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Evaluation of Anaerobic Baffled Reactor for removal of nitrogenous compounds from sewage generated from small habitat in Chitrakoot, India.

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ABSTRACT
Sanitation in decentralize treatment system getting popularity in India because of successful application of anaerobic methods to treat domestic wastewater, for which many Anaerobic Baffled Reactors (ABR) constructed and their performance were studied. ABR achieve a high reaction rate per unit volume of reactor by retaining the solid biomass in reactor for which vertical baffles arranged in series and wastewater forced to flow through them. The ABR at Sadguru Seva Sangh Trust (SSST) Chitrakoot, Satna (M.P.) is one of them, which was constructed to handle domestic wastewater generated from the premise. Wastewater contains carbonaceous, nitrogenous and phosphate impurities. It requires certain level of treatment to meet discharging standards laid by CPCB. Therefore, 0.2 MLD capacity ABR with twelve compartments was studied. Samples from ABR were taken in October month and analyzed for Nitrate, Ammonia and TKN in laboratory by adopting standard methods. Obtained results were statistically analyzed to get model for depletion of nitrogenous parameters from sewage.
It was found that complete TKN and Ammonia removal was occurred at 549.47 HRT. These nitrogenous compounds were stabilized into Nitrate and its concentration was found 368.14% in comparison to inlet. Thus model analysis for nitrogenous compound removal reflects need of 549.47 hours HRT which is uneconomical approach, however, effluent can be applied to agriculture fields after disinfecting. The detail of performance evaluation is discussed in this paper.
Keywords: TKN, Ammonia, Nitrate, Anaerobic baffled reactor, Hydraulic retention time.

I. INTRODUCTION

The decentralize treatment system getting popularity in India for sanitation of small communities. Many Anaerobic Baffled Reactors (ABR) and Upflow Anaerobic Sludge Blanket (UASB) were constructed across the India. Among them ABR achieve a high reaction rate per unit volume of reactor by retaining the solid biomass in reactor for which vertical baffles arranged in series and wastewater forced to flow through them. ABR has peculiar characteristics to handle higher hydraulic and organic shock load and it is the reason behind its acceptability for Decentralize Wastewater Treatment System (DEWATS) constructed in less populated habitats or small communities. The complex organic compounds are converted in simple organic compounds by the anaerobic microbial metabolism and finally stabilized as nitrate.

The ABR at Sadguru Seva Sangh Trust (SSST) Chitrakoot, Satna (M.P) is located at latitude and longitude are 25^0 09’ 05.49” N and 80^0 51’ 27.48” E respectively. An ABR of 0.2 MLD capacity was designed by Professor G D Agrawaland constructed by engineering department of SSST in 2010 to treat wastewater generated from its residential area. Wastewater from colony reaches to screen where floating impurities like paper, polythene, wooden pieces etc. get screened out and wastewater allowed to enter in ABR.

ABR is anaerobic unit, it contains 1 inlet, 2 parallel series of 10 upflow chamber in each unit and 1 outlet unit. Wastewater is treated in anaerobic environment in these chambers.
Design and volume of ABR volume and design of ABR is given in Table 1. The total volume of ABR was calculated as 667.24 cum. beside it 0.22 m space exists in ABR as free board.

TABLE 1 ABR MENSURATION

COMPARTMENT		**ABR DIMENSIONS**			**SURFACE AREA**	**VOLUME**
No.	NUMBER OF CHAMBER	WIDTH	LENTH	DEPTH*		
		M	M	M	M^2	M^3
1	1 (inlet)	8.10	2.47	2.78	20.01	55.62
2	2	4.00	2.50	2.78	20.00	55.60
3	2	4.00	2.50	2.78	20.00	55.60
4	2	4.00	2.50	2.78	20.00	55.60
5	2	4.00	2.50	2.78	20.00	55.60
6	2	4.00	2.50	2.78	20.00	55.60
7	2	4.00	2.50	2.78	20.00	55.60
8	2	4.00	2.50	2.78	20.00	55.60
9	2	4.00	2.50	2.78	20.00	55.60
10	2	4.00	2.50	2.78	20.00	55.60
11	2	4.00	2.50	2.78	20.00	55.60
12	1 (outlet)	8.10	2.47	2.78	20.01	55.62
					240.01	**667.24**

Wastewater flow was also adjusted by providing an overflow pipe at screening chamber in such a manner, so that maximum water depth over weir was stabilized to get uniform flow rate.

II. METHODOLOGY

The one liter samples were collected from ten upflow compartments as well as from inlet and outlet compartment, in twelve sampling containers. These sampling containers were stored in ice boxes, and analyzed within 24 hours of sampling. Three day sampling sessions were planned and 36 samples were obtained from each sampling locations. Since ABR under study had chance to get shock load on the any sampling day, hence sampling session was repeated again after short interval. On the sampling day samples were collected from compartments of ABR at 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22 and 24 hours. Samples were collected alternatively from both series of compartment, to get 24 hours representative sample. This composite sample was analyzed to quantify Nitrate, Ammonia and TKN in laboratory by standard methods (APHA 2002). Statistical analysis of data was also performed.

III. RESULT AND DISCUSSION

i) Composite sample were analyzed in laboratory for Nitrate, Ammonia and TKN and the data found are given in Table 2, 4 and 6 respectively. These data were normalized and given in Table 3, 5 and 7.

TABLE 2 MEAN NITRATE IN DIFFRENT SESSION IN (mg/l)

SESSION	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	1.3	1.2	1.3	1.4	1.5	1.6	1.5	1.5	1.6	1.7	1.8	1.9
10-12 October 15	1.4	1.3	1.4	1.5	1.6	1.6	1.5	1.6	1.8	1.9	1.9	2.1

TABLE 3. SESSION WISE NITRATE (%) IN DIFFERENT COMPARTMENT

SESSION	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	100.00	90.09	97.60	105.11	112.62	123.08	112.62	112.62	120.12	127.63	135.14	142.65
10-12 October 15	100.00	91.20	101.10	108.77	113.65	116.88	107.14	114.00	125.05	132.34	136.38	147.32
MEAN	100.00	90.65	99.35	106.94	113.14	119.98	109.88	113.31	122.59	129.99	135.76	144.99

STANDARD DEVIATION	0.00	±0.78	±2.47	±2.59	±0.73	±4.38	±3.87	±0.98	±3.49	±3.33	±0.88	±3.30

TABLE 4 MEAN AMMONIA IN DIFFERENT SESSION IN (mg/l)

SESSION	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	10.8	47.5	47.8	37.9	28.0	20.0	20.9	23.3	27.3	27.5	24.6	20.8
10-12 October 15	10.9	47.3	47.6	36.9	27.2	19.9	20.9	22.6	27.2	26.8	24.4	20.7

TABLE 5 SESSION WISE AMMONIA (%) IN DIFFRENT COMPARTMENTS

SESSION	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	100.00	440.09	442.91	350.76	259.54	185.25	193.72	215.34	252.96	254.84	227.57	192.78
10-12 October 15	100.00	434.08	436.43	338.10	249.41	182.72	191.64	207.36	249.75	246.14	224.24	189.95
MEAN	100.00	437.09	439.67	344.43	254.48	183.99	192.68	211.35	251.36	250.49	225.91	191.37
STANDARD DEVIATION	0.00	±4.25	±4.58	±8.95	±7.16	±1.79	±1.47	±5.64	±2.27	±6.15	±2.35	±2.00

TABLE 6 MEAN TKN IN DIFFRENTSESSION (mg/l)

SESSION	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	30.0	53.8	55.6	52.0	46.7	42.3	42.3	43.2	44.1	43.2	39.7	33.5
10-12 October 15	33.0	60.4	63.6	58.4	53.6	47.5	48.7	48.5	50.8	48.5	45.6	38.6

TABLE 7 TKN IN (%) IN DIFFERENTCOMPARTMENTS

SEASON	**COMPARTMENT**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1-3 October 15	100.00	179.30	185.18	173.42	155.79	141.09	141.09	144.03	146.97	144.03	132.27	111.70
10-12 October 15	100.00	183.00	192.82	176.82	162.53	144.00	147.64	146.85	153.79	146.85	138.27	116.88
MEAN	100.00	181.15	189.00	175.12	159.16	142.55	144.37	145.44	150.38	145.44	135.27	114.29
STANDARD DEVIATION	0.00	±2.62	±5.40	±2.40	±4.77	±2.06	±4.63	±1.99	±4.82	±1.99	±4.24	±3.66

ii) HRT of ABR compartment were found from mensuration of ABR and mean discharge (159170.674 l/d) obtained in sampling session (table 8)

TABLE 8 HRT OF DIFFERENT COMPARTMENTS OF ABR

	COMPARTMENT											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
HRT (in hrs)	8.38	16.76	25.14	33.52	41.90	50.28	58.66	67.04	75.42	83.80	92.18	100.56

iii) Obtained parameters were shown in table 9 for different HRT.

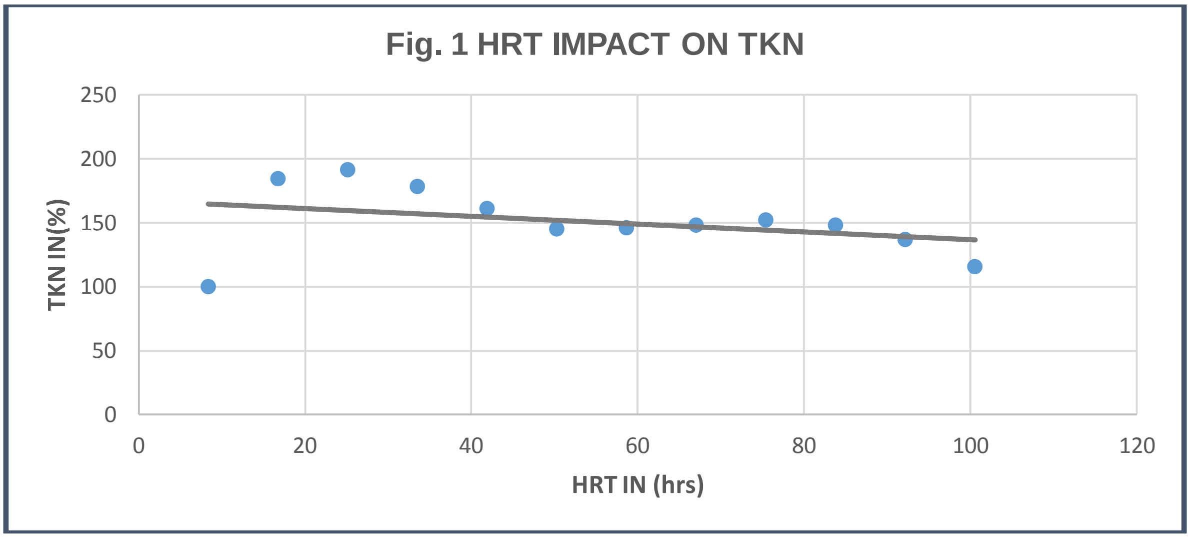
TABLE 9 WASTEWATER PARAMETERS OBSERVED IN DIFFERENT COMPARTMENT

	COMPARTMENT											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
HRT (in hrs)	8.38	16.76	25.14	33.52	41.90	50.28	58.66	67.04	75.42	83.80	92.18	100.56
NITRATE IN %	100.00	90.65	99.35	106.94	113.14	119.98	109.88	113.31	122.59	129.99	135.76	144.99
AMMONIA (in %)	100.00	437.09	439.67	344.43	254.48	183.99	192.68	211.35	251.36	250.49	225.91	191.37
TKN (in %)	100.00	181.15	189.00	175.12	159.16	142.55	144.37	145.44	150.38	145.44	135.27	114.29

iv) Evaluation of ABR for nitrogenous compounds

There were three parameters analyzed for nitrogenous compounds viz nitrate, ammonia and TKN.

a) TKN refers to total nitrogenous compounds present in substrate in the form of ammonia and organic nitrogen. The concentration of TKN indicates amount of nitrogenous compounds exist in substrate. Linear regression analysis among HRT and TKN (table 9) was shown in fig 1.



The mathematical expression obtained for the curve was given below

v_{tkn} = - 0.3041 u – 167.14 equation 1

Where,

u = HRT in hours,

v_{tkn} = TKN in faire season in percentage.

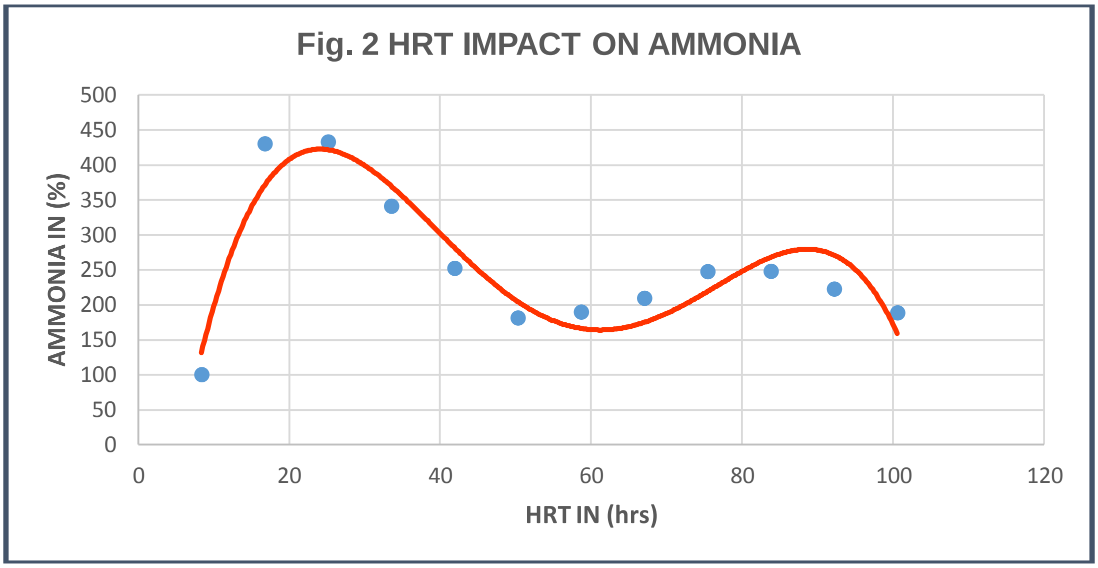
For complete removal of TKN i.e. nitrogenous compound

v_{tkn} = 0

u = 549.47 hours

Thus for complete removal of TKN, HRT requirement of ABR was 549.47 hours. It means depletion of nitrogenous compound in ABR was very slow.

b) Ammonia also indicate nitrogenous compound, which present as organic impurities at outside of the microorganism cells. Dependency among HRT and Ammonia was given in table 9 and regression shown in fig. 2.



The mathematical expression of curve was given below

$v_{ammonia}$= -0.0002 u^4 + 0.0382 u^3 – 2.9749 u^2 + 86.054 u -402.2 equation 2

Where,

u = HRT in hours

$v_{ammonia}$= observed ammonia in percentage.

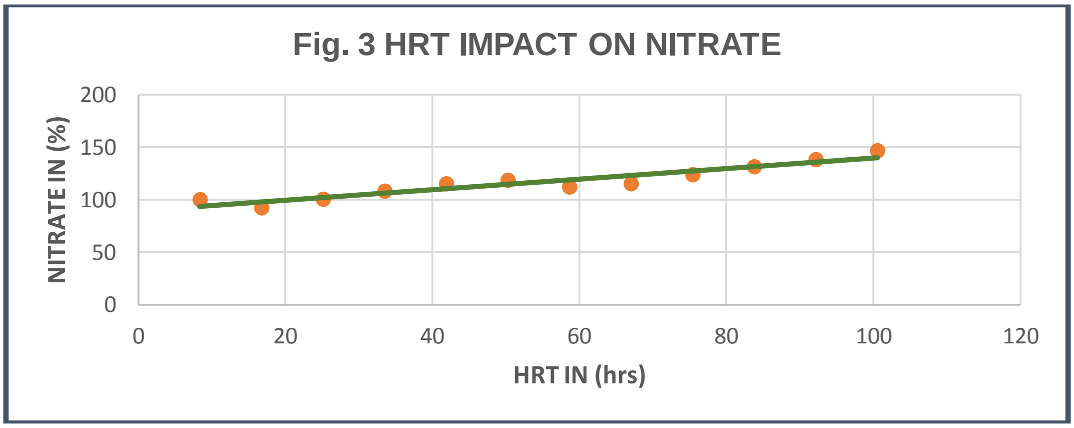
It was found from analysis for ammonia to become zero HRT requirement was 27.0 hours. But as shown in fig 2 Ammonia was regenerated again due to formation of new cells. This depletion and addition cycle was continue until entire nitrogenous compounds were oxidized. Which was achieved in HRT 549.47 hrs, when entire TKN was depleted.

So, putting u = 549.47 in above expression

$v_{ammonia}$= -0.0002 u^4 + 0.0382 u^3 – 2.9749 u^2 + 86.054 u -402.2

from which value of $v_{ammonia}$ found near to zero. It was validated the complete depletion of nitrogenous compound in substrate. Thus depletion model of ammonia was found suitable for nitrogenous substances depletion.

c) Nitrate indicates the final stable compound formed in substrate due to oxidation of nitrogenous compounds. Regression analysis of HRT and Nitrate for data given in table 9 was given in fig 3.



The mathematical expression of regressed curve was shown below-

$v_{NITRATE}$= 0.5078 u + 89.147 equation 3

Where, $v_{NITRATE}$ = observed nitrate in percentage

u = HRT in hours

For Nitrate reaches to its maximum concentration entire Ammonia, TKN or nitrogenous substance were get converted in to Nitrate. For which HRT was found 549.47 hrs from adopted model of nitrogenous compound depletion.

So, putting u = 549.47 hours for complete conversion of nitrogenous compounds, from which maximum nitrate was found 368.14%.

TABLE 10 CORRELATION BETWEEN VARIABLES

	HRT (in hours)	NITRATE (in percentage)	MEAN AMMONIA (in percentage)	MEAN TKN (in percentage)
HRT (in hours)	1			
NITRATE (in percentage)	0.94	1		
MEAN AMMONIA (in percentage)	-0.35	-0.45	1	
MEAN TKN (in percentage)	-0.35	-0.48	0.92	1

Correlation (table 10) among HRT, Nitrate, Ammonia and TKN was found 0.95, -0.35 and -0.35 respectively. It was also found that correlation among Nitrate, Ammonia and TKN was -0.45 and -0.48 respectively indicating that Nitrate increases almost at same rate as HRT increased but other two parameters decreased moderately. It may be due to conversion of Ammonia and organic nitrogen into Nitrate.

TABLE 11 EFFLUENT STANDARDS OF DOMESTIC WASTE WATER

S No.	PARAMETERS	UNIT	MAXIMUM PERMISSIABLE LIMIT	
			Land/ under ground	Surface water course
1	Ammonia_ Nitrogen	mg/l	1	
2	Nitrate_ Nitrogen	mg/l	10	
3	TKN	mg/l	25	

Source: environment protection act 2002 and amendment 2017

IV. CONCLUSION

Nitrate, Ammonia and TKN were found 2.0 mg/l, 20.75 mg/l and TKN 36.1 mg/l respectively (table 9) in compartment 12 where HRT was 100.56 (table 8). As per discharging standard of CPCB, India (table11), Nitrate concentration was within the limit but Ammonia and TKN were above the limit. Higher concentration of Ammonia and TKN indicates incomplete digestion of nitrogenous compounds, it also indicate that Nitrate concentration in effluent may further increase in higher HRT. It was found that nitrogenous compounds oxidization was hypothetically completed in 549.47 hours HRT (equation 1), when entire TKN and Ammonia were removed and Nitrate reaches to its maximum concentration. Therefore, it was concluded that depletion of nitrogenous impurity was insignificant and add-on aerobic unit needed.

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