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Integrated, Sustainable and Eco-friendly Surface and Groundwater Management in an Arsenic affected Rural Area of West Bengal, India

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Abstract— **The aim of the paper is to present cost-effective solutions, arsenic removal treatment system from arsenic prone groundwater source and ecological surface water treatment system as an alternative source of arsenic free water were developed for rural areas at Jyot Sujan village, Murshidabad District, West Bengal, India. 92-94% turbidity removal is possible from HRF 1 and 2, 99.22% turbidity removal is also possible from SSF1 and 2. And pH and bacteria are reducing from the combined surface water treatment system. A dual treatment method for groundwater comprising of oxidation-coagulation-filtration and adsorption by activated alumina is proven to be more economic having more capacity and superior reliability in terms of water quality prescribed by IS 10500, 2012 as compared to other arsenic removal processes using various other media.**

Keywords—ARU, cost-effective, HRF, integrated, SSF, sustainable

I. Introduction

In Department of Science and Technology (DST) sponsored “Energy Efficient Community based Water and Wastewater Treatment Systems for Deployment of India” (ECO-India) project, Indian-European Consortia, were responded to the challenge by delivering substantial innovation using conventional and leading Indian European novel technologies, together with advanced research[1]. In order to deploy reliable and cost-effective solutions, arsenic removal treatment system from arsenic prone groundwater source and ecological surface water treatment system as an alternative source of arsenic free water were developed for rural areas at Jyot Sujan village, Murshidabad District, West Bengal, India [2].

II. Material and Method

A. *Study Area*

The village Jyot Sujan were located at Dahapara GP, Jiagunge-Murshidabad Block, Murshidabad District, W.B having latitude 24˚9’11.23’’, longitude 88˚15’24.06’’. The JyotSujan settlement has a population of approx. 2000 out of which approx. 1500 are above 18 years belonging to about 250 households. There are 200 pupils studying in primary school, and 50 children in ICDS (integrated child development service) JyotSujan has a community Mosque where about 100 people offer prayers.

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The Malpara settlement has a population of approx. 400. The main occupation of both communities is farming, 40% of the surveyed people are farmers, and women are mostly house wife amounts to 45 % of the surveyed population. Apart from farmers, there are some people doing labour jobs on daily basis, survey shows about 14 % are labours. Fishery and animal husbandry are also a source of income for the villagers. The average monthly income for each household ranges from 1500 to 4500 INR.

The entire village was categorized as North (N), West (W), South (S), South East (SE), South West (SW) for site selection of Integrated scheme. Based on the preliminary results from evaluation of Socio economic survey, 98% of the respondents are interested in being covered integrated scheme and several reasons indicate the selection for location of the Integrated scheme in favour of Malpara part of the village for maximum monetory contribution toward infrastructure maintained and evident water transport and sanitation problems. The next possible location for the integrated scheme could be SE and/or SW part of the village for higher open defecation practices and water transport problems. In regards of the catchment area protection from contamination through open defecation Malpara and the south part of Jyot Sujan also provide the highest risk potential as the local population chooses locations in the catchment area of the pond for their defecation.

The general needs identified by the interview partners are provision of safe drinking water, improvement of sanitation facilities and increase of awareness on hygienic practices regarding water contamination. Further solid waste and waste water management would be welcome. Finally all important locations were agreed upon in the water committee.

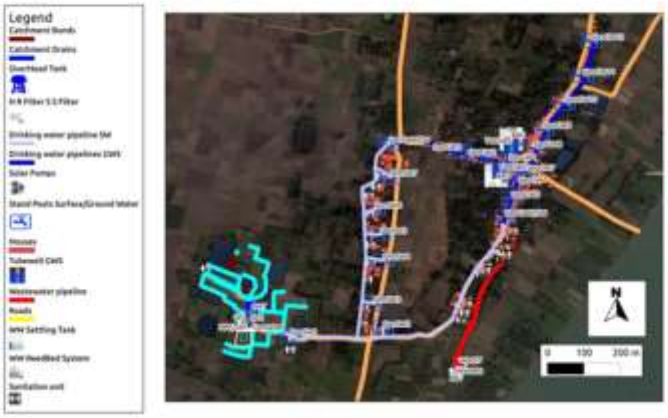

Figure 1. Overview map of pilot site showing planned setup of water supply

The above Figure 1 showed the water supply coverage by the surface water source and the groundwater source. The surface water scheme covers the Malpara settlement with stand posts and parts of south Jyot Sujan settlement with house connections. The surface water treatment plants consist of the horizontal roughing filter and slow sand filters and Activated Carbon Filter are located on the adjacent north facing plot of the pond. And Ground water treatment plant consists of Arsenic Removal unit was installed at Jyot sujan settlement.

B. *Surface Water Treatment Scheme*

The main treatment process consists of Horizontal Roughing Filter, Slow Sand Filter and Activated Carbon Filter. For this system the only photovoltaic solar pump is used to withdraw Pond water (Raw) for surface water treatment process. The HRF was fed from the raw water tank, from the HRF the water flowed into the SSF from where the water passes to the ACF and then into the treated water reservoir.

C. *Horizontal Roughing Filter (HRF)*

Basically, two horizontal roughing filters are placed parallel. The length, breadth and height of each HRF are 5.8 m, 0.73 m, 1 m respectively. HRF basically removes turbidity (<10 NTU). The specifications for the Horizontal Roughing Filter as based on a flow rate of 0.5m/h in case of both filter units running and 1m/h in case of only one unit running.

D. *Slow Sand Filter (SSF)*

There are two parallel slow sand filters. The length, breadth and height of each SSF are 4 m, 0.73 m, 2 m respectively as depicted in Figure 2. The grain size has been chosen as 0.2 mm for a 99% removal of total coliform. Test runs with smaller grain size up to 0.1 mm are foreseen to increase the removal efficiency. The basis for the design is a flow rate of 0.1 m/h in case of two filter units running parallel and 0.2 in case of only one unit running. The grain size has been chosen as 0.2 mm for a 99% removal of total coliform. Test runs with smaller grain size up to 0.1mm are foreseen to increase the removal efficiency. The basis for the design is a flow rate of 0.1m/h in case of two filter units running parallel and 0.2 in case of only one unit running[3].

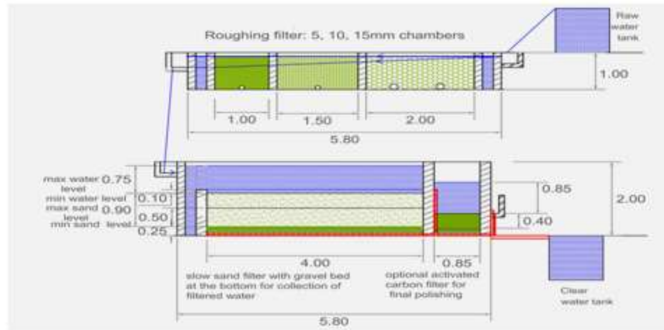

Figure 2. Composite (HRF-SSF-ACF) Surface Water Treatment Scheme

E. *Activated Carbon Filter (ACF)*

There are two parallel horizontal roughing filters. The length, breadth and height of each ACF are 0.85 m, 0.73m, 2 m respectively. ACF is used to remove colour and order of treated drinking water. The design specifications of the activated carbon filter are based on a contact time of max. 50 and min. 25 minutes in case of only one filter running.

TABLE 1. DETAIL SURFACE WATER TREATMENT SYSTEM SPECIFICATIONS

Complete Treatment System specifications			
Parameter	*Variable*	*Unit*	*Value*
Possible supply surface water scheme	Dsws	KLD	12.73
Process water 10%	Dprocess		1.27
Total water to be produced	Dtotal	KLD	14.00
Flow if continuous filtration of raw water	Qcft	LPH	583.24
time no pump 18 hours (20h for security)	tnp	hours	20.00
Capacity raw water reservoir size	Crw	KL / m³	11.66
no of filter units	Npump	no	2.00
Flow continuous filtration of 1 unit	Qft	LPH	291.62
HRF specification			
filtration rate	vF	m/hr	0.50
Area cross sectional filter	Acsf	m^2	0.58
Initial total Headloss	HL	m	0.06
SSF Specifications			
filtration rate	vF	m/hr	0.10
Area filter bed	Afb	m^2	2.92
diameter grain size filtration media	dfm	mm	0.20
Uniformity Coefficient (d60/d10)	UC		3.00
Initial Head Loss	HLfm	m	0.16
ACF Specification			
contact time	Tc	h	0.8
Area filter bed	Afb	m^2	0.58

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diameter grain size filtration media	Dfm	mm	5
Initial Head Loss	HLfm	m	0.0056

F. *Ground Water Treatment System*

The treatment process technology for removal of arsenic is based on the following principle of arsenic removal Unit (ARU) referred as Figure 3:

(a) Oxidation and Co-precipitation, (b) Adsorption

The oxidation of arsenite (As^{+3}) to arsenate (As^{+5}) is achieved by adding chlorine. Bleaching powder/sodium hypochlorite/calcium hypochlorite is added in proper dosage so that residual chlorine is restricted within maximum of 0.1 mg/L.

Co-precipitation for removal of arsenate is achieved by adding alum (aluminium sulphate) in right proportion. Aluminium hydroxide adsorbs arsenate during flocculation and settles in clariflocculator.

In second stage the clarified liquid is passed through up-flow filter where two layers of gravel and one layer of activated alumina are kept. During up-flow movement of water arsenate or arsenite if present are removed through adsorption process in activated alumina layer [4].

The iron in water is also removed in the purification process. Iron is removed by the following processes:

(1) Aeration during flush mixing, (2) Flocculation, (3) Filtration

Iron is mostly removed in clariflocculator after aeration and flocculation. If traces of iron particles remain in clarifloculator, then these are arrested in gravel layers of the filter. The above two-stage treatment system will be able to remove Arsenic and Iron in conformity to BIS-drinking water specification for desirable limit. The treated water may contain arsenic less than 10 ppb and iron less than 0.1 mg/L.

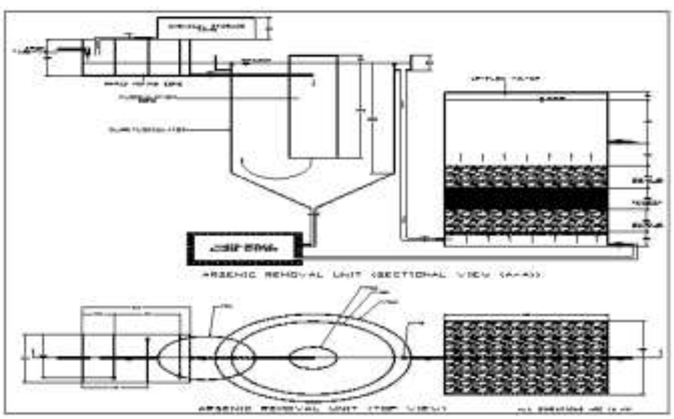

Figure 3 Arsenic Removal Unit

TABLE2. DETAIL GROUND WATER TREATMENT SYSTEM SPECIFICATIONS

Parameter Specification	*Unit*
Clarifier (Inner Diameter) Ht. of Clarifier (including Joist)	1350 mm 1900 mm
Flocculator (Inner Diameter)	450 mm
Mixing Channel	1350 mm (Length) 300 mm (Breadth)
Upflow Filter unit (Inner Diameter)	1250 mm
Ht. of Upflow Filter Unit	1788 mm
Filter Media	300 mm (Gravel) 300 mm (AA) 300 mm (Gravel)
Max. Pumping rate of well	1.25 m3/hr
Rate of Filtration	800 L/hr.
Sludge Tank	Length 2.0 m Breadth 1.5 m Depth 1.2 m

III. Result & Discussion

The basic treatment process for the drinking water consists of roughing filters, slow sand filters (HRF/SSF) and activated carbon filter with modifications to established concepts [5] with recent research results. Using this treatment system, 92-94% turbidity removal is possible from HRF 1 and 2, 99.22% turbidity removal is also possible from SSF1 and 2. Bacteria are reducing at different stages and finally sodium hypochlorite is added for disinfection by maintaining residual chlorine 0.6 mg/l at source point from the treatment system which has shown in Table 3. Water quality result of Groundwater treatment scheme shows in the Table 4. From the results of Groundwater pretreatment and post treatment water quality, it showed that the efficiency of Arsenic removal unit is remarkable and after post treatment water quality parameter results below permissible limit as per IS: 10500, 2012.

TABLE 3. WATER QUALITY VALUE OF SURFACE WATER TREATMENT SCHEME

Source	*Turbidity (NTU)*	*pH*	*Bacteria (MPN per 100 ml)*
Pond Water	30-350	7.8-8.2	350-10000
HRF-1	3-12	7.8-8	150-4956
HRF-2	2-8	7.75-7.9	148-4567
SSF-1	0.2-1.5	7.59-7.8	4-8
SSF-2	0.3-1.8	7.51-7.72	3-8

TABLE 4. WATER QUALITY VALUE OF GROUND WATER TREATMENT SCHEME

Parameters	*Pre-treated Water*	*Post Treated Water*
Turbidity (NTU)	4.46-16	0.42-1.7
Total Hardness (mg/L)	150-200	120-150
pH	7.2-8.1	7.9-8.0
TDS(mg/L)	301-351	280-371
As (mg/L)	0.16-0.1	0.007-0.01
Iron (mg/L)	0.37-2.11	0.06-0.74
E Coli (MPN/100 ml)	>20	Absent
Total Coliform (MPN/100 ml)	8	Absent

IV. Conclusion

A technical feasible, socially acceptable and low cost integrated solution has been elaborated with the treatment efficiency of two (surface and ground water) systems are really applicable for arsenic affected areas in rural India. The main challenges of awareness and ownership by the community are overcome by involving all relevant groups of the community in the water committee and patiently working out compromises which are supported by all water committee members. The developed concept promises an overall sustainable eco-friendly operation and maintenance regime. The performance efficiency also proved the scope of the pilot as a best practice model for communities in areas with non-potable groundwater sources.

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