STORM AND WASTEWATER RENOVATION AND REUSE IN URBAN AREAS EXPLOITING SOIL-AQUIFER-SYSTEM: *AKSHAYDHARA* CONCEPT

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ABSTRACT

The Akshaydhara concept (Gupta and Sharma, 1996), has been examined in a typical urban context of Ahmedabad City. It has been shown that if the available high quality water resources were to be utilised only for potable purposes, we have plentiful. To meet the requirements on non-potable uses, if we could segregate and renovate and recycle the grey component of th edomestic wastewater, there would again be no shortage. Based on a set of new and recent experiments, it has been shown that shallow soil-Aquifer system can be used with advantage for renovation and recycling of the grey wastewater component. It has also been shown that there may be no adverse impact on salt balance on the groundwater quality, if artificial recharging of even 20% of the storm water runoff (or 10% of rainfall) can be added to the soil-Aquifer system.

1.0 INTRODUCTION

High population density and overall relative economic prosperity of urban areas means that they must import food, water and energy resources from the surrounding regions. It also means that there is a greater production of wastewater both of domestic and industrial origin.

This scenario of 'high consumption - high waste generation' can go on only as long as the surrounding areas can provide the required food/water/energy resources and absorb the generated liquid and solid wastes. But, in an overall situation of increased environment consciousness coupled with high population growth and limited land, water and energy resources, this urban profligacy is unsustainable. However, if we could utilise our land/water/energy resources more efficiently, the waste generation and environmental degradation would be correspondingly reduced. Further, by converting our waste products to recyclable products we can decrease our dependence on fresh resources.

Let us examine a typical urban scenario with the example of Ahmedabad City. In Table 1, we give the Water budget for the city of Ahmedabad including the area under administrative control

Table 1 : Water budget for the city of Ahmedabad including the area under administrative control of Ahmedabad Municipal Corporation (AMC) and Ahmedabad Urban Development Authority (AUDA).

1.	Total area of Ahmedabad (AUDA+AMC)	~400 km^2
2.	Average annual rainfall	~730 mm
3.	Therefore, total rainwater availability	~292 x 10^6 m^3
4.	Rain water available as runoff (Assuming 50% of the total rainwater)	~146 x 10^6 m^3
5.	Estimated population of Ahmedabad (AUDA + AMC)	~4 x 10^6
6.	Average daily domestic water consumption	~110-130 lpcd*
7.	Yearly domestic water consumption	~160.6 x 10^6 m^3
8.	Natural groundwater recharge: ~ 15% of the rain water	~292 x 0.15 x 10^6 =43.8 x 10^6 m^3
9.	Annual excess consumption of water in Ahmedabad (AUDA + AMC)	(160.6 - 43.8) x 10^6 =116.8 x 10^6 m^3
	This excess is partly met by the surface water from the Sabarmati river and from April 2000 by import from Mahi river. The balance represents groundwater depletion.	
10.	The estimated grey water generated (73%)	~80 lpcd
11.	Annual grey water generated	~116.8 x $10^6$$m^3$
	Therefore, the exess consumption can, in principle, be made up through recycling of the grey water generated.	
12.	Potable water requirement	~25 lpcd
13.	Annual requirement of potable water for Ahmedabad (AUDA + AMC)	~36.5 x 10^6 m^3
	This water requirement representing ~ 1/6 of the total consumption can be easily met by the available surface and ground water resources.	

* *lpcd = Liters per capita per day*

of Ahmedabad Municipal Corporation (AMC) and Ahmedabad Urban Development Authority (AUDA). It is seen that presently the total water consumption is about 161 MCM, which is approximately 55% of the average annual rainfall or approximately 110% of the estimated annual runoff. Also noteworthy is the estimate of average annual groundwater recharge. This is only ~15% of the rainfall. It is also shown that if the available water resources of Ahmedabad were to be utilised only for potable purposes we have plentiful. To meet requirements of non-potable uses, if we could renovate and recycle the grey wastewater there would again be no shortage. We are talking about recycling of only the grey component because its volume is large and its contaminant content relatively low. However, this calls for establishing a system of (1) segregation of domestic wastewater into the dark (from toilets) and grey (from kitchen and bath) components and (2) renovation and recycling of the grey component. But before one considers renovation and recycling of wastewater, one would like to examine if the City can not manage by rooftop or runoff harvesting of the rainwater only? Considering the rooftop area to be <10% and its runoff coefficient <0.8, the rooftop harvesting potential works out $<24X10^6\ m^3$. This amount, though substantial is substantially less than that responsible for groundwater depletion. That may still be secondary to the fact that to realise this potential, investment would have to be made in creating storage for this volume in such a way that its quality is preserved and its recovery possible as and when needed. Where do you create this reservoir volume? Rooftops are distributed through out the city. Therefore, individual citizens must find construction of rooftop water harvesting structures economical and compatible with their life style so as to participate in a big way to make even minor difference to the water budget. That these two requirements do not easily get fulfilled is the reason rooftop rainwater harvesting not becoming popular in spite of the acute water shortage. Runoff harvesting, as can be seen from Table-1, generates even larger volume with the added concern about the quality.

2.0 AKSHAYDHARA : A COMPLETE SYSTEM FOR URBAN WATER SUPPLY AND SANITATION MANAGEMENT

We also need to consider that in India most rainwater is available during the months of June to September. The number of rainy days varies from 5-50. During the actual rain, spells are generally intense, generating a lot of storm run-off, which, in urban areas, causes local flooding and disruption to life. As mentioned earlier, the problem in harvesting substantial quantities of rainwater in urban areas is the lack of storage space and the cost of artificially creating such facilities. Another problem relates to the vast amount of wastewater that is generated. There is a need to recycle this water for use. Thus, an ideal solution would address both issues together by providing for a quick disposal of storm run-off to avoid local flooding, and renovation & reuse of wastewater on long term basis.

The philosophy behind the *Akshaydhara* model (Gupta and Sharma, 1996) is total water management, in terms of supply, use, conservation and wastewater segregation for renovation by soil and aquifer system (Figure 1):

2.1 Vital components

The *Akshaydhara* means pristine, perennial flow. The concept is based on the results of experiments in Ahmedabad, involving manipulation of shallow aquifers and storm water runoff through percolation wells for accelerated groundwater recharge and recycling of domestic wastewater through the local soil-aquifer system.

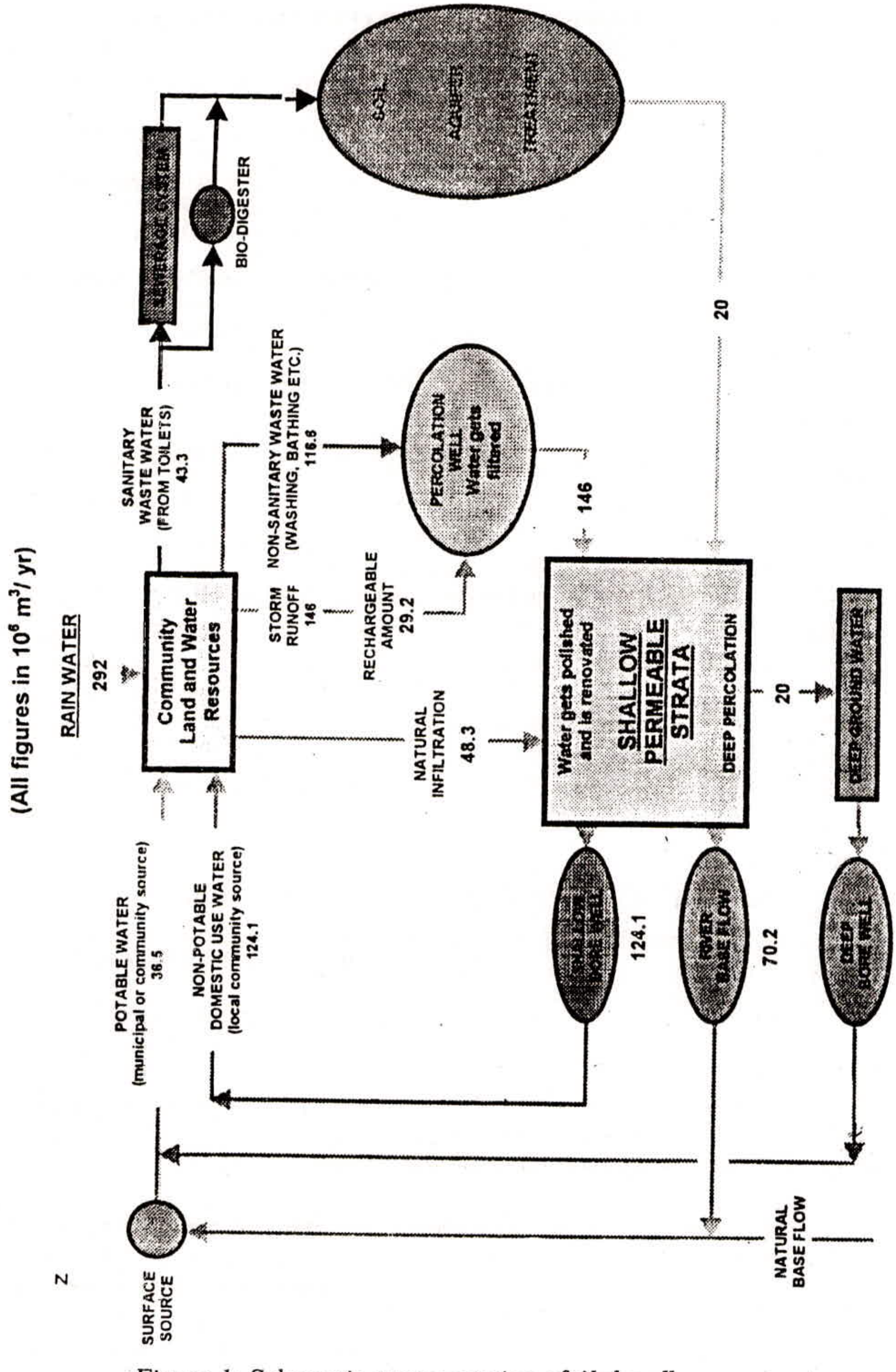

Figure 1: Schematic representation of Akshaydhara concept as applicable to Ahmedabad.

The system comprises of rainwater harvesting followed by surface/subsurface aquifer storage. An important component of this system is artificial recharging of underground aquifers that have been depleted due to large-scale exploitation. Akshaydhara visualises the inadvertent decline of water table as the availability of a subsurface reservoir space. The storage capacity of this reservoir space is larger than all surface reservoir capacity that may ever be available. Geographically, this space is more where there is larger use of groundwater. Water for recharging is obtained not only from storm water runoff, but also from segregated grey water (from dark toilet source component) throughout the year. In most urban areas, this component is significantly larger than the rainwater that can ever be harvested (Table-1). Before meeting the water table, this grey water component undergoes partial treatment by flow through the unsaturated soil zone. Because of the limiting infiltration/ recharge capacity of soils and aquifers, the system also has to be a spatially distributed one but now rather than individuals, it is the communities with their technical/ administrative infrastructure can be involved. This makes the system practically feasible.

As mentioned earlier, the non-sanitary (grey water) component of domestic wastewater is much larger (>70%) in volume and much less dangerous than the sanitary component (dark water). *Akshaydhara* sets out to manipulate the soil-aquifer system to affect treatment of storm water and domestic wastewater to increase groundwater recharge. Part of the treated, recharged water is pumped and used locally to meet non-potable requirements of the community (Figure 1), thereby conserving high quality water sources. Unutilised recharged groundwater through natural subsurface flow would result in rejuvenating surface water bodies like rivers and lakes.

These perspectives open up new opportunities for artificial groundwater recharge on a massive scale. For practical reasons, major sources of recharge water have to be storm-water and renovated domestic sewage effluents. Today, both are considered to be a source of nuisance.

3.0 SOME EXPERIMENTS

The feasibility of an integrated scheme to use storm water drainage to recharge groundwater was examined through a set of experiments at Ahmedabad (Gupta, Sharma and Shah, 1995). Initial experiments involved filtration of storm water using gravel beds into borewells with perforations facing shallow (less than 20 metres) unsaturated sandy horizons. The results, though encouraging, yielded recharge rates too low (5-20 litres/minute) to recommend the method as an effective storm water recharge measure.

To overcome this problem, it was decided to increase the percolation area of the aquifer being recharged and to provide a temporary underground storage for the large amount of runoff collected during heavy rains. Based on these considerations a percolation well, in many ways similar to a conventional soak pit, was designed and constructed in Maninagar, Ahmedabad with a catchment area of approximately 1500 m^2. Despite a heavy monsoon in Ahmedabad during 1994, with at least 3 spells with more than 100 mm of rainfall within 24 hours, the percolation well did not overflow and the collected water was dissipated within 96 hours. The system resulted in a groundwater recharge of about 1800 m^3 during the entire monsoon season. This established the percolation well as an important building block in the *Akshaydhara* concept.

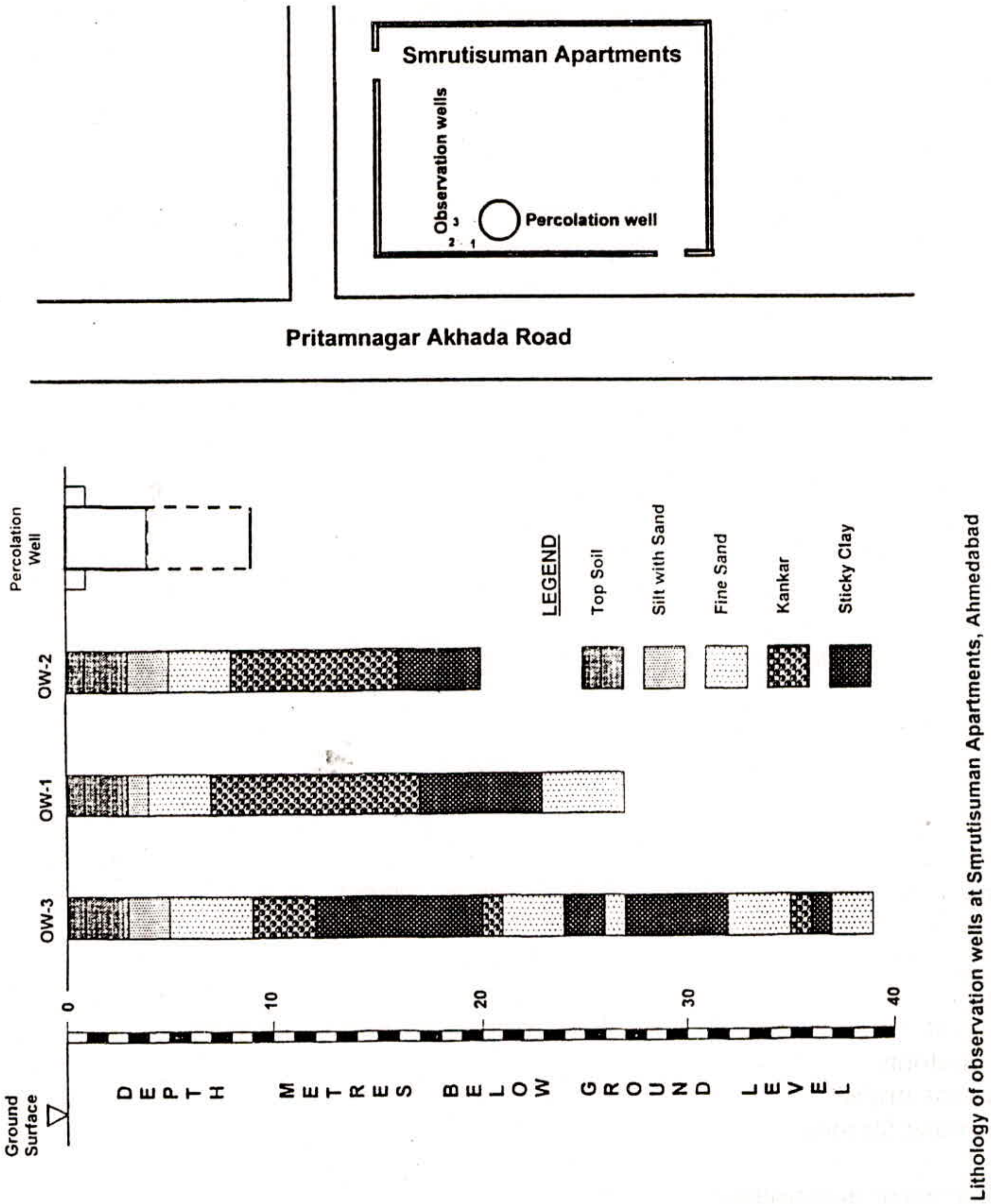

Figure 2: Schematic representation of the percolation and observation wells at Smrutisuman Apartments in Ahmedabad. The percolation well receives segregated domestic grey water from 16 families residing in the apartment building.

An experimentation to evaluate and demonstrate the efficacy of percolation well system as an easily replicable technology for renovation of storm and grey water and its reuse for household applications was carried out at Smrutisuman Apartments at Pritamnagar in Ahmedabad. A percolation well was constructed in June 1995 within the premises of the apartment, which receives (i) grey wastewater from 16 families and (ii) storm-water from the 800 m^2 area of the Society. As a part of the experiment, three observation tube wells (OW-1 at depth 27 m; OW-2 at depth 20 m and OW-3 at depth 39 m) were constructed for water quality monitoring in the immediate vicinity (<3 m away) of the percolation well (Figure 2). No adverse impact on the quality of local groundwater has yet been observed.

The renovation and reuse of domestic wastewater at the dwelling level also seems to be a useful proposition. A "Two Tank Purification System" was constructed at a bungalow having a large plantation area. This system is nothing but a modified sand filter in which the segregated grey component of the domestic wastewater is diverted to the system and this water percolates slowly through a porous sand bed (Figure 3). During this passage the physical and biological quality of the water improves to some extent through filtration and a complex of biological, bio-chemical and physical processes. The impurities present in the raw water are considerably removed in the upper 0.5 to 2 cm of the filter bed.

Another important component of the *Akshaydhara* concept is the development of appropriate technology for renovation of municipal wastewater for use in irrigation and groundwater recharge. Between 1995-1998, work on a pilot project in the Sabarmati riverbed, off the Vasna Sewage Treatment Plant was undertaken. The project comprised of infiltrating primary settled sewage through infiltration basins and pumping out the treated water from a shallow (approximately 20 m) bore well located in the middle of the infiltration basin (Figure 4). Wastewater was treated by filtration through soil layers, anaerobic and aerobic oxidation of dissolved organic matter in the filter bed and in the unsaturated zone (less than 1 m) below and further filtration during saturated flow (approximately 50 m).

The filter beds were periodically dried to rejuvenate their infiltration capacity. The pilot project was operated for more than 6 months during which renovated water at the rate of 1000 m^3 per day had been obtained through two infiltration basins 100 m x 100 m x 0.5 m, with two pumping wells at their centres (Gupta and Nema, 1998). In terms of quality, the renovated water was better than conventional secondary treated water in all aspects (Figure 5). The performance of the SAT system with respect to various parameters and the cost of treatment was estimated to be 30 per cent less, including the cost of recovery of the renovated effluent water. This effluent water conformed to both World Health Organisation (WHO) and national standards for unrestricted irrigation of even vegetable crops that are consumed raw. It can also be used as process water for industries, thereby reducing pressure on deep aquifers.

The experiment demonstrated that a soil-aquifer-treatment (SAT) system can work with high loading rates, even using the primary treated sewage. Elimination of costly conventional biological treatment steps led to considerable cost reduction without compromising on effluent quality. A full-fledged project of 55 million litres per day capacity system, based on the pilot studies, has been submitted to AMC. Presently, the project has not elicited much encouragement

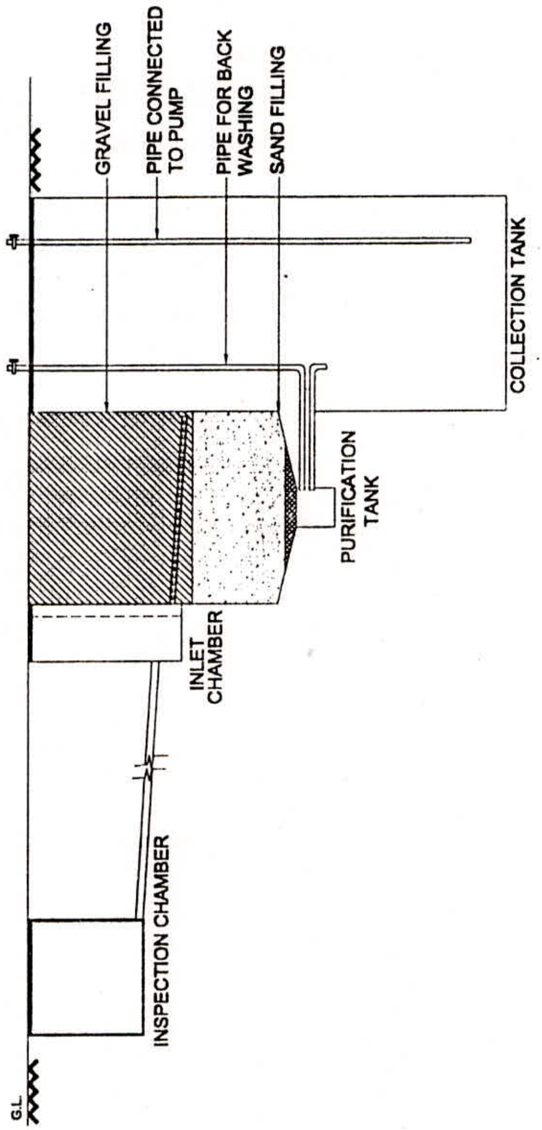

Figure 3: Schematic representation of the Two Tank Purification System for segregated domestic grey water for horticulture reuse installed in a private bungalow at Ahmedabad.

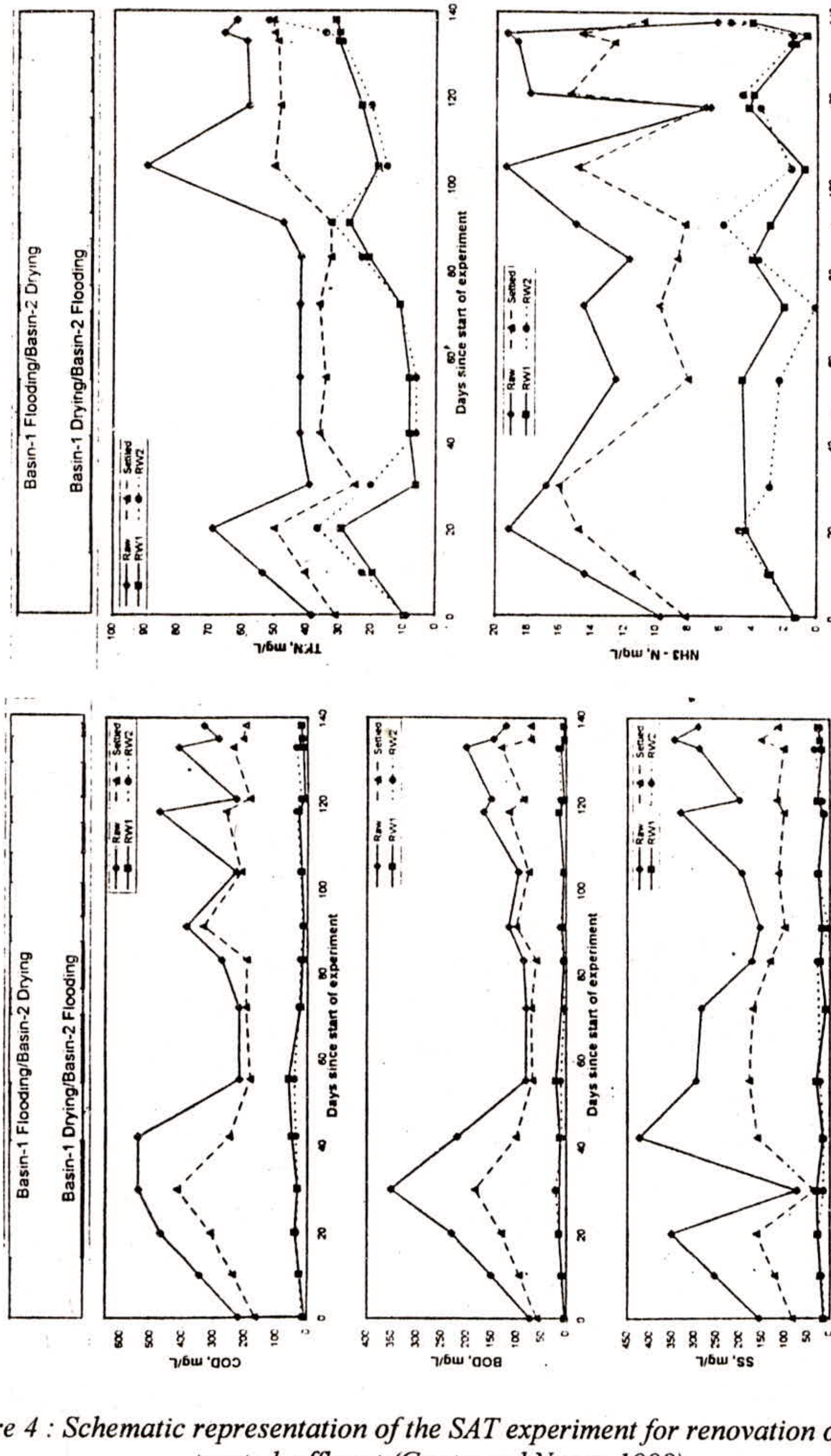

Figure 4 : Schematic representation of the SAT experiment for renovation of primary treated effluent (Gupta and Nema, 1998).

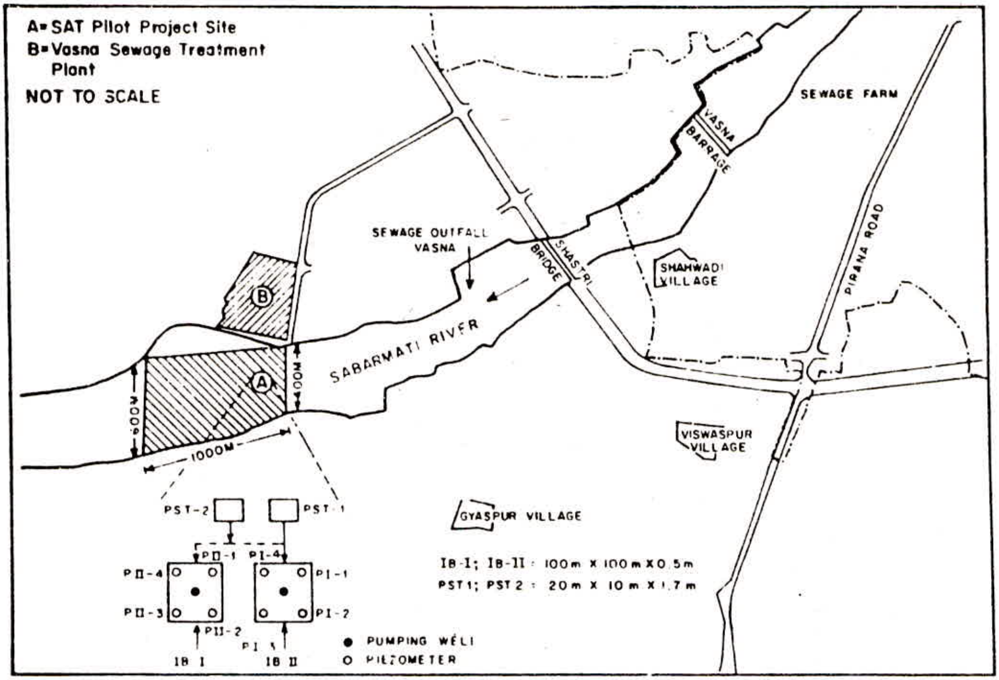

Figure 5: Ahmedabad SAT system performance with respect to parameters COD, BOD, SS, TKN and NH^3-N.

because of the psychological fear of utilising the renovated sewage on a large scale. However the authors hope that these problems can be sorted out.

Extrapolating the success of the SAT experiment that utilised raw sewage and only a limited depth of unsaturated zone, we feel that Percolation Wells using segregated grey wastewater can be an effective distributed means of wastewater renovation and recycling. During the process of recycling, in addition to other constituents, one expects a major increase in the total dissolved solids (TDS) content of the grey water to the extent of about 15%. In Table 2, Salt Budget for Ahmedabad is estimated under certain simplifying assumptions. It is seen that if shallow aquifer system (which at present has become almost dry and is not exploited) is used for renovation of grey water and an additional rainwater runoff is recharged to the shallow aquifer system, its salt content will be little less than the ground water being presently exploited.

4.0 CONCLUSIONS

We have shown that most urban areas even in arid/ semi arid climatic zone of the country can solve their water supply and sanitation problems without importing large quantities of water from the surrounding regions and in the process depriving them. This is possible through

Table 2 : Salt Budget for Ahmedabad

1	Average salt content of ground water Source in Ahmedabad (AUDA + AMC)	~1200 ppm
2	Average salt content of surface water in Ahmedabad (Sabarmati + RASKA)	~400 ppm
3	Storm water salt content	
	If collected from roof tops	~200 ppm
	If collected from street run off	~300 ppm
	Thus, average rain water salt content can be taken as	~270 ppm
4	Total salt from ground water in 10^6 m^3	~1.2 x 10^6 Kg

Approximately 25% of the water consumed in Ahmedabad (AUDA + AMC) is surface and balance 75% of ground water origin.

5	Total salt present in the water consumed -	
	Ground water (1.2 x 10^6 x 160 x 0.75)	~144 x 10^6 Kg
	Surface water (0.4 x 10^6 x 160 x 0.25)	~16 x 10^6 Kg
	Thus, total salt (144 + 16) x 10^6	~160 x 10^6 Kg

Since 73% of used water is assumed to be generating grey wastewater (Table 1), its salt content will be higher than the input water by about 15%.

Therefore, the grey water will be having 15% more salt than the initial source water in every cycle of reuse i.e. (0.75 x 1200 + 0.25 x 400) x 1.15 = 1150 ppm

To reduce the increased salt during recycling, we need to mix the grey water with rain water.

6	Salt content of the run off (roof top+street) water that we may be able to recharge ~20% of runoff i.e.~ 29.2 x 10^6 m^3 with salt content ~270 ppm	~0.27 x 29.2 x 10^6 =~7.88 x 10^6Kg
7	Salt content of grey water	~1.15 x 116.8 x 10^6 =~134.32 x 10^6Kg
8	Therefore, if the recharged runoff and the grey water mix, their total salt content will be	~142.2 x 10^6Kg
9	The total volume of mixed water	~29.2 + 116.8 x 10^6 =~143.00 x 10^6 m^3
10	Therefore, the average salt content	~142.2 / 143 =~994.4 ppm say 1000ppm

This is less than the ground water salt content of 1200 ppm and equal to the salt content of the mix of surface + ground water consumed in Ahmedabad.

application of the *Akshaydhara* concept, which involves use of soil-aquifer-system for renovation and recharge of storm and segregated domestic wastewater of non-toilet origin (the grey water) into shallow aquifers. Several pilot scale experiments have been successfully completed to individually test the components of the *Akshaydhara* concept.

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