

Assessment of Hydraulic load variations in DEWATS: a Case Study of Beedi Workers Colony

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Abstract

In the decentralised sanitation sector the nongovernmental organisation “Consortium of DEWATS Dissemination Society” (CDD) with support of BORDA has been implementing large numbers of Community Based Sanitation -Decentralised Wastewater Treatment Systems (CBS-DEWATS) throughout India. CBS relies on communities to use their “social capital” to organise themselves, “participate” in development processes and take over the required responsibilities concerning operation and maintenance of the facility. The hydraulic load is the major parameter for the dimensioning of a Decentralised Wastewater Treatment Systems (DEWATS), however very difficult to foresee at the design phase. It is therefore important to better understand the factors that influence this parameter. In this study, one project is taken as an example to present the effects that water scarcity, sewer line maintenance, community behaviour changes and ultimately pre-implementation community involvement can have on the amount of wastewater discharged to a DEWATS. Wastewater production is calculated through field surveys, effluent measurement campaigns and a detailed study on the sewer line status is conducted to check the losses of wastewater at household level.

The study has shown a 20% flow-reduction to the DEWATS over a two year period. The water-scarcity in the community is by far the strongest influencing factor for this phenomenon, followed by faulty household connections and the shift of some households to out-door laundry washing. The observations made during this study suggest that a sound community involvement is vital even to the short term sustainability of community based DEWATS projects if the communities are to be responsible for maintenance of the installations

Keywords: CBS DEWATS, Water consumption, Wastewater Production,

Symbols used

Q_{out}	measured DEWATS effluent	c	completely connected
Q_{office}	office building wastewater production	k	grey water (kitchen and bathroom) fraction of wastewater
$Q_{community}$	community wastewater feeding DEWATS	p	partially connected
$Q_{environment}$	untreated wastewater flow to the environment	n	not connected
Q_{total}	community wastewater production	P_B	number of people discharging black-water
dQ_s	flow reduction due to water scarcity	P_{KB}	number of people discharging kitchen and bathroom grey water
dQ_b	flow reduction due to piping breakages	P_W	number of people discharging laundry grey water
dQ_w	flow reduction due to outdoor laundry washing	A	population equivalent black water flow to DEWATS
q	per capita wastewater production	B	population equivalent kitchen- and bathroom-effluent to DEWATS
q_{2010}	per capita wastewater production in 2010	C	population equivalent grey water flow from washing area to DEWATS
x	factor for partial connections	D	population equivalent black water flow to environment

t	black water fraction of wastewater	E	population equivalent kitchen- and bathroom-effluent to environment
w	laundry water fraction of wastewater	F	population equivalent grey water flow from washing area to environment

INTRODUCTION

Rapid urban growth in many parts of the world results in polluted surface and ground water. This is mainly because of over exploitation of water resources, wastage of rainwater and, a major concern - lack of appropriate sanitation facilities. In response to the deficiencies of present sanitation systems, in recent years decentralised approaches are increasingly being followed to address the sanitation problems in urban settlement. Decentralised Wastewater Treatment Systems (DEWATS) provides a cost-effective and long-term option for meeting public health and water quality goals, particularly in densely populated areas. DEWATS offers reuse options, doesn't depend on any form of external energy and needs little maintenance (Parkinson. J et.al. 2003). The non for profit "Consortium of DEWATS Dissemination Society" (CDD) with support of the "Bremen Overseas Research and Development Association" (BORDA) has been implementing large numbers of Community Based Sanitation (CBS)-DEWATS throughout India. CBS relies on communities to use their "social capital" to organise themselves, "participate" in development processes (Mansuri et al. 2003) and take over the required responsibilities concerning operation and maintenance of the facility. A typical CBS-DEWATS project therefore includes the assessment of the need of sanitation facilities, baseline studies in the selected community, evaluation of technical and social options, development of an action plan with the community and the establishment of a community based organisation.

The hydraulic load is the major parameter for dimensioning of a DEWATS, however very difficult to foresee at the design phase. It is therefore important to better understand the factors that influence this parameter.

In this study, one project is taken as an example to present the effects that water scarcity, sewer line maintenance, community behaviour changes and ultimately pre-implementation community involvement can have on the amount of wastewater discharged to a DEWATS. Sewer line maintenance is taken as an indicator for community responsibility towards this particular project. The community's perception on their responsibility concerning operation and maintenance was then compared to assumptions made at the pre-implementation phase of this project.

METHODOLOGY

The Plant

The Beedi Workers Colony (BWC) is a government low income housing project. All Houses in BWC include toilets, showers, kitchens and laundry spaces. The community water supply depends on a bore-well within the colony and on additional deliveries from private water suppliers. 120 households in BWC are connected to a DEWATS through a Simplified Sewer System (SSS). This DEWATS unit was installed at BWC with a treatment capacity of 36 m³/day with technical support from CDD Society and the Central Pollution Control Board (CPCB). It was built with funding support from RGRHCL (Government of Karnataka Public Limited Company), CPCB and BORDA. The piping system and household connections were completely rehabilitated beginning 2010. The pre-treatment units are two parallel Biogas Digesters (BGD) with equal dimensions. Their effluents are further treated by an Anaerobic Baffle Reactor (ABR) and a Planted Gravel filter (PGF) before being discharged to a percolation pit. At present, the effluent from office building next to community is also connected to the plant.

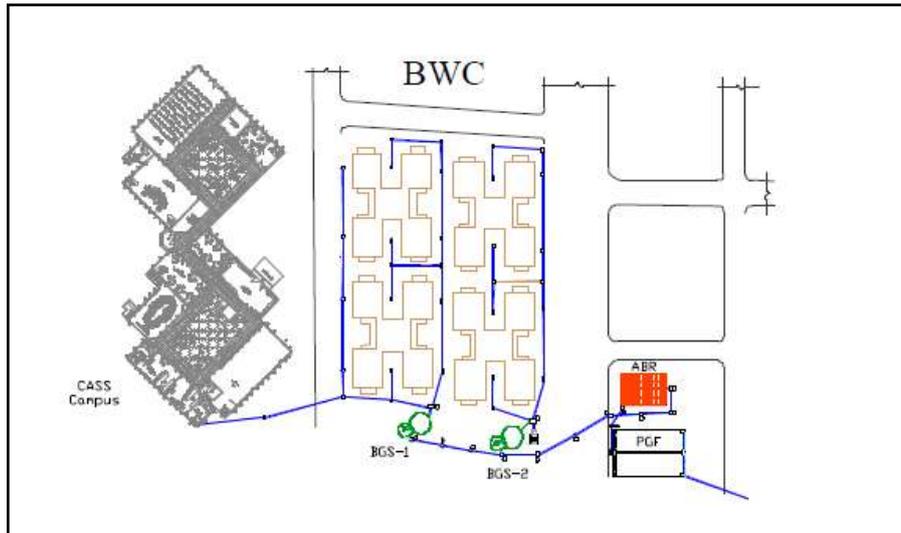


Figure 1: Site Layout of Beedi Workers Colony and Office building

DEWATS effluent measurements

Two DEWATS effluent measurement-campaigns for effluent measurement from DEWATS unit with a water-meter connected after the ABR were each conducted over 6-7 days in the years 2010 and 2012. Former investigations have shown that inflow-fluctuations are not altered throughout an ABR system (Reynaud et al., 2009). Storm-water is known to generally affect the flow to a plant (Reynaud, 2012). The presented data-sets therefore only include measurements done on days without rain. The integrity of major sewer lines was checked with food-dye tests.

Water use and wastewater production estimates

The community water consumption is estimated through the bore well pumping duration and capacity as well as the filling frequency and capacity of community storage tanks.

The influence of the office building on the DEWATS feed is approximated through staff numbers and by estimating their water consumption at 50 l/cap*d of which 80% is discharged as wastewater (CPHEEO, 1999). These values are verified by comparing the DEWATS effluent on working and non working days.

Field surveys

Household questionnaire surveys were conducted in 2010 and 2012 to assess the population number, water use practices, and the perceived responsibility of the population concerning the maintenance of sanitation facilities. The community perception is compared to the assumptions recorded in the project documentation at the pre-implementation stage. A detailed field study was conducted in June 2012, to check the status of each household sewer connection concerning breakages, leakages and additional connections. Information about the condition of the household grey-water and black-water connections and the number of people living in each household was gathered. It was observed that several households had shifted to wash their laundry outside of their houses. This wastewater is discharged directly to the environment. Grey-water therefore had to be further differentiated between kitchen and bathroom effluent and water from the washing-area. Connections were classified as “connected”, “partially connected” or “not connected”. All connections were known to be in good order during the campaign in 2010.

Calculating the wastewater streams in 2012

In 2012 several household connections to the DEWATS piping system were found broken, blocked or leaking. In order to put the wastewater production measured at the ABR outlet into relation with the population it was therefore important to establish the actual number of population equivalents contributing to the different wastewater streams reaching and not reaching the DEWATS (see figure 2). The field survey conducted in June 2012 allowed identifying factors at household level influencing the wastewater streams. Also, the number of people contributing to each wastewater fraction could be approximated (see table 1). Black-water was estimated to be 30% of the total wastewater-flow (t) and grey-water fractions from kitchen and bathroom (k) and from the washing area (w), were estimated at 40% and 30% respectively (Indian Standard (BIS):1172-1993). The flow-reduction (x) through observed household connections classified as “partially connected” was estimated to be 50%. Population equivalents are then calculated for the 3 wastewater fractions reaching the DEWATS and being discharged to the environment using the equations 1 to 6. The sum of population equivalents contributing to the flow to the DEWATS is used to calculate the average per-capita wastewater-production of the community following equation 7. This value then permits to estimate the total wastewater-production of the community and the fractions of it being discharged to the environment (equations 8 to 10). The reduction of produced wastewater caused in this community by water-scarcity, breakages and outside-shifting of laundry-space are calculated with the equations 11 – 13.

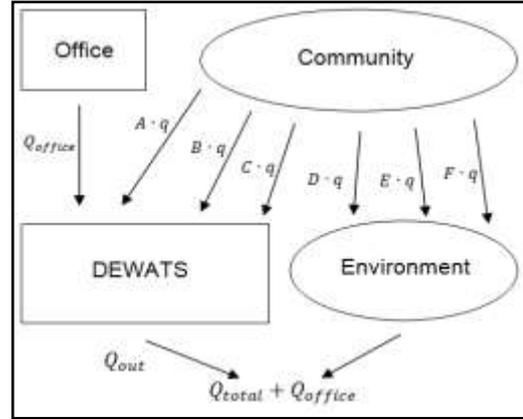


Figure 2: Wastewater streams as observed in 2012

$$A = (P_{BWC} + x \cdot P_{BWp}) \cdot t \quad (1)$$

$$B = (P_{KBc} + x \cdot P_{KBp}) \cdot k \quad (2)$$

$$C = (P_{Wc} + x \cdot P_{Wp}) \cdot w \quad (3)$$

$$D = (P_{BWn} + (1 - x) \cdot P_{BWp}) \cdot t \quad (4)$$

$$E = (P_{KBn} + (1 - x) \cdot P_{KBp}) \cdot k \quad (5)$$

$$F = (P_{Wn} + (1 - x) \cdot P_{Wp}) \cdot w \quad (6)$$

$$q = \frac{Q_{out} - Q_{office}}{(A+B+C)} \quad (7)$$

$$Q_{total} = Q_{community} + Q_{environment} \quad (8)$$

$$Q_{community} = (A + B + C) \cdot q \quad (9)$$

$$Q_{environment} = (D + E + F) \cdot q \quad (10)$$

$$dQ_s = (A + B + C) \cdot (q_{2010} - q) \quad (11)$$

$$dQ_b = (D + E) \cdot q \quad (12)$$

$$dQ_w = F \cdot q \quad (13)$$

Limitations:

A number of assumptions had to be made for simplifications during this study.

- Per capita wastewater production was not differentiated between age-groups
- It is assumed that no water loss or flow increase occurs due to undetected leakages and blockages in the major sewer lines or reactors
- The error of the household survey data is estimated to be small enough to enable a rough indication of the situation
- The household survey data includes responses from 96 households whereas 24 households could not be contacted
- Uncertainties in the different estimated fractions were reduced by varying those estimates.

RESULTS AND DISCUSSION

Wastewater production, water use estimations and community population

In 2010 the average wastewater production Q_{out} measured during office working days was 24.9 m³/d with a percent standard deviation of 10% over the measurement days. The flow measured on an office non-working day was about 3 m³ less than during working days (Miller A, 2011).

In 2012 the average wastewater production Q_{out} measured during office working days was 19.0 m³/d with a percent standard deviation of 3% of the measurement-period. The flow measured on an office non-working day was with 15.9 m³/d about 3.1 m³ less than during the week.

The estimated community fresh water consumption in 2010 is 32.0 m³/d and 20.0 m³/d in 2012. The office wastewater production is estimated to be 2.2 m³/d and 2.5 m³/day in 2010 and 2012 respectively. Those values are about 30% smaller than the differences calculated between effluent measurements on working and non-working days. However, because the latter are based on comparably small data-sets they are considered less representative than the estimations based on the fresh water consumption and will not be used for further calculations.

The population of the community in 2010 was 605 people (Miller A, 2011) and 654 people in 2012 which leads to an average per capita water consumption of 53 and 31 l/cap*d in the two years based on the estimated water consumption of community. This leads to an average per capita wastewater production in 2010 of 37 l/cap*d when subtracting the estimated office wastewater production from Q_{out} .

Wastewater streams in 2012

The result of the sewer system field survey is listed in Table 1. The table shows the number of people contributing to the wastewater-streams “black water”, “grey water from kitchen and bathroom” and “grey water from washing area”.

Table 1: shows the number of people connected to DEWATS based on the status of sewer lines

	Symbol	Completely connected (-c)	Partially connected (-p)	Not connected (-n)
Black water	P_{BW}	577	35	42
Grey water - kitchen & bathroom	P_{KB}	544	58	52
Grey water - washing area	P_W	540	36	78

The values presented in table 1 were then used to calculate the population equivalents, the per capita wastewater production and the different wastewater streams observed in 2012. They were

also used to quantify the 3 causes contributing to the change of wastewater flow observed from 2010 to 2012 (see table 2). The variables x, t, k and w were changed from 0.3 to 0.7, from 0.2 to 0.3, from 0.3 to 0.5 and from 0.2 to 0.4 respectively. The minimum and maximum values represent the maximum variations that these alterations provoke on the calculation outcomes. In 2010 the average amount of wastewater produced per person in the community was 37 l/cap*d compared to 29 l/cap*d in 2012 based on the effluent measurement campaign. The presented values lead to per capita wastewater production to freshwater consumption ratios in 2010 and 2012 of about 71% and 94% respectively. This indicates that due to water-scarcity basically all water available to the community in 2012 was being used for household purposes. In 2010 on the other hand more water was available than actually used in the households. This indicates that the per capita wastewater production measured then is representative for times without water stress. The field questionnaire survey confirmed this: the interviewees explained in 2012 that they could no longer use water for outdoor purposes and had to drastically reduce their domestic water-usage.

Table.2 The different wastewater streams discharge in 2010 and 2012

Symbol	Unit	2010	2012		
			Standard	Min	Max
A	pop. equivalents		178	119	180
B	pop. equivalents		229	172	287
C	pop. equivalents		167	112	223
D	pop. equivalents		18	12	20
E	pop. equivalents		32	24	41
F	pop. equivalents		29	19	38
q	l/cap*d	37	29	28	29
Q _{total}	m ³ /d	22.66	18.8	18.5	19.1
Q _{environment}	m ³ /d		2.3	2.0	2.6
dQ _s	m ³ /d		5.0	4.7	5.3
dQ _b	m ³ /d		1.4	1.2	1.7
dQ _w	m ³ /d		0.8	0.6	1.1

The effect of water-scarcity on flow reduction in 2012 is found to be by far the strongest of the 3 considered factors and is estimated to be about 5 m³/d. In 2012, approximately 2.3 m³ of wastewater is being discharged daily into the environment of which about 1.4 m³ is due to broken or leaking pipes. Approximately 0.5 m³/d or 10% of the black-water produced by the community is discharged untreated. The least strong influence was found to be the decision of some households to change their laundry washing area: about 0.8 m³/d of laundry-water is not being treated by the DEWATS because a number of

households have shifted to wash their clothes outdoors.

Responsibility of Stakeholders

The observed poor maintenance of sewer connections and the resulting discharge of untreated wastewater and especially black-water is a reason of concern. According to design documentation, it is the community's responsibility to maintain piping and treatment facilities.

Awareness about DEWATS and responsibility for maintenance. The household survey results show that out of 96 houses only 56 households are aware that a DEWATS is treating the wastewater the produced from their community (Figure.3). Only 43% of the interviewees see the responsibility of maintenance of sewer lines and sewer connection with users and the Beedi Workers Colony Association (BWCA).

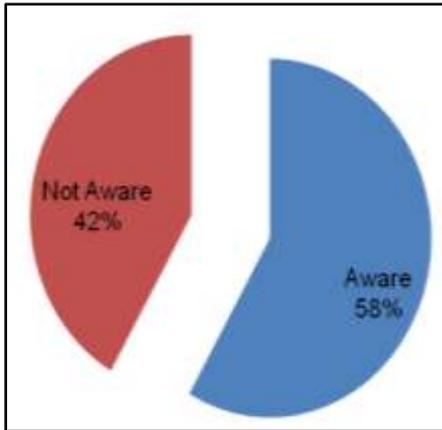


Figure 3: Awareness of people that their wastewater is treated by a DEWATS

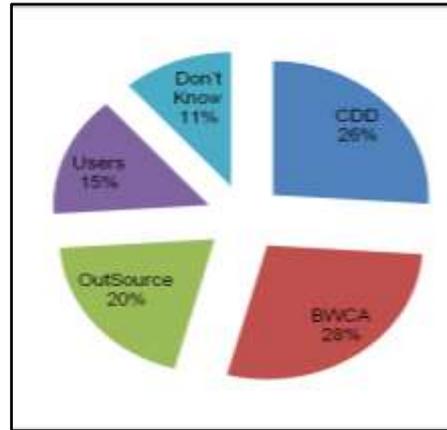


Figure 4: Perceived responsibility of the community for O&M of sewer-connections and -lines

The DEWATS at BWC was initially implemented with a focus on research and development activities on technical aspects of DEWATS. Unlike with other CBS projects, minimal effort was undertaken towards community awareness, capacity building on DEWATS and operation and maintenance training. The drawback is clearly seen in this example where a lack of initial community involvement clearly jeopardises the sustainability of the project, especially considering the project feature, the sewer system, was about 2 years time of the study.

CONCLUSIONS AND RECOMMENDATION

Wastewater production measurements have shown a 20% flow-reduction at the DEWATS presented in this study over a period of two years, although the connected population had increased from 605 to 654 people. Data from the field-surveys presented in this paper shown that water-scarcity in the community is by far the strongest influencing factor for this phenomenon and contributes to about 5 m³/d of flow-reduction. Faulty household connections and the shift of some households to out-door laundry washing accounts for approximately 1.4 m³/d and 0.8 m³/d flow-reduction respectively. Water scarcity is a common problem in many low income urban areas due to population increase and it is recommended to consider including rain-water catchment options for future project implementations. Pipeline breakages and leakages in the sewer systems however are partly due to lack of awareness and commitment of the community, since it is the community which is initially assumed responsible for operation and maintenance needs of the installation. The surveys showed that the here presented community had little awareness of operation and maintenance issues. This can be traced back to the non-typical minimum initial community involvement in this project. Due to the relatively young age of the piping system and its considerable degradation in only two years it is therefore hypothesized that a sound community involvement is vital even to the short term sustainability of community based DEWATS projects if the communities are to be responsible for maintenance of the installations. Also, an intensive capacity-building effort is required to overcome the constraints that hinder the long-term sustainability of sewer systems and decentralised wastewater systems. As a final outcome it is recommended that piping should always be built as unexposed as possible in order to prevent breakages.

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