Rural Water and Sanitation System in India

Preliminary Design Review

I. Objective

Safe drinking water and clean sanitation is still a faraway dream for many villages in the country. In this project, we attempt to design a local sustainable water supply system and a manageable sanitation system for these rural regions.

II. Subsystems Overview

The entire scope of problems, factors and solutions to solve the problems of safe drinking water and manageable sanitation in rural India is beyond this project; it involves multilateral issues including rainfall pattern, geographical vicinity with water resources, load patterns from agriculture, industry and household usage, sewerage outflow, bio-degradation capacity of soils, government investment, political issues, drought and flood occurrences, and community awareness.

However, in this project, we sharply restrict our domain towards:

1. Solving the problem of making safe drinking water reach every household, through permanent and *sustainable* methods. This includes making the water source, its usage and recycling sustainable, to ensure the community is sustainable. The sustainability has to come from not just the source, but from local authorities, government and industries to control pollutant release into fresh-water sources.
2. Designing a manageable sanitation system, that lasts longer, is hygienic and requires near zero maintenance. Here, we mostly handle in the context of household sewerage wastes.

As a result, the system can be split into the following subsystems, based on their goals:

1. Water Distribution Network
2. Water Storage and Treatment
3. Water Source Sustainability
4. Isolated and Efficient Sanitation Network
5. Manageable Sanitation Collection and Disposal

We elaborate on the objectives, requirements, design and lifecycle of these systems in detail, in the rest of the document, after a thorough problem analysis and objective identification.

In this project, we use the Systems-Approach to solve the problem, through context specific solutions, with tighter integration, aiming to convince local authorities, the government and donors that commitment and effective participation from all stakeholders are needed to achieve 100% safe drinking water and hygienic sanitation coverage.

III. Problem and Requirement Analysis

The most important step to address these issues in the Indian rural context merely happens to be to identify the causes for the current state of affairs. The requirements are merely to resolve these issues:

Water distribution network:

1. does not reach every rural household
2. is not climate and flow resistant - breaks continuously – people give-up
3. develops growth of bacteria and toxic metal salts due to usage oscillations
4. people used to wells, houses don't have taps and water pipelines

Water storage and treatment:

1. at some places, no concrete structures at all – break often due to climate change
2. no protected structures to keep water contamination free for longer periods
3. cannot take peak loads – demand-supply gap
4. misused or inappropriately operated by villagers
5. no municipality supervised treatment and maintenance, unlike urban areas
6. treated water does not meet drinking\environmental standards
7. unavailability of continuous electricity

Water source sustainability:

1. uncontrolled well-digging
2. lack of information about simple, low cost sustainability measures
3. population not aware of effects of direct waste dumping
4. population not aware of pollution due to chemical fertilizers\pesticides
5. industrial polluters not controlled or,
6. industrial treated water doesn't conform to drinking\environmental standards

Isolated and Efficient Sanitation Network:

1. most village household still don't have latrines
2. sanitation network either doesn't exist, or
3. open drainages cause disease spread, foul smell and toxic releases
4. poor community can't afford toilets and closed sewerage mechanisms
5. lack of awareness of ill effects (mortality rate of < 5year babies)
6. bad network with leakages comes into contact with drinking water

Manageable Sanitation Collection and Disposal:

1. no such structures in most villages (open public areas used as toilets), or
2. open drainages directed to rivers streams and lakes
3. not treated before dumping directly into rivers
4. no local containers to save construction cost of houses
5. leaking, unrepaired wastewater containers
6. not manageable by localities and require constant external aid to cleanup

IV. System Design

We now propose a design to solve these issues part by part – each subsystem towards its local goals. However, as an integrated hole, we make a note that the system should be in general, fault tolerant to human maintenance failure or due to collapse of a sub-system; to some extent. For instance, if a sewerage collection tank suddenly leaks, the drinking water system should be isolated enough to prevent contamination. Such failure propagation paths should be sealed inherently in the system. These have to be ensured during implementation through careful planning and tested construction. We shall see more details in what follows.

Water distribution network:

Goals: All the problems and requirements listed above for distribution, in essence, when negated, turn out be the properties of a good water distribution system.

The network has to reach every household, pressure should be sufficient enough to allow equal tapping by all, independent of location. This includes proper civil engineering domain expertise and careful planning before placing the water pipelines.

Pipes should be resistant to thermal and humidity changes. This might require investment from beneficiaries (such as mills and industries depending on agriculture output of such rural areas). Concrete roads above critical pipelines will allow better dissipation of pressure from heavy vehicles reducing their breaking frequency to a large extent. Lead free bacterial resistant pipes should be used, if continuous supply cannot be maintained. Pipes should not have inward leakages to prevent contamination from dirty water.

An analogous, but more thorough planning and design procedure in mentioned in the sanitation network design.

Water storage and treatment:

Goals: Water storage structures to be stable, durable and protective of the quality of the stored water. Overhead tanks should be able to take peak loads. Storage structures should be maintainable by locals and work irrespective of climatic conditions.

Strengthen of structural components: The choice of ground level or elevated storage structures depends on volume requirements, topography, potential for freezing, security issues of water transmission and distribution lines. Foundations for overhead storage tanks must be designed and constructed to ensure uniform support. Unequal settlement impacts the distribution of stresses in the structure and may cause leakage. Water storage structures should be built with suitable watertight roofs or covers that exclude birds, animals, insects, and excessive dust. The roof or cover of the storage structure should be watertight with no openings except properly constructed vents and piping for inflow and outflow.

Location of pumping houses: Pumping houses should be located in such a way that water reaches the pump houses all the time irrespective of the environmental conditions and available pressure.

Water regulation: Amount of water reaching a particular terminal should be regulated. Also water stagnated for long periods of time should be discharged.

Location Choice for Water tanks: They should be on high altitudes so that less number of pump houses is sufficient for distributing water. They should be on suitable geological locations. i.e the ground below can support the weight of the Storage structures.

Water leakage: Leaks can be repaired and prevented by a properly designed construction choices listed above.

Water source sustainability:

Goals: Sustainable measures have to be used to keep the water sources running and re-charged for use at all times. Drinking water has to be provided throughout the year at all costs.

Domestic pollution can only be controlled through awareness campaigns and Industrial pollution can only be controlled through strongly implemented government policies and heavy penalizations. Farmers have to be educated about effect of chemical fertilizers and pesticides in drinking water. Other than this, source sustainability is case specific:

Ground water is available in most of the places. Bore wells are the prime means of using the ground water along with the wells. These can be recharged, through deep drainage or deep percolation; it is a hydrologic process where water moves downward from surface water to groundwater. Recharge occurs both naturally (through the water cycle) and through anthropogenic processes, where rainwater and or reclaimed water is routed to the subsurface. Groundwater is recharged naturally by rain and snow melt and to a smaller extent by surface water (rivers and lakes). Recharge may be impeded somewhat by human activities including paving, development, or logging. These activities can result in enhanced surface runoff and reduction in recharge. Use of ground waters, especially for irrigation, lowers the water tables. Groundwater recharge is an important process for sustainable groundwater management.

Groundwater recharging can be made effective through:

1. Using Bore pipes: We can not only extract water through bore-wells but also replenish the ground water by redirecting the rain water through them at places where heavy rain occurs for some duration and then ceases.

2. Decreasing de-forestation: Tree roots are the prime ways of water getting into soil, by decreasing vegetation cover, ground water levels in that area will be affected. This information should be provided to the rural people to raise awareness.

3. Covering the dried up wells: Dried up wells should not be left open; they should be covered up, and recharged by above methods, so they can be used to replenish them. The three layer technique (sand, brick powder, pebbles) can help to increase the effective water seeping capacity of that place.

Rain water harvesting is the accumulating and storing of rainwater for reuse before it reaches the aquifer. It can been used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses. Rainwater collected from the roofs of houses make an important contribution to the availability of drinking water. In some cases, rainwater may be the only available, or economical, water source. Rainwater harvesting systems can be simple to construct from inexpensive local materials, and are potentially successful in most habitable locations. Roof rainwater may not be potable and may require treatment before consumption. As rainwater rushes from your roof it may carry pollutants, such as mercury from coal burning buildings, or bird faeces. Although some rooftop materials may produce rainwater that would be harmful to human health as drinking water, it can be useful typical home water needs. Household rainfall catchment systems are appropriate in areas with an average rainfall greater than 200 mm (7.9 in) per year, and no other accessible water sources. Overflow from rainwater harvesting tank systems can be used to refill aquifers through groundwater recharge process mentioned above.

Water from other means: This case appears when no source is near-by and the water has to be transported through some means like pipes and tunnels. This requires high cost and effort both for developing, maintenance and transport.

Isolated and Efficient Sanitation Network:

Goals: A proper sanitation network helps to take away all sewerage wastes properly from all houses and surrounding environment in a hygienic way, without causing stagnation or coming in contact with open areas \ roads \ other pipelines and spreading diseases. The sewer system capacity should be such that it can withstand the current sewage wastes and also the wastes possible in future. Villages lacking a good sanitation system, require a complete phase of planning and design:

Planning:

1. Layout of the collection and conveyance system
2. Estimate present and future wastewater flow
3. A recycle system for the wastewater collected like a stabilization pond

Design:

1. Obtain a topographical map of the area.
2. Draw all possible sewer lines with due consideration that flow should be gravity-assisted.
3. Plan for the installation of manholes.
4. Estimate the number of present and future connections each line will serve.
5. Estimate future wastewater flow by multiplying the projected population in the future
6. Determining pipe size: Pipe size depends on the flow, slope and roughness coefficient of the pipe in use. Cumulative population along a sewer line is also a key factor in determining the diameter of the pipe needed. If no more than 1,000 residents live along a line, 8-inch diameter piping should be sufficient for the entire length of the line.

Population	Pipe diameter
1 to 1,000	8 inches
1,000 to 2,500	10 inches
2,500 to 5,000	12 inches
5,000 to 7,500	14 inches
7,500 to 10,000	16 inches

Manageable Sanitation Collection and Disposal:

Rural sanitation has to be promoted as a total package consisting of safe handling of drinking water, scientific disposal of waste water, safe disposal of human excreta, solid waste management and construction of treatment plants etc. However, there has hardly been any significant change in the sanitary conditions in the villages in India for the past two to three decades. Hence, we need to implement a revitalized program which develops procedures to ensure a clean, safe environment. The sanitation provided should be manageable in terms of the control of the flow of waste materials it delivers. Also, a facility which provides sanitation should maintain cleanliness and meet all environmental standards.

Primary Goals:

1. Proper waste disposal (without any side effects)
2. Maintaining high control over the flow of materials (waste/recycled)
3. Blockages/Breakages should be minimized
4. Conducting regular inspections on functioning of the sanitation system

Secondary goals:

1. Generating awareness about disadvantages of inefficient water sanitation methods
2. Mobilization of NGOs to support the program for supervision, monitoring, training and development work
3. Efficient recycling of waste materials

Requirements:

1. Sufficient financial resources
2. Existence of a proper sanitation network structure
3. Low cost loan schemes through NGOs should be adequately supported
4. Skilled task force, that makes sure that sewer lines are maintained & effective
5. Proper governmental regulation to manage and regulate sanitation methods

Design:

1. Proper Waste Disposal

The design for proper waste disposal involves the following two methodologies:

a. Incineration: Incinerators are designed to efficiently and safely burn waste at specified rates and temperatures, with the residuum ash containing no combustible material.

Advantages:

-> Waste volume reduced to less than 5%

-> At sufficiently high temperature and residence time, any hydrocarbon vapor can be oxidized to carbon dioxide and water.

-> Relatively simple devices capable of achieving very high removal efficiency

-> Heat can be recovered

-> Avoids contamination by reducing infectiousness / pollutant levels

-> Most gases are burnt - well designed systems will give no visible smoke or odor

-> Easy to maintain

-> Only solution for certain waste types

Components:

-> Waste pre-treatment - pre-heating or shredding

-> Waste loading systems – conveyors, hoppers, sprayers, etc.

-> Burner management system
-> Combustion chambers
-> Heat recovery
-> Air pollution control device
-> Stack discharge
-> Ash disposal
-> Emission monitoring systems

b. Open Dumping: Solid wastes are mainly disposed to landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing of waste. But it has its disadvantages:

-> Risk from health-hazard-insects, rodents etc.
-> Damage due to air pollution
-> Ground Water and run-off pollution.

2. Sewage Water treatment

a. Up flow anaerobic sludge blanket: Anaerobic process using blanket of bacteria to absorb polluting load; suited to hot climates. Produces little sludge, no oxygen requirement or power requirement, but produces a poorer quality effluent.

b. Land treatment (soil aquifer treatment – SAT): Sewage is supplied in controlled conditions to the soil. Soil matrix has quite a high capacity for treatment of normal domestic sewage, as long as capacity is not exceeded. Some pollutants, such as phosphorus, are not easily removed.

3. Detection of blockages/breakages

Positive displacement flow meters can be used to measure the sewage material flow in a given direction. This greatly reduces blockage/breakage spot identification efforts and hence the repair time.

V. Quality Assurance

1. Quality assurance certification checks by government should be made mandatory on water pipelines and content of lead dissolution.
2. Water purity check has to be conducted on water storage structures at regular intervals to ensure that water is not contaminated and that treatment plants are working properly. Water quality should adhere to ISI drinking water standards.
3. Power consumption should be checked to see the performance of pump houses.
4. Sewer systems have to assure a future load of population after at least 25 years.
5. Use pipe 8 inches or more in diameter for new sewer lines.
6. All pipelines and structures should be industry tested against resistance to heat, humidity and pressure. Chemical transitions should not turn water toxic.

VI. Risk Analysis and Mitigation

1. Subsystems, as mentioned should be fault tolerant to each other.

2. Effective breakage/blockage detection methods described should be implemented to minimize repair times at major pipeline bursts that may otherwise lead to water scarcity or sanitation problems for an entire village.
3. Deteriorating water tables and polluted fresh water sources have to be immediately identified and replenished, before they become permanently unusable.
4. Ground Strength checks have to be conducted regularly (once in a decade or so) to see whether ground is strong enough to support the storage structures.
5. Aggressive environments can lead to corrosion, loss of strength, and toxic releases. Such places should be avoided for constructions, or other insulating materials have to be used.
6. Storms & Floods - Storm containers can be built, which are connected to the main sanitation network; and used in case of storm or flood where excessive water flowing through the drainage pipes is redirected to the containers, where it is stored temporarily and is passed for filtration once the situation is under control.
7. Open Dumping - At the time of floods or storms, the pits might get exposed to the outside environment leading to breeding of mosquitoes and rodents, spreading diseases and polluting the environment. So, either the pits should be dug deep enough, closed properly or incineration should be used as an alternative.

VII. Stakeholder Promotion

Finally, it is important to attract more people towards the idea that their contribution towards improving rural life is of personal, social as well as national significance. Problems and ideas presented here should attract more stakeholders. For instance, agriculture is India's financial backbone, and it's the government responsibility, to make rural life sustainable. Companies and Industries that depend on products from these poor farmers, have to realize their moral responsibility to ensure a better life for them, by strictly implementing pollution control, water conservation, disposal and recycling measures. In effect, all the stakeholders have to realize, they are actually in net profit, and are themselves sustainable, if they "improve efficiency and sustainability of life in rural India".

VIII. Lifecycle and Budget

The life cycle of the physical infrastructure, under the design principles elaborated, should be aiming towards at least 25 years. Serious financial assistance is required for certain manageable sanitation equipment. While this can be substituted with new de-centralized household sanitation approaches, they are still difficult to implement in the poorer sections of rural India.

However, after initial investments by stakeholders, the system can be run at near zero maintenance costs, if villagers are skilled with proper maintenance and operation of their own local equipment. Also, awareness can reduce issues such as pump overloading, sanitation choking, etc.

While, physical structures can be designed with a fixed lifecycle in view, water sources cannot be "reconstructed", and have to made sustainable, under all circumstances, at all costs. We cannot today, afford to have any more wells or streams dried up. Sustainable measures mentioned, have to be implemented by force, by the government, as the topmost priority, as water is a fundamental element for survival of humans and plants.