countries are commonly highly skewed in favour of upper-income households. Table 1 gives data from a city in Sudan which are reasonably typical of the situation in many developing countries. They show that, in this city, the highest-income households consume 15 times as much water as the lowest-income households. Such an imbalance is most undesirable, because, in practice, it means that the poor do not have access to water supplies adequate to meet even their basic health needs, while the rich consume much more water than is necessary either to meet their basic needs or to provide adequate levels of convenience.

**Table 1. Water consumption and housing density in El Obeid, Sudan**

Housing density and water-supply service level <sup>a</sup>	Water consumption (lcd)
Low density, in-house water	242
Medium density, in-compound water	64
Medium density, in-compound water and standpipes	37
Medium density, standpipes	21
High density, standpipes or traditional water sources	16

a/ 41 per cent of the population was served by in-house or in-compound supplies, and 59 per cent by standpipes (total population: 140,000).

Source: S.E.U. Bannaga, "Factors influencing domestic water use in developing countries, with reference to El Obeid, Sudan", *Journal of the Institution of Water Engineers and Scientists*, vol. 33, No. 6, pp. 539-546, 1979.

One reason why middle-income and upper-income households consume excessive quantities of water is that legal and technical instruments, such as engineering and plumbing codes of practice and regulations governing the provision and distribution of water supply continue to stipulate unnecessarily high standards of service and outdated water-demanding fixtures.

## **B. The need for water conservation**

Water conservation is essentially a means through which efficient use can be made of existing supplies. It is needed not only to ensure that low-income settlements have a chance of receiving sufficient water supplies to meet their basic needs but also to delay increasingly expensive expansions to urban water-supply systems. Water conservation needs to become an integral part of water-resource planning but it requires a shift in policy thinking. In the past, rapidly increasing urban water demands, for both residential and commercial/industrial purposes, have been met simply by exploiting new and costly water sources. The rational use, including conservation, of existing supplies was rarely considered. This approach, although still widely followed in both industrialized and developing countries is now an outmoded philosophy, as is eloquently described by Postel:<sup>5</sup>

"Today's water institutions - the policies and laws, government agencies, and planning and engineering practices that shape patterns of water use - are steeped in a supplyside management philosophy no longer appropriate to solving today's water problems. Aquifer depletion, falling water tables, and streamflows diminished to ecologically damaging levels are increasingly widespread. Though the conventional approach of continuously expanding supplies may work when water is abundant, it is not well suited for an era of growing scarcity, damage to the environment, and capital constraints.

"By increasing water productivity - the benefit gained from each litre used - food production, industrial output, and cities can expand without a parallel increase in water demands. Investments in water efficiency, recycling, and conservation can increasingly yield more usable water per dollar than can conventional water supply projects. But their potential is severely undermined by pricing policies and water laws that encourage inefficiency and waste. Removing these institutional barriers is crucial in order to expand the many new water-conserving methods now in limited use. Only by managing water demand, rather than ceaselessly striving to meet it, is there hope for a truly secure and sustainable water future."

In both industrialized and developing countries, the need for water conservation is very great: existing water supplies are failing to meet unchecked demand, and alternative sources are becoming scarce and expensive. In the United States of America,

for example, 170 of the country's 756 large water systems (those serving more than 50,000 people) will require expansion by 1990 to meet projected demands, and the necessary development of new water sources will cost some \$US2,531 million.<sup>6</sup> Replacement and rehabilitation of existing water-supply systems are expected to cost at least as much again, and complementary investments in wastewater collection and treatment (new systems, upgrading of existing facilities) are predicted to bring the annual water and wastewater capital investment costs to over \$US20 billion.

Water-conservation techniques can reduce such investment costs. For example, reducing leakage in Bombay's water-distribution system, which is currently 18-36 per cent, by 10-15 percentage points would save some 250,000 m<sup>3</sup> of water per day; the cost of developing a new supply to provide this quantity of water would be around \$US170 million.<sup>7</sup> In Mexico City, where water use already exceeds renewable supplies by over 30 per cent, the single simple act of replacing all the American-style flush toilets in the city, which consume 15-20 litres of water per flush, with a Swedish design, which uses only 3 litres per flush, would save an estimated 7 m<sup>3</sup>/sec of water and, so, immediately turn the city's current water-supply deficit of 4 m<sup>3</sup>/sec into a surplus of 3 m<sup>3</sup>/sec, with enormously high consequent savings in deferred costs.<sup>8</sup>

## C. Methods of water conservation

Four main groups of water-conservation methods can be identified:<sup>4</sup>

- |                              |  |
|------------------------------|--|
| (a) Structural methods:      | flow-control devices, metering, recycling systems;                     |
| (b) Operational methods:     | leakage detection and repair, reduction of excessive line pressure;    |
| (c) Financial methods:       | pricing (tariff) policy;   |
| (d) Socio-political methods: | legislation (including building and plumbing codes), public education. |

These methods are discussed in detail in the following chapters.



## II. STRUCTURAL METHODS OF WATER CONSERVATION

### A. Flow-control devices

This section concentrates on flow-control devices (water-saving plumbing fixtures) that can be used in conjunction with the three levels of water-supply service commonly found in developing countries:

- (a) Multiple-tap in-house supplies (full internal plumbing with sinks, showers and/or baths and cistern-flush toilets);
- (b) Courtyard supplies (single yard-tap, sometimes called a "patio connection", or on-plot well or rainwater catchment);
- (c) Hand-carried supplies (public standpipes or communal wells).

The opportunities for water conservation are greatest with multiple-tap in-house supplies, as water consumption in households with this level of service is highest. Significant opportunity for water conservation also exists, however, at the other two levels of service, although, in the case of hand-carried supplies, often the most immediate problem is that of increasing water consumption to around 30-50 lcd, in order to control the transmission of water-washed diseases.

#### 1. Multiple-tap in-house supplies

There is extensive information on water consumption in industrialized countries, where almost all households have in-house connections. Generally, in-house consumption ranges between 100 and 300 lcd; for example, Flack<sup>9</sup> estimates typical in-house domestic water consumption in the United States of America as 64 US gallons per capita per day (243 lcd), with the following breakdown:

	lcd	Percentage
Toilet	97	40
Bath/shower	73	30
Bathroom sink	12	5
Laundry	37	15
Dishwasher	12	5
Culinary	12	5

In the United Kingdom of Great Britain and Northern Ireland, Rump<sup>10</sup> estimates domestic water consumption to be 110 lcd, with the following breakdown:

	lcd	Percentage
Toilet	36	33
Personal washing/bathing	28	25
Laundry	14	12.5
Washing up	9	8.5
Car washing and garden use	3	3
Drinking, food preparation, cooking, cleaning and other	20	18

Data from other industrialized countries indicate water consumption to be within the 100-300 lcd range, for example:<sup>10</sup>

Belgium	128	lcd
Canada	103	lcd
Denmark	212	lcd
Federal Republic of Germany	118	lcd

In contrast there is little detailed information from developing countries. White<sup>12</sup> reports water consumption between 30 and 300 lcd, although figures below 50 lcd are not common. In a recent comprehensive survey of domestic water consumption in an upper-middle-class zone of Ibadan, Nigeria,<sup>13</sup> the mean consumption was found to be 89 lcd, with the following breakdown:

	lcd	Percentage
Toilet	40	44.9
Personal washing/bathing	20	22.5
Car washing	5	5.5
Food preparation, cooking and cleaning	25	28.1

This survey indicated that modern household appliances were not very common, although more common than might be imagined: for example, 14.5 per cent of households had a clothes-washing machine, and 3.2 per cent had a dishwasher. Car washing was found to be a high water-consuming activity: 93.5 per cent of households owned at least one car, and each was washed once a week in 53.7 per cent of households and five times a week by a surprisingly large 30 per cent of households. Floor



scrubbing was another water-consuming activity and probably accounted for a substantial proportion of the figure of 28.1 per cent quoted above; 20 per cent of households scrub floors once a week, and 6.7 per cent do it twice weekly.

Water consumption in excess of 100 lcd is not necessary for reasons of either health or user-convenience. The principal reason why consumption often exceeds this figure, mainly in houses with multiple-tap in-house connections but also in houses with yard-taps, is that plumbing fixtures which are unnecessarily extravagant in water usage have been installed. These plumbing fixtures - cistern-flush toilets, taps (faucets in North American terminology) and showerheads - were developed in an era of plentiful water supplies, and their continued use in unmodified form in an age of diminishing water resources and rapidly increasing supply costs needs to be reconsidered.

#### *(a) Cistern-flush toilets*

North American cistern-flush toilets typically consume 19 litres/flush (5 US gal/flush); in the United Kingdom, the standard toilet uses 9 litres/flush. Recent developments in the United Kingdom and Sweden<sup>14</sup> have shown that flush volumes of 3- 6 litres can be achieved by improved design which considers not only the toilet unit itself but also the associated drainage system.<sup>15</sup> An American toilet which only uses 3.8 litres (1 US gallon) per flush has also been developed.<sup>16</sup> Plumbing regulations might be important in this respect: for example, in the United Kingdom, the minimum permitted water seal depth is 50 mm, which, in conjunction with mandatory syphonic discharge, makes it virtually impossible to reduce flush volumes below 4.5 litres.<sup>17</sup> A Swedish design (see figure 1<sup>18</sup>), which requires only 3 litres/flush, has, in contrast, a 35 mm water-seal depth, and discharge is via a rubber flap valve. The cistern-discharge mechanism is important: rubber flap valves, which are common in North America and Europe (but illegal in some countries, for example, the United Kingdom), often leak and can, thus, waste enormous quantities of water. Syphonic discharge avoids leaks but requires a greater flush volume (to initiate the syphonic action).

Flush volumes can be effectively reduced by user-controlled flushing devices. Dual-flush (usually full or half volume) or variable-flush cisterns have been successfully developed which can substantially reduce flush-water consumption (by as much as 60 per cent); the user discharges only enough water to clear the bowl (the bowl may contain faeces, urine or only paper, the presence of each of which requires a different volume to clean the bowl).<sup>14</sup>

#### *(b) Showerheads*

In houses with multiple-tap in-house supplies, whole-body washing is done either in a bath or in a shower. Baths consume much more water than

showers: recent figures from the United Kingdom, for example, indicate a usage of some 80-120

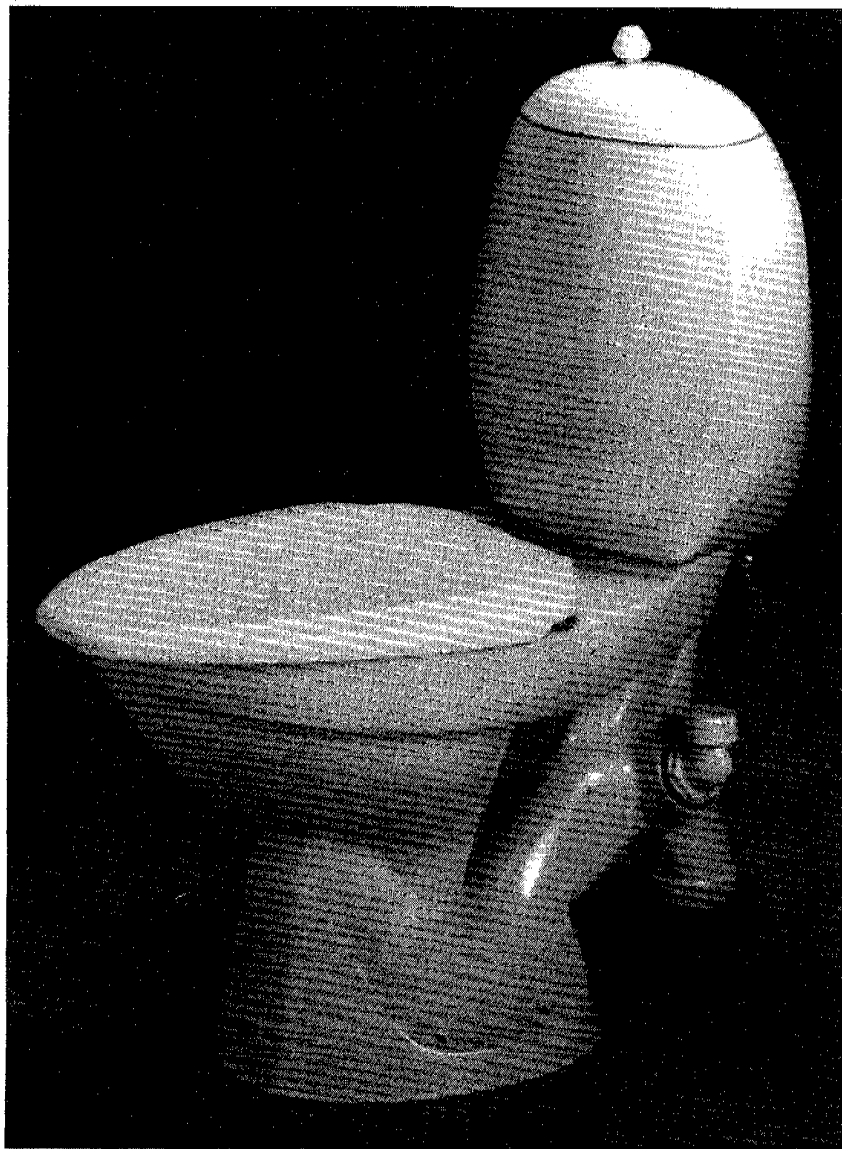


Figure 1(a). Swedish 3-litre toilet.<sup>18</sup>

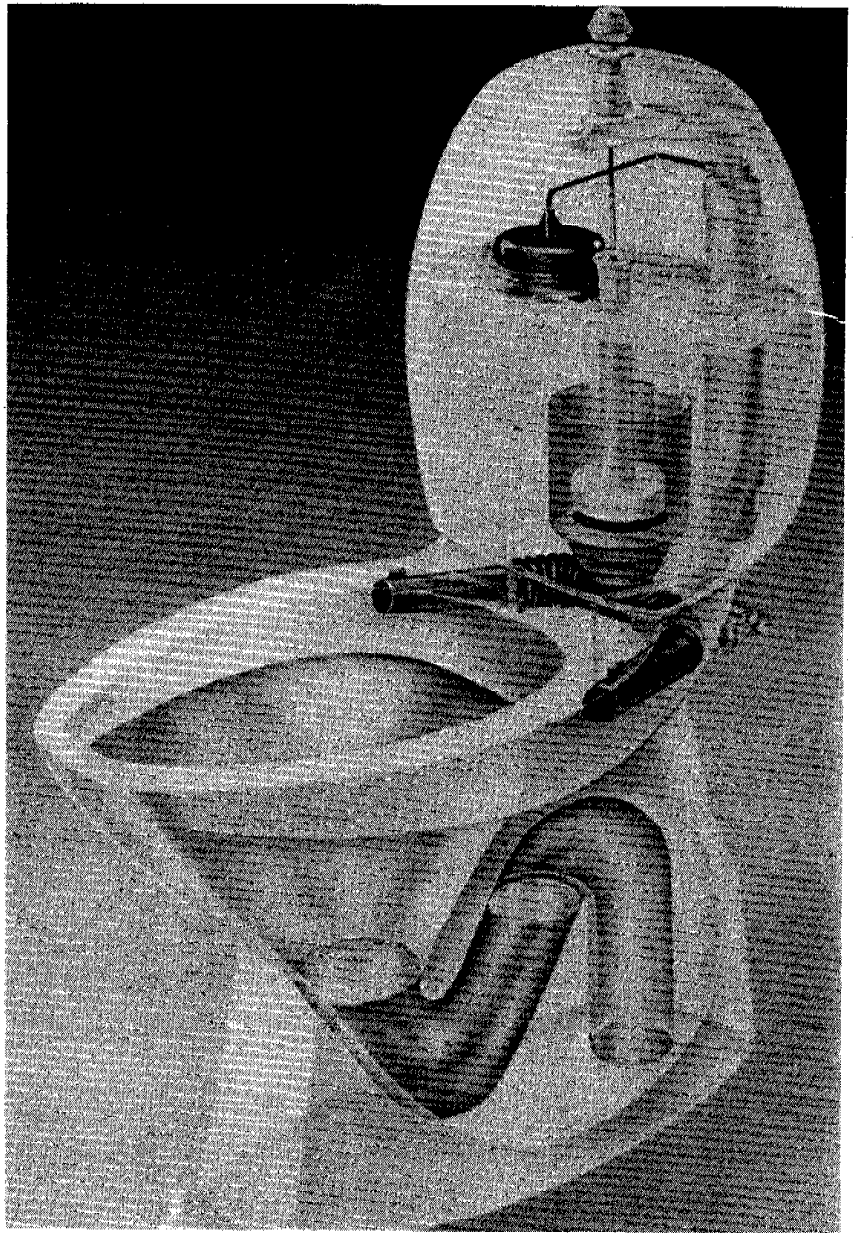


Figure 1(b). Detail of Swedish 3-litre flush toilet. <sup>18</sup>

litres in a bath as opposed to 10-30 litres in a shower.<sup>10</sup> Water consumption during showering is controlled by the water-flow rate, by the time taken and by the turning off of water when soaping up. Only the flow rate can be controlled by structural methods, but public information/education programmes might be able to influence the other two factors. A variety of simple and inexpensive devices can be used to reduce the flow rate to an acceptable value of 3 litres/minute; without such devices, the flow rate is, commonly, greater than 5 litres/minute and, often, in the range 20-60 litres/minute. The devices which are suitable for use in developing countries can be grouped into:

(a) Flow-control showerheads which are complete units incorporating a fixed or variable (pressure-controlled) orifice which sets an upper limit to the flow;

(b) In-line flow restrictors which are fitted immediately upstream of a standard showerhead (see figure 2<sup>19</sup>), the simplest type being simply an orifice insert which is very inexpensive and highly suitable for retrofitting (the cost is so low that some North American water utilities have sent them out free, with fitting instructions, to consumers with their monthly water account) and other types being pressure-controlled variable orifices which are screwed in between the pipe outlet and the showerhead;

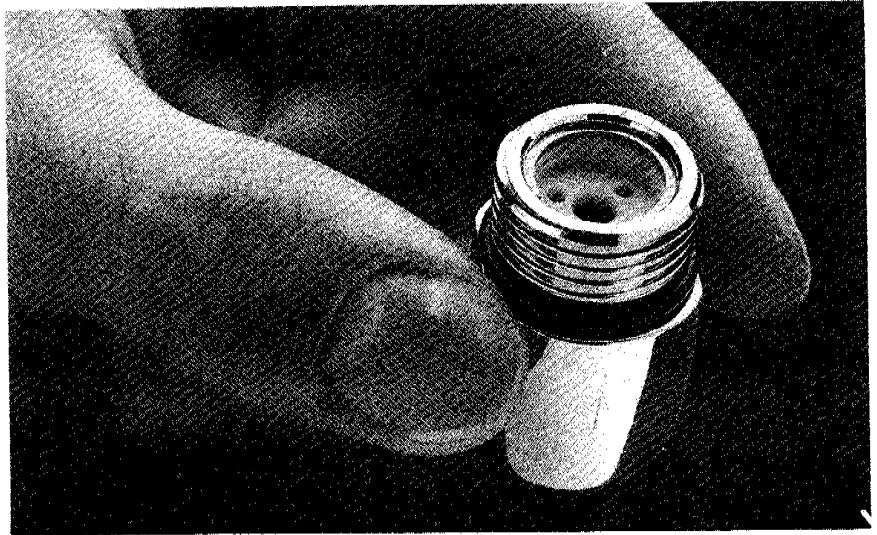


Figure 2. Flow-control unit for showerheads and taps.<sup>19</sup>

(c) Shower-control valves which permit the water to be switched off while soaping up without adjusting any temperature- control device (e.g., thermostatic mixing valve).

Water savings can be very high, but the precise amount of savings depends on the household water pressure (this depends on the mains pressure or, if an in-house storage tank is used, on the local hydraulic head). Even at relatively low pressures, the savings in warm climates can be significant, as many people will shower at least once and, often (if the water is available), three times per day. If the water is heated, energy savings will also be made.

(c) *Taps (faucets)*

Water use at taps can be divided into two demand categories - flow demand (for example, to fill a water vessel rapidly) and volume demand (for example, to fill a bath). Volume demand is, almost by definition, not amenable to management, since the volume is fixed; for example, it matters little to the householder whether it takes  $x$  or  $2x$  minutes to fill a bath (provided, of course,  $x$  is not too large). With communal standpipes and individual yard-tap supplies, flow demand predominates, whereas, with multiple-tap in-house supplies, both types of demand are present, but opportunity exists only for flow-demand management.

Water use can be reduced substantially by using spray or aerating taps. Spray taps (see figure 3) reduce flow rates from 30 litres/minute or higher (the flow rate from conventional taps) to 3-10 litres/minute, depending on the spray-orifice geometry and the in-house water pressure; hand and face washing is perfectly satisfactory at these flow rates. Aerating taps (see figure 4) entrain air into the water flow and, so, achieve substantial flow reductions. They have an advantage over



Figure 3. Spray tap.<sup>19</sup>

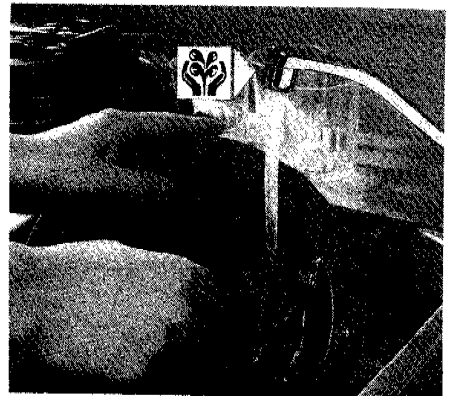


Figure 4. Aerator tap.<sup>19</sup>

conventional taps in that they prevent wastage by splashing; they are, thus, especially suitable for kitchen sinks where spray taps might not be acceptable.

*(d) In line flow limiters*

The water flow to an individual house or a group of houses can be controlled by the use of in-line flow limiters which restrict the flow to a predetermined maximum value independent of the in-line water pressure. Flow limiters which restrict the flow to a maximum of between 25 and 1000 litres/hour are available (see figure 5<sup>20</sup>). Field trials of these water-saving plumbing fixtures are strongly recommended, in order to assess local consumer acceptability. This is especially important with flow-control devices; the field trials should determine the minimal flow rate that does not give rise to complaints, although flow-rate reduction might, of course, be achieved by operational methods (for example, line-pressure regulation) as well as structural methods.

Overall water savings resulting from the use of water-saving plumbing fixtures depend on which fixtures are installed. In the United States of America, it is estimated that a low-volume flush toilet, reduced-flow showerhead and aerator taps can yield a combined saving of 35 per cent (see table 2). In developing countries (for which no data are available), the savings might not be as high but will, nonetheless, still be significant.

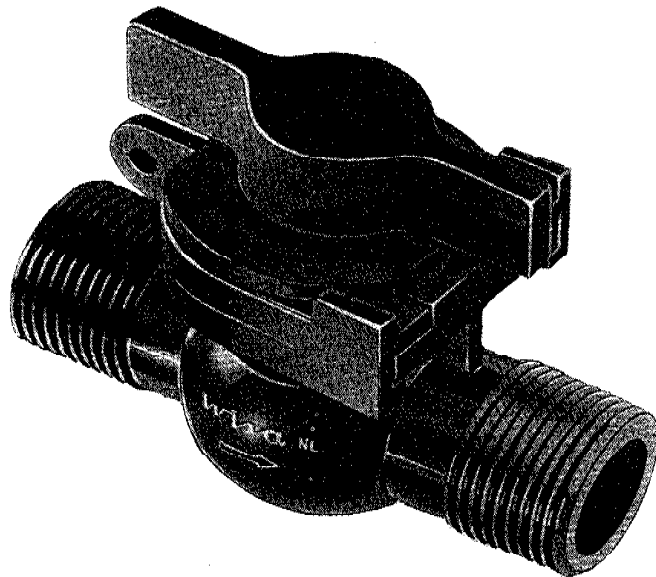


Figure 5. In-line flow limiter.<sup>20</sup>

Courtyard supplies include on-plot wells, rainwater-storage tanks and a piped supply with one tap per household or compound; the last is sometimes referred to as a yard or patio connection. Consumption in houses which have a single yard-tap supply generally varies between 15 and 90 lcd,<sup>12</sup> although water usage less than 20 lcd is uncommon and might indicate an unsatisfactory supply (e.g., an intermittent supply giving only a few hours' service each day). No information is available on the breakdown of water consumption by water-use category.

Table 2. Water savings resulting from the installation of selected flow-control devices in the United States of America

Programme	Water consumption (litres per household per year)
Without water-saving plumbing fixtures	
Normal toilet	138 000
Normal showerhead	110 000
Normal taps	33 000
	281 000
With water-saving plumbing fixtures	
Low-volume toilet	96 000
Reduced-flow showerhead	66 000
Aerator taps	19 000
	181 000
Overall water saving (litres)	100 000
Overall water saving (percentage)	35

Source: Flack.<sup>9</sup>

(a) Taps

In controlling water wastage, tap design is important (see above). With courtyard connections, self-closing valves (see figure 6<sup>21</sup>) are recommended in order to avoid wastage, and good drainage is essential.

There is little opportunity for water conservation other than the use of in-line flow limiters (see above) and good tap design to avoid wastage.

(b) *Pour-flush toilets*

There are recent designs of squat-pan and pedestal-seat toilet bowls which minimize the amount of water required for flushing. The Indian<sup>22</sup> and Brazilian<sup>23</sup> designs, shown in figures 7 and 8, require only 2-3 litres per flush when manually flushed. Both models can be easily upgraded to operate as low-volume cistern-flush toilets: the Brazilian design then requires 5 litres/flush (see figure 9<sup>24</sup>), but the Indian model requires only 1.5 litres/flush (see figure 10<sup>22</sup>). The cistern used



Figure 6. Self-closing "Talflo" trap installed on a public standpipe.<sup>21</sup>



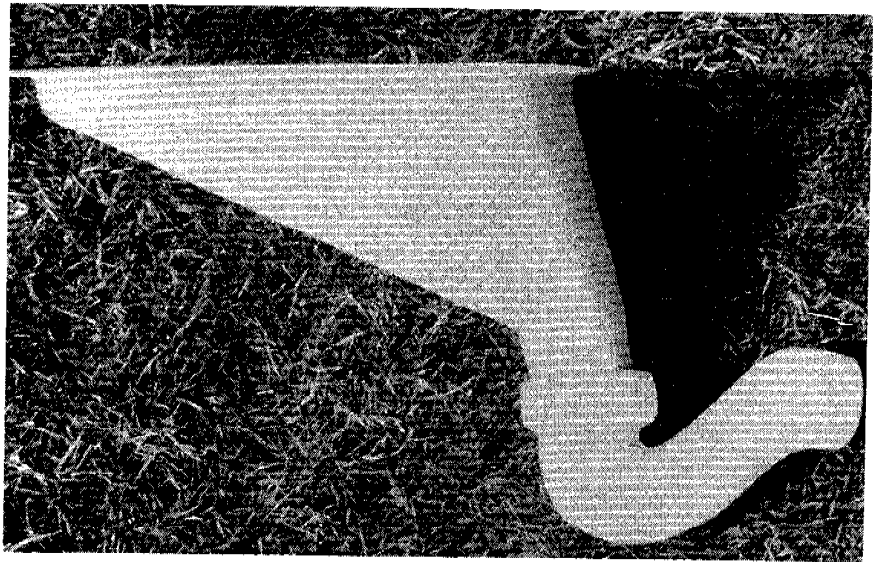


Figure 7. Indian pour-flush GRP squat pan capable of being upgraded to low-volume cistern-flush operation by the addition of the unit shown in figure 9.

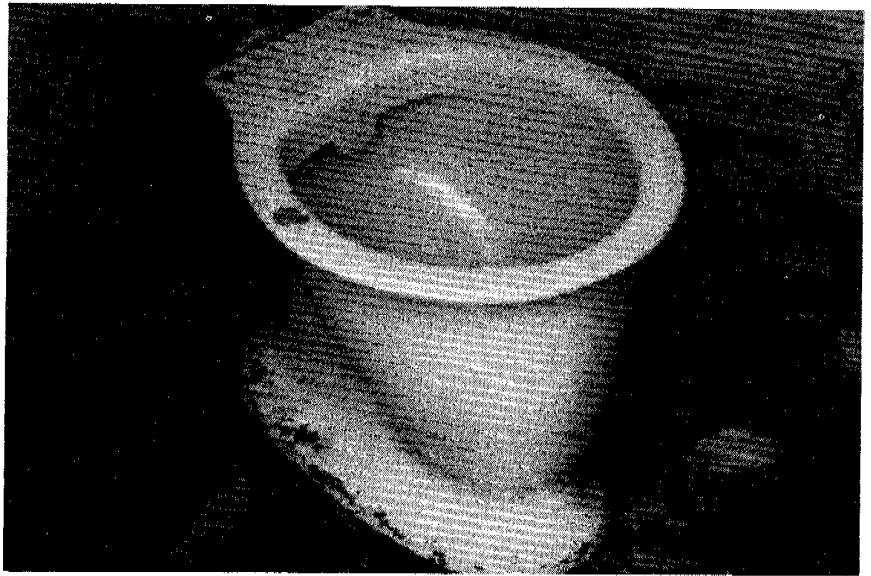


Figure 8. Brazilian pour-flush toilet bowl capable of being upgraded to low-volume cistern-flush operation<sup>23</sup> (see figure 10).

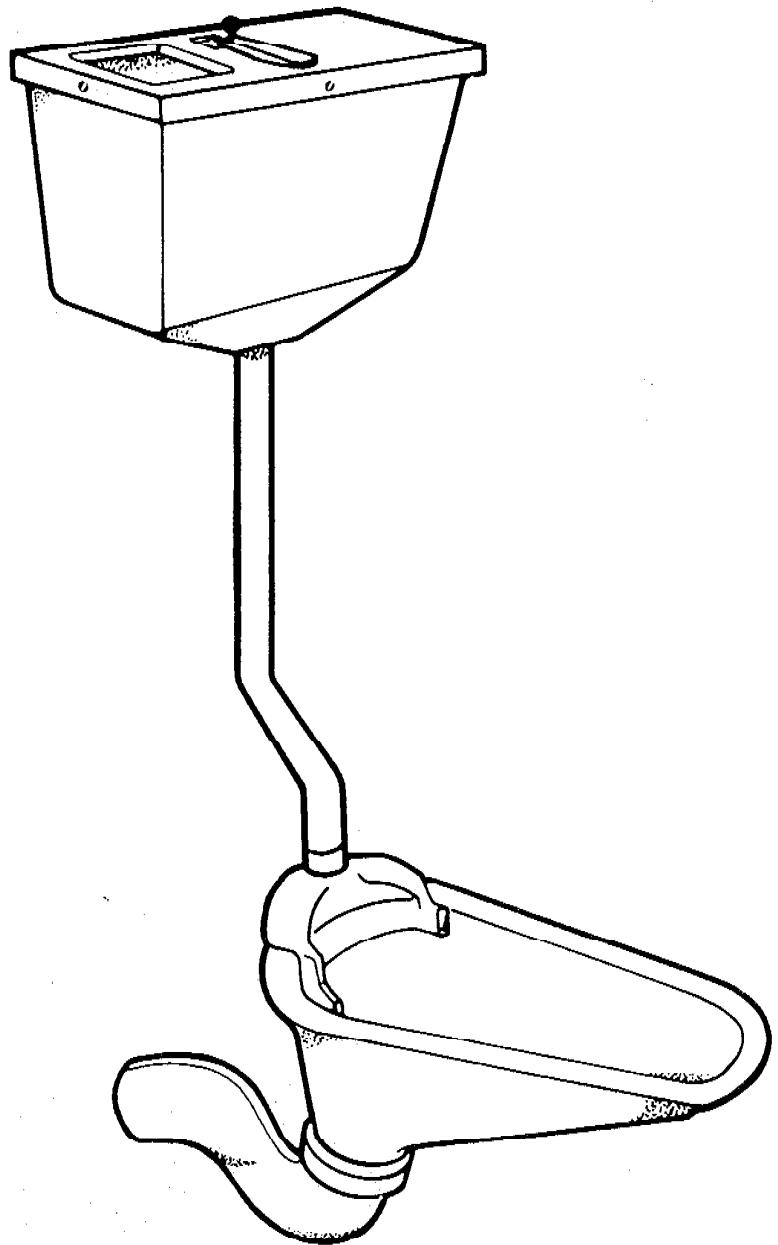


Figure 9. Pour-flush squat-pan upgraded to low-volume cistern-flush operation.<sup>22</sup>

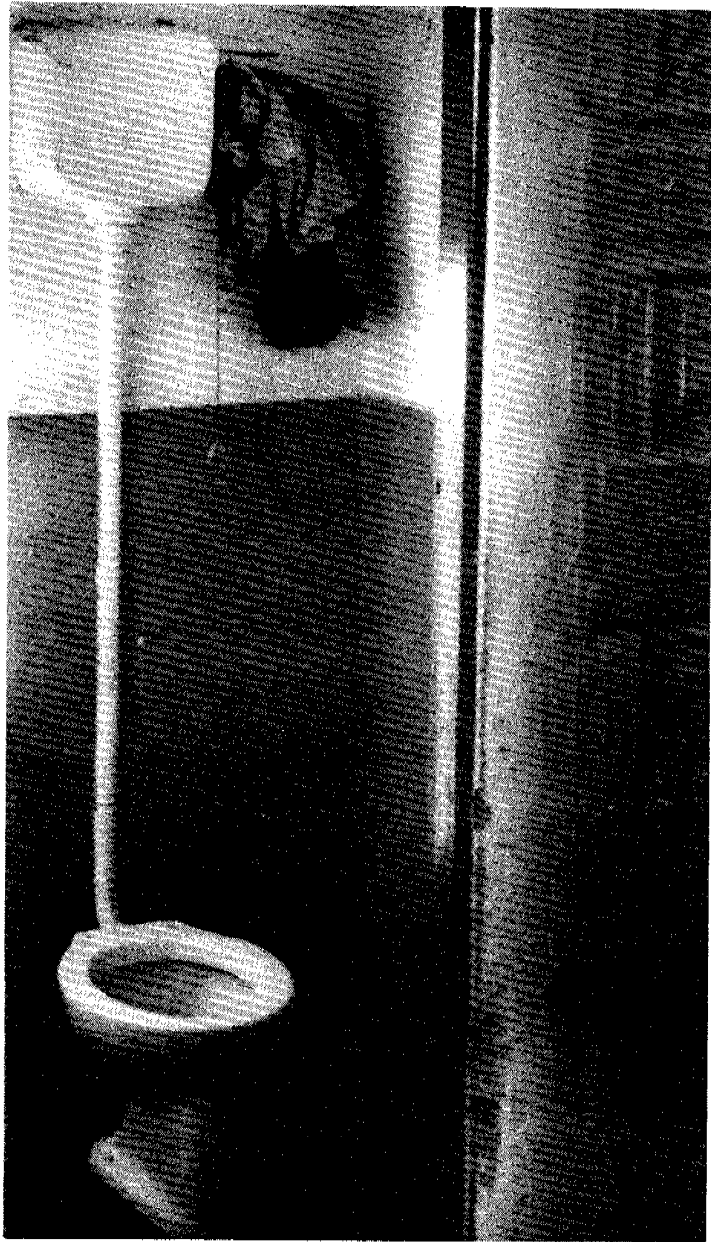


Figure 10. Brazilian pour-flush toilet bowl upgraded to low-volume cistern-flush operation.<sup>23, 24</sup>

in conjunction with the Indian model contains an upper and a lower compartment; the upper compartment has a volume of 15 litres and acts as a small storage tank, and the lower compartment has a volume of 1.5 litres. Operating the cistern closes the outlet from the upper compartment and opens that from the lower one and so discharges the flushing water; when the cistern is not in use, the outlet from the upper one remains open and that from the lower one closed, so that the lower compartment is refilled in readiness for the next flush. This cistern is, thus, very useful in areas of intermittent water supply, as it contains a reserve of some 10 flushes (but the volume of the upper compartment could, of course, be made greater than 15 litres to provide a greater storage capacity).

### *3. Hand-carried supplies*

Hand-carried supplies include both reticulated public standpipes and unreticulated communal supplies, such as wells, springs and surface waters. The quantity of water carried home depends on several factors, such as distance to the supply, regularity of the supply, time spent queuing, place of clothes washing and cost of the water, especially when purchased from water vendors. In general, the quantity of water consumed varies between 10 and 50 lcd<sup>12</sup> although consumption, usually, is below 20 lcd. In general, therefore, the problem is that water consumption is too low rather than too high, and, consequently, the scope for water conservation is small, although wastage control is obviously important. The supply objective is to enable sufficient water for meeting basic needs to be carried home. Emphasis should, therefore, be given to the following:

(a) Good design and construction which minimize wastage at the supply point (a significant proportion of the water drawn from wells and handpumps is generally lost through poor design and system maintenance), with particular attention to good drainage;

(b) Design and provision at an affordable cost of a suitable water-carrying vessel for use by women and children;

(c) Sufficient supply capacity related to local water-drawing customs (if water is drawn only in early morning and late evening, but the supply system is designed for average daily demand, heavy queueing will result in crowded facilities being stressed mechanically at peak times, insufficient water will be drawn, and there will be considerable personal annoyance and water wastage, with damage to the facilities likely to result);

(d) Safe and easy access to the supply;

(e) Provision of an adequate number of supply points to serve the target population.

### *Standpipes*

Considerable thought has recently been given to improved standpipe design. Two handbooks have been prepared which set out the principal design parameters, together with practical construction details.<sup>25</sup> Tap design should allow for rapid and effective closure, while being relatively maintenance-free, rugged and vandal-proof; self-closing taps are generally preferable to avoid wastage. Heavy-duty brass taps might be stolen and sold for scrap; it might, in such circumstances, be cheapest to use plastic taps, which have no scrap value, and, as their service life is short, to replace them regularly. Flow control can be achieved by fixed or variable orifices (see above). The design of the standpipe should take into account the locally preferred type of water-carrying vessel: the design should permit it to be filled and lifted with ease. If this is not done, considerable wastage of water through spillage can be expected, and, if adequate drainage is not provided, muddy conditions will be created which will further exacerbate spillage and encourage mosquito-breeding.

The number of households served by one standpipe varies enormously: often, a figure of 100 households per standpipe is used (for example, in Brazil and Mozambique), although, in "water co-operatives" in the Philippines, one standpipe is shared by only six households. It is important for the water-supply authority to determine the standpipe density that is perceived as satisfactory by local consumers. Often, people are dissatisfied with standpipes, because there are too few of them, and their aspirations are thus for a yard-tap supply. Costs can be kept down by having a standpipe supply with each standpipe serving some 5-20 households; households can then be billed for the service either individually or, most easily, as a group. Sympathetic location of the standpipe can ensure that it is regarded as a "private" rather than a public supply.

## **B. Metering**

Metering of domestic water consumption can be used to conserve water, since it places a financial incentive on consumers to reduce consumption: studies in the United States of America<sup>9</sup> have shown that metered consumption is significantly less, often up to 30 per cent less, than unmetered consumption. Metering is especially effective when used in combination with a sliding-scale tariff structure which severely penalizes excessive consumption (see chapter IV). In developing countries, little is known of the degree to which water consumption is reduced by metering supplies. While initial reduction in consumption can often be dramatic, it has, however, proved difficult to sustain. When meters were first introduced in Rangoon, for example, a 30 percent reduction in consumption was achieved.<sup>26</sup> After 15 years, however, 90 per cent of the meters were not functioning properly.<sup>27</sup> In a study of an installed metering system in Lahore, Pakistan, it was observed that only the installed meters were working. Meters were frequently stolen or tampered with, repair facilities were

inadequate, and spare parts were unavailable: consumer complaints were numerous, and the average life of the meters was only five years.<sup>28</sup>

It is common that not all domestic connections are metered: usually, unmetered connections are for low-income households who are assumed to consume some minimal quantity, often 15 m<sup>3</sup> per month, for which a flat rate is charged. This ensures that basic needs are supplied at low cost - a family of eight, for example, with each person consuming 50 lcd, has a total consumption of 12 m<sup>3</sup> per month. Zone metering can be used to measure actual total consumption in unmetered areas, and, if this is too high, in-line flow limiters can be installed.

The introduction of metering in an unmetered city or unmetered zones of a city should only be undertaken as a water- conservation technique if the benefit from so doing (the value of the water saved as a result of reduced consumption) is more than the cost (for example, meter-installation costs, cost of employing meter readers, cost of monthly or quarterly billing) and if metering does not penalize "basic needs" consumption in low-income settlements - generally these should remain unmetered, while metered consumption should be introduced only in high- income areas. In practice, the cost of repairing water meters can amount to a sizable part of an urban water agency's recurrent budget and can demand considerable foreign exchange to sustain. In one African country recently, the cost of replacement meters regularly used up half the water agency's foreign-exchange allowance. The Lahore study concluded that consumption reduction of the order of 80 per cent was required to justify metering. The reduction in consumption which can be expected to occur as a result of installing meters depends, of course, on the tariff structure adopted (see chapter IV). Detailed advice on the benefit-cost analysis of metering is given by Middleton and others.<sup>29</sup>

### **C. Recycling systems**

Recycling systems, such as those which use filtered sullage for toilet flushing, are not considered appropriate for developing countries, on the grounds that they are not mechanically simple and their maintenance requirements are high. Their use is, in any case, extremely rare, even in industrialized countries.

### **D. Impact on sewerage and sewage treatment**

The use of water-saving plumbing fixtures can reduce in- house consumption by 30-35 per cent (see chapter IV), and, thus, wastewater flows can be reduced by a similar amount. There exists, therefore, the possibility that the hydraulic-flow regime, particularly regarding solids transport in existing sewers will be adversely affected as a result of decreased sewage flows. However, experience in Mexico, Sweden and the

United States of America. has shown that such problems do not in practice occur: decreased sewage flows do not cause increased sewer blockages.

The sewage from areas in which water-saving devices have been installed is, of course, stronger than "normal" sewage, and this might be expected to cause problems at sewage-treatment works. There are, however, no reports that this is the case. With waste-stabilization ponds, which are generally the wastewater-treatment process of first choice in developing countries, no difficulty is to be expected: anaerobic and facultative ponds, which are designed on the basis of permissible organic loadings, will be of the same size, but their resulting hydraulic retention time will be longer (so that excreted pathogen removal will be correspondingly improved), and maturation ponds, which are designed on the basis of hydraulic retention time, will be similarly unaffected. Providing that the ponds are properly designed, no adverse operational effect (for example, odour release) will occur as a result of the strong wastewater.





### III. OPERATIONAL METHODS OF WATER CONSERVATION

#### A. Unaccounted-for water

Unaccounted-for water (UFW) is the difference between net water production - the volume of water put into a water-distribution network - and legitimate consumption, whether metered or not.<sup>30</sup> It can only be calculated, and thus a decision taken as to whether it is worth reducing, if both total production and total consumption can be measured or accurately estimated. The former can be easily metered (however, additional meters might need to be installed, or existing meters recalibrated), but the latter presents great problems, especially in developing countries where not all domestic consumption is metered (see chapter IV). Total consumption is the sum of all metered consumption, plus unmetered domestic consumption (which needs to be measured by a simple household survey) and unmetered "public" consumption (such as fire fighting, mains flushing, consumption at public toilets) for which a realistic estimate has to be made. UFW calculated in this way includes:

- (a) Water lost through leakage in the distribution system (up to but not including property meters or stopcocks);
- (b) Water consumed but not recorded by consumers' meters or otherwise accounted for by consumption estimates in unmetered areas;
- (c) Water consumed through illegal connections.

Water losses due to (b) and (c) can be reduced by checking the accuracy of domestic meters (even newly installed meters might be up to 30 per cent in error<sup>30</sup>) and by increasing vigilance in detection. However, water losses due to leakage generally account for a very high proportion of all UFW. Since this might be 20-50 per cent of total water production, leakage detection and repair can be a very effective and cost-efficient method of water conservation.

#### B. Leakage detection and repair

Because leakage losses are usually such a large proportion of total UFW, especially (but by no means exclusively) in developing countries, leakage detection and repair need to be given high priority in any water-conservation programme, since they are capable of saving much water which can then be used for such purposes as augmenting existing supplies in low-income settlements. When UFW accounts for 25 per cent or more of total water production, leakage detection and repair programmes are generally

cost-effective,<sup>30</sup> although a benefit-cost analysis should be done in each case.

Short-term consultancy contracts for leakage detection and repair are often poor value for money, not because the consultant does not do his work properly but because the effort often stops when his contract expires, since there is no real commitment, in terms of work-force and equipment, to leakage control within the water-supply authority.<sup>31</sup> In urban areas, effective leakage detection and repair programmes will usually require the establishment of a special "leakage control section" within the authority or, if such a section exists, its expansion so it can do its work properly. Due recognition needs to be given to this area of work which, for too long, has not received the priority it deserves - In India in 1987, for example, (and many other countries too), "the careers of water supply engineers are not made by reducing leakage, and all the recognition seems to be going to engineers who implement new projects. This gives little encouragement to leak control engineers and (their) staff" staff."

A leakage-control section needs good staff, good equipment and good training programmes. The work of such a section requires careful planning and sustained action. Comprehensive guidelines for two consecutive five-year operational plans for reducing losses due to leakage have been recently prepared by the World Bank,<sup>30</sup> and a summary of the tasks to be undertaken in the first five-year period is given in table 3. Such a programme requires good practical training and, often, collaboration with a water-supply authority in an industrialized country with a good track record in leakage control.

Leakage-detection programmes require each supply district or zone within the city to be individually metered, so that leakage areas can be first identified and fully characterized. Information is needed on the location, materials and age of all pipes, valves and other fittings. Detailed investigations should be carried out in areas which have unexplained high night flows, and individual leaks within each district can then be located using either traditional sounding techniques or modern instruments, such as the leak-noise correlator.<sup>32</sup> In areas subject to intermittent supply, the procedure for leak detection is complicated; a suggested method is presented in table 4.

Experience in India<sup>33</sup> has shown that leakage-control programmes can reduce water lost through leakage in areas served by an intermittent supply by as much as 94 per cent (see table 5). Leakage-control programmes generally show initially very high financial returns, but, as the programme becomes established and leaks are repaired, the returns will fall; benefit-cost analyses should be done at regular intervals to determine when the programme ceases to be cost-effective.

### C. Reduced line pressures

Pressure reduction is an effective means of water conservation, especially in the absence of other conservation techniques, but it is least effective when water-saving plumbing fixtures (of chapter II. A) are used, since these regulate the flow independently of pressure. In developing countries, where intermittent supplies are necessitated by insufficient pressure being available for the whole city, the opportunity for savings are small but might still be significant, especially (as is often the case) when leakage losses are high, since these increase substantially with line pressure.<sup>34</sup> Line pressures should be no more than 4 bar but not less than 1.33 bar in order to prevent contamination of the supply.<sup>9</sup> The effectiveness of line-pressure reduction in reducing demand may be judged by the practice (not to be encouraged) of some water managers increasing line pressures towards the ends of months in which consumption has been below average in order to increase it to the average, so as not to lose revenue.<sup>35</sup>

**Table 3. First five-year plan for extended action to control leakage losses in metropolitan urban areas**

Task	Time required (weeks) <sup>a</sup>	
	Individual	Cumulative
1 Review of existing leak detection and repair system	4	4
2 Review of progress on remapping	2	6
3 Training and equipment	8	14
4 Technical assistance	8	22
5 Pressure reduction	13	35
6 Monitoring of net production and district flows	26	61
7 Retest of production with meters	26	87
8 Metering of large night consumption rates	26	113
9 District inspectors appointed	26	139
10 Pilot wastewater district established	26	165
11 Study of production and consumption	26	191
12 Re-estimate proportions physical and non-physical	4	195
13 Study of waste control	26	221
14 Concentration of effort	22	243
15 Economic appraisals	13	256
16 Re-examination of policy and budget	4	260
<b>Total</b>	<b>260</b>	<b>260</b>

a/ Times given are minimal estimates, and some tasks might take longer than shown. However, since some can be undertaken concurrently, the over-all time estimated is realistic.

Sources: Jeffcoate and Saravanapavan.<sup>30</sup> This comprehensive World Bank publication should be consulted for further details.

**Table 4. Recommended procedure for leak detection in areas served by an intermittent supply**

Task No.	Task description
1	<i>Prior to test:</i>
1.1	Identify zone(s) to be tested.
1.2	Make arrangements, if necessary, for temporary zone metering <sup>a</sup> and installation of pressure gauges at far ends of zone.
1.3	Check zone boundary valves for watertightness, and repair (or replace if leaking).
2	<i>On day of test:</i>
2.1	Cut off all consumer connections as soon as normal supply hours are over.
2.2	Isolate the zone by closing all boundary valves.
2.3	Connect the zone to the supply and charge the mains until sufficient pressure is developed at the far end of the zone.
2.4	Open valves on fire hydrants to allow any trapped air to escape: recharge mains as necessary.
2.5	Close main supply valve and open bypass valve: consistent recorded flow indicates amount of leakage within the whole zone.
2.6	If leakage flow is high, determine which subzones have highest leakage by closing valves on the supply main one by one, starting from the far end of the zone: the flow reduction at each step indicates the leakage in the last section.
2.7	Locate leaks with sounding rods and/or leak-noise correlators.
2.8	Restore normal supply conditions.
3	<i>After testing:</i>
3.1	Repair located leaks.

a/ This is most simply done by installing a local bypass, with valve and meter, around the main supply valve for the zone.

Source: Adapted from Pavamani and Kumar.<sup>7</sup>

**Table 5. Leakage losses<sup>a</sup> in distribution systems in selected Indian cities with intermittent supplies, before and after leakage-control measures**

City	Population of each zone	Number of house connections in zone	Hours of supply per day	Percentage of waste flow <sup>b</sup>		Percentage reduction in waste flow	Initial per capita flow (l/d)
				Initial	Final <sup>c</sup>		
Bombay	8 000	241	15	28.5	8.5	66.0	60
	7 847	281	15	33.0	7.4		
Aurangabad	6 177	377	3.5	28.6	12.0	55.5	16.3
Delhi	1 562	260	13	17.7	10.0	41.0	-
Madras	2 000	170	6	36.0	7.0	84.0	75.6
	618	-	18	3.7	-	-	6.4
Lucknow	1 517	149	24	19.0	6.0	64.0	24.7
Calcutta	15 552	117	24 <sup>d</sup>	24.6	6.0	75.0	34.0
	7 819	216	24 <sup>d</sup>	25.0	3.1	87.0	33.1
Ahmedabad	1 555	184	6	20.1	2.0	94.0	38.0
	1 703	-	5.5	25.5	2.5	90.0	27.5

a/ Leakages up to but not beyond household stopcock

b/ Waste flow calculated as waste flow during supply hours divided by total average daily flow in system

c/ After leak repairs

d/ 24-hour supply, but part of time under low pressure

Source: Raman.<sup>33</sup>



# IV. FINANCIAL METHODS OF WATER CONSERVATION

Water-tariff structures can be used as an effective means of water conservation, if they are such that the cost charged increases with increasing consumption. In order to protect the interests of low-income consumers, who generally have a low consumption, there should be a "social tariff" that prices the first block of consumption, which corresponds to basic needs, very cheaply; thereafter, each block of consumption should become progressively more expensive. Usually, it is assumed that only the first block of consumption is consumed in low-income households which are not, therefore, metered and, so, pay the minimum tariff, irrespective of actual consumption (zone metering and in-line flow limiters (see chapter II. B) can be used to measure and limit actual consumption).

One example of a social tariff is the following which was introduced in the state of Mato Grosso do Sul in southern Brazil in September 1983 (\$US1 = \$Cr 700):<sup>37</sup>

10 m <sup>3</sup>	\$Cr 500 per month
10-15 m <sup>3</sup>	\$Cr 810 per month
15-20 m <sup>3</sup>	\$Cr 1510 per month
20 m <sup>3</sup>	\$Cr 2275 per month

The first category is the charge for unmetered yard-tap supplies. The costs per m<sup>3</sup> of water at the upper margin of consumption in the first three categories (i.e., 10, 15 and 20 m<sup>3</sup> per month) are \$Cr50, \$Cr54 and \$Cr75.5 respectively, and \$Cr91 for a consumption of 25 m<sup>3</sup> per month, so the tariff becomes very progressive above a consumption of 15 m<sup>3</sup> per month. It is also a very social tariff, since 65 per cent of the population served is in the first two categories.

A more obviously progressive tariff structure is the following from Trinidad and Tobago, where metered domestic supplies are charged at the following rates (January 1986; \$US1 = \$TT3.6):<sup>36</sup>

	0- 10 m <sup>3</sup>	\$TT 15 per quarter
plus	10- 50 m <sup>3</sup>	\$TT 0.50 per m <sup>3</sup>
	50-100 m <sup>3</sup>	\$TT 0.75 per m <sup>3</sup>
	100-150 m <sup>3</sup>	\$TT 1.05 per m <sup>3</sup>
	150 m <sup>3</sup>	\$TT 1.20 per m <sup>3</sup>

Unmetered yard-tap supplies are charged \$TT46 per quarter, and standpipe supplies, for houses within 400 m of a standpipe, \$TT23 per quarter (which correspond to metered consumptions of 65 and 26 m<sup>3</sup> per quarter respectively; the latter is sufficient to meet the basic needs (30 lcd) of a family of nine).

It is clearly in metered consumers' interests to reduce their demand, so that they pay less, but only if the resulting reduction in charges is attractive; that is, it must represent a significant sum of money. What constitutes "significant" in this context, of course, varies greatly. In the above example for Brazil, there is little incentive for the rich to reduce consumption since even the highest charge is so small a proportion of their income (only 1.3 per cent for someone earning \$Cr174,000 (\$US248) per month, equivalent to five minimum salaries).

An effective pricing policy, directly aimed at individual water conservation, is to place a high surcharge on consumption in the highest consumption block which is above a given percentage of the consumer's total consumption in the previous year. Such a policy was introduced in 1981 in the city of Aurora, Colorado, where consumption was charged as follows (1 gallon = 3.78 litres).<sup>9</sup>

<15,000 gallons/month	\$1.03 per 1,000 gallons
15,000-20,000 gallons/month	\$2.06 per 1,000 gallons
20,000 gallons/month to 70 per cent of consumption in 1980	\$2.06 per 1,000 gallons
>this amount	\$4.12 per 1,000 gallons

The objective of such a surcharge policy should be to make the installation of water-saving plumbing fixtures (see chapter II. A) financially attractive to the consumer, and the policy should, therefore, only be introduced after explanatory notice has been given to the consumer, to enable the consumer to purchase and install such devices (which require, of course, to be available in the market; this will generally need careful planning in developing countries, especially if the devices have to be imported). The consumers should be given worked examples of the costs involved and the savings that can be achieved by the installation of the various devices.



# V. SOCIO-POLITICAL METHODS OF WATER CONSERVATION

## A. Legislation

Legal methods to enforce water conservation are effective only if they can be and are continuously enforced. There are two methods - modification of building (or plumbing) codes and water-use restrictions.

### 1. *Building code modifications*

Modification of existing building (or plumbing) codes will be required to permit the use of water-saving plumbing fixtures, if these contravene the code. Moreover, modification of existing codes can be used to specify the installation of such devices in all newly-constructed houses, offices and factories. This is probably the most effective way of promoting their use and gaining public acceptance of them.

### 2. *Water-use restriction*

The legal restriction of water use, for example, the prohibiting of garden watering, is usually only effective as a short-term method of conservation when supplies are running dangerously low. Often, voluntary and, then, mandatory restrictions are called for. The success of the former depends on the consumers' appreciation of the need for their imposition, and, thus, increasing public awareness is important (see chapter VI); the success of the latter depends on the penalties involved and how well the restrictions are enforced. Long-term measures might include the imposition of a legal upper limit to the amount of water that a household can consume per month, with disconnection being the ultimate penalty. However, such a method of water conservation is not likely to be popular, and surcharging (see chapter IV) should normally be introduced first.

## B. Public education

Public education is a key component in the success of any water-conservation programme. Users, many of whom probably have very little idea of how water is supplied to them, must understand why they should be expected to participate in such a programme. The full story must be explained to them in a way that they will understand. However, it is important to realize that, in developing countries, "they" are not a uniform consumer group (see table 1), and, thus, different "water-conservation

messages" are required for each type of consumer (supplied by public standpipe, yard-tap or multiple-tap in-house connections).

To make effective use of their water-supply and sanitation services, consumers need information on a wide range of topics including:

- (a) Methods of water supply and waste disposal available to them;
- (b) How to use water frugally;
- (c) The cost of wasting water (especially by leaking or dripping taps);
- (d) Methods of repair and maintenance;
- (e) Availability of water-saving plumbing fixtures and technical assistance for their installation;
- (f) The rationale behind water-supply service levels, charges, bye-laws and regulations;
- (g) The value to the community of water as a national resource.

Publicity campaigns to reduce water wastage and unnecessary consumption have been found to be highly cost-effective in a number of industrialized countries.<sup>38</sup> There is limited experience of water-conservation publicity campaigns in developing countries but no reason to suggest that, if socio-cultural preferences are taken into account, similar campaigns would not be equally effective.

Many water-supply authorities have public relations departments, and these should be responsible for designing and implementing public education programmes for promoting water conservation. A variety of educational media can be used - for example, radio, television and newspaper announcements, and mailing out of leaflets or booklets (especially those using a comic-strip format) with the water bill: the precise choice depends on local advertising practice. Competitions, for example, to paint a poster to encourage water saving, can also be effective, particularly among the young and especially if there are good prizes to be won.

Public education programmes should be a sustained effort, not just a one-off affair, otherwise, any resulting reduction in consumption is likely to be only a short-term achievement, and consumption might, thereafter, gradually increase to its previous level or above. Sustaining public interest over the long term requires care to avoid boredom: the actual message must be regularly changed, and again local advertising practice should be followed for good advice. Sustained public education programmes do, of course, have their costs, and these should be less than their associated benefits (which might be estimated as up to a 5 per cent reduction in water consumption<sup>9</sup>).

## VI. CASE STUDIES

### A. United States of America

Water consumption in the United States of America is extremely high - generally well over 300 lcd. Water-supply costs are increasing rapidly, and many states have introduced water-conservation programmes, especially those in the arid South-West.<sup>39</sup> Two case studies are presented here, both given by Flack.

#### 1. *Washington Suburban Sanitary Commission (WSSC)*

WSSC, which serves 1.2 million people in Montgomery and Prince George's counties in Maryland with some 490,000 m<sup>3</sup> of water per day (that is, a water consumption of 400 lcd), established a water-conservation programme in October 1971 in an attempt to reduce wastewater flows. The local building code was changed to specify the use of water-saving toilets and showerheads, aerator taps and pressure-reducing valves on mains with a pressure over 4 bar. Public awareness of the programme was ensured by:

- (a) Mailing of water-saving handbooks to all customers;
- (b) Holding of water-saving workshops for property managers;
- (c) Production and distribution of a water-conservation handbook for garden and lawn watering;
- (d) Production of a film on water conservation;
- (e) Spot announcements on local television and radio stations;
- (f) Sponsorship of a "Water-saving idea" competition.

Plastic bottles, to be filled with water and placed in existing toilet cisterns (so as to reduce the flush volume to below 19 litres), were distributed to all consumers, together with dye pills to detect leakage through the rubber cistern trap valve. Additionally, showerhead inserts were distributed on request. The total cost of the programme was \$US431,000 (that is, some 36 cents per person), and the resulting water savings have significantly reduced per capita domestic use, although precise data are not available. The programme is still in existence.

#### 2. *Denver Water Department (DWD)*

DWD supplies some 745,000 m<sup>3</sup> of water per day to 900,000 people in the Denver Metropolitan Area, Colorado (that is, a consumption of around 800 lcd). Public awareness and voluntary water conservation were initiated by:

- (a) Production of a brochure giving "tips to save water";
- (b) Lectures at local schools on water conservation;
- (c) Production of an animated colour film on water conservation;

(d) Spot announcements on local television and radio stations:

(e) Production and distribution to all consumers of a water news publication.

Programme costs for 1973-1975 were \$US50,000, plus \$US35,000 for the colour film (that is, 10 cents per consumer). A voluntary and, then, mandatory programme of water-use restriction was introduced in the summers of 1977 and 1978. These restrictions on lawn watering, car washing and other outside uses achieved considerable water savings, despite a near record drought.

## B. Mexico City

Mexico City has a population of over 10 million people, and the average water consumption is 320 lcd. Water is expensive to supply to this rapidly growing metropolitan area (average growth rate: 3.2 per cent during 1975-1985), and currently the newest supply to the city involves pumping water up from the Valle de Mexico which lies some 1,000 m below Mexico City. Further augmentations to the city's water supply will be very expensive, and it is against this background of water scarcity and escalating costs that the city introduced in 1985 its Efficient Water Use Programme (Programa del Uso Eficiente del Agua).<sup>40</sup>

The fundamental objective of this programme is to ensure that consumers can satisfy all their water-use needs with small quantities of water. The programme has five specific objectives:

- (a) Obtain maximum use of existing supplies;
- (b) Improve the administration of water-supply and sewerage services;
- (c) Regulate the supply of water and sewerage services;
- (d) Encourage efficient water use by consumers;
- (e) Reduce the quantity of water used by toilets, showers and other plumbing fixtures.

Additionally, the programme includes such activities as leak detection and repair (the city has over 12,000 km of primary and secondary distribution mains); updating of plumbing codes; improved consumption control by metering; installation of some 500,000 water-saving devices per year; and elimination of in-house water losses.

Since 40 per cent of all water used in Mexico City is for domestic purposes (flush toilets, showers, sinks), emphasis has been given to the adoption of water-saving fittings and fixtures, and to the training of plumbers in their installation. The medium-term plan is that low-water-use fittings and fixtures should be used by all consumers. Three strategic actions are in force:

- (a) Mandatory installation of water-saving fittings and fixtures in all new houses;

(b) Their installation in existing unsewered houses prior to their connection to a public sewer;

(c) Promotion of their use in existing houses which have both water-supply and sewerage (some 75 per cent of the total), and a revised tariff structure designed to encourage their installation.

Specially designed 4-litre flush toilets and low-flow shower-heads and taps are all in local manufacture. A vigorous public education programme is also in operation - slide shows, video-films, brochures, personal letters to consumers and car stickers have been produced to increase public awareness of the magnitude of the water crisis. Governmental and other public buildings all use only water-saving plumbing fixtures, and a pilot-scale study on domestic water use has shown that consumption can be decreased by as much as 35 per cent, principally owing to the replacement of existing cistern-flush toilets (which use around 20 litres per flush) by 4-litre flush toilets.<sup>41</sup> The programme has been very successful and will continue at least for the immediate future.



# VII. RECOMMENDATIONS

## A. National action

1. Governments should ensure that public water-supply authorities initiate water-conservation programmes, so as to permit maximum use of existing supplies before any new supplies are developed.
2. Such water-conservation programmes should normally include the following:
  - (a) The introduction of leakage detection and repair programmes as a component of routine maintenance of water- distribution systems;
  - (b) The review of local water-tariff structures with the aim of introducing equitable and resource-conserving structures;
  - (c) The initiation of public education programmes;
  - (d) The introduction of incentive schemes to promote the adoption of water-saving plumbing fixtures;
  - (e) The facilitation of, initially, the importation of watersaving plumbing fixtures and, then, their local manufacture;
  - (f) The modification of existing building regulations and/or codes of practice to:
    - (i) Permit the use of water-saving plumbing fixtures;
    - (ii) Require their use in all new buildings;
  - (g) The retrofitting of water-saving fixtures in all existing governmental buildings, so as not only to reduce water consumption in them but also to demonstrate to the public that the government believes in their use.
3. If pilot-scale testing of water-saving plumbing fixtures is required (for example, in order to determine minimal acceptable flows from taps and showerheads), governments should provide the necessary resources for such an exercise.
4. Governments should publish their experience in water conservation, so that others may learn from them.

## B. International support

1. Agencies, such as the World Bank and regional development banks, should, in collaboration with governments, produce a set of model standards, specifications, building regulations and/or codes of practice, and general guidelines for local manufacture of water-saving plumbing fixtures.
2. Such agencies should facilitate
  - (a) The establishment of leakage detection and repair sections in national urban water-supply authorities;

(b) The training of staff in these sections:

(c) The provision (on loan if necessary) of modern leak- detection equipment.

3. These agencies should provide governments with advice on socially progressive water-tariff structures, and on the development of locally appropriate public education programmes.

4. Bilateral and multilateral aid agencies should actively encourage the adoption of water-conservation programmes in all new urban water-supply projects, and they should encourage water- supply authorities in their own countries, which have the necessary experience in this area, to second staff to water- supply authorities in developing countries which are embarking on water-conservation programmes.



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20. Manufactured, for example, by Wisa BV, Arnhem, The Netherlands.
21. For example, the "Talflo" valve manufactured by F.W. Talbot and Co. Ltd., Winchester, England.
22. Manufactured under agreement with Ifo Sanitar AB, Bromolla, Sweden, by EID Parry (India) Ltd, P O Box 12, Madras 600001, India.
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