Traditions Of Water Conservation, Sanitation And Augmentation: Insights From Gujarat

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Abstract

Evaluation of traditional, traditional-modified and modern rainwater harvesting and sanitation systems in Gujarat (India) has revealed a strong case for blending traditional wisdom while devising modern solutions to contemporary problems. Traditional systems adapted to local conditions in India perform well and users prefer water from these sources than water coming from other ones. Also, traditional-modified systems providing drinking water have been well accepted. The main constraint of the roof-top based rainwater harvesting systems is that it limits the water availability since collected rainwater is not particularly sufficient to supply water to users throughout the whole year. Also, the microbial contamination may pose problems at times. Traditional systems that have been modified with modern components in order to improve water quality or water quantity are especially promising.

Keywords: rainwater harvesting, traditional knowledge, water quality, sanitation.

Introduction

The following Zen story is thousand years old. It has been discussed to bring forth a key argument that we would be explained in the following paragraphs.

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> A monk was known to teach in a very subtle manner. He had many disciples and he tried to teach them individually according to their own capacities and skills. One day, one disciple in particular started to argue with him about the need for conservation. The monk asked him to bring a glass of water. The disciple brought him water. When monk had taken the water, the disciple took the empty glass and on the way back to the kitchen, he threw the remaining droplets in the glass away by inverting the glass a few times. The monk saw him doing that. He called him back and asked him what he actually did.
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> *The disciple said, "Nothing, I just brought the glass of water as you asked me to do and then, I took the empty glass back". The monk asked, "is that all, try to remember everything". The disciple recalled the whole sequence of steps and while he was bringing the water he said, "While taking the glass back, I threw just a few drops of water away".*
>
> *The monk said, "What! Just…."*

The disciple achieved Zen by concentrating on the word "Just" and realized that even a drop of water could have multiple destinies. Throwing it away was certainly not a responsible act. Taking it forward, the story is talking about a society where there was no such water scarcity but, the idea of sustainability is redundant throughout the story as well as the evident foresightedness is exemplary.

Another way of looking at the morale of the story would be the concept of sanctity attached to the natural resources, especially water, which reverberates throughout our history. The Vedic concept of "*Panch maha bhoot*" i.e. five elements namely earth, water, fire, air and space which are to encapsulating life, put forth the primacy of natural resources in any form of life existing in the planet. A biblical psalm from the Old Testament *"He sendeth the springs into the valleys which run among the hills. They give drink to every beast in the field; the wild asses quench their thirst. By them shall the* *fowls of the heaven have their habitation, which sing among the branches. He watereth the hills from his chambers…. He causeth the grass to grow for the cattle, and herbs for the service of man…) does express the significance that needs to be attached to water. The Koran states that one cannot not refuse surplus water without sinning against Allah and against Man. A quote from Holy Koran says, "By means of water we give life to everything"*, (Quran, 21: 30). The Prophet Mohamed also said: "Excess in the use of water is forbidden even if you have resources of a whole river". Thus, a common thread about conservation, cooperation and co-evolution of systems runs through the history.

Coming back to scarcity and related incentives for cooperation, Gupta (1981) argued that incentives for cooperation are maximized in the wake of moderate scarcity.

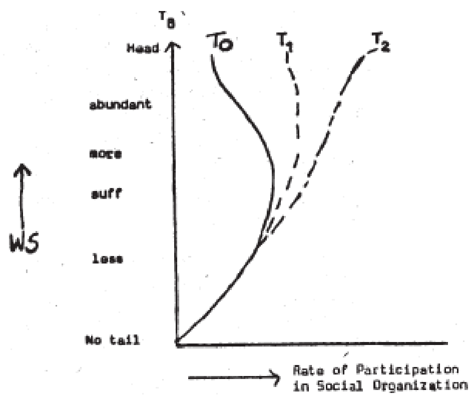

Figure 5

Starting with a very low scarcity, people within any institution have very less incentives to cooperate. As the scarcity increases, the incentives increase up to a certain optimal point where the incentives are maximized and then it starts decreasing. Thus, at a very high scarcity there is also a very less incentive for cooperation. When there is too little water, nothing much is gained by cooperation and when there is abundant water, when the point of cooperation is achieved each point can have as much as one needs.

In a way, the Zen story stresses the need for creating a conceptual scarcity which would, in turn, raise incentives for cooperation and, consequently, would lead to sustainability. It propounds a pre-emptive response to an apparently invisible problem (obviously, two thousands year ago, there was no apparent need for such a dictum, when abundant water existed) which makes the usual knee-jerk reactions of the policy makers today quite unlikely. Their reactions could be characterized by the latter half of the graph wherein there is a demand for cooperation when scarcity increases considerably beyond the optimal point. Thus, results are also quite predictable. The dynamics of institutional building, traditions, culture and education becomes apparent.

Honey Bee network: Initiatives and Perspectives

Traditional, cultural, institutional, educational and technological innovations are required to transform the situation of land and water use. When we conserve water, we invariably conserve land, too (Gupta, 2007; Gupta *et al.* 2004). Gupta (2005) observes that: "If technology is like a word, institutions are like grammar, and culture could be considered as a thesaurus while education creates the mindset." Notwithstanding the pioneering work in the field of knowledge technologies some economically rich people, the Honey Bee Network has been working on several other dimensions of creativity at grassroots such as: institutional innovations, common property institutions (CPRI), cultural, and educational innovations. Honey Bee Network is a crucible of like-minded individuals, innovators, farmers, scholars, academicians, policy makers, entrepreneurs and non-governmental organizations. It helps cross pollinate ideas from one creative community to others, helping them adding value, protecting their identity and ensuring that benefits are shared amongst them fairly (Gupta, 2006, SRISTI 1993).

The CPRI database of Honey Bee network (www.sristi.org/cpri) contains 138 case studies collected from around the world on common property resources' management. Among these, around

38 are directly related to the management of water resources like Neerkattis, Karaikarars in India, gravitation, farmer based on irrigation systems in Nepal and many others from around the world. These cases focus on sustainable management practices of different communities, particularly on informal rules of engagement evolved around water. Also, an annotated bibliography on peasant innovations in the sustainable worldwide development which was published by the Network in 1990 (Gupta, Capoor and Shah, 1990)[2]. It includes farmers' innovations in agriculture and allied fields-pest management, soil management, disease management, nutrition management in livestock etc.; natural resource management- water management, conservation and storage.

Situation in Gujarat

Indian economy has been growing at an unprecedented rate with Gujarat performing better than the national average. The state has a high agriculture based GDP despite having only the 2% of India's water resources. Nearly 51% of Gujarat experiences, less than 30 days of annual rain (Kumar *et al.,* 2007). Around 90% of water is lost through evaporation, run-off and base flow (Bohra and Sharma, 1991). The per capita availability of water is 880 m^3 and in some regions in Northern Gujarat the figures are as low as 407 m^3 per capita which is much lower than the UN criteria of 1000 m^3. Evidently, the ground water level of the state has been declining. In order to be able to deal with the crisis, many projects have come up in the past in the form of dams, reservoirs, check dams etc. Although the State owns a water storage of 14.92 billion cubic meters (BCM), it also owns other projects under construction and into consideration (some of which might have completed by now) that turn out to be 22.17 BCM. The requirement is likely to climb up to 35.3 BCM the

[2] Anil k. Gupta, J. Capoor and R. Shah. 1990. Inventory of Peasant Innovations for Sustainable Development: an annotated bibliography. Ahmedabad, India: Center for Management in Agriculture, Indian Institute of Management

current year and to 46 BCM in 2025. Rainwater harvesting measures, if adopted on a large scale, may alleviate water scarcity even during severe drought years to some extent (Cochran and Ray, 2009; Hatibu and Mahoo, 1999).

The first part of the paper deals with the review of studies on traditional water harvesting, storage and distribution and sanitation to a limited extent in India and worldwide. A review of study objectives of our project, field studies, and ongoing studies and also the activities of WASMO is presented in the second part. The last part deals with policy gaps and suggestions for further studies and action.

PART 1

Water Harvesting

Lately, there has been a renewed emphasis on finding new ways to manage, newer sources to manage and newer uses to manage natural resources such as water. But, a very few have endeavored to find out what we left behind, may be a few decades or few centuries ago. Sen (1993) has rightly argued about the acute need of reviving the "dying wisdom" (Agarwal and Narain, 1997) of traditional water systems' management to meet modern day water requirements.

Traditional water harvesting systems in India

During the Bronze Age period, a city named Mohenjo-Daro (meaning "Mound of the Dead"), situated on the right bank of Indus river, was built around 2450 B.C. They were careful about the proper use of water for different purposes like cooking, drinking, washing and irrigation purpose (Krishnamurthy, 1996).

The Satvahanas (1st Century B.C.-2nd Century A.D.) are believed to have introduced brick and ring wells. The Chola period (985-1205 A.D.) witnessed the introduction of quite advanced irrigation systems, which brought about prosperity in the Deccan region[3]".

As time passed, traditional structures for water harvesting have also evolved due to local ingenuity and changing environmental conditions. Wells are popular structure for harvesting and storage of water in Rajasthan as well as in other parts of India. Several innovations have been put forward by local communities based on their needs and local conditions. Bawari, Jhalara (Narain *et al.* 2005, Ferroukhi and Suthar, 1994), Khatri (Honey Bee, 2000) Kundi, and Tankas are few innovative examples of well (Vangani, Sharma and Chatterji, 1998). Another example of canal based irrigation is that of *Guhls*, which are a traditional form of irrigation system in the hilly regions of north-western India. Kutccha Guhls to concrete Gulhs in Himachal Pradesh and Himalayan mountain regions of Pakistan (Kumar *et al.* 1991; Agarwal and Narain, 1989; Dani and Siddiqui, 1986) are examples of such innovations.

Traditional water harvesting and run-off agriculture

In ancient times, run-off agriculture was widely practiced over the whole arid-region of the Middle East, southern Arabia and North Africa. Even today, in arid Jaisalmer district of Rajasthan, agriculture is facilitated using a *'Khadin'*. Here, water run-off from a rocky upper level area is impounded in the lower area by constructing a bund. Once the water percolates, seeps off or evaporates, there is a sufficient moisture in the soil to grow the Rabi crop (Kolarkar, 1989).

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[3]http://megphed.gov.in/knowledge/RainwaterHarvest/Chap2.pdf, Information on rain water harvesting, Meghalaya Government, Shillong, downloaded on Dec 10,2010

Water supply and sanitation

To meet the water supply and sanitation targets of the Millennium Development Goals (MDG), huge number of people in urban areas require new services by the end of 2015: at least 300,000 people per day demand for water supply and at least 400,000 per day ask for sanitation (WHO & UNICEF, 2000, 2004) and this for every day during 2001-2015 (Mara and Alabaster, 2008). "As for the latest estimation, 94% of rural and 91% of urban population in India have access to safe drinking water." This is a significant improvement in drinking water supply compared to the 2001 census report which revealed that only the 68.2 % of households in India have access to safe drinking water (Khurana and Sen, 2007).

Communicable diseases constitute a significant portion of the overall disease burden in India (Planning Commission of India 2002, National Commission on Macroeconomics and Health [NCMH] 2004). Diarrhea accounts for almost one-fifth of deaths among children, fewer than 5 years in India - nearly 535,000 children (Boschi-Pinto *et al.* 2008). Child mortality and the prevalence of diseases due to poor sanitation (for example, diarrheal diseases) remain high, despite gains in the last two decades. A large proportion of this burden is related to water, soil, and food borne disease *e.g.* dysentery, amoebic dysentery, botulism, poliomyelitis, diarrhea, typhoid, hepatitis and worm infestation all represent potential health hazards in sewerage contaminated waters (Anonymous, 1990)[4]. Studies have rightly argued that "Improving access to sanitation in India will, similarly, reduce the communicable disease burden and child mortality"[5]. In India, between 1992- 1993 and 2005-2006,

[4]Also see http://www.annualreviews.org/doi/pdf/10.1146/annurev.mi.25.100171.002341

[5] Sekhar Bonu and Hun Kim, Sanitation in India: progress, differential, correlates, and challenges.Mandaluyong City, Philippines: Asian Development Bank, 2009.www.adb.org/Documents/.../**India-Sanitation**/occassional-paper.pdf , downloaded on Dec 10, 2010

household ownership of toilets almost doubled from 12.9% to 25.3% in rural areas[6].

In Gujarat, basic facilities like water supply and sanitation are still not satisfactory. There is still a situation where the 54.4% of people have no facility of household toilet as compared with to the 55.4% in India. (Bonu and Kim, 2009; Ramachandraiah, 2004). There is hardly an improvement when compared to 1998-1999, when 54.9% people had no household toilet facility. The same report has put Gujarat in the category of those states which have both rural and urban areas sanitation facilities below an arbitrary benchmark (90% toilet coverage in urban areas and 60% coverage in rural areas). This does not portend well as far as the basic amenities such as health and hygiene are concerned. Though situation has been improving lately.

PART 2

Objectives and Rationale of the field study

A great part of water studies have focused on management, storage and conservation aspects of traditional systems. The crisis of water related disputes has also been discussed by many researchers. However, there is still a lack of literature on the scientific study of water quality or portability in these systems. With reference to water, quantity and quality issues are interlinked (Moench and Metzger, 1992; Kumar 1995a; Biswas 1996). There are studies on water quality where river water, ground water etc., has been scientifically tested and validated (Shah *et al.* (2008); Bharadwaj (2005); Samantray *et al.* (2009); Kumar and Ballabh (2000); Biswas *et al.* (1994); Athavale, R. N. (2003)). Nevertheless, there is a dearth of studies on water portability of traditional systems about water harvesting. Review of literature suggests that there is a lack of data integration

[6] ibid, 2010

between studies on water quality, at one hand, and water availability and supply, at the other hand.
Different systems of water management used in Gujarat were studied in detail. Three case studies were pursued as a part of the project.

Traditional systems

Virda

Introduction

Virdas yield fresh water in the region where the groundwater and soil are highly saline with salinity levels reaching as high as 98000 *ppm*.
Virda is a traditional water harvesting system found in the Banni area of Kutch's district and in the Northern-western Banaskantha and Sabarkantha's districts as well as in some places of the Northern Gujarat. The region is characterized by arid conditions with a day temperature's range going from 10° C to 50° C, meaning an annual rainfall of about 300 mm in short and intensive spells. The ancient wisdom of constructing these men-made ponds first came up during the Kathi's regime. However, not as many *Virdas* have been built in recent years.

Utility

Virda yields fresh water for two up to three months per day and yields about 1000 liters. It is abandoned when the water gets salty. The V*irda*'s durability depends on the intensity of its exploitation as well as water holding capacity of an open tank (Honey Bee, 5 (2):5-7, 1994). The duration of use varies from 20 days to four months. It gradually becomes saline. When tanks are full during monsoon, these *Virda* get plugged by silt and debris, but can be easily revived by clearing these.
Runoff water collected in the natural depressions and artificially excavated tanks provide pastoral-communities with water during and after the monsoon. Water stays in these tanks for a maximum period of three months. Afterwards, tanks turn dry

and '*Virda*' are the only means of providing fresh water for the rest of the period.

They provide drinking water to several villages like Erandawali, Shah, Habib, Mamad, Nani Sadai and Vad (Distt.- Kutch). The population of Erandawali (1200), Shah (2500), Habib (800), Mamad (1400), Nani Sadai (1000) and Vad (550) (Distt. - Kutch) have been served by the *Virdas* for more than 500 years.

The reason for *Virda* to be able to yield fresh water in the saline desert condition is that the long-standing water in the tanks which leaches salts away in the soil including the salts in and around the tank bed while infiltrating that below. During the monsoon period, the soil becomes free of salts and, consequently, the water stored in these layers remains fresh. The '*Virda*' is charged by the water at the top layers of the ground above the saline level as suggested by Chokkakula and Patel (Honey Bee, 5(3):7, 1994). Over a period of two to three months, the continuous draining of water from layers around and below the *Virda* occurs and creates a temporary negative pressure. After some time, the saline groundwater rises from below and the *Virda* becomes saline.

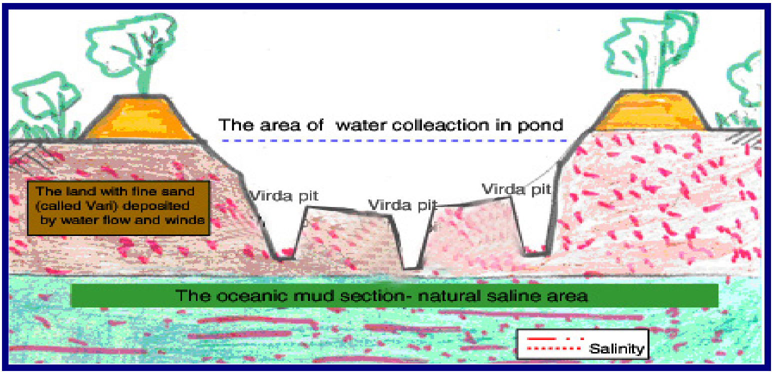


Fig.1 Stage - First year's winter up to summer

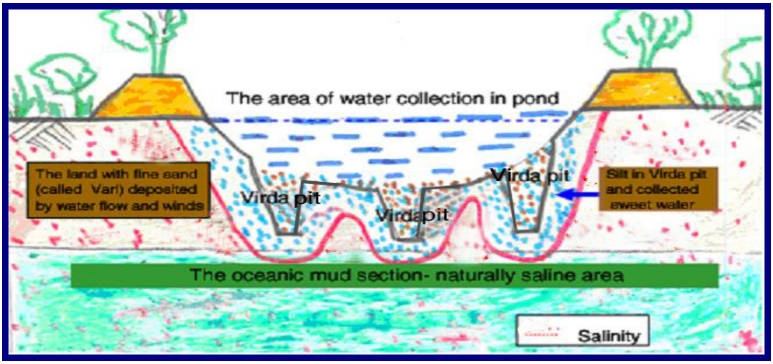


Fig.2 Stage – First year's monsoon up to end of Second year's winter:

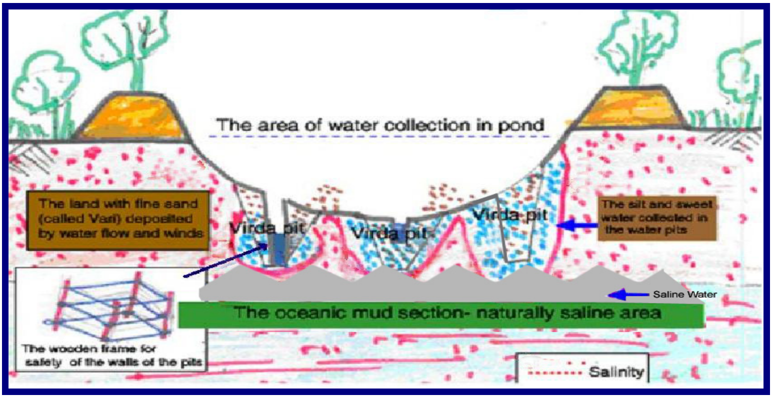


Fig. 3 Stage: Second year's summer

Chemical and Microbial Analyses

pH, TDS and Total hardness: No health-based guideline value is proposed for TDS, pH and total hardness of water. The pH is a measure of intensity of acidity or alkalinity and the concentration of hydrogen ions in water. TDS is the concentration of cations and anions. A high content of dissolved solids elevates the density of water, influences osmo-regulation of fresh water organisms, reduces solubility of gases (like oxygen) and reduces utility of water for drinking, irrigation and industrial use (Shah *et al.* 2008). The palatability of water

with TDS level, of less than 600 mg/litre is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/litre.
The results above show that pH and TDS level of the studied water samples were within the recommended limit. In some instances, consumers can tolerate water hardness up to 500 mg/litre.[1] Result shows that the analyzed samples of water fulfill the optimum standard.

Chemical analyses. The provisional guideline for Arsenic is of 0.01mg/liter and for Fluoride are 1.5 mg/liter[1]. The analyzed water was safe from their adverse effects as the chemicals were well within prescribed limits. Guideline for Chloride and Sulphate has not been established as they don't have direct link to adverse health impacts.

Microbial analyses. In general terms, the greatest microbial risks are associated to ingestion of water that is contaminated with human or animal (including bird) faeces. The presence of *E. coli* provides evidence of recent faecal contamination and it is considered the most suitable index of faecal contamination in water. Total Coliforms are an indicator of infection. Coliforms should be absent immediately after removal, and the presence of these organisms indicates an inadequate treatment. *Pseudomonas sp.* can causes a range of infections but it rarely causes serious illness in healthy individuals without some predisposing factors[1]. As the above analyzed water sample contains microbes, the consumption of such a water could lead to gastro intestinal diseases. Hence, it is unsuitable for human consumption (Khurana and Sen, 2007 and WHO, 2000 & 2008).

Innovation in the traditional system

Lateral Virda

Introduction

Lateral *Virda* is comparatively a recent modification in the form of a lateral hole dug in the existing *Virda* (above mentioned case study). In the Govindpura village (Taluka Veraval, Distt.-Junagarh) and Ramnath and Rabade village (Taluka- Kalol, Distt.-Panchmahal), this technology has been catering water needs for approximately 20,000 people not only for drinking purposes but also for irrigation in the last 30 years. In these villages, the soil is rocky with a hard layer of rocks below 10-15 feet and represents a great difficulty in digging up a new *Virda*. Hence, the ancient system had been modified about 30 years ago.

Construction

In the current system, a lateral hole is dug in the existing *Virda* so that the water from the adjacent pocket flows in-to it. It saves effort, energy, time, space and also expenses that would be incurred while shifting. Sometimes, more than 20 lateral holes can be dug depending upon the availability of water in the above mentioned villages. The size and dimension of the lateral *Virda* depend on several factors such as soil properties, water demand, owners' affordability *etc*. The diameter of a hole varies from four to six inches and the length can be extended up to 300 feet with the direction pointing slightly upwards so that the water can easily come downwards in the lateral *Virda* due to gravity.

Chemical and Microbial Analyses

1. Kandach village

a. **Bore well water:** Two samples of bore well water were analyzed in a period of 4 hours. The pH level was under the limit for both the samples but the total hardness levels of both samples were slightly higher than the standard limit given by the World Health Organization (WHO). TDS level was higher than the optimum limit and was near to the unpalatable limit. In chemical analyses, arsenic was absent while fluoride was found to be above the safe limit in earlier sample but after 4 hours, the amount of fluoride reduced under the 0.5 mg/liter. This comes under the standards of potable water. But, the presence of microbes like Coliforms, *E.coli* and *Pseudomonas spp.* indicated that there are signs of water impurity which can lead to several water borne diseases.

b. Pot water: Two samples of pot water were analyzed in a four hours time span. The pH level was under the optimum limit. However, the total hardness levels of both samples were slightly higher than the standard limit given by WHO. TDS level was also higher than the optimum limit and it was near to the unpalatable limit. Due to a higher amount of TDS and due to the hardness of total water, it is suggested tp avoid drinking water. In chemical analyses arsenic was absent while Fluoride was present above the safe limit in the earlier sample but after 4 hours, the amount of fluoride reduced to 0.0 mg/liter. This was below the standards of potable water. Nevertheless, the presence of microbes like Coliforms, E. coli and Pseudomonas sp were of serious concern.

2. Ramnath village:

a. Bore well water: The pH and TDS level were under the optimum limit for both samples but their level of total hardness was slightly higher than the standard limit given by WHO. In chemical analyses, arsenic was absent while Fluoride was present above the safe limit in the earlier sample. The amount of fluoride is also very close to the guideline value for potable water. However, the presence of microbes like Coliforms, E. coli and Pseudomonas sp were evidence of water impurity which can lead to several water borne diseases.

b. Pot water: The pH and TDS level were under the optimum limit. However, the total hardness levels of both samples were slightly higher than the standard limit given by WHO. In chemical analyses, arsenic was absent; while Fluoride was present above the safe limit in the earlier sample but after 4 hours the amount of fluoride reduced to 1.0 mg/liter. This comes well within the standards of potable water. But, the presence of microbes like Coliforms, E. coli and Pseudomonas sp represent signs of water impurity.

Traditional system

Lime treated Drinking Water

In Parwada and Gorimja (Jamnagar) such a traditional technology has been serving more than 10000 people for the last 300 years. Indigenous people used lime for water treatment. For this, they used pots made of soil powder filled with lime and covered the mouth with a piece of cloth. Then, they used to put the pots in tank and the lime used to leach out slowly through the pores of the vessel and, thus, purifying the water. Nowadays, some people put 3-4 lime packets of 1-2 kilogram each depending upon the size of the underground tank. These packets are lightly pierced so that lime leaches out slowly. The packets are replaced by fresh ones for more effectiveness and sometimes chlorine, too, is used for the same purpose.

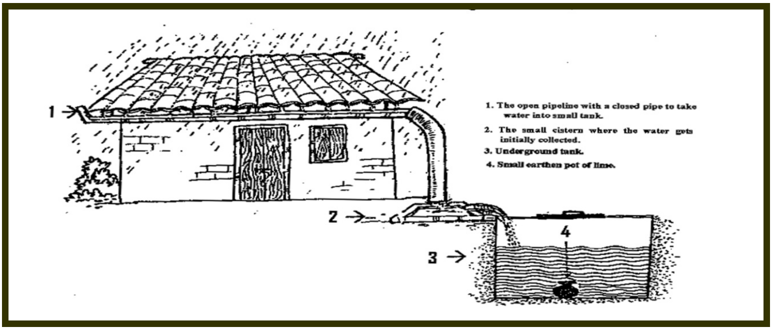


Fig. 4 Sketch of lime treated drinking water storage method

According to those analyses on drinking water treated with lime, two sources in Parwada village were selected; *i.e.* Tank water and pot water. Two water samples were tested on the same parameters.

TDS, pH and Total hardness. The results above show that pH and TDS level of the studied water samples were under the recommended limit of WHO. The degree of water hardness may vary.

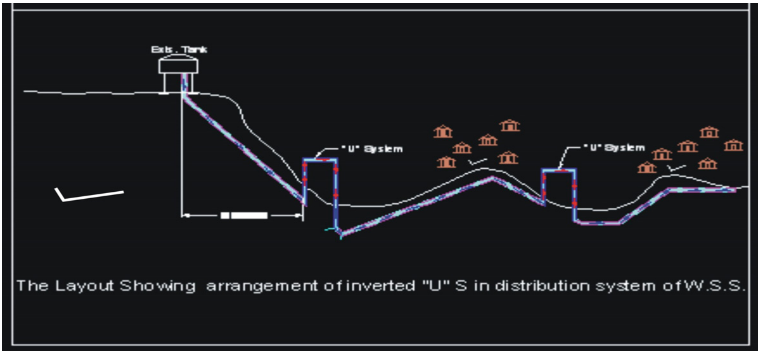
Chemical analyses. The value of sulphate, fluoride and chloride did not change significantly after four hours. Arsenic was absent in all four samples.

Microbial analyses: Micro-organisms like *Coliforms, E. coli and Pseudomonas spp.* were found in a considerable amount in all samples, thus, making the water unsuitable for drinking consumption.

Contemporary systems

Drinking water supply (distribution)

The **'∩'** System (Known as Reverse U system) installed in Varli village in the Bhuj's district of Gujarat is serving approximately 2500 people since 2005. The Varli village has an uneven topography with some parts of the village in low lying areas while some others in upper reaches. As a result, the upper area of the village could not get water. There was no canal in the area; therefore, government started supplying under ground water around 30 years ago by building a towering water tank so that water would flow with pressure. Since water supply depended on the pressure system, even if a single tap opened in the low lying areas, the water would not reach the upper parts. As a result, many times there were disputes over the issue of water supply to upper parts.



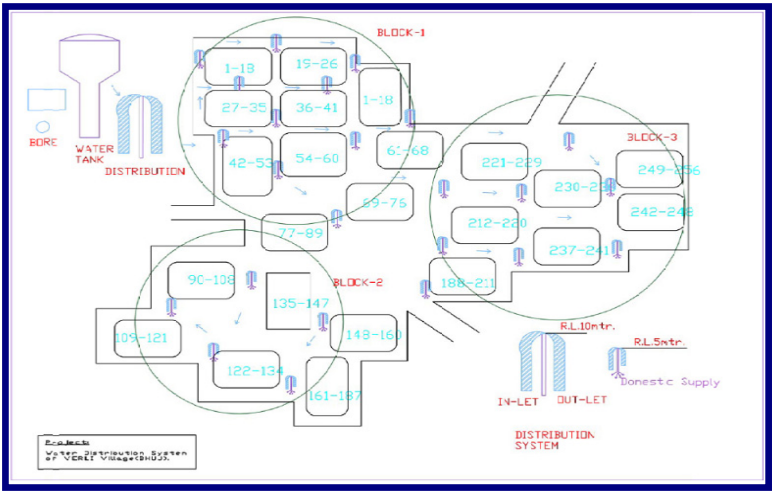


Fig.: Lay-out of water distribution system in Varli (Bhuj District).

Finally, around six years ago, villagers held a meeting in order to put an end to daily disputes in order to find a permanent solution to the persistent problem. Four members of the committee named "***Pani Samiti***" (Water Management Committee) was formed and Jayantibhai Ahir, Babubhai, Welgibhai and Memabhai were appointed as members able to find friendly solutions. The present chairman is Babubhai. To solve the problem related to budget (since it required significant amount of money), they approached WASMO (Water and Sanitation Management Organisation, Gujarat). After a long discussion, WASMO agreed to finance the project with 90% of the financial support and the remaining 10% as *Lok fala* a voluntary contribution by villagers.Each household was supposed to contribute about Rs.100, although some people could afford to contribute more for this project.

The committee members decided to implement the reverse U system in the whole village. With the existing bore well they built water tank near the bore in the village (located at around 150 meters on the outskirts of the village).

Chemical and Microbial Analyses

With reference to analyses on drinking water supply with '∩' System (Known as Reverse U system) two sources of Virli village had been selected; *i.e.* bore well water and far from bore well water. Two water samples from each location were tested at the same time using the same parameters.

TDS, pH and Total hardness. The results above indicate that pH and TDS level of the studied water samples were within the recommended limit (WHO standard).

Chemical analyses: Sulphur concentration near the bore well and from the bore well were not so different. Fluoride and Chloride were also found nearly constant in concentration from all 4 samples and were within the limit. Arsenic was absent in all four tested samples.

Microbial analyses: *Coliforms, E. coli* and *Pseudomonas spp* were found comparably less near the bore well as compared to far from bore well.

Underground sanitation system: Community efforts in Water management and sanitation in Vikaliya

Vikaliya: Demography and Geography

This technology has been serving approximately 5000 people (with 500 houses) in the Vikaliya village (Taluka- Gadhara, District- Bhavnagar) since 1989. Vikaliya village (with a population of 5000 inhabitants) is a recipient of '*Nirmal Gram Puraskar*' (Award for cleanliness village, instituted by Government of India in 2005 under the Total Sanitation Campaign).

Due to the rocky structure underneath of one and half feet, water could not percolate easily causing problems of sanitation in the village. The streets used to permanently remain muddy and, as a result, villagers felt the need of a proper drainage system.

Community effort

Finally, in 1989, three people from the community, namely Jivrajbhai Adhavbhai Singhala, Mohanbhai Singhala and Kanjibhai Merambhai Der decided to approach villagers on the basis of community participation principle. About twenty years ago, when the concept of an underground drainage system firstly came about in the rural Gujarat, these three men managed to convince the community that such an idea could be executed successfully. Villagers agreed to contribute with 1250 rupees per household. The drainage system has been functioning since 1989 without a single instance of choking or blockage.

Lessons

Here, people have done huge developments in terms of participation. The need came from the community and was so strongly felt that the development plan, technology and resources were found within the village. The participation occurred at the cognitive level contrary to the current practice at micro level development projects.

Today, this drainage system connects approximately 500 households and works without any problem.

Villagers devised a unique way of ensuring participation by making visit to dissenting households and, thus, creating a social pressure in order to ensure a due participation and cooperation.

Drainage system in Vikaliya: one innovation leads to another

The construction of check dams by villagers spelled prosperity for the whole village as cultivation practices moved to BT cotton. BT cotton has been successful in the village. Even the *Harijan* community supported the project since they were mainly involved in construction works or in farm laborers: in their own words "*Jo kheduta ne fasal saari thay toh aapanne pann dhando saaro mali shake chhe*" (If farmers get good crops, then, we all would gain from that as farm laborers or construction workers do).

The work of check dams was only completed after the exemplar personal level contribution from villagers. An unprecedented example of such an act was when a man stood up in the village meeting and said that the money he had kept aside for his parent's *kriya* (rituals after the funeral), would be put in the check dam fund. This act prompted other people to do the same. Another highly inspiring example is that of Smt. Ambaben who had saved up a sum of Rs. 1, 00,011/- to be used for her, after death rituals, since she didn't have a son. But she decided to give the entire amount to check dam construction activity. And the first check dam near the village was named after her. Doodhiben became widow at the age of 23 after which she returned to her paternal home to live with her brother's family. She also contributed her life's savings for this cause. Throughout her life, she worked hard and managed to save 61,000/- rupees. *'Doodhi sarovar'* is a part of the village and stands as a hallmark of her sacrifice and service to society. When the check dams were built in the village, people voluntarily contributed with whatever they had.

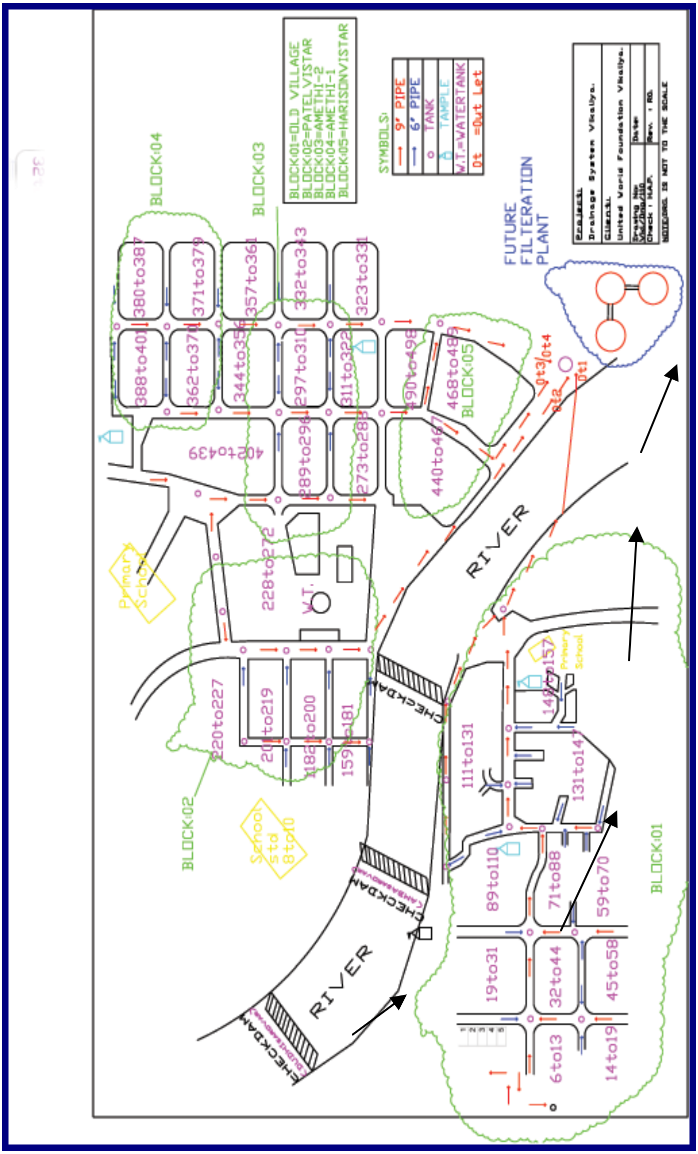


Fig.5 Layout of sanitation system in Vikaliya village (Bhuj district).

Fig. 6 Amba Sarowar, first check dam build near the village after Ambaben donated Rs. 1, 00,011/- for construction activity.

There is a total of 121 check dams in the village out of which some were built by *'Saurashtra Jal Dhara'*. The biggest benefit from check dams has been the recharge of the ground water level. During discussions, it was revealed that there was no groundwater untill 500 feet before check dams came into existence.

There are certain norms, which have been laid down in the village, for the use of check dams. Firstly, no one is allowed to drill a bore well deeper than 200 feet. This was decided after an accident in which all the water from some check dams disappeared and after several enquires it was realized that the water had disappeared in a bore well which was deeper than 500 feet. Secondly, no one is allowed to attach a pump directly into the dam.

With regards to maintenance and desalinization of check dams, *'Saurashtra Jal Dhara'* provided an equipment which is used by the *Panchayat* to clean tanks.

<u>Chemical and microbial analyses</u>

As far as this analysis is concerned, two sites were selected for water collection, one from block no.1 and another one from block no.2 as well as one sample taken each time from the final outlet. Samples were tested by using the same parameters.

Summary of chemical and microbial analyses
The evidence of microbial counts was found in all sample cases. This needs considerable attention for drinking waters' disinfection mechanisms such as chlorination or boiling the water.
The results obtained from laboratory tests show that the pH, total hardness and TDS level were within the limit as well as it occurred for WHO quality standards. Sulphate, fluoride and chloride were at the optimum level and arsenic was absent in all sample case.
Microbial analyses of the sample indicated reasonable counts of different indicator organisms which is a matter of concern. The presence of microbes like *Coliforms, E. coli* and *Pseudomonas* could cause water borne diseases after consumption.

PART 3

Conclusions and recommendations

Modern water supply systems predominantly rely on centralization. In contrast, the traditional systems are very much adapted to local situations and problems: the Virda is a response to saline groundwater, the lateral Virda is a measure to use infiltrating water in hard rock areas with saline groundwater and the lime treatment is a response to arid condition as well as directed to ensure long term storage of water during dry seasons. One exception to this, is the case of equal water supply in Varli village in Bhuj, where centralization has been a mindful strategy in local conditions.

Virda and Lateral Virda are also indirect rainwater harvesting technologies. Both are open systems, contamination can easily happen and, thus, water is not potable. Traditional systems which have been modified with modern components in order to improve water quality (as it is the case of equal water supply system) or water quantity (as for the Lateral Virda) are especially promising as the old knowledge is improved with contemporary materials and equipment and the best of both systems is combined.

For all systems, Operation & Maintenance is a decisive factor for systems functioning or non-functioning. Also, for Virda systems, maintenance is a crucial aspect: users have complained that maintenance works require time and a lot of material, particularly in the case of Lateral Virda.

In general, roof top rainwater harvesting systems are more flexible as they can be installed in all houses, given that the material of the roof is suitable for collecting rainwater and sufficient for storage capacity. The only external factor is precipitation. In the traditional or indirect rainwater harvesting system, also, geological conditions have to be considered. The advantage of traditional technologies, where water is collected from land surface, is that a large area is used for collection of rainwater as the roof top area may not be sufficient to supply one family with water for the whole year.

The indigenous knowledge is precious and needs to be conserved and has to be checked whether knowledge is extrapolated with or without modification to other areas with similar geological and climatic conditions.

Similarly, adaptation for sanitation system in rural areas is also a good sign of development. Creating awareness about hygiene and sanitation will help to improve health standards in rural areas. Still, there is a strong aim for further improvements because sewerage water from underground sanitation system in Vikaliya is still released in rain-fed river, which not only contaminates underground water but also mixes water with rain during rainy seasons. This creates problems for people living in lower reaches and also create bad odour and provide breeding space for mosquitoes.

Many of the traditional water harvesting systems have been abandoned due to a variety of physical, social, economical, cultural and political factors that have caused their deterioration or due to the decline of institutions that have favored them. Prinz (1996) has suggested "the importance of social and economic aspects in the context of analyzing the failures of water harvesting projects and not just the focus on technical lacunae". As argued by Gupta (2007), there are plenty of examples where technological problems or needs have been solved by institutional innovations and vice versa.

Institutions do play a significant role when it comes to management of natural resources such as water. Among the institutional innovations compiled in SRISTI database are: Indigenous Irrigation Engineers - *Waders and boyis*; Voluntary Community Labour - *Kudi maramath* (repair) in South India; Water conveyance without check - natural diversions to drain flood water in the case of *Kuhls/Guhls*; Water conveyance with check - checks are made as for the case of *Kulo, Kurambo, Bandhara, Anicuts.*

Traditional sources under consideration definitely play a significant role in reducing water stress in arid regions of Gujarat. Chemical analyses are necessary for assessing water as potable but the presence of *Coliforms, E. coli* and *Pseudomonas* makes it unsuitable for human consumption. It could cause various water-borne diseases. This is where one could find the inter-linkages of water and sanitation with reference to human and animal health. Special attention needs to be given to ascertain the causes and, thus, remedial action to prevent the same. The focus should be on a holistic approach to assess these systems by taking into account technological, social, economical, political and environmental factors.

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