URBAN WATER SUPPLY IN A DEVELOPING COUNTRY: THE CASE OF DELHI

A book study on *Water, Unreliable supply in Delhi*,
by Marie-Hélène Zérah

INTRODUCTION

The action takes place in Delhi, capital of India. Delhi is a good example of a third-world mega-city. More than 250 million Indians are living in cities. The rate of urbanization is relatively slow (below 30%) but it is concentrated in three large urban centers : Mumbai (Bombay), Kolkatta (Calcutta) and Delhi which have more than 10 million inhabitants. The future economic development of India will take place in these cities (contribution to future growth estimated at 80%[1]), and good infrastructures are essential to their sustainable development. "Good quality infrastructure leads to substantial gains in productivity and a rise in the standard of living. It reduces poverty and at the same time increases life-expectancy through improved health and sanitary conditions, better transport and irrigation networks as well as access to education, improved environment and better utilization of natural resources."[2]

The study is concentrated on inefficient water infrastructure. The problem lies more in the quality and cost of water-supply than in the accessibility itself.
Many of the water shortages around the world stem from the widespread failure to value water's true worth. Gross under-pricing of water, whether for agriculture or for domestic or industrial use, perpetuates the illusion that it is plentiful, and that nothing is lost by wasteful

[1] C. Bartone et al, *Toward environmental strategies for cities : Policy considerations for urban environmental management in developing countries,* Urban Management program, Series paper no. 18, World Bank, Washington D.C., 1994.
[2] Zérah, p. 15.

practices. Fixing a price of water that is close to the real cost of supplying it has to become a key component of both urban and industrial conservation. This will foster a greater efficiency of water use.
Moreover, inefficiency in water-supply has an impact on the standards of living, on water resources and on the urban economy as a whole.

First will be reviewed Zérah's case-study of the economics of water supply unreliability in Delhi. Then, this work will be discussed as a starting-point for public policies.

PART 1: REVIEW

Delhi water supply, particularly with regard to its unreliability, was not put under the microscope examination until Marie-Hélène Zérah did so in her book *Water: Unreliable Supply in Delhi*. This book is a condensed and translated version of her PhD thesis submitted in 1997 to the Institute of Urbanism, Paris. The book has both lucidity and clarity of expression.

It spans over seven chapters. The introductory chapter provides a view of the water infrastructure in the cities of the developing countries as well as the research work carried out in various parts of the world on the quality of public water supply systems. Like any other infrastructure, the water supply sector is confronted with a number of problems and constraints, like price, subsidy, cost recovery, losses and poor maintenance. In most cases, statistics on the percentage of population with access to potable water do, not take into consideration the quality of services provided to users.

I will here divide the first part of the report in three sections : First, we shall be introduced to general aspects of unreliable drinking water supply, with focus on Delhi. Then, we will

summarize the proceedings and the findings of the household survey of the author. And finally, we will see her conclusions on the economics of water supply unreliability.

Unreliable drinking water supply

The first chapter gives a detailed account of per capita water availability and various performance indicators of the public water supply systems in many countries, including India. As brought out in this chapter, the efficiency of the water infrastructure network in developing cities is often constrained by a combination of inadequate operations, maintenance systems and financial difficulties.

In developing countries, the urban transition is much faster than what it has been in developed countries. The deterioration of water resources (river pollution, depletion and contamination of ground water) is accelerated by demographic pressure and untreated individual wastewater. Higher investments are made to capture water from remote areas and to implement more sophisticated water treatment methods. Several development programs by international organizations[3] proved relatively unsuccessful, though access to water has improved on a global scale. In Asia, more than half the population is not directly connected to a municipal network[4]; others have inadequate supply (water is not supplied continuously). Discrepancies are often found within the cities: less than 18% of lower income households have individual connections[5].

Paradoxically, the poor then purchase water from water deliverers and end up paying more for water. The bad quality of water distributed also has serious consequences: 80% of the illnesses that affect inhabitants of developing countries originate from polluted water. In 16 of the 38 cities studied by the Asian Development Bank (1993), inhabitants had to boil drinking water and in 21 cities they bought water from commercial bottled water companies.

Developing cities also face technical and financial deficiencies: The percentage of unaccounted for water is estimated to be at 35 % (30% in Delhi), 3 times higher than in developed countries[6]. Defective maintenance accelerates the deterioration of existing investments, and new investment is usually made in projects that use sophisticated techniques

[3] International drinking water supply and sanitation decade launched in 1977.
[4] There's often one public tap for 500 inhabitants.
[5] World Resources Institute, 1996, figures for developing cities.
[6] Asian development bank, 1997.

which people are unable to maintain and operate. Water agencies have very limited financial resources, and for many of them (including Delhi), "revenue from water sales does not even cover the running and the distribution costs of the network.[…] Political authorities are reluctant to increase the price of water, […] an electoral issue. […] In addition, in all cultures, water is a free gift from god. Therefore, raising awareness about water being a rare natural resource that should be treated as an economic good that people have to pay for makes it a delicate and complicated exercise"[7].

Reforms are taking place, based on the resolutions of the Dublin conference on "Water and Environment"[8]:

- To preserve water resources through sustainable management, taking into account economic and social development.
- To encourage participatory management by involving users, planners and the deciding authority at all levels.
- To recognize and encourage the role of women in resources management.
- To consider water as an economic good.

In these reforms, the central debates are on private vs. Public sector and on centralization vs. Decentralization. Privatization is supposed to introduce "objectives of performance" and decentralization to give "greater responsibilities for water agencies". But the role of central government must remain to reduce regional inequalities. According to Marie-Hélène Zérah, "models of public-private partnerships have to be evolved"[9].

In 2001, urban India represents around 60% of the national GDP, but lack of infrastructure prevents the balanced economic growth of cities. The deterioration of water resources has become a regular subject for the press, as 70% of the water resources are polluted[10]. In Delhi, the statistics of access to water are subject to high doubt: According to the Census of India (1993), it is of 96%, but of 90% for the ministry of urban affairs and employment (1993), of 69% for the Asian Development Bank (1993) and of 57% for the Society of Development Studies of New-Delhi. The discrepancies can be explained by the difficulty in assessing the population served by a collective source and estimating the slum population. But even the lowest figures must be taken with precaution, as there is often very low pressure or no water at all…

[7] Zérah, p. 29, 30, 31.
[8] In January 1992.
[9] She evokes the 'french model' !
[10] National Environmental Engineering Research Institute.

In India, water supply and sanitation is a state subject. The central government has a coordinating role and gives recommendations[11] : The adoption of the full cost recovery principle, the financial autonomy of agencies, long term training and water resources management based on the preservation of the water table and quality and on the development of nearby water resources. The states are responsible for this development. The distribution, maintenance and managerial functions are looked after by the municipalities. In Delhi, the metropolitan water-agency has 'a great level of autonomy'… Could it take the opportunity of decentralization?[12] This could help in taking as objective to promote a bottom to top approach to development.

The second chapter deals with water supply unreliability. Issues related to the quality of service provided to the consumers of water supply networks have not so far been sufficiently studied. Research on water supply unreliability is recent. Although a few studies with large samples are available, they are research on household behaviors towards water supply unreliability. The World Bank began to undertake research on households after the major work done by Lee and Anas on the impact of deficient water infrastructure on industries in Nigeria.
This chapter brings out clearly that reliability is not merely a technical concept but also an economic one that should be taken into consideration while designing water supply projects. This is important because unreliability of water supply causes deposits, deterioration of the inside of water pipes and reduces the effectiveness of anti-corrosive and water treatment chemicals. Moreover, when water consumers use motors to suck up water from the main waterlines, there are chances of the clean water getting mixed with sewage water. This is the situation that Delhi is facing today…

Traditionally, the price of water is fixed at 4 to 5% of the income of the households, thanks to high subsidies. But those practices bring wastage and poor maintenance, which are not sustainable. Considering water as both an economic and a social good, M-H Zérah compares methods of assessing the demand of users.
One method of estimation is based upon each user's willingness to pay or willingness to accept compensation (WTP or WTA)[13]. The former is subject to users' budgetary constraints, and so is chosen in developing countries to assess access to basic service. To measure this

[11] See www.nic.in/cwc/cwc4.htm (central water commision)
[12] The 74th amendment to the Constitution affirms the importance of local democracy.
[13] Lecture by dr. J.J. Bouma.

demand, one uses the contingent valuation method (CVM)[14] in which several hypothetical scenarios are proposed to the respondents in a questionnaire. This method has been widely discussed, as it requires rigor in its application. At each stage the participant has the choice to stop or to continue paying. But several biases can appear : sample bias, strategic bias (the respondent tries to influence the provision of the good), interview and subjectivity(the respondent interprets the expectations of the interviewer), and the starting value of the bid. Zérah remarks that all case studies using this method converge on their results: households, even the poorest ones, are able and willing to pay more to have access to safe water[15]. "These studies are important both from a theoretical and an operational point of view. They invalidate the theory that households refuse to pay for water and they are a measure of the demand for water that can be taken into account when making project proposals"[16].

Other methods are more rarely used. Zérah mentions a study in which the value of the time used for water collection by households has been calculated[17]. This study showed that households are not only ready to pay for water but that there is a non-negligible time opportunity cost (although it showed high differences in this cost between high and lower income households).

For her own study, Zérah starts on the assumption that "for city dwellers with domestic connection, one can be certain that lack of reliability has an impact on their willingness to pay as also on household behavior". The concept of unreliability was introduced by Munasinghe (1979). In developing countries, infrastructure projects often do not integrate reliability and have an erroneous perception of users needs. But it is necessary to determine the level of service for which users are willing to pay or the level of breakdown that users are willing to accept. The minimum optimal level of reliability is defined at the point where the total benefits are equal to the total costs, or (to speak in microeconomic terms) where the marginal cost of supply equals the marginal cost of breakdowns.

In cities of developing countries, lack of reliability is a characteristic of the water supply system itself: doubtful quality, intermittent supply, seasonal disruptions are all rampant. In normal conditions the supply is unreliable.

The total cost of unreliability is the cost of reducing water supply unreliability (new investments, improved maintenance) plus the cost of unreliability (pollution, productivity loss,

[14] Lecture by drs. K. Schuijt.
[15] She refers to Mac Phail 1993, Briscae 1993, Whittington et al. 1992, Crane 1994, Whittington et Lauria 1993.
[16] Zérah, p. 49.
[17] Ukunda, Kenya, in Whittington et al., 1989.

etc.) and the cost related to water quality (waterborne diseases, individual compensatory strategies).

For Zérah, "the evaluation of the cost of users' strategies is an indirect method of measuring the demand for water", as compared with direct methods such as WTP. It is an alternative, which has already been used in a number of case studies[18]. They show that the lack of reliable water supply has an impact on the willingness to pay. This is very clearly demonstrated by the fact that a farmer in north Gujarat, which is a water-shortage area and where groundwater levels are low, is willingly to pay about Rs 3,000-Rs 4,000 per hectare for irrigation water from tube wells, which are owned by a group of farmers in the form of 'irrigation companies'. He is reluctant to pay for the unreliable water supply from the government canals at the rate of Rs 830 per hectare[19].

"These studies verify that households with in-house connections often undertake long term investments to solve problems of water quality and water supply unreliability", with a diversity of strategies, and that "proportionate to their income, the poorer households ended up paying more for water than households with higher revenues"[20]. According to Zérah, such studies are easier to apply than those of WTP and that their results are comparable to those of the CVM. She claims her study to be the first using such an approach within a large metropolis.

The third chapter shows the current situation of water supply in Delhi, in terms of its quality and constraints.

Being the capital, Delhi has a special status and benefits from highly subsidized service. Even though the average consumption of water is officially estimated at 240 lppd (the highest in India), daily newspapers denounce shortages. Because of physical losses of 30%, the average per capita consumption is reduced to 173 lppd. In 2001, its population should have reached between 12.8 and 14 million inhabitants. Until 1998, the institution in charge of water was the Delhi Water Supply and Sewerage Disposal Undertaking (DWSSDU), under the municipal corporation of Delhi (MCD). Since 1998, it became the Delhi Water Board (or Delhi Jal Board) which is autonomous and is still responsible for pollution monitoring, water resources management and treatment of waste water. Zérah's research was conducted at the time of the DWSSDU.

[18] In south Asia, we can mention Faisalabad and Gujranwala in Pakistan (Altaf, 1994), Jamshedpur (Sethi, 1992), Vadodara (Vaidya, 1994) and Dehradun (Choe et al., 1996) in India.
[19] B N Navalawala, EPW (Economic and Political Weekly, Mumbai).
[20] Zérah, p. 58.

Situated on the banks of the river Yamuna, the city is mainly supplied by surface water from the Yamuna and the dam on the Beas (a tributary of the Indus). Underground water represents 11% of water resources, but it is limited and diminishing. Sub-soil water has become polluted[21], and water-table levels decreased by 2 to 4 m. between 1983 and 1994. In addition, as we will see, a large number of private tubewells have been dug by households (and also the industrial sector), out of any regulation. Concerning surface water, Delhi has no primordial right on the Yamuna and uses water from the Tajewala dam on the Haryana, waiting for 3 other dams (Tehri, Kishau and Renuka)[22]. It negotiates with neighbor-states to get more water from the Yamuna[23]. The water supplied in Delhi is treated, but risks of water contamination during distribution are extremely high (in a cholera epidemic in 1988, 643 people died and 85000 fell ill), leading the Supreme Court to order solutions[24] in 1997. A major concern is the uneven distribution of water between areas and households[25]. The areas of New-Delhi, with a high concentration of well-off households, benefit on average from a better supply. On the eastern bank, development is recent (with a large number of unauthorized colonies) and the network is inadequate. Some studies on slum areas reveal very low levels of consumption[26], sometimes less than 50 lppd. But "as water is supplied free or almost free[27], the price of water may not influence consumption". Levels of service show considerable differences between the North (with constant supply) and South (with a very unreliable supply), because water treatment plants are almost all situated in the North of the city. At the same time, only 40% of the daily production is paid for: As a result, half the DWSSDU expenditure was financed by loans.

"Policies aiming at improving the distribution system as well as looking at cheaper supply alternatives should be promoted"[28] : reduction of leakage, rationalization of distribution, rainwater harvesting, better trained personnel… All this necessitates supplementary financial resources (altogether with the involvement of the civil society), thus a change in prices and tariff structure (progressive tariff, this is under way). This is what has been suggested by the Planning Commission. "For long-term planning of Delhi's water requirements, it had urged the development of nearby water resources, promotion of rooftop water harvesting, amendment of the existing building bye-laws, adoption of measures to prevent deterioration of

[21] According to the Central Ground Water Board, Ministry of water resources.
[22] They would cost Delhi 3 billion rupies (in 1997, 1$ = 33.5 Rs.). See map 1.
[23] An agreement was signed on May 12th, 1994.
[24] …new treatment plants
[25] More than 80% of the demand is for domestic purposes.
[26] Lall 1991, Vhai 1990, Ali 1990.
[27] 0.021 US$ per cu m, with a cost of production of 0.079 US$ per cu m.
[28] Zérah, p. 76.

the water table, measures to control the percentage of unaccounted water renovation and modernization of water supply network systems and recycling of waste water. So far, the Delhi government has achieved precious little in these directions."[29]

The household survey

The fourth chapter deals with the matrix and methodology of the household survey conducted to determine the characteristics of the levels of unreliability of water supply in Delhi. The household survey represented seven million inhabitants, i.e., 75 per cent of the total population of Delhi. More than 80 per cent of the households under survey were owners. Approximately, 13 per cent of the household heads were illiterate or semi-literate. The monthly income of the surveyed households covered a wide range from Rs 625 to Rs 16,000 and above, and it averaged Rs 5,667 per month.

The household survey was conducted on 600 in-house water connections (708 households), in 4 urban zones[30], with 11 DDA colonies[31], 6 resettlement and rehabilitation colonies, 22 private colonies, 14 unauthorized regularized colonies and 6 urban villages. In the South (Lajpat Nagar), 75 % of the inhabitants live in private colonies, the level of education is much higher than average and so is the income (Rs. 8120). In the East (Shahdara II), development is chaotic and income levels are the lowest (Rs. 3900). The West (West I) is the most homogeneous zone, with middle-class households. The North (Civil Lines I) has both low and high incomes.

Preparatory work led to the framework of the questionnaire (see Box 1). Many households also spontaneously exceeded it, for example stating that they were giving bribes to meter readers (sometimes the meter reader himself asks for this illegal 'contribution').

The fifth chapter brings out some interesting findings. As we have already seen, the three essential parameters of water supply unreliability are intermittence, lack of pressure and unpredictability, along with the issue of quality:

[29] B N Navalawala, EPW (Economic and Political Weekly, Mumbai).
[30] See map 2.
[31] Delhi Development Authority… public housing.

- Intermittence : Approximately 13% of the households did not receive water every day. 7% did not have any water because the pressure was too low; 3.4% only got water in the winter. Supply was heterogeneous : only 40% had water 24 hours a day, more than a quarter had less than four hours. In the South and West, 37% got less than 2 hours per day (for an average of 5 hours in the South, 10 hours in the West, 16 hours in the East and 20 hours in the North). The study shows that income and intermittence are not correlated, there is even a negative statistical relationship. Floor of habitation has much more influence (better be on the ground floor with 16 hours a day on average). In DDA colonies, more than 70% received less than 6 hours: the service provision is here planned as irregular (with 'part-time' pumping stations). The determining factor is the geographic zone, which confirms the considerable influence of the distribution network.

- Water-pressure : The proportion of households with good pressure was below 10%; 50% received water at an average pressure; 17% had none or extremely poor pressure. "The percentage of households having good pressure did not exceed 12% in any of the zones"[32].

- Unpredictability : Less than 20 % of the households received water at an uniform pressure during different days of the week, irrespective of the zones.

- Quality : More than a quarter of the households treated water daily; 6% did so when they anticipated risks. So, at least one third of the households had doubts about the quality of water (but this depends on the level of education and income). The number of waterborne diseases is a better measure of quality: They occurred in 11.7% of the households in the last 2 years. Five water-quality tests showed that quality could be very poor (in 2 tests) both in affluent and poor colonies.

Zérah has constituted an "indicator of unreliability", based on the number of supply hours and the pressure[33], with a 7-levels scale. It shows that less than 6% had a service comparable to that of developed countries. More than 8% did not have any water or almost none (level 7) and 15 % had a very irregular supply at very little pressure (5 and 6)[34].

[32] Zérah, p. 95.
[33] See tables 1 and 2
[34] See figure 1

In Lajpat Nagar no household had a service that could be compared to that of developed countries[35]. "The proportion of households with a very unsatisfactory level of service was much higher in resettlement colonies. At the same time, however, affluent households did not have a more reliable service."[36]

The sixth chapter is on compensatory strategies, i.e., how consumers adapt to the situation (reducing consumption, reorganizing activities) or resort to one or several compensatory measures (digging wells and tanks, etc). The typology of compensatory strategies, as identified by the author, covers everything that is being done in Delhi in the absence of reliable and adequate water supply, which also lacks sufficient pressure.

Household strategies should logically be subject to the level of unreliability and income, as each strategy has a cost. Each strategy has been considered independently[37]. The study reveals that households are not satisfied with one solution as they resort to at least two options. The most frequent is storage[38]. Almost 30% reorganized their activities in accordance with the water supply, and so many used the sub-soil water to compensate unreliability. The inhabitants of Lajpat Nagar relied on a large panoply of strategies.

-Storage strategies: On an average, people spent 38 minutes a day for storing municipal water. Those with a monthly income lower than Rs. 3500 spent more than 40 minutes, against 26 min. for those having more than Rs. 8000 per month. Water tanks allow a greater margin of independence. But in the case of reservoirs with motors, most people install electric pumps on the main water-line itself and pump water directly during supply hours : it increases the risks of contamination and reduces the pressure in the network. Given the cost of investment (Rs. 4 per litre for water tanks plus 1500 to 3500 Rs. for a motor), only households with an unreliable supply and sufficient income should resort to it. But such an assumption is partly invalidated : Concerning tanks with electric motors, 40% of households in Lajpat Nagar resort to it. When monthly incomes exceeded Rs. 12000, one third of the households adopted this system. When it was lower than Rs. 1250, only 10% did. But from Rs. 3500 onwards, the predominant cause was unreliability, which compelled such an investment even if households did not have high incomes. Concerning tanks without motors, this strategy was favored by

[35] See figures 2 to 5
[36] Zérah, p. 100.
[37] See box 2
[38] See table 3

50% of households with a monthly income between Rs. 5000 and 8000, but much less by others. It prevailed most in DDA colonies (70%)… because the DDA already had installed them. But all households with high unreliability preferred to install motors. This strategy was much more a precaution or a buffer.

-Pumping strategies: The average price of digging wells is estimated at Rs. 150 per meter. The average cost of handpumps, 8.5 m. deep is Rs. 1275, against Rs. 6300 to 8000 for tubewells (25 m. with motor). Handpumps were widespread in Shahdara II (80% of all handpumps found), except in DDA colonies. Almost 20% of households with a very low income had invested in handpumps[39]. They were mainly found close to the river (less to dig) and in non-authorized colonies where they precede municipal connections. 40% of their owners only used them in summer and in case of emergency. Tubewells, by far the most expensive strategy, were mainly used by landlords and high-incomes[40], with high unreliability (5 or above), that is mainly in the private colonies of Lajpat Nagar. With the rapid decline of the water-table, it is unsustainable and even more costly (digging deeper due to the drying up of their wells).

-Adaptation strategies: Water recycling was marginal in all the zones. But reorganizing one's activities[41] was more probable, depending on unreliability and income: with less than Rs. 3500 and unreliability-level 4, 47.7% reorganized their activities.

"Affluent households who suffer most from unreliability are at the same time the most independent as they usually own tubewells."[42] There were thus varying levels of inequalities between households: inequality in the service provided, inequality in the choice of compensatory strategy and thus inequality in the quantity of water stored that was augmented with increase in income.

-Qualitative strategies: In Lajpat Nagar, more than a half of the households treated water as against less than one tenth in Shahdara II. In certain colonies "water was drunk straight from the handpumps without any treatment", despite the foul smell of water

[39] See figure 6
[40] See figure 7
[41] i.e. waking up early, staying awake at night… Even households with tubewells or reservoirs reorganized their activities. The former did so because they wanted to reduce their electricity consumption, the latter to switch on their motors when the water was available.
[42] Zérah, p. 119.

and the diseases amongst children. Levels of education and income played a role in the decision to treat water[43]. Almost 68% with a monthly income of more than Rs. 12000 treated water… but only 3% below Rs. 1250. But only 15% of the highly educated treated water in Shadhara II (70% in Lajpat Nagar) : There is a 'neighbourhood effect' which promotes awareness regarding quality. Indeed, half of the households that raised complaints were in Lajpat Nagar : There, one third had protested at least once in the last two years.

The economics of water supply unreliability

The last chapter is the crux of this book in terms of the economic cost of unreliable water supply in Delhi.
The cost of reducing unreliability includes both monetary[44] and time opportunity[45] costs. According to the study, "the total cost for the whole of Delhi amounts to Rs. 3 billion annually, that is an average cost of Rs. 2000 per household"[46]. Time opportunity costs represent half of it[47].

But the average cost hides considerable differences : 39% of the households had not made any investment and spent less than Rs. 40 a year, whereas 15% spent more than Rs. 2000 per year (monetary costs). Concerning the time opportunity cost, it was zero for 38% of the households and more than Rs. 4000 for 5% of them. The monetary cost was 8 times higher for households having an income of more than Rs. 8000 than for those with an income below Rs. 3500. But the average time opportunity cost was 2.5 times hugher when income was below Rs. 3500 than when above Rs. 8000. Calculating the proportion of income spent on compensatory strategies leaves no doubt about the inequalities[48].

The average water bill payed by households was RS. 28 per month… their unreliability costs were 6.5 times higher[49]. "The average willingness to pay for all households also shows that

[43] See figure 8
[44] investments, electric charges, repairs and cleaning.
[45] For time opportunity cost, Zérah assesses the cost of an hour to be Rs. 5. The calculation is based on daily wages for an unskilled worker.
[46] Zérah, p. 128.
[47] See table 4
[48] See figure 9
[49] See table 5

despite the existence of compensatory strategies and the culture of unreliability, households were prepared to increase their monthly billing by more than 50% for an improved supply."[50] Looking more closely, one sees that the WTP was Rs. 15 per month for households at unreliability-level 3, Rs. 25 at level 4, Rs. 37 at level 5 and Rs. 55 at level 6 (yet Rs. 29 at level 7 because of deep distrust in the abilities of the DWSSDU). Households with an income higher than Rs. 8000 were ready to pay 4.5 times more than those with earnings below Rs. 3500. But "if one calculates a willingness to pay on income ratio, one notices that poorer households were eventually prepared to pay as much in proportion to their income, as the more affluent households"[51].

The last point that Zérah makes is to denounce the assumption that "unreliability could be used as a tool to regulate consumption". Her study shows, on the contrary, that "consumption increases due to irregularity because of large storage capacities and water wastage"[52]. In this case, compensatory strategies allow people to get around DWSSDU's intentions.

Unfortunately, in this study, the external cost of unreliability was not available : cost of deterioration of the water-table, cost of waterborne illnesses for the community… (as well as the cost of unreliability for industries and households without connections).

[50] Zérah, p. 133.
[51] Zérah, p. 138.
[52] Zérah, p. 140.

PART 2 : DISCUSSION

The case study conducted by Marie-Hélène Zérah was delivered in the context of a passionate debate over the "right infrastructures" to cope with the water crisis in Delhi at the turn of the millenium.

This case study, in its microeconomic basis, has limitations, and I will first shortly discuss them. But it shows the right direction to look to : The situations she denounced are even worsening by now. This study is thus a starting-point for elaborating new public policies: we will here focus on the issue of water harvesting.

Economic limitations of the study

The first concern raised by this study is the valuation of the time opportunity cost for households: Does it have the same value for households with low and high incomes?
The results of such a calculation can be criticized and interpreted differently according to the importance given to time loss on economic productivity. One could easily argue that households with low income invest more time in compensatory strategies because they have a lower time-opportunity cost than the average one expected in this study.

Doubts can also be expressed on the method of 'spontaneous' willingness to pay, which has been used here. The author seems to prefer the calculation of unreliability costs to the contingent valuation method. It is however useless to debate over which method is "better", as both are only part of a more global analysis of economic values (use value, non-use value, bequest value) of an ecosystem (as explained in the lecture of drs. K. Schuijt). Investments should be based on such a global view.

The cost-benefit analysis chosen by M-H Zérah would be qualified by the lecturer dr. Bouma as technocentric and with a low 'sustainability level' : only private short-term costs are evaluated. In order to guide public policies, more 'ecocentric' studies should have been given, including for instance the long-term economic costs of the depletion of the water-table…

Nonetheless, this case-study by M-H Zérah can still be a starting-point for a process of change.

A worsening situation

In 2001 Delhite newspapers still witness a very poor, if not worsening, quality and reliability of the drinking water delivered in the city. I give you here one typical example, taken from the *Statesman* of May 10th, 2001. The title of the article was "Karawal Nagar gets coloured water":

Tap water comes in different colours in Karawal Nagar in East Delhi. "Sometimes, it is like cola and sometimes like an orange drink," is how the residents describe the Delhi Jal Board (DJB) supplied aqua pura. However its not the only problem. The residents say the water tastes foul. Most of the residents have hand pumps in the houses but rely on DJB-supplied water for drinking and cooking. "At first, we used to fill the water in buckets and wait till the colour settled down at the bottom and then pour it into vessels. But as this water also tastes very bad and often gives stomachache we just leave the tap run till the colour and odour subsides." said Ram Kishore, a resident. An effective if wasteful solution one might think. " But these days no matter how long we wait, the colour does not change," he laments. Asked why they do not complain to the DJB, the residents mostly jhuggi dwellers- have a simple answer: "Its with great difficulty that we got the tap installed. If we complain, they may seal the tap." On the other hand DJB's executive engineer in the area, M C Ram denied the whole issue saying, "If at all there is any colour present in the water, it could be yellow because of chlorine which is used to purify the water or brown, because of the natural iron content."

As hinted by M-H Zérah, mismanagement and unreliability in drinking water supply can lead to severe water diseases. Here again, let us look at a typical example. The source here is the Center for Disease Control and Prevention in Atlanta, USA. The article is by Arti Kapil,

Seema Sood, V.P. Reddaiah, Bimal Das, and Pradeep Seth of the All India Institute of Medical Sciences, New Delhi, India :
An outbreak of paratyphoid fever caused by S. Paratyphi A occurred during September and October 1996 in a residential area of New Delhi, India. […]The second suspected source of infection was the water supply. The residential area receives water intermittently from a central reservoir. The water and sewage pipelines lie close to each other; the sewer line has many joints close to the water pipes, so the water may become contaminated with human excreta from the sewer line. New Delhi had a heavy rainfall toward the end of August and the beginning of September 1996, which led to waterlogging in the residential area. The contaminated soil might have entered the water pipes (because of negative pressure inside the pipes created by intermittent water supply) and contaminated the water supplied to these households.

Groundwater depletion is continuing and accelerating, as M-H Zérah suggested. Groundwater levels are depleting by as much as 2-6 metres in Alipur and Kanjhawla blocks, about 10 m in the Najafgarh block, and spectacularly though sadly by about 20 m in Mehrauli over years.[53] According to Mr Kapil Narula of TERI, the most unhygienic water being consumed by Delhiites comes from handpumps. On the issue of salination of ground water, Mr Hafeezur Rehman of TERI says that due to over exploitation of the ground water a higher amount of percolation takes place in the soil. In the process a greater salt concentration reaches the ground water level.

At the same time, surface water pollution is getting no better on the Yamuna. This has even led the Indian Supreme Court to repeatedly condemn both industries and the central Government. On January 27, 2000, the Environment News Service (ENS) reported this :
On Monday, the supreme court prohibited the discharge of untreated industrial effluents into the Yamuna in the states of Delhi and Haryana. Industries here are primarily responsible for the toxic condition of the river. […]A division of the Supreme Court passed the order on basis of a report of the Central Pollution Control Board (CPCB). The court asked the Board to file a fresh report on the quality of water by March 1. The CPCB report said that the Yamuna's water was not fit for drinking and contained pollutants in excess of the standards fixed for the

[53] Source : TERI (Environmental institution funded by TATA Group), 2001. One can also read : *Effects of urbanisation on changes in ground water quality and quantity in delhi state, india* , S. M. Trivedi, B. R. Yadav, Navindu Gupta* and H.Chandrasekharan, Water Technology Centre and *Division of Environmental Sciences, Indian Agricultural Research Institute, New Delhi, 1999

lowest quality drinking water.[…] Nearly 800 industrial units in Delhi alone stand in the danger of being asked to close up shop for polluting the Yamuna River directly or releasing toxics in the drains that flow into the river. These 800 are in addition to the 1,374 units which were served with closure notices earlier for similar pollution offenses. […]Though all activity is likely to center around effluent treatment plants, neither the Delhi government nor the Delhi Pollution Control Board laid down standards for the effluent treatment plants. With no strict guidelines, the 372 units that reopened had installed their effluent treatment plants according to their own standards.

The Water borne diseases are caused by consuming polluted water. In Delhi the situation is very grave in this respect. The main health-effects of water pollution are Typhoid Fever, Dysentery, Hookworm Disease, Jaundice, Poliomyelitis, Pneumonia, Influenza, and Whooping Cough. In the year 2000, there were around 66,000 reported cases of such infections.[54]

Parts of Delhi have been intermittently reporting cholera outbreaks in recent times. Statistics of cholera cases in Delhi in recent years show they doubled between 1997 and 1998.

While there were 900 recorded cholera cases in 1996 in Delhi and 950 in 1997, the following year witnessed 1,900 cases. There was, however, a decline in 1999 to 1,400 cases.[55]

In 2000 955 people were reported to have suffered from cholera (for 2000, the numbers aren't sure yet). Also 1106 people suffered from Malaria. Major reason for water borne diseases is, as we have seen, mixing of drinking water lines and sewer lines.

The city is not even aware of the health risks of a chemical laden Yamuna. The chemicals and metals which the rivers carries and discharges into ground water can lead to neurological complications, the blue baby syndrome, allergies, skin problems and poisoning, which in some cases can't even be detected.[56]

Public policies: the example of water harvesting

Rooftop water harvesting has tremendous potential in Delhi. Traditional water supply systems were often well adapted to the local conditions, local culture and habits. The introduction of

[54] Source : *Swach Delhi,* ACORD (Asian Centre for Organisation Research and Development) for Solid Waste Management Project (Govt. of India, MOEF & Delhi Govt., MCD, NDMC) funded by UNDP.
[55] Source : The Hindustan Times. May 29, 2000
[56] Source : *Swach Delhi…*

centralized water supply systems has, in certain circumstances, led to the decay and deterioration of these systems. The study by M-H Zérah also points out that recycling of water and reorganization of activities was more a reaction to unreliability of supply than a matter of choice for households. This reveals that a vigorous drive for mass awareness of judicious use of water has a great role to play in Delhi, where hardly 6 per cent of the surveyed households reuse water, that, too, only for cleaning the floor or watering plants.

Delhi receives an annual rainfall of about 610 mm, but most of it is lost as run-off. If this water is harvested, it can meet nearly half the city's demands. A few pilot projects were conducted at the campuses of JNU (Jawaharlal Nehru University) and IIT (Indian Institute of Technology). Check dams and rooftop water harvesting structures were installed, which resulted in a rise in water levels in about 60-m radius from the dams and the water harvesting areas. A project has been started at the President of India's estate to recharge groundwater, using water that would otherwise flow into the drains.
Some of the benefits of rainwater harvesting are as follows

- Increases water availability
- Checks the declining water table
- Is environmentally friendly
- Improves the quality of groundwater through dilution mainly of fluoride, nitrate, and salinity
- Prevents soil erosion and flooding especially in the urban areas

Local original solutions exist in the context of water harvesting :The centuries old "*baolis*" or step-wells…
Delhi is bestowed with many ancient water reservoirs called *baolis*, built in the time of various dynasties that ruled this historic and ancient city. Constructed centuries ago to provide and store water and as a back-up during droughts, most of the *baolis* today lie in ruins, wasted and disused.
In 1998 the Indian National Trust for Arts and Cultural Heritage (INTACH) conducted an elaborate study on the benefits of reviving these *baolis*. The report titled 'Blue Print for Water Augmentation in Delhi' suggested several steps for harvesting ground water to the Delhi government. According to Suresh Rohilla of INTACH, " Because of the steep depletion in the level of ground water, we must start making use of traditional methods of harvesting rain water inside these *baolis*."

The stored water (whose volume has been estimated at 8.87 million cubic meters) can be used either from the surface or can be extracted from the ground while these step wells and ponds simultaneously serve to recharge underground aquifers.
The study also draws comparison between building new dams and maintaining the *baolis*. It says it is far cheaper to keep the baolis recharged than to go in for the high cost and environmentally controversial dam projects.[57]
The INTACH study also suggests an increase in the storage capacity of ancient ponds by desilting and widening them. For years these ponds have been used as dumping grounds. The water quality can be improved by replicating the principles of wetlands, by the systematic induction of aquatic plants and fish… a very inexpensive treatment, which looks like the kind of comprehensive solutions promoted by dr. H.L.F Saeijs.

At the same time, a number of other inexpensive solutions are present :
May be we should look at decentralized rain storm water disposal and open up the good old concept of brick lined storm water drains which exist outside every house but have been either plastered or replaced with huge storm water drains. These closed storm water drains presently stand silted and do not serve the purpose in any case. The flooding of streets with the most insignificant showers illustrate the redundancy of these. In addition strategic areas should be excavated for harnessing the rain water off the roads. Apart from being far more cost effective, easier access to these would also provide for better maintenance.[58]

Households could also combine the Kitchen and Bath waste with the soil disposal system. The kitchen and bath waste would be disposed of in the storm water drains traditionally outside the house as enumerated above. This would be the Delhite version of the 'Grey water' introduced by lecturer dr. Van Ast !

But such reforms imply a change in mentality, as explained by Dan Johnson in his analysis[59]. :
By following the industrial tradition of ignoring preindustrial wisdom, today's planners are also ignoring solutions to contemporary problems and insights on the historical roots of these problems. […] *"Alternative" supposes "otherness," and to technocrats attached to culturally-dominant water and sanitary packages, it is understood as "second-rankness." However, a*

[57] INTACH, *Blue Print for Water Augmentation in Delhi,* New-Delhi, 1998.
[58] Source : ANANGPUR.COM
[59] Dan Johnson, *Urban and Rural Water Harvesting in Delhi NCT: Analysis of a Plan for Delhi's Water Supply,* University of Washington.

shift in perceptions that honors preindustrial wisdom would make space for better, "alternative" ways of managing water . […] *The change is from the pump-and-dump mentality toward the principles of permaculture, applied at a grand scale. In permaculture, the special qualities of natural systems are consciously applied to the design and operation of human systems.*

A longer extract of this article, with the author's own policy options, is added as appendix at the end of the paper.

Nevertheless, official responses to these issues are already taking place:

Water harvesting has been made mandatory in the capital for all new buildings constructed on plots of 100 square meters and more, the new rules come into effect immediately. If the Central Ground Water Authority gives it the go ahead, the Delhi Government will soon be harvesting nine million cubic metres of rainwater, in the outer Delhi areas close to the Najafgarh Drain.

All set to take off, it is a project for on-channel storage of water, including a pilot project in the reaches of the Najafgarh Drain. Once operational, it is expected to provide water for irrigating fields in the nearby villages and also drinking water.

The Irrigation and Flood Control Department of the Delhi Government had come up with the project, following the Intach study report submitted in 1997. The project was approved the next year. Explaining how it worked, a senior official in the I and FC department said: "We will deepen the existing drain, to hold rainwater collected in the monsoons. As soon as the monsoon end, we will close the regulators at Kakrala and the collected water will be distributed throughout the year."

Following the order of the supreme court, Delhi is supposed to have 16 additional sewage treatment plants instead of 9. The installation of 16 should have been completed by 1997, Of the remaining seven, 5 are expected to function by the end of 2000. The other two should come up by 2001.

CONCLUSION

The rapid expansion of low and middle income urban areas in Delhi, due to migration from rural areas, has resulted in a significant growth in informal settlement areas around the city. Poor water quality and insufficient quantity, on the one hand, and lack of sanitary facilities or improper disposal systems, on the other, are exposing the people in these areas to waterborne and fecal diseases. Solid wastes and storm water drainage exacerbate problems. In some areas of Delhi, the quality of life does not meet acceptable health and social standards. This situation might create critical environmental, security and health problems. The sustainable supply of potable water and the disposal of waste (both liquid and solid) for Delhi is now a real problem.

Over the last couple of decades, the quality of municipal services, particularly in mega cities, has steadily deteriorated. Delhi is not an exception to it. This has been caused both by the worsening financial state of the urban municipal corporations as well as the fall in managerial standards. Thefts and leakages in water supply have increased. Pipelines have corroded and fallen into disrepair. The municipal corporations do not have the money to invest in maintenance or repair or setting up of new systems.

Against this backdrop, the participation of the private sector is being viewed as a 'forefront' strategy to remedy the present situation. The Indian water market has tremendous potential. Given the big urban population and the speed of urbanization, investment needs are tremendous. Some experts put the market potential in urban India at almost Rs 8,700 per household per year. Rehabilitation and upgrade of existing water supply systems could form a big part of the private investment because they promise shorter gestation periods and more value for money in the short run. To customers, this would mean an immediate improvement in the quality of water supply.

Transfer of experiences, technology and management practices from developed to developing countries have not proved to be as effective as initially expected for several reasons. No single solution exists for the current problems of Delhi's water management. Site-specific and cost

effective strategies need to be developed and implemented. Long-term solutions lie not only in the construction of a new infrastructure but also in concurrent implementation of demand management and conservation practices, in development of appropriate strategies and regulatory frameworks, and in transformation of existing institutions to become increasingly more efficient. Without such an integrated and concerted approach, sustainable water management in Delhi will simply not be possible.

For the group discussion of this paper, I suggest we could talk about:

- On the one hand, rain-water harvesting: Is this a sufficient solution to the crisis of supply in Delhi? What other public policies, based on the assessments of this paper, would you suggest?
- On the other hand, privatization: Based on the lectures by drs. Klostermann and dr. Correljé, would you favor a privatization of drinking water supply in Delhi?

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Appendix I

Urban and Rural Water Harvesting in Delhi NCT: **Analysis of a Plan for Delhi's Water** Supply

by Dan Johnson

University of Washington

« The present situation has a historical genesis. Urban development in India prior to British colonization and cultural dominance was remarkably different than development occurring today. The fundamental difference is cultural, such that preindustrial Indian values and social patterns produced a different kind of place than industrial values and social patterns do today. By following the industrial tradition of ignoring preindustrial wisdom, today's planners are also ignoring solutions to contemporary problems and insights on the historical roots of these problems.

The city of Delhi has been built upon seven times since the 800s. Earlier cities at Delhi had a water supply based on tanks (*johads*), wells, and natural streams draining the forested ridge outcrops, both in the north and the southern Aravallis. In 1639, with the siting of *Shahjahanabad* (known today as the old city or Old Delhi), the water supply of the city was for the first time based on the river Yamuna (*Jumna*). The Western Yamuna Canal was completed to bring the river waters to the city from 75 km north. This was the beginning of Delhi's dependence on river water. In the past, far fewer than one million people inhabited the region, dependent on rain-fed streams and storage. With the construction of New Delhi and the subsequent post-independence population explosion, driving the urban population above 10 million, the capture of river water has reached to the Himalayas. Since the introduction of piped water, tubewells with diesel pumps, and rapid urbanization, most of Delhi's preindustrial water systems have fallen into disuse and neglect. […]

The concept of "alternative" is defined in relation to the ideological dominance of most official water projects. "Alternative" supposes "otherness," and to technocrats attached to culturally-dominant water and sanitary packages, it is understood as "second-rankness." However, a shift in perceptions that honors preindustrial wisdom would make space for better, "alternative" ways of managing water . […]

1) Natural drainage channels in the urbanscape and regionscape

Storm drainage must be designed to correspond as closely as possible to natural patterns, allowing water to be retained and absorbed into the soil at a rate similar to natural conditions. Water quality is enhanced by vegetation and storage, which themselves in turn contribute to the diversity of habitats in the urban ecosystem. Vegetated soils and woodlands provide storage by trapping and percolating water through the ground with minimum run-off and maximum benefit to groundwater recharge. A large number of natural drainage channels wind their way across the city and the region on their way to the river Yamuna. There are nine major seasonal streams in the vicinity of Delhi, all emerging from the ridges and the Aravallis. A few are in good shape, whereas many are carriers of polluted water, with certain stretches having become open lavatories. Undesirable activities would be prevented with the provision of alternatives. When a city's water resources are recycled back into the system, instead of being sent away as runoff, there are reduced costs and increased benefits.

The channels would be shaped, landscaped, and deepened where necessary. Their cleanliness would be maintained with the use of "roots zone" systems, mosquito weed and other marsh plants, guppy fishes to consume mosquito larvae, and aeration. Their banks would be the green matrix of the city, and while serving their primary

function of on-channel groundwater recharge they would also modify the micro-climate. From a climatic point of view, a fine matrix of open spaces, distributed evenly over the whole city, is generally more effective than reliance on a few large open spaces. The impact of major open spaces, the "green lungs" of the city that have long been the ideal of landscape planning in Europe and America, may well be limited in the overall urban climate. Jane Jacobs has observed that the term "green lung" is only applicable to park spaces themselves and has little effect on the overall quality of the air in the city. However, at a small scale, a well-treed open space is a cooler and more pleasant place on a hot day. In *Hinduism and Ecology*, Ranchor Prime writes that "Trees such as mango, neem, or banyan have always been planted along the roads to give shelter and shade, their leaves acting as natural air-conditioners. Sadly these big shade trees along the roads are now becoming rare, but wherever they are found, rooted in the soil of India, they carry with them a brooding sense of magic and history." Restoring the Indian wisdom of trees and small spaces is part of the Delhi water harvesting plan.

2) Groundwater recharge check dams in gullies and gorges of the Aravallis

The best groundwater recharge in a natural system is done as close as possible to the point where rain falls, by the natural vegetation of that place. Nature doesn't often store water, but delays the flow through the ground before it continues its cycle, to maintain the correct moisture regimes for each part of the system.

The check dams proposed for the Delhi Aravallis are similar to, for example, the rural check dams being rebuilt in Rajasthan, near the Sariska Wildlife Sanctuary, using local, traditional knowledge and community labor. Previous dams on the same sites had been built by the villagers' parents and grandparents, but in the years after Indian independence, these ways had fallen into neglect. Villagers had grown dependent on the government with the increasing state control of their commons, and had lost trust in the traditional methods of water management. While large dams like the Tehri Dam are "inherently anti-ecological", small check dams have many ecological benefits, such as raising the local water table (which has made wells and streams wet year-round), increasing the abundance of tree growth below the dams, and benefitting wildlife with seasonal water stored in the reservoirs. Human and nonhuman neighbors further downstream benefit from the deep seepage of water to their wells and the stream enhancement from seasonal wash to perennial resource. Forests and deep-rooted natural vegetation provide a similar groundwater recharge, but without forests in Rajasthan or Delhi, these small dams are helpful.

3) Groundwater recharge storage basins

There exist a large number of abandoned quarries that have been fully worked to the water table, and neglected natural depressions that would be identified and improved for storing surplus water transferred to them from the drainage channels or from their local watersheds. That apart, their functions would be the same as the water channels. […]

The change is from the pump-and-dump mentality toward the principles of*permaculture*, applied at a grand scale. In permaculture, the special qualities of natural systems are consciously applied to the design and operation of human systems. […]

Today's water inadequacies in Delhi have led administrators to believe that there is a supply crisis, when in fact never have the readily accessible quantities been so great, while somehow water is being experienced as scarce. Much of our water problems are man-made. By examining the organic order of preindustrial Old Delhi, one can see that it was formed at human-scale around household and community needs, and was maintained by a symbiotic relationship between the supporting countryside and the walled city. It had a rain-and-river water system that worked. With the British takeover of India came the introduction piped water supply networks and rapid urbanization. Most preindustrial water systems fell into disuse and neglect. It is in this context that

Appendix I

"alternative" solutions have to be considered. A shift in perceptions that honors preindustrial wisdom would make space for "alternative" ways of managing water, compatible in principle with the organic-emulation concepts of permaculture. The costs of the proposed dams in the Himalayas can be utilized in a radically different, ecological manner and in a compressed time-frame. A substantial and multi-featured contribution to restoring Delhi's organic order can be made through water harvesting. »