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SCIENTIFIC CORRESPONDENCE

Rejuvenating our rivers – The *Akshaydhara* concept

With increasing population and urbanization, it is becoming clear that there is a need to evolve a development strategy that ensures providing the current requirements of resources without compromising the sustainability and growth of future generations. With this perspective, as one looks for solutions to the present-day problems, one often comes to the realization that some of our development policies and practices, particularly concerning water resource management, have not blended with our socio-economic and hydrometeorological constraints. In our opinion, the present practice of wastewater disposal, whether treated or untreated, into surface water bodies is not suited to our country. This practice is flawed for the following reasons:

i) In our country, a very large section of the population, both in rural and urban areas, uses raw water from surface water bodies for human consumption. The secondary treated sewage water can contain up to 20,000 *E. coli* bacteria/100 ml of water that, even when diluted several times in the receiving body, is more than the safe limit for drinking water.

ii) In actual practice, local municipal bodies as well as industries discharge largely untreated wastewater into the surface water bodies, namely rivers, streams, lakes, etc. This practice is largely responsible for fouling up of a large number of surface water bodies including the revered Ganga and other major rivers.

iii) The rainfall is highly seasonal in large parts of our country, and occurs over a short rainy season with a very long (almost three fourth of the year) dry period. As a result, rivers and lakes naturally experience progressive decrease and sluggishness in their flow soon after rainy season. This causes progressive decrease in the self-purification capacity of surface water bodies during the course of a year. Therefore, with the approach of summer season, whereas the wastewater volume increases, the diluting volume decreases, leading to progressive increase in the fouling up of rivers and lakes.

iv) Compounding the problem further is overall increase in wastewater generation due to (a) increased population, (b) increased urbanization, (c) increased industralization, and (d) increasing backlog of creating and maintaining costly sewerage systems and treatment facilities.

v) Increased population has also necessitated higher agricultural production. The largest increase in food production in the country has come about as a result of the green revolution from regions where irrigated agriculture/horticulture has been possible.

vi) Increased abstraction of surface water for domestic, irrigation as well as industrial applications has also contributed directly to dwindling of flow in river courses.

vii) Large-scale exploitation of groundwater for a variety of uses and a consequent lowering of groundwater levels over the years has also contributed to decrease in the river discharge due to reduction in effluent groundwater discharge making up the base flow component.

Thus, a combination of several factors has resulted in dwindling of river flows and the present state of decay of our rivers and other surface water bodies. With progressive increase in economic activity, use of water and resulting generation of wastewater is bound to increase and the problem of degradation of rivers can only become worse unless the base flow can be rejuvenated. This can only be achieved by artificially enhancing the recharge of water to shallow aquifers.

Artificial recharge of groundwater, however, requires two things: (i) surplus water of reasonable quality for which there may be no immediate use and; (ii) an appropriate technology for recharging this water. In our context, one can only think of two sources that may be termed as surplus and may be available for recharging of groundwater substantially. These are: (i) domestic wastewater – a year round dependable source amenable to renovation through an appropriate scheme and; (ii) storm water – essentially a source of nuisance for populated areas due to temporary flooding and disruption of civic life. In addition, the industrial wastewater, once pre-treated to meet existing pollution control standards, can be allowed to supplement the domestic effluent for recharging.

Domestic wastewater may be further sub-divided into two components; (i) the sanitary component, comprising of toilet waste and (ii) the non-sanitary component comprising of wastewater originating from kitchen, bathing, washing, etc. This non-sanitary component of wastewater is more than 70% of the total amount of sewage generated and is much less dangerous than the sanitary component that contains harmful pathogens. The two components of wastewater are carried by separate drains in the prevailing practice of building construction but are mixed subsequently outside the house into a common sewer. Therefore, if we are to

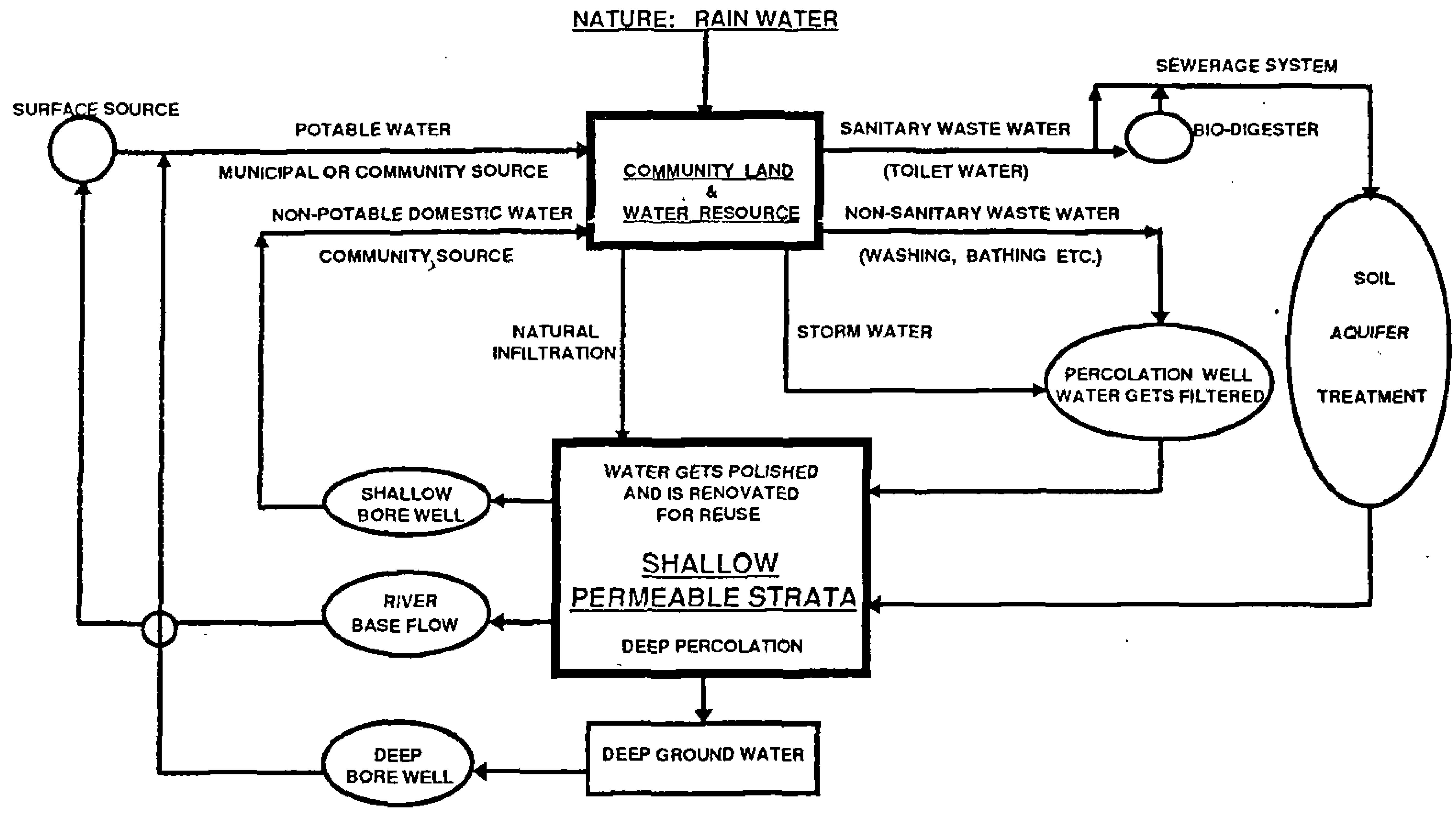

Figure 1. Block diagram representation of *Akshaydhara* concept: A system for total water management.

use the domestic wastewater as a source of recharge water, it would be desirable to have a system that keeps the two components separate and treats/renovates them independently. From a practical point of view, however, in areas where adequate sewerage facilities already exist, it may not be possible to separate the two components, in which case we must look for a third system for renovation of the municipal wastewater.

At first, it may appear that the seasonally available storm water is an unreliable source of recharge water. It is, however, not so because we know from experience that even in a year of deficient rainfall, we get 3–4 intense spells (rainfall >5 cm/day) of rain. The runoff generated is largely of low salinity and relatively free from pathogens, but has large suspended impurities in the form of clay and silt as well as some floating waste. Therefore, if we can devise technological means for effectively filtering the storm water at a rapid enough rate so as to divert a large fraction of the runoff generated in the urban areas to the groundwater reservoir in a time short enough compared to inter-rain spell intervals, we could achieve the dual objectives of storm water drainage and groundwater recharge.

Having identified the possible sources of surplus water, we are now required to identify the technological means for effecting the groundwater recharge. The technology should incorporate: (i) renovation of the storm- and waste-water and, (ii) their effective recharge into the shallow unconfined aquifers.

We have designed and field tested percolation well[1] as a practical hardware component to realize effective renovation and recharge of storm water and the segregated non-sanitary component of domestic waste water. A percolation well is a modified form of the well-known soak pit and is designed to provide: (i) a large volume for temporary holding of runoff water and, (ii) large infiltration area from where water can be recharged directly into a shallow permeable formation at a rapid rate. Thus, a percolation well provides an integrated mechanism for renovation and recharge. With slight modification, such percolation wells can be used in two situations, namely (i) to renovate and recharge segregated non-sanitary waste and storm water from housing units and, (ii) storm water from streets and open public lands. Depending on the expected volume of inflow, a single or a battery of percolation wells may be used. Where a sewerage system is already functional and the municipal waste water of domestic origin is available at a single or a few points, we propose use of soil-aquifer-treatment (SAT) systems. These involve use of infiltration beds and shallow pumping wells with cyclic wetting and drying of the infiltration beds to effect renovation of waste water and its recovery for use in agriculture, industry and for groundwater recharge[2]. A pilot scale SAT system using this concept is already being field tested at Ahmedabad with encouraging results. Figure 1 shows a schematic diagram of our proposed complete water management system defined as *Akshaydhara*.

In the above-mentioned strategy for enhancing groundwater recharge using the storm water and renovated waste water, we are using the system components which are either already in use in some form (e.g. percolation well as an improved version of a soak pit) or have been field tested successfully at least to a limited extent (e.g. the SAT system and the percolation well for recharge of storm water). What is, therefore, new is putting together these components in the form of an integrated system. With such a system in operation, we now have the framework of a scheme to rejuvenate our rivers.

Firstly, any wastewater should be subjected to a primary level of treatment before it is ready for discharging. The industrial wastewater may require special treatment depending on the nature of its toxic load.

Secondly, discharge of any wastewater should be done into shallow depth permeable layers (where hydrogeology would permit such disposal) closest to the source.

Thus in our approach, shallow underground aquifers are used: (a) as a receiving body for the treated wastewater; (b) as an active filter medium for further renovation and polishing; (c) as a means of transmission of the renovated water from the point of discharge to the point of appearance in a stream, lake or recovery through a pump and; (d) as a temporary storage of the renovated water. Thus shallow underground permeable formations/aquifers are central to our concept of wastewater disposal, renovation and recycling.

In our proposed mode of wastewater disposal, pockets of the shallow underground aquifers are likely to receive some amount of pollution load. While most of this load is of bio-degradable nature, some areas will have to be not only earmarked but also monitored for spread of the pollution plume.

One may, however, apprehend increase in the dissolved solids in the underground aquifers because of higher load of soluble salts in the wastewater. This is proposed to be off-set by recharging the low salinity storm runoff water into the shallow aquifers during monsoon season. Some of the recharged water, both of waste- and storm-water origins, will leak into deeper aquifers, undergoing further quality improvement in the process. Thus, a major part of the recharged water would either be recycled or appear as clean groundwater discharge into streams and lakes. Therefore, surface water bodies rather than receiving direct discharge of treated/untreated wastewater, will now receive renovated water resulting from soil-aquifer-treatment. This water should, in general, be clean provided the renovated water has reached the surface water body after traversal of sufficient (~500 m) distance through the aquifer.

In the foregoing, we have outlined our *Akshaydhara* strategy that is a complete water management system. The key element here is manipulation of shallow aquifers to effect renovation of storm- and waste-water through soil-aquifer-treatment and its transmission to surface water bodies, through groundwater flow, maintaining their pristine water quality perennially. In addition, the strategy will also result in (i) groundwater conservation and recharge and, (ii) increased sanitation and general improvement of the living environment. To be effective, the system has to blend with development programmes of different regions having varying hydrogeological and socio-economic conditions. This calls for appropriate research and experimentation in terms of: (i) improving technology for wastewater renovation; (ii) increased understanding of pollutant removal/retardation during movement through soil-aquifer medium and; (iii) monitoring containment and movement of subsurface pollution plumes.

We realize that this approach cannot replace the existing practice overnight or everywhere, but we do believe that a conscious effort through research and innovation will overcome the practical difficulties that may be encountered. This proposed approach will result in an environmentally sustainable integrated system of water resource development and sanitation at affordable costs.

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The gynandromorph of *Armigerus subalbatus* (Diptera: Culicidae)

Armigerus subalbatus (Coquillet), one of the most common mosquitoes in Kerala, is well known for its vicious man-biting habit[1]. It breeds predominantly in foul-smelling water and septic tanks in urban areas[2]. We describe here the morphological differences in mouth parts and the ratio between male, female and gynandromorph of *Armigerus subalbatus*.

The gynandromorph is a genotypic mosaic, which phenotypically appears as a combination of male and female tissue[3]. A line of demarcation between male and female organs is always apparent. The gynandromorphs are divided into three broad types[4]. (a) Anterior ♂-posterior gynander: where the anterior region is phenotypically male, head has antennae and palpi typically of a male. The posterior region is phenotypically female, with wings of the female type and abdomen with well-developed ovaries. (b) Anterior ♀-posterior gynander: where the anterior region is typically female and posterior region male. (c) Bilateral gynander: where the right side of the body resembles a male and the left side a female. Head, mouth parts and abdomen of the right side resemble those of a typical male. Head, mouth parts and abdomen of the left side resemble those of a female. Thus, one side of the body – either right or the left, is male-like and the other side is female-like.

Gynandromorphs have been found in the natural population of mosquitoes[3]. They have been described from eleven Culicine genera[3]. Most specimens have head of one sex and the abdomen of the other sex[3]. More than half of the mosquito gynandromorphs have been found in the genus Culex[4]. The gynandromorph of the genus Culex, Anopheles and Aedes have been reported earlier[3,5–7]. The genetic cascade of events resulting in gynanders has been worked out in some detail in Culicine mosquitoes. However, what role can this play in the regulation of sexual differentiation is