A SUSTAINABLE RURAL-WASTE WATER MANAGEMENT TECHNIQUE TRANSFORMING VILLAGES

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N.B.1,*N.B.2*[**]

1. Introduction

1.1. Background

Let us go back 5000 years to the ancient settlements of Mohenjo-Daro and Harappa[c]. One of the outstanding aspects of that era was their excellent town planning.

"The quality of municipal town planning suggests knowledge of urban planning and efficient municipal governments which placed a high priority on hygiene. The streets of major cities such as Mohenjo-daro or Harappa were laid out in a perfect grid pattern, comparable to that of present day New York. The houses were protected from noise, odors, and thieves. As seen in Harappa, Mohenjo-daro, this urban plan included the world's first urban sanitation systems. Within the city, individual homes or groups of homes obtained water from wells. From a room that appears to have been set aside for bathing, waste water was directed to covered drains, which lined the major streets. Houses opened only to inner courtyards and smaller lanes.

The ancient Indus systems of sewage and drainage that were developed and used in cities and settlements throughout the Indus Empire were far more advanced than any found in contemporary urban sites in the Middle East and even more efficient than those in most areas of modern Pakistan and India today."[d]

Today, we are talking about the same area (Punjab), which is the working area as far as this paper is concerned.

1.2. Situation in Rural Punjab today:

The ancient culture described above got annihilated, perhaps by a massive earthquake or change in flow of rivers many centuries before the birth of Christ. Rebuilding was never done in a planned manner. Barring a few cities, built in recent times, all development, urban, Peri-urban and rural has been unplanned and driven purely by greed, selfishness

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[*] M.P. Singh is also Technical Adviser to Village Life Improvement Foundation.
[**] Paper presented in the Tech for Seva Conference, September 28-29, 2013.
[c] Indus Valley Civilization
[d] Taken from: http://ancientindiantownplanning.blogspot.in/2010/02/mohenjadaro-harappan-town-planning.html

and with total disregard of the environment. Upto about a decade years ago, rural living areas were congested with no consideration for commons spaces, hygiene or waste disposal . Open drains carrying mixed water occupied nearly a fourth of the width of a street. These open drains ended up in village ponds and the dirty water, used for irrigation and bathing cattle .

The Village life Improvement Foundation, began its work in the year 2000. Its aim is to provide healthy and dignified living conditions in villages .We took up the task of providing clean drinking water, underground sewerage for the whole village;waste water treatment and clean paved roads with street lights. Over the years villages, we have completed our work in 14 villages of Punjab. This paper discuss theevolution of water treatment technologies used in these villages.

2. Evolution 1

2.1 Our first interventions

Our first two interventions were in Village Kharaudi, District Hoshiarpur and in village Brahmpura, District Ludhiana

At the time of intervention the sewage of these villages flowed in open drains. There were two ponds in the village where all the rain water and waste water would collect.

The street were unpaved and had stagnant water which was ground for breeding mosquitoes.

We provided the following:

1) Sewerage connection to each household.
2) *Conventional Gravity Sewers* for transporting sewage
3) These sewers discharged into a collection chamber
4) From this chamber, the sewage was pumped into a conventional two-chamber Septic Tank ensuring inflow at a uniform rate via a dozing pump. This Septic tank had a HRT [a] of 72 hours, in Anaerobic conditions.
5) The water from the Septic tank was then pumped into a recirculating sand filter This was achieved via a pre-programmed recirculation pump. This process is Aerobic
6) Finally, the sewage was discharged into a lagoon, exposing it to the UV rays of the sun.
7) In Brahmpura, the existing Water supply was also augmented.

[a] Hydraulic Residence Time

8) In both villages streets were paved, rendering them much wider and cleaner.
9) Solar street lighting was provided

2.2 Parallel Intervention by Govt. Of Punjab:

Around the same time, The Punjab State Council for Science And Technology introduced the Small Bore Settled Sewerage system. In this system:

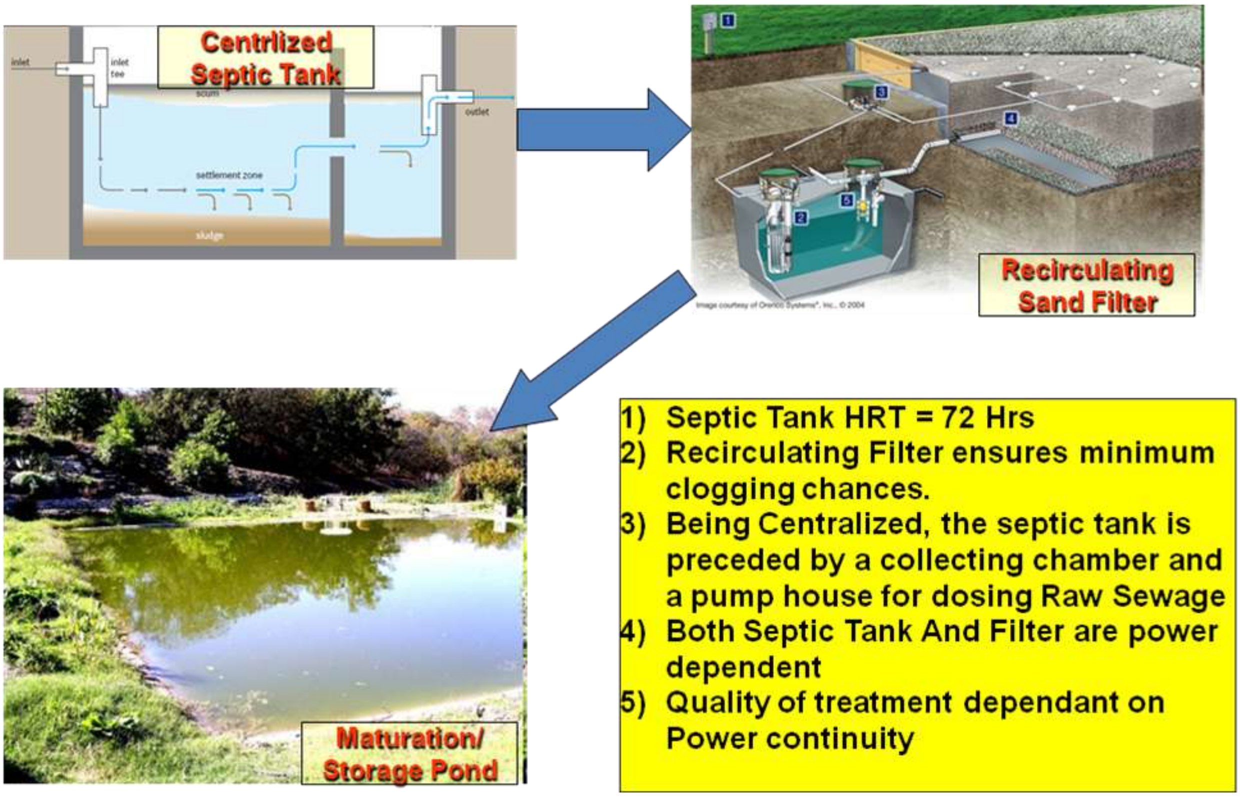
1) A small settler is provided outside or even inside every house, where solids settle.
2) Near solid free water is transported in small bore pipes.
3) Near zero slopes can be maintained as there are no solids to carry.
4) Wherever needed Nolson Siphons are provided to increase the velocity of water.
5) The water is collected in a deep well and then pumped out to Aeration Tanks for further treatment.
6) The first demonstration of this technology was at Village Ulana.

A per-capita cost comparison of the two systems is reproduced below:

Sr.No.	Description	Ulana Details (Govt)	Brahmpura Details (VLIF)
1.	Projected Design Population	2478	3500
2.	Waste Generated/ Capita	80 litres	80 litres
3.	Treatment Scheme Provided	Aerobic followed by floculative lagoon	Anaerobic, followed by recirculation filter and then lagoon
4.	Green House Gases	Let out at 210 different places	*Let out at one place and can be harnessed as biogas.*
5.	Per Capita Cost of Sewage collection System including manholes etc.	**Rs. 1455/-** (High due to 210 septic tanks)	(24,50,000/3500) **Rs.700/-**
6.	Per Capita Cost of Treatment Plant	**Rs. 638/-**	(22,45000/3500) **Rs. 642/-**
7.	Total Per Capita cost before pucca streets	**Rs. 2093**	**Rs. 1342**
Thus the per capita cost of Brahmpur technology is actually less by nearly 30%			
8.	Street Concreting: per capita cost	**Not done**	(3946000/3500) **Rs.1128/-**
9.	Total per capita Sanitation cost	**Not done**	**Rs. 2470**

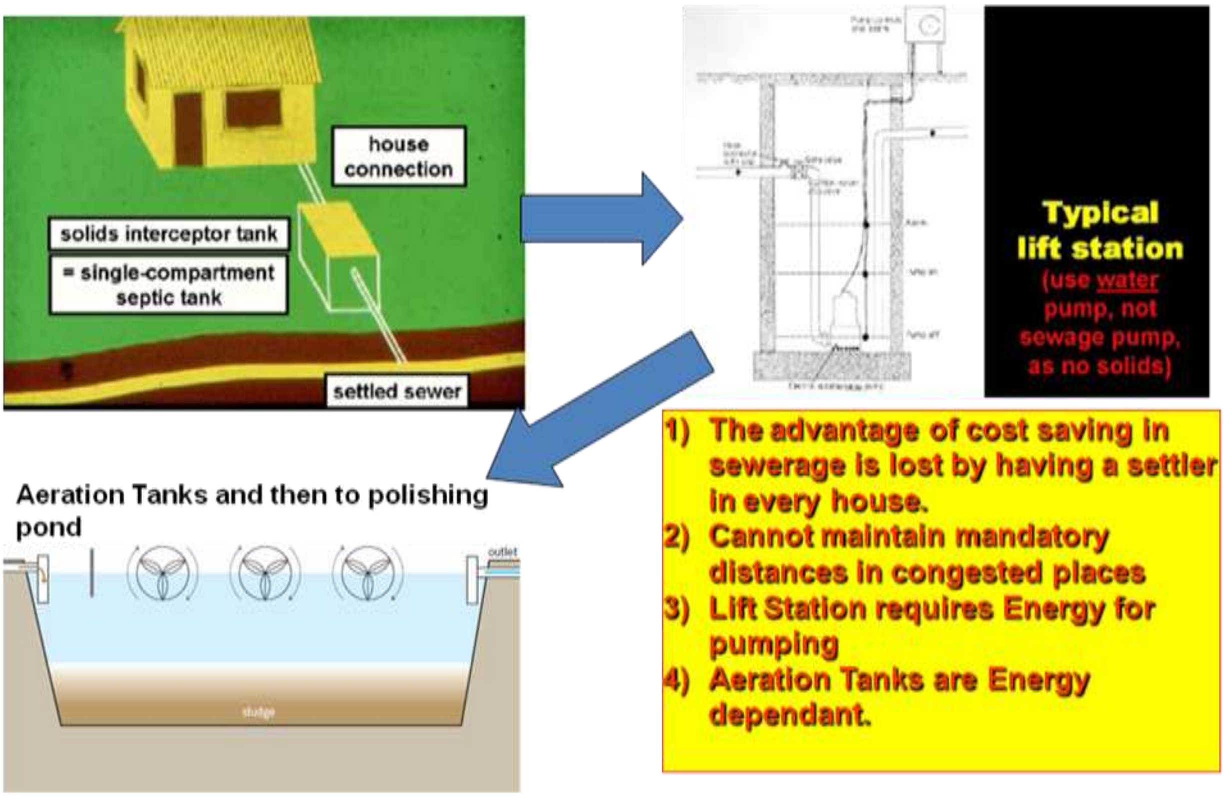
The then President Dr. Abdul Kalam, visited our village Kharodi to study this initiative and directed the Rural Development Ministry, GoI, to do a study and see how the same model could be replicated. The Ministry sent Ms. Shipra Saxena to submit a report. She studied both models described above and gave her report. The above table is a part of that report. The whole report can be downloaded from the Ministry's website. The link is given in the footnotes.[a]

<u>Treatment System Adopted at Kharaudi & Brahmpur by VLIF</u>



[a] Link to Ms. Saxena's Report:
http://www.mdws.gov.in/hindi/sites/upload_files/ddwshindi/files/pdf/casestudy_kharoudi.pdf

Treatment System Adopted by Govt; of Punjab at Ulana



2.3 Lessons from the first Interventions:

1) The Small Bore Technology (Govt.) was good for sparsely populated villages, where it is technically possible to have settling tanks in individual houses. In congested areas, the mandatory distances between various utilities and structures cannot be maintained.
2) *The Small Bore Technology could have been workable if there was a settler for a group of houses instead of one in every house.*
3) The treatment associated with the Small Bore System was power intensive. This is objectionable on two counts. Firstly, in the present day context it is very important for such interventions that the system remains Carbon Neutral as far as possible. Utilization of so much energy tilts the Carbon to the negative side. Secondly, it is important to have continuous power.

4) The GHGs[a] (Methane, largely) are allowed to escape into the atmosphere in every house in the Small Bore System *The only advantage of the small bore system was that the pipes were laid almost flat, hence not very deep.*
5) Even in the system used by us, there was energy expended in running the dozing pump, and then the pump of the recirculation filter.
6) Since we had a centralized treatment, and the flow was with gravity, higher slopes were required, hence the sewerage system became very deep by the time it reached the treatment site.

3. Evolution 2

3.1 Simplified Sewerage System

Looking at the drawbacks of our system, as well as those of the Small Bore System, we decided to attack the sewerage system design. We zeroed in on Prof. Dunkan Mara's (University of Leeds) Simplified Sewerage System. This does away with certain parameters applicable to large urban areas and simplifies the design. It comes down to hydraulic basics. The gradient is designed for the start of the Design Period and the diameter of the pipe is designed for the end of the design period. (More details of Simplified Sewerage as applied to our conditions can be had from the authors.)

This results in shallower and smaller diameter pipes.

We follow Simplified Sewerage to date. It is the most economical system for densely populated areas and is cheaper than primitive onsite systems. At present VLIF has completed waste water treatment in 14 villages.

4. Evolution 3:

4.1 Hybrid Settled & Gravity Sewrage System

For treatment of the water, we decided to invert the problem. Instead of comparing our system to the Small Bore Settled Sewerage System we decided to have 'Settled Sewerage' as part of our new system. All we had to do was to combined the Primary Treatment for a group of houses, instead of a Septic Tank outside/inside every house.

[a] Green House Gas.

Spots for settling sewerage were chosen according to existing natural flows of water. *<u>We had to however be careful to provide simplified sewerage from all the houses in a group to the settlement site. Using both a Hybrid System and the Settled and Gravity Sewerage.</u>*

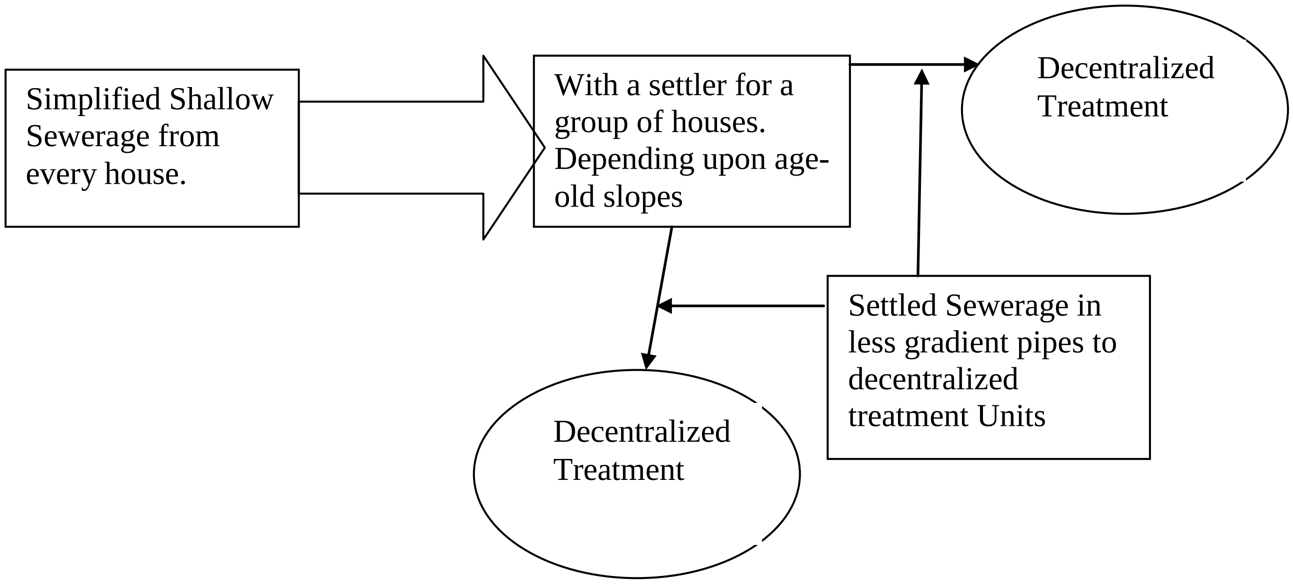
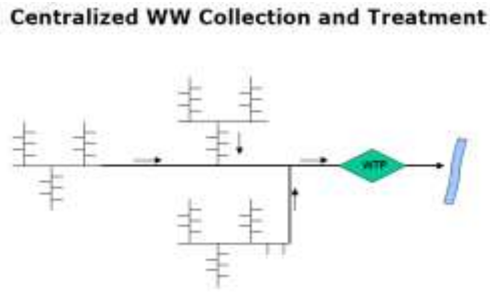
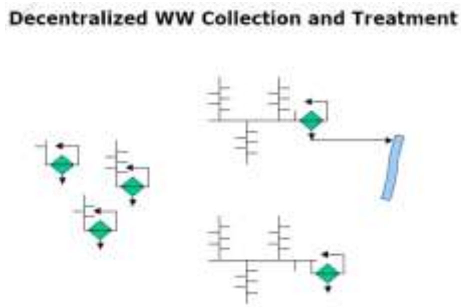


Fig.1:Figure shows that both Settled Sewerage and Simplified Sewerage can co-exist.

The primary and secondary underground treatment systems were located around the location of the nearest pond or the lowest crossroad with enough space. This resulted in:

1. Shallower gravity sewers.
2. Slimmer sewers.
3. No power requirement.
4. The outlet sewer carries no solids, therefore, has minimal slope with rapid conveyance capacity.
5. Very low level of maintenance.





Upto 4 or 5 such units can cover the whole village. Since the units are small and the overall depth is low, there is a cost saving.

A brief description of the system is produced below:

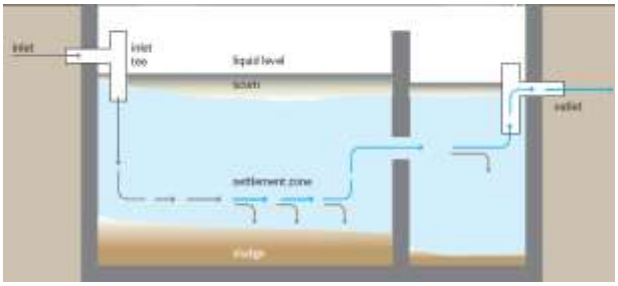
4.3 Decentralized Wastewater Treatment System (DEWATS)

In the DEWATS system both anaerobic and aerobic techniques are applied. Natural sewage treatment processes are achieved by using methods that utilise the naturally occurring physical principles combined with biological activities of microorganisms.

Microbes in the treatment facility are generated from microbial populations that occur and grow naturally in the wastewater itself.

4.3.1 Components of DEWATS System

a) Preliminary Treatment/ Settling Tank

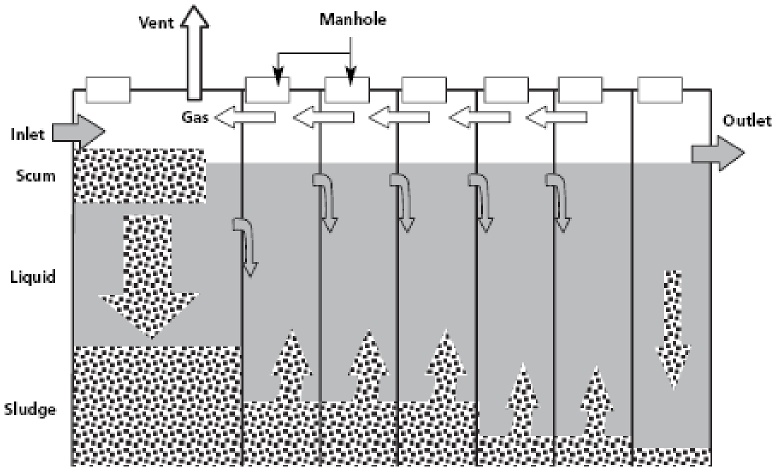


- A unit called a settling tank is used for this phase.
- It is a sedimentation tank in which settled sludge is stabilised by anaerobic digestion.
- Dissolved and suspended matter leaves the tank untreated.
- The treatment efficiency of a septic tank is in the range of 30 per cent BOD[a] removal.

[a] Biochemical Oxygen Demand

- *A settling tank can also be incorporated into an anaerobic baffled tank as the first section of Baffled Reactor*

b) Primary/ Secondary Treatment

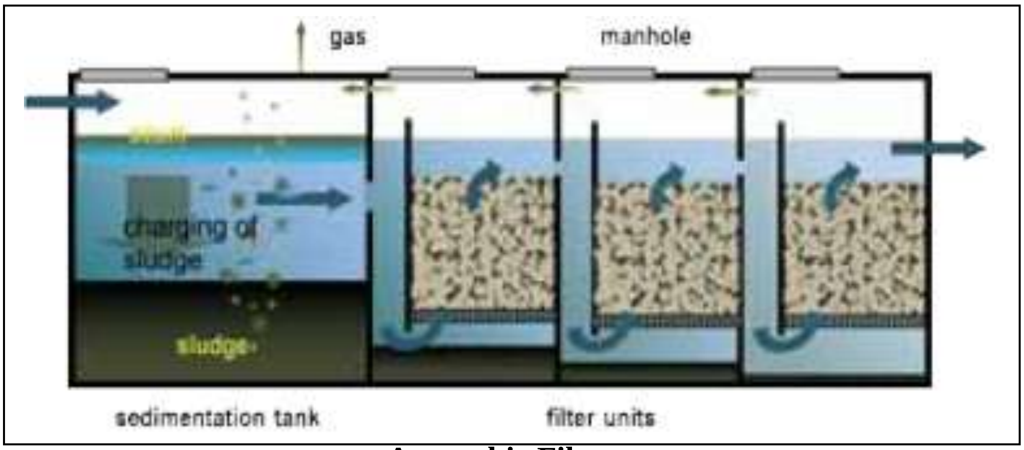


<u>Baffled Reactor with Settler at the beginning</u>

- Baffled reactor is used for this phase.
- Several tanks (upflow chambers) are built in a series to digest degradable Matter.
- Baffles guide WW between the chambers from top to bottom and up again.
- During the process the fresh influent is mixed and inoculated for digestion with the active Sludge Blanket deposit of suspended particles and microorganisms occurring naturally at the bottom of each chamber in such conditions.
- Because of the physical separation of Chambers, various microorganisms are present at different stages, allowing high treatment efficiency
- There is around 70% reduction of BOD at the end of this phase. That is why we term it as Primary/Secondary Treatment.
- As the Wastewater is made to pass through the Sludge Blanket in each chamber, with all chambers combined , it is equivalent to a simplified UASB[a] reactor

[a] Up-flow Anaerobic Sludge Blanket.

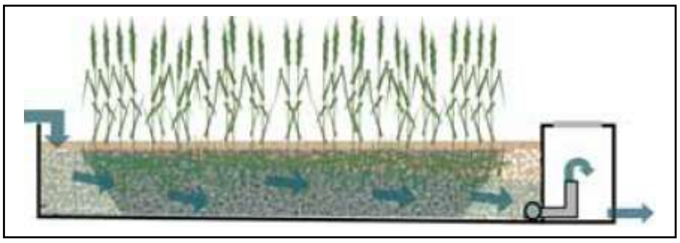
c) **Advanced Secondary treatment (Anaerobic Filter), for high BOD/COD[a] Loadings**



Anaerobic Filter

- At the end of the treatment device a chamber can be set aside as an anaerobic filter in order to improve further the treatment efficiency.
- A filter media allowing contact with the sewage stream is used, which is very efficient in retaining and digesting the remaining pollutants.
- The problem of encountering clogging is minimized due to the digestion and treatment in the baffled reactor.
- The primary and secondary treatment systems are constructed below ground level and are built together as a single and compact setup.
- Nearly 80 % of the original pollution load is removed at this stage.

d) **Tertiary Treatment : Planted Filter/ CW[b]/ RZ[c] Treatment/Reed Bed Treatment**



[a] Chemical Oxygen Demand
[b] Constructed Wetlands
[c] Root Zone

Horizontal planted gravel filter acts through the combined effect of the filter material and plants growing on the filter media. Usage of sand as the main filter materials was replaced by pebbles and granite stones.

The wastewater is resupplied with oxygen while passing through the planted gravel filter. The effluent is odor free. Since baffled reactor is being used to provide secondary treatment the size of the planted filter is reduced or totally eliminated.

This leads to a cost reduction and also less space is needed above ground.

Further use of Phytoremediation, the treatment of environmental problems (bioremediation) through the use of plants that mitigate the environmental problem without the need to manually handle the contaminant material and dispose of it elsewhere. The use of **VETIVER GRASS** along with other plants for Phytoremediation further increases the efficiency. Moreover, the issue of N2O[a] emission is effectively taken care of. N2O has a GWP[b] of 320 tCe[c] (IPCC[d] This stage can be laid out along walls or sidewalks as the above ground vetiver grass cover can be an added greenery to any site.

Alternatively, the treated water can also be polished further in an aerobic pond with Vetiver grass grown in floats. This non invasive strain of Vetiver grass is tolerant to air temperatures ranging from -15 to 55 degree Celsius, Soil PH 3-10, Annual Rainfall of 30cms to 500cms, extremely tolerant to Heavy Metals, tolerant to Fire, with a high resistance to pests and diseases. It is also highly effective for removal of excess nutrients from water.

e) Polishing Ponds

Vetiver Floats in a Polishing Pond,

[a] Nitrous Oxide
[b] Global Warming Potential
[c] Tonnes Carbon Equivalent
[d] Intergovernmental Panel on Climate Change

Vetiver grass grown on floating pontoons can be used successfully in aerated polishing ponds. This hydroponic treatment method can effectively remove heavy metals and reduce N & P levels. In addition, vetiver can be planted at the high water level around the ponds to further reduce the nutrient loading, also to stabilize the pond banks and get rid of blue green algae. Vetiver planted in five rows in a constructed wetland can reduce total Nitrogen levels by 99 percent and total Phosphorus levels by 85 per cent. Moreover, this system can also be used after any of the previous treatment stages.

5. **The DEWATS Design for villages: CASE STUDIES OF WASTE WATER MANAGEMENT IMPLEMENTED BY VLIF.**

6.1 Awan Ghore Shah, Distt. Hoshiarpur[a]

The original situation of the Baffled Reactor was much closer to the last manhole and right next to a gigantic water body.

We had planned to have the entire treatment at that point, with treated water falling into the water body.

Unfortunately, the Village elders decided to fill up the tank with earth and dug up another one far away, as is clear from the plan below.

We were compelled to relocate the treatment system further downstream. We altered the last leg of the sewerage to have minimum depth.

The water table in this village is very high. There was danger of the water in the reactor leaking into the ground. So we reduced the depth of the reactor and increased the number of chambers. We also provided a liner to prevent any chance of seepage and provided additional water proofing arrangements.

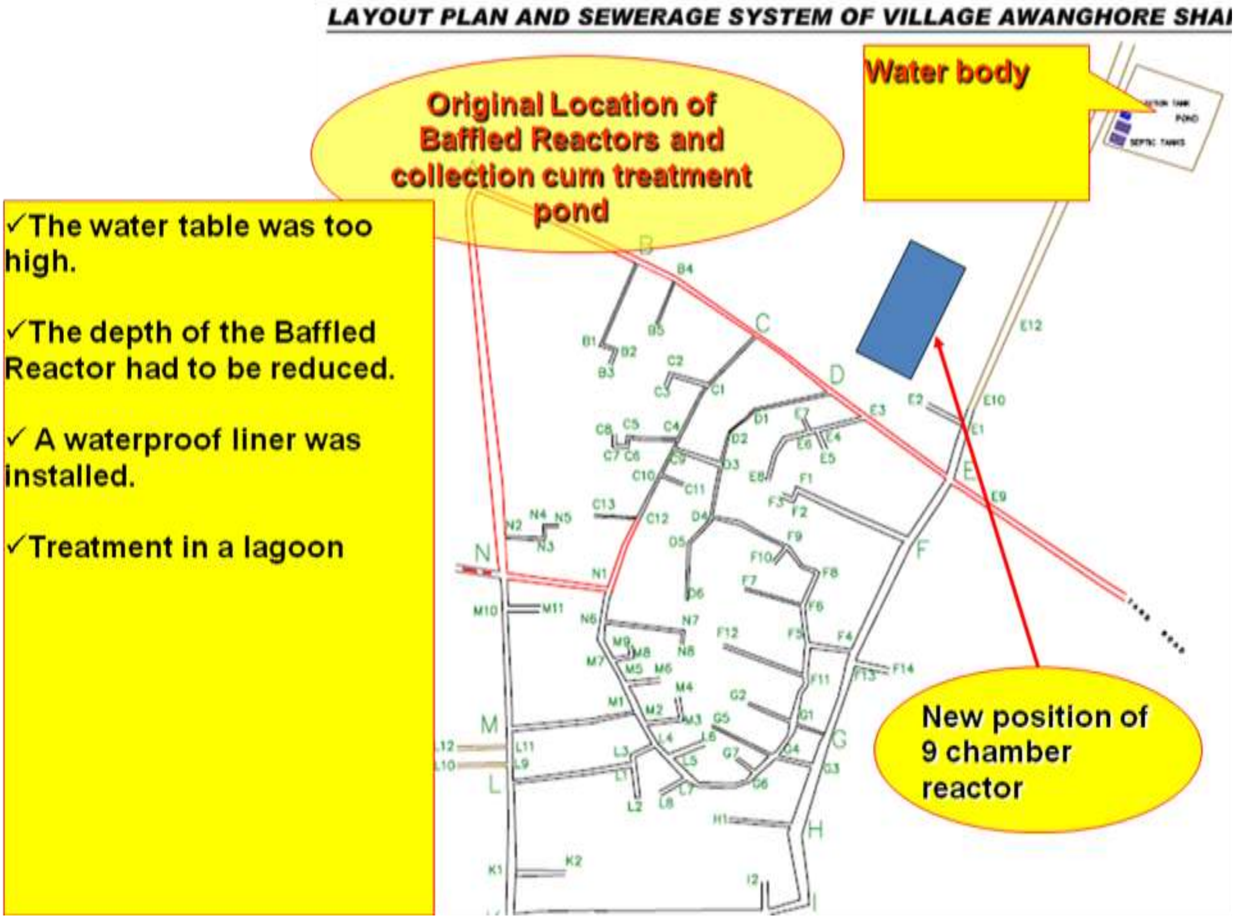
After the baffled reactor, the BOD reduction was 85%, whereas in our preceding write-up we have claimed only 70% reduction.

The old location of the pond was very near the location of where the reactor is. But since we now follow a hybrid system, we transported the sewerage via low sloped pipes as it is settled sewage carrying no solids.

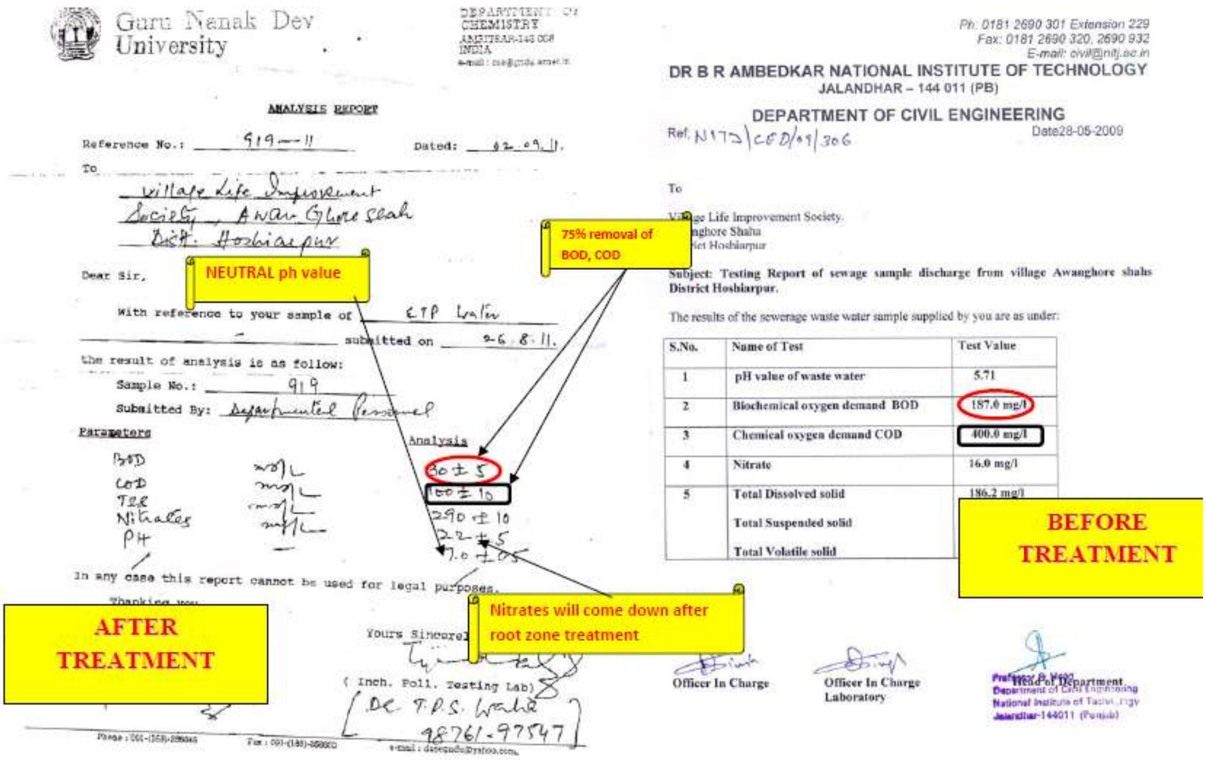
The effect of the decision to fill up the pond and shift the treatment will be described later in this section.

Layout plan follows:

[a] Map and layout courtesy Village Life Improvement Foudation.



6.1.1 Before and after Test Reports of Awan Ghore Shah



Guru Nanak Dev University

DEPARTMENT OF CHEMISTRY
AMRITSAR-143 005
INDIA

ANALYSIS REPORT

Reference No.: 919—11 Dated: 02.09.11.

To
Village Life Improvement
Society, Awan Ghore Shah
Distt. Hoshiarpur

Dear Sir,

With reference to your sample of ETP Water submitted on 26.8.11.

the result of analysis is as follow:

Sample No.: 919

Submitted By: Departmental Personnel

Parameters		Analysis
BOD	mg/L	50 ± 5
COD	mg/L	100 ± 10
TSS	mg/L	290 ± 10
Nitrates	mg/L	22 ± 5
pH	—	7.0 ± 0.5

In any case this report cannot be used for legal purposes.

Thanking you,

Yours Sincerely

(Inch. Poll. Testing Lab)
Dr. T.P.S. Walia
98761-97547

Ph: 0181 2690 301 Extension 229
Fax: 0181 2690 320, 2690 932
E-mail: civil@nitj.ac.in

DR B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY
JALANDHAR – 144 011 (PB)

DEPARTMENT OF CIVIL ENGINEERING

Ref. NITJ/CED/09/306 Date28-05-2009

To

Village Life Improvement Society,
Awanghore Shaha
District Hoshiarpur

Subject: Testing Report of sewage sample discharge from village Awanghore shahs District Hoshiarpur.

The results of the sewerage waste water sample supplied by you are as under:

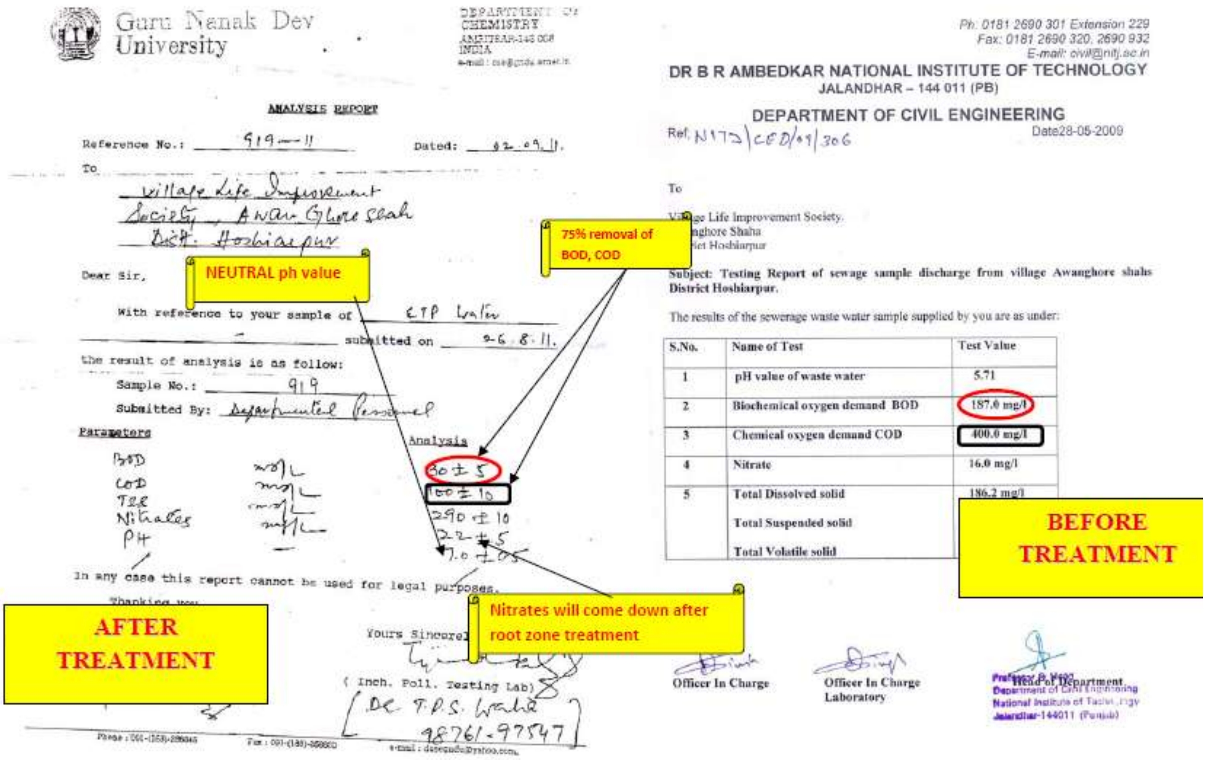
S.No.	Name of Test	Test Value
1	pH value of waste water	5.71
2	Biochemical oxygen demand BOD	187.0 mg/l
3	Chemical oxygen demand COD	400.0 mg/l
4	Nitrate	16.0 mg/l
5	Total Dissolved solid	186.2 mg/l
	Total Suspended solid	
	Total Volatile solid	

Officer In Charge

Officer In Charge Laboratory

Head of Department
Department of Civil Engineering
National Institute of Technology
Jalandhar-144011 (Punjab)

6.1.1 Before and after Test Reports of Awan Ghore Shah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DEPARTMENT OF CHEMISTRY
AMRITSAR-143 005
INDIA

ANALYSIS REPORT

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To
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Dear Sir,

With reference to your sample of ETP Water submitted on 26.8.11.
the result of analysis is as follow:
Sample No.: 919
Submitted By: Departmental Personnel

Parameters		Analysis
BOD	mg/L	30 ± 5
COD	mg/L	160 ± 10
TDS	mg/L	290 ± 10
Nitrates	mg/L	22 ± 5
pH	—	7.0 ± 0.5

In any case this report cannot be used for legal purposes.

Thanking you,

Yours Sincerely
(Inch. Poll. Testing Lab)
[Dr. T.P.S. Walia
98761-97547]

Ph: 0181 2690 301 Extension 229
Fax: 0181 2690 320, 2690 932
E-mail: civil@nitj.ac.in

DR B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY
JALANDHAR – 144 011 (PB)

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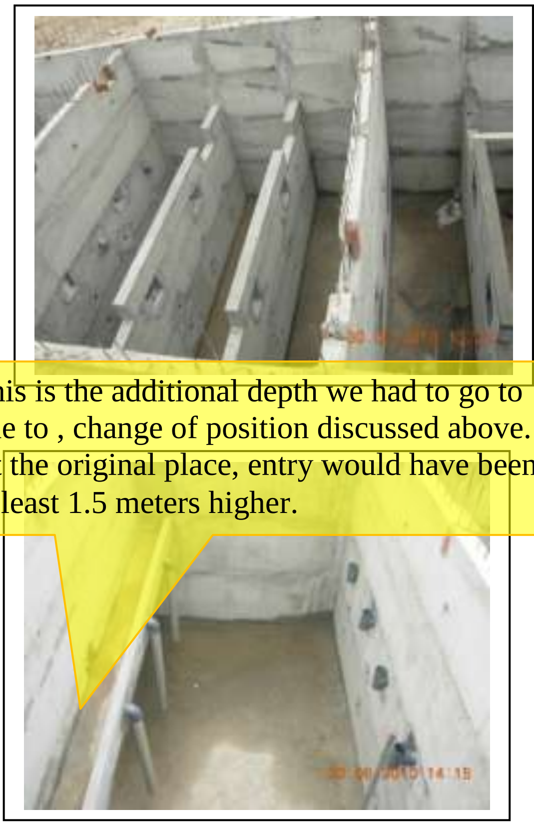
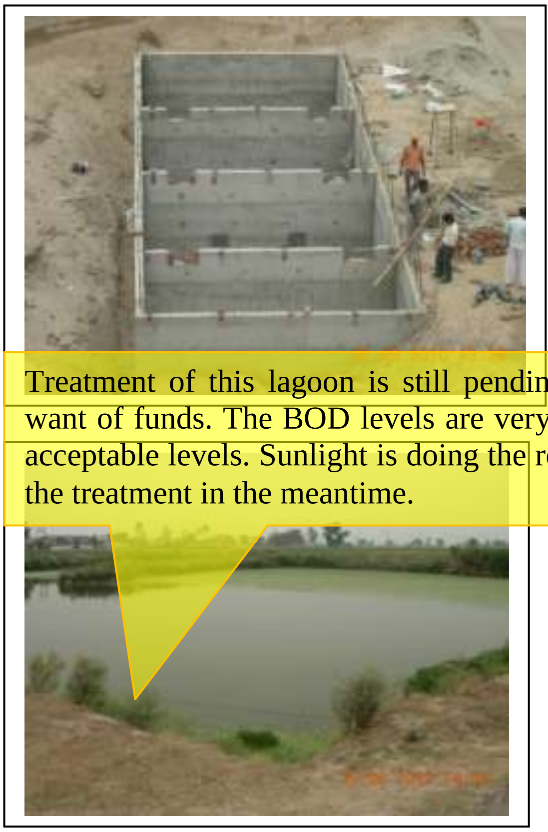
Officer In Charge   Officer In Charge Laboratory   Head of Department, Department of Civil Engineering, National Institute of Technology, Jalandhar-144011 (Punjab)

6.1.2 Photos Baffled Reactor and the Lagoon

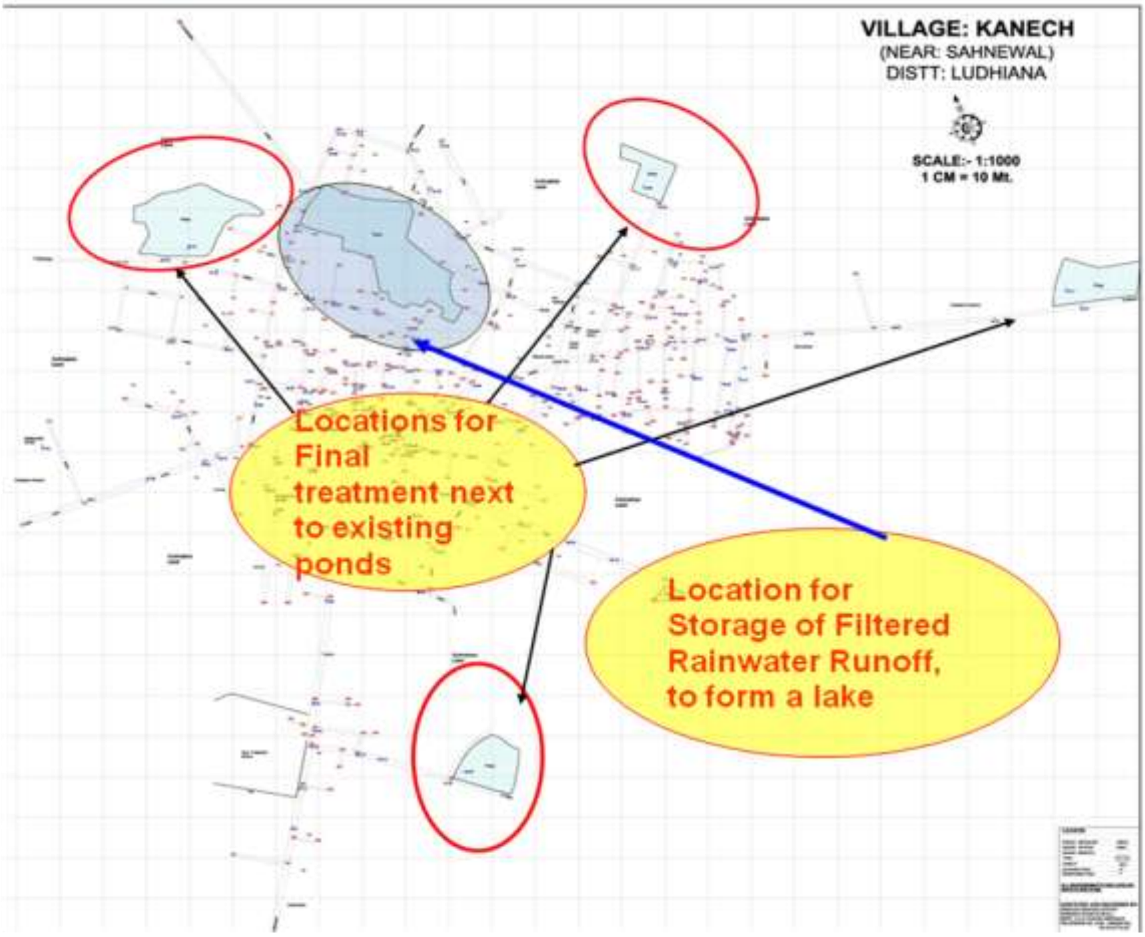


This is the additional depth we had to go to due to , change of position discussed above. At the original place, entry would have been at least 1.5 meters higher.



Treatment of this lagoon is still pending for want of funds. The BOD levels are very near acceptable levels. Sunlight is doing the rest of the treatment in the meantime.

7.2 Village Kanech, Distt Ludhiana (Ongoing Project)[a]

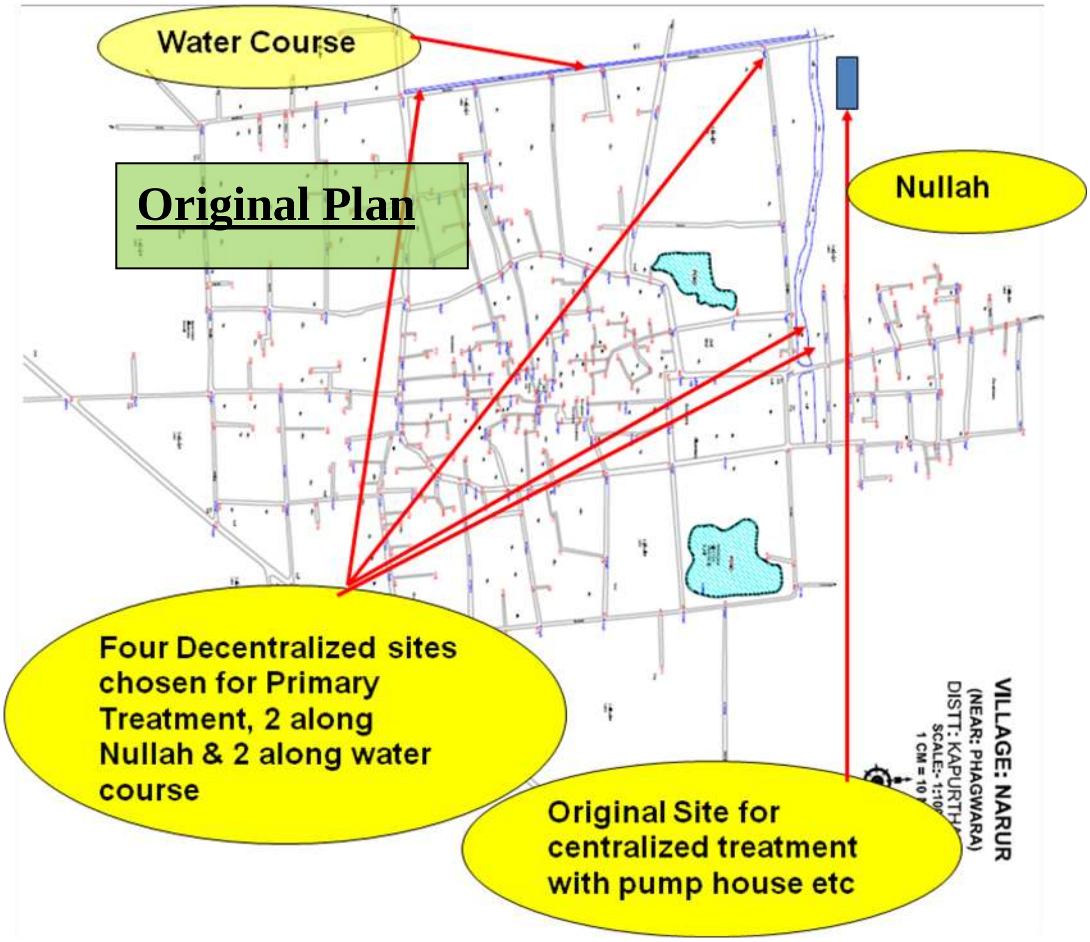


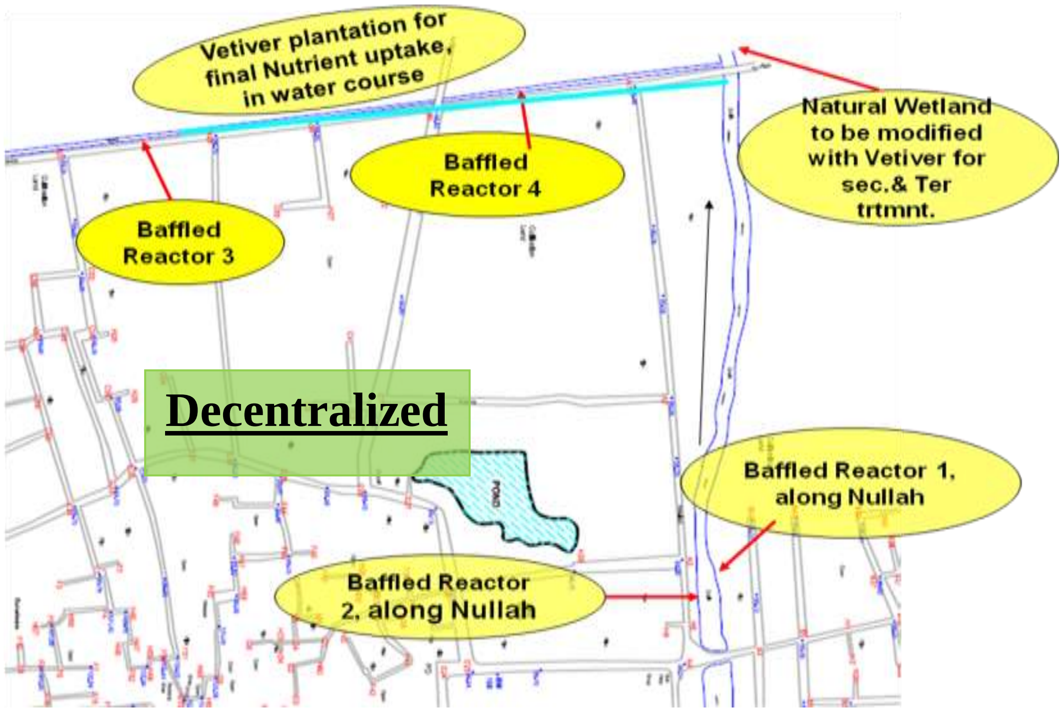
Two NRI brothers from this village took it upon themselves to transform the village. They provided leadership to this project. They personally studied all the available technologies before accepting DEWATS .Theyeven installed a miniature model of the process in their house. When they took the effluent samples to the lab, the analyst would not believe that it was treated water. He instead thought it was water from the bore well. As is clear from the map above, the treatment was done at four different locations, following natural slopes and discharging into 4 different existing ponds. One large pond has been set aside for filtered rain water runoff.

The village has installed its own interlocking tile making facility, for paving all the streets.

[a] Map and layout courtesy Village Life Improvement Foundation

7.3 Village Narur, (Ongoing Project)[a]





[a] Map and layout courtesy Village Life Improvement Foundation

Street before intervention

Street after intervention

Notice the inflow level, compared to centralized treatment at Awan Ghore Shah. This is tremendous cost Saving

Baffled Reactor under Construction

Baffled Reactor Complete

In the village, all natural slopes have been used. Two baffled Reactors have been provided .

These join at a natural wetland, which further joins a Nullah (Drain). Vetiver will be planted in and on the slopes of the drain for the final treatment.

Conclusion :

To conclude, one must reiterate that using old natural slopes and minimum energy is the most effective method of carrying waste water. With some trial and error VLIF has found that simplified sewerage system and DEWATS system are the best means to manage waste water in villages.

We can now say that our system is economically viable; has a huge social impact and Environmentally too it scores very high:

a) Study[a] in village Kharaudi and Brahmpura show that after we completed the project ,incidence of waterborne disease (i.e. diarrhea morbidity) have been reduced by almost 70% and Malaria by 97.1 %
b) Pride and dignity of village ,specially women, enhanced.
c) Since we follow the existing path of flow, there is least disturbance to the environment.
d) None of the components of the system release uncontrolled Methane gas.
e) Fossil fuel is saved, as we use no energy for lifting the water.
f) The Vetiver system picks up all the Nitrogen in the wastewater; hence no Nitrous Oxide is released in the atmosphere.
g) Low maintenance cost as minimum least human intervention is needed, once the system is underway.

We do not claim that this system is perfect and are striving to improve and innovate with every new village we take up. A word here, about public participation is important .No matter what technology is used, it is local leadership, and support that really makes the 'change' possible .The change can be seen in the clean streets, flush toilets in each house, improved health of children, dignity and pride in the villages. It completely transforms the village.

Way forward

VLIF – will now begin work on solid waste management as well, that too with a decentralized method of collection. We plan to educate the householders to utilize kitchen

[a] Impact Assessment of Village Life Improvement Projects in Punjab .A study by Gurmail Singh ,Reader Dept of Economics, Punjab University ,Chandigarh and Sawarn Singh Senior Research Analyst , Population Research Center , Punjab University, Chandigarh. For Punjab Development Society, Jalandhar. Dated July 14, 2007.

waste and produce methane gas for their own use. This is being done in Pune; we hope to replicate it in Punjab, with some innovations.

Vlif is engaged in making rural life at par or even better than urban living.