Design of Laboratory Based Waste Water Treatment Plant

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RESEARCH ARTICLE

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ABSTRACT

The use of conventional water and wastewater treatment processes becomes increasingly challenged with the identification of more and more contaminants, rapid growth of population and industrial activities, and diminishing availability of water resources. It is need of present day to find out proper and reliable technology which is use for treatment of waste water. This paper present the finest design of laboratory scale wastewater treatment plant, which is a combination of natural and physical operations such as primary settling with cascaded water flow, aeration, agitation and filtration (Dual media filter), hence called as hybrid treatment process. The economical performance of the plant for treatment of sewage showed in terms of reduction of organic load of sewage pollutants such as COD (80%), TDS (80%), TSS (81%), and total hardness (78%). Hence, this technology could be a good alternative to treat wastewater for landscaping, gardening, toilet flushing, floor washing, and irrigation.

***Keywords*—**waste water treatment plant, waste water, natural technology, pollutant.

INTRODUCTION

Due to rapid Urbanization and growth of world population, the municipal bodies are problems of collection, treatment and disposal of waste water. Wastewater generated by local bodies off either on land or into the surface of water. The land disposal causes ground water pollution whereas the disposal into surface water affects the aquatic life. There is no adequate sewerage system in any of municipal bodies in Maharashtra state (MPCB, 2009). Due to paucity of funds of the local bodies discharge their domestic's effluents in nearby river through /local nalla without any treatment and it is a major source of surface water pollution. Scientists around the world are working on new strategy for water conservation (Ingole *et al.*, 2013; Dhote et al., 2013; Pangarkar *et al.*, 2010 Rao *et al.,* 2003). It is an opportune time, to refocus on one of the technique to recycle water through the reuse of waste water by economical way. Sewage is non-industrial waste water generated from domestic processes such as washing dishes, laundry and bathing. Waste water is distinct from black water in the amount and composition of its chemical and biological contaminates (from feces or toxic chemicals). Dish, shower, sink, and laundry water comprise 50-80% of residential waste water (Hussain *et al*., 2002; Emerson, 1998).

Waste water treatment is an environmental friendly process as a control of water pollution. Many people have investigated the various waste water treatment methods extensively on the international and national levels and many researchers tried to reduce the cost for recycling of the water (Ingole *et al*., 2013; Dhote et al., 2013). The household waste water can be reused for other purposes, especially landscape irrigation, floor washing, car washing and toilet flushing. Grey water has some pollutants that are considered as fertilizer for the plants. Phosphorous, nitrogen, and potassium are excellent sources of nutrients when reusing waste water for irrigation of landscaping and gardens (Pangarkar *et al*., 2010). Benefits of grey water include using less fresh water, sending less waste water to septic tanks or treatment plants, less chemical use, groundwater recharge, plant growth, and raises awareness of natural cycles (Emerson 1998, Little *et al*., 2001, and Dixon *et al*., 2003).

Throughout the world, supply of water to the rural population has been a challenging risk. In India, the 'water shortage' is one of the major issues coming from the rural area. Due to this, the government of Andhra Pradesh has designed and constructed a number of slow sand filtration for rural water supply schemes in the state (Rao *et al*., 2003). Our designed waste water treatment process is like a low technology systems, also called extensive or natural systems, are based on the imitation or adaptation of processes that occur naturally in soils and water bodies. The various conventional intensive technologies are in competition with natural systems to treat the waste water of medium and small size communities. In big cities, the sophisticated technologies are used by authorities and plants operated by highly skilled personnel to abide by discharge regulations and prevent the failure that could damage the environment. Large town can afford high treatment expenses, which is not the case for rural communities (Brissaud, 2007).

Experiences of treating waste water by natural treatment systems have not been widely reported. In general terms, waste water has lower concentration of organic matter, nutrients and microorganisms. The concentration of phosphorus, heavy metals and xenobiotic organic pollutants are around the same levels (Lopez-Zavala 2007, Erikson *et al*., 2002, Garland *et al*., 2004). The pollutants of waste water are reduced by a natural treatment system (laboratory scale) was the aim of this study. This is a socio-economical treatment method gives the wide significant in the rural development.

MATERIALS AND METHOD

Laboratory scale waste water treatment plant has been designed for 50 lit/hr capacity restricted four stage physical operations such as primary settling with cascade flow of water has 20 liters capacity, aeration has 20 liters tank capacity, agitation has also 20 liters and filtration unit of 20 liters.

The laboratory scale waste water treatment plant is explained in figure 1(a) contained the operation of primary settling tank with cascade flow of water as shown in figure 1(b), aeration as shown in figure 1(c), the agitation as shown in figure 1(d) and last major operation of plant is a filtration. The gravitational force was used for the flow of water from primary settling tank with 04 steps of cascade system to the aeration, agitation and filtration unit to the storage tank. The 0.18 m diameter agitator and 0.125 HP motor was used in the agitation operation. The easily available and natural materials were used as filter beds in the filtration unit such as fine particles (equal size) sand bed, course size bricks bed, charcoal bed, wooden saw dust bed and bed of coconut shell covers. The bed height of each material was determined and finalized by the experimentation.

Fig. 1: Experimental set up of Lab scale wastewater treatment plant, (a)Sedimentation (b) aeration (c) agitation (d) Filtration Unit and (e) collection tank.

Fig.2(a):Primary Settling Unit (Sedimentation tank)

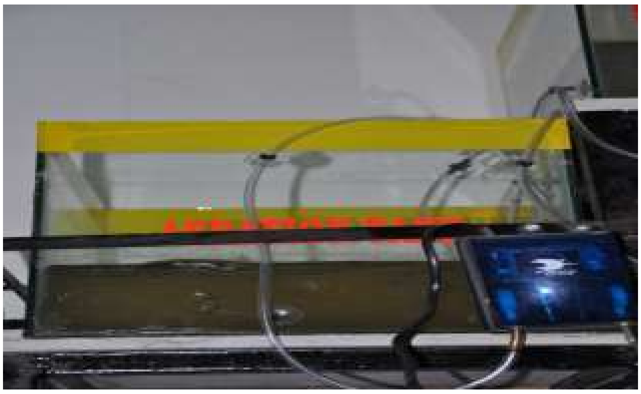

Fig. 2(b): Aeration Unit

Fig. 2(c): Agitation unit

Fig. 2(d): Recycling and Collection tank.

Sampling of Waste water: Municipal wastewater was collected during January 2012 to December 2013 from 10 sampling stations of 10 Amba nallas, which cover entire Amravati city. The surface water quality changes from season to season and is easily polluted. For this purpose, samples were collected from 10 nallas throughout the year on a monthly basis. Samples were collected during the first week of each month, between 7.30 am to 8.30 am in clean plastic bottles, labeled properly and brought to the laboratory for analysis.

Methods of Sampling*:* Municipal wastewater sample is collected from about 40-50 cm below the surface, to avoid the collection of surface impurities, oils etc. Before sampling, 30 L polythene bottles were rinsed with 0.1N chromic acid, than washed twice with distilled water. A separate sample was collected in bottle to measure the Dissolved oxygen (DO).

Analysis of Sample: These samples were analyzed by standard method for water and waste water analysis (APHA, 1995) at laboratory. The following 18 water quality parameters were analyzed: Temperature, pH, Turbidity, Total dissolved solids, Total suspended solids, Total hardness, Dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, Chromium, Copper, Cadmium, Manganese, Nickel, Lead, Iron, Arsenic, Iron, Zinc.

RESULTS

pH test for filter bed height calculation

In the filtration unit natural materials such as fine sand, coarse sand, gravels and bricks, were used as an adsorbent. The sample of water was taken before and after filtration and the positive effect on pH level at 0.5 lit/min (LPM) of water flow rate. The filter fine sand sand brick were given the maximum effect on pH level from 6.69 to 7.20 and the minimum effect found for bed of bricks. The bed of coarse sand and saw dust material were found the fair change in pH level 6.69 to 7.96. The deviation in pH by each filter bed was found because each filter bed having the different capacity of adsorption of ions.

For the further experiment the depth of each bed were selected as 8 cm, 8 cm, 24 cm, 12 cm and 6 cm for coarse sand, gravels, fine sand, bricks and saw dust covers respectively set from bottom to top in the filtration unit based on pH level effect. The maximum pH effect found by fine sand bed was kept at top second in position after brick from top in the filtration unit.

Table:1 : Average Characteristics of Physicochemical Parameters form 10 sampling station on Amba nalla, Amravati , Maharashtra.

Site Code	Seasons	Temp		pH		TSS mg/l		TDS mg/l		Hardness mg/l		DO mg/l		BOD mg/l		COD mg/l	
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
S1	Rainy	21.0	20.0	7.98	7.38	518	41	950	178	615	166	Nil	4.5	128	32	189	46
	Winter	19.0	19.0	7.37	7.44	415	32	718	168	702	172	Nil	5.2	112	26	156	28
	Summer	23.0	21.0	6.91	7.24	422	35	887	172	1002	188	Nil	2.9	156	38	225	52
S2	Rainy	20.0	18.4	7.69	7.31	503	38	903	176	620	166	0.2	4.8	132	30	127	23
	Winter	19.0	18.4	7.33	7.30	420	32	712	167	705	172	0.2	3.8	130	34	159	28
	Summer	24.0	21.6	6.98	7.33	415	30	884	172	1010	188	Nil	4.4	128	32	203	48
S3	Rainy	20.0	19.6	7.72	7.37	510	38	927	177	610	166	0.2	3.9	130	32	131	24
	Winter	19.0	18.2	7.52	7.39	324	30	720	168	700	170	0.2	4.0	122	30	171	33
	Summer	22.0	20.3	6.89	7.32	328	30	877	167	947	182	0.3	5.1	112	24	199	47
S4	Rainy	19.0	18.7	7.91	7.42	480	37	910	176	604	162	0.2	3.9	130	32	143	26
	Winter	18.0	17.5	7.42	7.28	354	33	728	165	718	172	0.4	3.0	156	38	181	34
	Summer	23.0	21.4	6.89	7.18	335	28	830	170	980	188	0.4	4.9	104	26	192	45
S5	Rainy	20.0	19.2	7.96	7.35	452	37	900	174	628	169	0.3	5.3	97	23	141	25
	Winter	19.2	18.8	7.54	7.33	353	31	730	167	711	175	0.3	4.2	86	23	185	34
	Summer	22.0	21.3	6.95	7.27	330	30	843	174	992	188	0.2	5.9	104	24	193	46
S6	Rainy	19.0	18.4	7.81	7.53	472	41	899	175	653	170	Nil	4.3	176	40	121	22
	Winter	18.5	18.5	7.37	7.32	321	30	711	166	728	176	Nil	4.4	162	38	156	28
	Summer	23.5	21.1	6.88	7.19	340	32	812	169	998	188	Nil	5.3	178	40	185	34
S7	Rainy	20.0	19.6	8.02	7.59	520	44	882	172	682	170	Nil	4.1	166	38	189	34
	Winter	18.0	17.9	7.28	7.30	431	34	702	165	754	172	Nil	4.1	166	38	163	29
	Summer	23.0	21.7	6.69	7.20	468	37	811	170	1020	190	Nil	4.7	142	36	201	48
S8	Rainy	20.0	19.8	8.22	7.54	504	40	988	183	682	170	Nil	3.6	156	38	183	45
	Winter	19.4	19.1	7.64	7.45	418	33	753	169	763	175	Nil	3.2	188	42	167	32
	Summer	23.0	21.2	6.76	7.11	422	34	888	175	1055	198	Nil	4.1	182	40	219	51
S9	Rainy	20.0	19.3	8.15	7.55	508	41	1003	190	704	171	Nil	3.6	174	40	191	37
	Winter	19.0	19.3	7.50	7.39	433	32	803	168	788	179	Nil	3.1	192	44	180	36
	Summer	22.8	20.8	6.93	7.27	420	30	908	175	1102	210	Nil	3.2	204	48	257	57
S10	Rainy	21.3	20.2	8.30	7.68	508	37	998	190	786	178	Nil	3.2	186	42	199	48
	Winter	19.8	19.3	7.59	7.36	400	32	807	168	804	180	Nil	3.2	198	46	192	45
	Summer	23.1	22.2	6.69	7.23	408	32	920	176	1250	245	Nil	3.0	208	56	289	67

Table:1 : Average Characteristics of Heavy metal form10 sampling station on Amba nalla, Amravati , Maharashtra.

Site Code	Seasons	Cr		Cu		Cd		Mn		Ni		Pb		Fe		As		Zn	
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
S1	Rainy	0.00	0.00	0.18	0.08	0.00	0.00	0.18	0.08	0.09	0.00	0.00	0.00	0.35	0.05	0.00	-	3.55	1.10
	Winter	0.00	0.00	0.20	0.08	0.00	0.00	0.15	0.08	0.05	0.00	0.02	0.00	0.10	0.00	0.00	-	3.00	1.10
	Summer	0.00	0.00	0.24	0.14	0.00	0.00	0.22	0.13	0.07	0.00	0.02	0.00	0.25	0.05	0.00	-	3.40	1.10
S2	Rainy	0.00	0.00	0.10	0.01	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.34	0.08	0.00	-	2.81	0.71
	Winter	0.00	0.00	0.13	0.01	0.00	0.00	0.20	0.09	0.01	0.00	0.05	0.00	0.30	0.08	0.00	-	2.00	0.38
	Summer	0.00	0.00	0.13	0.01	0.01	0.00	0.15	0.07	0.04	0.00	0.05	0.00	0.28	0.08	0.00	-	2.85	0.80
S3	Rainy	0.00	0.00	0.14	0.07	0.00	0.00	0.15	0.07	0.07	0.00	0.00	0.00	0.41	0.10	0.00	-	3.12	1.00
	Winter	0.00	0.00	0.20	0.09	0.01	0.00	0.24	0.16	0.09	0.00	0.00	0.00	0.32	0.09	0.00	-	3.18	0.98
	Summer	0.00	0.00	0.21	0.15	0.00	0.00	0.28	0.16	0.06	0.00	0.00	0.00	0.45	0.14	0.00	-	4.44	1.28
S4	Rainy	0.00	0.00	0.06	0.00	0.01	0.00	0.20	0.09	0.05	0.00	0.00	0.00	0.30	0.09	0.00	-	3.43	1.10
	Winter	0.05	0.01	0.00	0.00	0.02	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.10	0.00	0.00	-	2.47	0.53
	Summer	0.00	0.00	0.08	0.00	0.00	0.00	0.35	0.28	0.03	0.00	0.00	0.00	0.28	0.09	0.00	-	4.56	1.32
S5	Rainy	0.00	0.00	0.16	0.07	0.01	0.00	0.20	0.09	0.00	0.00	0.00	0.00	0.37	0.13	0.00	-	4.47	1.30
	Winter	0.20	0.14	0.20	0.13	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.15	0.02	0.00	-	4.04	1.04
	Summer	0.00	0.00	0.25	0.17	0.02	0.00	0.30	0.21	0.03	0.00	0.00	0.00	0.28	0.09	0.00	-	4.87	1.03
S6	Rainy	0.00	0.00	0.31	0.21	0.15	0.07	0.32	0.21	0.01	0.00	0.00	0.00	0.33	0.09	0.00	-	3.83	1.02
	Winter	0.15	0.08	0.31	0.21	0.04	0.00	0.21	0.13	0.01	0.00	0.02	0.00	0.21	0.07	0.00	-	3.72	0.88
	Summer	0.05	0.00	0.35	0.19	0.20	0.09	0.40	0.29	0.02	0.00	0.00	0.00	0.35	0.13	0.00	-	5.82	1.77
S7	Rainy	0.00	0.00	0.22	0.11	0.16	0.09	0.20	0.14	0.02	0.00	0.00	0.00	0.23	0.10	0.00	-	4.29	1.52
	Winter	0.00	0.00	0.28	0.16	0.16	0.08	0.01	0.00	0.02	0.00	0.02	0.00	0.38	0.15	0.00	-	4.00	1.09
	Summer	0.00	0.00	0.32	0.25	0.20	0.09	0.28	0.17	0.01	0.00	0.00	0.00	0.40	0.18	0.00	-	4.82	1.27
S8	Rainy	0.00	0.00	0.22	0.14	0.00	0.00	0.10	0.02	0.03	0.00	0.02	0.00	0.23	0.03	0.00	-	3.86	1.09
	Winter	0.04	0.00	0.24	0.15	0.10	0.03	0.01	0.00	0.00	0.00	0.03	0.00	0.34	0.07	0.00	-	3.00	0.90
	Summer	0.00	0.00	0.25	0.15	0.00	0.00	0.29	0.18	0.03	0.00	0.03	0.00	0.41	0.18	0.00	-	4.16	1.18
S9	Rainy	0.00	0.00	0.25	0.15	0.19	0.08	0.30	0.18	0.03	0.00	0.00	0.00	0.36	0.18	0.00	-	32.92	13.13
	Winter	0.09	0.02	0.20	0.09	0.10	0.02	0.35	0.23	0.03	0.00	0.02	0.00	0.41	0.18	0.00	-	37.00	13.08
	Summer	0.00	0.00	1.00	0.57	0.20	0.08	0.40	0.28	0.04	0.00	0.03	0.00	0.45	0.21	0.00	-	40.11	13.98
S10	Rainy	0.00	0.00	0.30	0.18	0.16	0.04	0.38	0.28	0.05	0.00	0.02	0.00	0.40	0.20	0.00	-	48.61	15.91
	Winter	0.18	0.10	0.38	0.23	0.20	0.09	0.40	0.20	0.05	0.00	0.02	0.00	0.45	0.20	0.00	-	50.87	18.72
	Summer	0.10	0.10	1.50	0.63	0.25	0.17	0.48	0.31	0.05	0.00	0.02	0.00	0.50	0.31	0.00	-	53.53	18.97

Table 3: Average Removal of Organic Load from waste water

Parameters	Before treatment	After treatment	% Removal
pH	7.42	7.35	-
TSS	424.4	34.36	81%
TDS	846.8	172.73	80%
Hardness	810.43	179.86	78%
DO	0.26	4.09	-
BOD	150.16	35.66	77%
COD	182.9	38.4	80%
Chromium	0.029	0.015	52%
Copper	0.280	0.148	48%
Cadmium	0.073	0.031	58%
Manganese	0.229	0.138	40%
Nickel	0.035	0	100%
Lead	0.013	0	100%
Iron	0.324	0.112	65%
Arsenic	0	-	-
Zinc	11.76	3.976	66 %

Effect of flow rate on removal of waste water pollutants

The samples of raw wastewater i.e. before cascade stage and. after filtration stage were taken with varying flow rate of water, shows the effect of flow rate of waste water on pH level and the resultant pH were nearly constant i.e. 7.27 (average) up to 1 lit/min, while increases pH level for further increase in flow rate. The characteristics parameters of wastewater such as TDS, TSS, COD and total hardness were determined and all these are pretentious by flow rate of water after flow rate of 1 lit/min. The wastewater average organic load removal was found 84 % at the water flow rate of 1.25 lit/min. The removal capacity of organic load of wastewater was decreased by raising flow rate of wastewater. Similar finding where observed by Pangarkar *et al*. (2010).

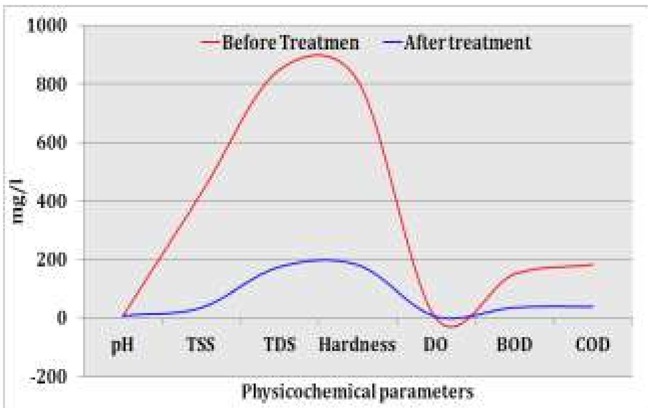

Fig. 3: Average Removal of Reduction in Physico-chemical parameters of waste water

Time effect on flow rate of waste water

The time required to flow the water from initial stage to final storage tank at various water flow rates. The input and output flow rates of water were nearly found the equal rates because there were no accumulations of wastewater.

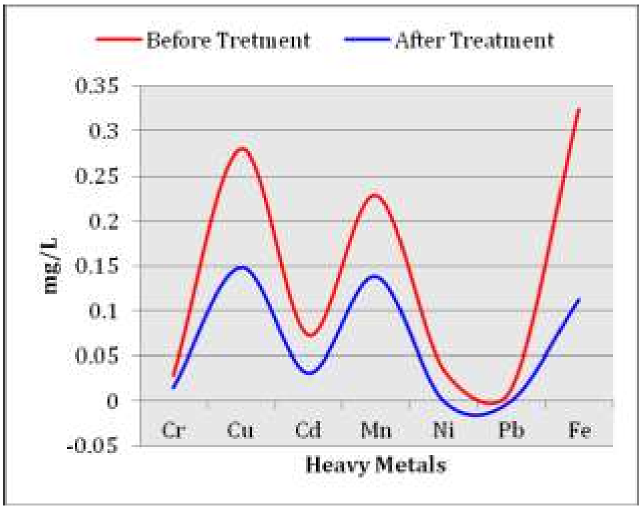

Fig. 4: Average Removal of Reduction in Heavy metals form waste water

Performance of each stage of the system

The pH of wastewater was changed by each stage of system. The aeration, agitation and filtration stages were found the involvement for change in pH of wastewater. The pH level was changed mainly between 6.69 to 6.91 in agitation and 6.85 to 7.68 in filtration stage.

Due to cascade, the course size and fine solid particles are settled down by gravitational force and only clear water flows towards aeration stage of the plant and found 17 % of TSS was removed in the cascade stage. The major role of aeration was controlled the TDS and COD, BOD of wastewater. The Oil, soap, detergents contained in wastewater was removed by agitation operation. From the investigation, average pollutants removal efficiency of agitation operation was found up to 29 %.

All pollutants removal efficiency was increased by the filtration stage and found 80 % of COD, 81 % of TSS. The average removal efficiency of all pollutants for filtration stage was increased from 26 % to 69 %. The filtration stage found major role in the system for removal of pollutants from wastewater. Hence the filtration stage was studied here and data of removal of load of pollutants on wastewater by each filter bed was investigated.

Performance of the laboratory based treatment plant for removal of Heavy metals load

Heavy metals contamination in waste water is common now days; in present investigation we found fare level of 10 selected heavy metals in all the season of analysis. The average highest level was found for Zn 11.76 mg/l while after treatment it was 3.98 mg/l. Efficiency of treatment plant to remove organic load of heavy metal was found 66% which is its great achievements. At different stages of cascade organic load removal capacity may varied from 11% to 28 % but best parts of this is filtration unit. Among 10 selected Heavy metals Nickel and Iron were removed 100 %, while for other load lies between 40 % to 80 %.

Performance of the laboratory based treatment plant

The wastewater was collected from different spot Amba nala, Amravati, India. Total 10 samples of wastewater were taken at first day of morning and evening of every week and the performances of system were investigated for these 10 samples of wastewater at steady state conditions and the average value data are summarized in table 3. The highest organic load in wastewater found 289 mg COD/lit and lowest were found 121 mg COD/lit. The solids in wastewater were found to have about 76% dissolved and 24% suspended particles. From table 2, all the parameters found in wastewater were reduced and found better performance of the natural system. The average 75 % of organic load was removed and 46 % anions and 49 % cations were found to be adsorbed by the natural adsorbents used in filtration. The traces of potassium, magnesium and calcium were found and removed fully from wastewater.

DISCUSSION

The results presented in this study establish the potential applicability of the developed methodology. This laboratory scale waste water treatment plant is a combination of natural and physical operations such as settling with cascaded water flow, aeration, agitation and filtration, hence called as hybrid treatment process. All the natural and easily available low cost materials were used for the treatment process. The coconut shell covers are the waste materials, which can be easily procured and used as an efficient adsorbent in water treatment process for the removal of water pollutants and heavy metal ions from waste water (Sekhar, 2008).

In economy of the plant, the power supply, which is an important part of the operating cost of the conventional system and it is a today's major issues of India, was required a minimum, because system works on the natural force for flowing of water from first to last stage. The easily explicable operation, less maintenance of the plant and hence does not required the highly skilled personnel. After the investigations due to the low energy demand, low operation and maintenance cost, lesser time consuming operation, this gives a significant and efficient method for rural communities and small industrial units for treatment and reuse of waste water.

The laboratory scale model shows the better and effective performance by the experiment and balances advantages and disadvantages of the system. As per the Indian standard, the treated water is used for landscaping, gardening, toilet flushing, floor washing, car washing and irrigation. Still, more research is needed about soil structure of the area which over applicable for irrigation and this will be presented shortly.

CONCLUSIONS

The present study demonstrates the reuse and treatment of waste water (sewage) for the purpose of landscaping, gardening, irrigations, plant growths and toilet flushing. Based on finding of this study, this treatment technology can be considered as a viable alternative to conventional treatment plants in rural region since they are characterized by high potential for COD, TDS, TSS, total hardness, oil and grease, and heavy metals removal. The benefits found are low energy demand, less operating and maintenance cost, lower load on fresh water, less strain on septic tank, highly effective purification, and ground water recharge. Hence, this is an environmental friendly, without chemical operation, cost effective and resourceful plant for rural development.

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