Research Journal of Recent Sciences _____ ISSN 2277 - 2502
Vol. **1(ISC-2011),** 41-46 **(2012)** *Res.J.Recent.Sci.*

Performance Evaluation of Reed Grass (Phragmites karka) in Constructed Reed Bed System (CRBs) on Domestic sludge, Ujjain city, India

Manderia Sushil
School of Studies in Environment Management, Vikram University, Ujjain, MP, INDIA

Available online at: www.isca.in
(Received 21th November 2011, revised 10th January 2012, accepted 24th January 2012)

Abstract

Proper utilization and disposal of solid waste specially domestic sludge was one of the most critical problem facing in city because domestic sludge is dump on outskirts of city without any treatment. Reed bed technology was based on ecological principles for management and disposal of domestic sludge. Experimental set up was formulated for treatment / conversion of complex organic matter into simple organic compound. The size of cemented tank used for sludge treatment were 3.5 ft length x 2.0 ft breadth and 3.0 ft depth for constructed reed bed system (CRBs). The CRBs was composed of a gravel bed supported below on a layer of pubbled, local clay. CRBs was planted with locally grown grass, Phragmites karka. Performance of reed in CRBs for domestic waste was evaluated for removal efficiency of some physico-chemical parameters. Plants placed in this rectangular design at the rate of 6 to 8 plants per tank and parameters assessed before and after 15 days of intervals i.e. pH, conductivity, salinity, organic carbon, organic matter, total kzeldhal nitrogen (TKN), organic nitrogen (Org.-N), nitrate-nitrogen (NO_3−N), ammonium nitrogen (NH_4−N), and available phosphorus (Av.-P), total phosphorus (T-P) while plant parameters fresh & dry weight of root, shoot, whole plant biomass and TKN in oven dry tissue. Removal rates were analysed as TOC (48%), TKN (61%), NH_4−N (50%), NO_3−N (58%) and total phosphorus (65%) respectively. The overall results established that it's very cost-effective treatment technology and removal efficiency was above 50%. The use of reed beds provides an efficient alternative for domestic sludge treatment.

Keywords: Constructed reed bed systems (CRBs), domestic sludge, *Phragmites karka* (reed), cemented tank, cost effective, removal efficiency.

Introduction

Domestic sludge contains essential nutrients and is potentially beneficial as fertilizers for crops /plants. Sludge is treated to remove or alter contaminants in order to minimize the impact of discharging into the environment in sustainable manner. Sludge is rich in organic content and nutrients like nitrogen, phosphorus and essential trace elements. Now a days, the treatment and disposal of domestic sludge has become a major problem to the human being, prompting widespread research and development into its possible reuse. Most of the research efforts[1-4] has been done to assess the feasibility of reusing the sludge in the construction and manufacturing process of industries. Currently, some researchers try to find low-cost and environmental solution for septage handle and disposal like co-composting with organic waste, anaerobic digestion, settling ponds, settling/thickening tanks, sludge drying bed, constructed wetland [5-10].

The urban sludge in developing countries are the victim of the city, because of the widening gap between the increasing waste generation and unavailability of commiserating economical resources to address the issue through conventional technologies. Hence, biological machines may prove to be a novel tool for sustainable management of domestic sludge. CRBs being natural, biological systems operating solely on solar energy is low cost and almost negligible operation and maintenance [11-12].

CRBs utilizes the principle of plant uptake for sludge treatment, similar to constructed wetlands for wastewater treatment [13-15].

Reed beds provide sludge dewatering through plant uptake, evapo-transpiration, and drainage. Reed beds chemically alter the sludge as the plants use nutrients and minerals in the sludge for growth. The final product is a well-decomposed, stabilized, humus-like residue suitable for land application [16-17].

Sludge applied to reed beds is turned into a compost-like material that can be used as a soil conditioner. Reed beds act to dewater and reduce the organic content of the sludge, reduce the metals concentrations of the sludge, and stabilize the sludge for subsequent disposal. This research paper is an attempt to evaluate the performance efficiency of CRBs with various parameters in domestic sludge.

Material and Methods

A field scale unit of Reedbed system was established at IEMPS, Vikram University in the southern area of Ujjain ($75^{o}43'$ E longitude $23^{o}09'$ N latitude, 491m above mean sea level) in the state of Madhya Pradesh, India. The climate of the area is characterized with summer, monsoon, post-monsoon and winter seasons. About 90% (870mm.) of the rainfall occurs during monsoon (mid June to mid September). The average temperature varies between 7ºC to 38ºC. The study was carried out in two parts / phases:

Construction of CRBs: Site selection: Sampling sites were selected for sludge collection was Ravindera Nagar and Mahananda Nagar residential colony. Sludge was anlaysed for few physico-chemical parameters following standard protocol[18]. Physical parameters i.e. pH, density, moisture content, colour and chemical parameters i.e. nitrogen, phosphorus, organic carbon & matter, C/N ratio were analysed. Plants parameters analysed were fresh & dry weight of shoot, root, whole plant and TKN in oven dry tissue.

Design: After preliminary study design were done for sludge treatment. The size of cemented tank was 3.5 ft length x 2.0 ft breadth and 3.0 ft depth, three sets were taken for sludge treatment, one set is control where no plant was grown, in second set Ravindera Nagar sludge and in third set Mahananda Nagar sludge was added respectively. In the system bottom layer is filled with gravel, pebbles, sand and soil then sludge was added and reed grows in the sludge.

Planting of Reed (Phragmites karka): Propagation – seed / seedling / rhizome / field collected plants. In each design / system reed plants from nursery were transplanted in 6 to 8 number.

Reed growth: Morphology (Root - Rhizome and Shoot length): The reed grass develops an extensive and dense root zone system, which spreads into the gravel beds of CRBs. These plants absorb nutrients from the CRBs through their root-rhizome system. Biomass production: It increased tremendously in root zone in both fresh weight and dry weight.

Performance evaluation of the system with different Reed Sludge complex parameters: The treatment potential of reed was assessed through various parameters as studied in physico-chemical characteristics. Fertility of Reed sludge complex was determined with various parameters analysed at 15days intervals. CRBs are designed to optimize the physical, chemical, and biological processes naturally occurring in the system. The microorganisms that flourish in these systems can degrade a wide range of organic chemical compounds into simpler compound. Optimization of sludge management can help in reducing sludge handling costs. CRBs typically require few months for growth of vegetation, biofilm establishment and sizeable time for development of litter.

The availability of ample nutrients in the domestic sludge through the CRBs and tropical warm climate favors the growth of plants. Analysis results (table 1 - 4) of pH indicate decrease from 7.9 to 6.9 and 8.10 to 7.15 at Mahananda nagar and Ravindera nagar respectively. The pH range between alkaline to neutral and no seasonal variations observed. Conductivity and salinity analysis depict that significant reduction occurred after treatment. It reduces from 1.25 to 0.55mMho in Mahananda nagar sludge followed by 1.30 to 0.60 mMho at Ravindera nagar sludge. It cannot alter soil type when used as soil conditioners. Progressive organic matter removal and sludge stabilization in the beds was also observed. Organic carbon and matter reduces 44% in Ravindera nagar sludge while in Mahananda nagar sludge it was 26% only. This may be due to absorption of organic carbon by reed plants for growth and development. Total nitrogen as well as other form of it decreases in sludge treatment. More reduction in total nitrogen at Mahananda nagar sludge followed by Ravindera nagar sludge respectively. Phosphorus content also reduces in both experimental set up. Nutrient removal during plant growing season averaged 60% for total kjeldahl nitrogen, 73% for total phosphorus and 64% for organic matter. The reed grass develops an extensive and dense root zone system, which spreads into the gravel bed of constructed system. These plants absorb nutrients from the bottom through their root rhizome systems. Plant biomass fresh weight was $425g/m^2$ and $412g/m^2$ and dry weight $152g/m^2$ and $162g/m^2$ at Mahananda nagar sludge followed by Ravindera nagar sludge respectively. The minimum and maximum concentration of TKN values were $0.327 \sim 16.120g/m^2$ ODT of reed grown in Mahananda nagar domestic sludge followed by $0.335 \sim 16.058g/m^2$ ODT of reed grown in Ravindera nagar domestic sludge respectively.

Conclusion

The purpose of this study was to evaluate the effectiveness of CRBs system. CRBs are capable to convert domestic sludge into compost-like material which can be used as soil conditioner. First, the reed root system provides oxygen to the sludge, which increases the activity and population of microorganisms that mineralize the sludge; second, the growth of the plants makes use of the nutrients, minerals, and water in the sludge. The CRBs are simple to operate, without chemical additives or complex electronic controls, and are very low maintenance. Consequently, the energy and operational requirements of reed beds are very low. *Finally*, CRBs are an effective, low-tech form of bioremediation for the treatment of municipal and others sludges. It is an effective process using plant life to help in the necessary process of treating some of the byproducts of human communities[19].

Acknowledgements

Author extends thanks to Head, School of Studies in Botany, Vikram University, and Ujjain for providing necessary facility for work.

References

1. Billore S.K., Singh N., Sharma J.K., Dass P. and Nelson R.M., Horizontal subsurface flow gravel bed constructed wetland with *Phragmites karka* in central India. *Wat. Sci. Tech.*, **40(3)**, 163-171 **(1999)**

2. Billore S.K., Singh N., Sharma J.K., Krishnamurthi R., Kobayashi T. and Yagi R., Ujjain clay as low cost sealant and liner for artificial Ponding and bentonite alternative, *Current Science*, **78(11)**, 1381-1383 **(2000)**

3. Billore S.K., Singh N., Ram H.K., Sharma J.K., Singh V.P., Nelson R.M. and Dass P., Treatment of a molasses based distillery effluent in a constructed wetland in central India, *Wat. Sci. Tech.*, **44(11-12)**, 441-448 **(2001)**

4. Billore S.K., Ram H., Singh N., Thomas R., Nelson R.M. and Pare B. Treatment performance evaluation of surfactant removal from domestic waste water in a tropical horizontal subsurface constructed wetland. In, *Proceedings of the 8th International Conference on Wetland Systems for Water Pollution Control*, Dar es Salaam, Tanzania, 16–19 Sept. **(2002)**

5. Koottatep T., Polprasert C., Oanh N.T.K., Heinss U., Montangero A. and Strauss M. Potentials of vertical-flow constructed wetlands for septage treatment in tropical regions, *Advances in Water and Wastewater Treatment Technology*, 315-323**(2001)**

6. Billore S.K. and Prashant Sharma, Treatment performance of artificial floating reed beds in an experimental mesocosm to improve the water quality of river Kshipra. *Water Sci Technol*, **60(11),** 2851-9 **(2009)**

7. Kengne I.M., Dodane P.H., Akoa A. and Kone D. Vertical-flow constructed wetlands as sustainable sanitation approach for fecal sludge dewatering in developing countries, *Desalination*, **248(1-3)**, 291-297 **(2009)**

8. Valencia R., den Hamer D., Komboi J., Lubberding H.J. and Gijzen H.J., Alternative treatment for septic tank sludge, Co-digestion with municipal solid waste in bioreactor landfill simulators, *Bioresource Technology*, **100 (5)**, 1754-1761 **(2009)**

9. Tsalkatidou M., Gratziou M. and Kotsovinos N., Combined stabilization ponds–constructed wetland system, *Desalination*, **248 (1-3)**, 988-997 **(2009)**

10. Troesch S., Liénard A., Molle P., Merlin G. and D. Esser, Treatment of septage in sludge drying reed beds: A case study on pilot-scale beds, *Water Science and Technology*, **60 (3)**, 643-653 **(2009)**

11. Nielsen S. Sludge drying reed beds, *Water Science and Technology*, **48 (5)**, 101–109 **(2003)**

12. Ruiz T., Wisniewski C., Kaosol T., F. Persin, Influence of organic content in dewatering and shrinkage of urban residual sludge under controlled atmospheric drying. *Process Safety and Environmental Protection*, **85 (B1)**, 104-110 **(2006)**

13. Cooper P., Willoughby, N., Cooper, D.J. The use of reed beds for sludge drying, *Journal of the Charted Institute of Water and Environmental Management.* **18(2)**, 85 - 89 **(2004)**

14. Nielsen S. Sludge reed bed facilities, operation and problems, *Water Science and Technology*, **51(9)**, 99–107 **(2005)**

15. Nielsen S. and Willoughby N., Sludge treatment and drying reed bed systems in Denmark, *Water and Environment Journal*, **19 (4)**, 296-305 **(2005)**

16. Meuleman A.F.M., Beekman J.Ph. and Verhoeven J.T.A., Nutrient retention and nutrient-use efficiency in *Phragmites australis* stands after wasterwater application, *Wetlands*, **22(4)**, 712-721 **(2002)**

17. Shao L., He P., Yu G. and He P. Effect of proteins, polysaccharides, and particle sizes on sludge dewaterability, *Journal of Environmental Sciences*, **21 (1)**, 83-88 **(2009)**

18. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington DC **(1992)**

19. Uggetti E., Llorens E., Pedescoll A., Ferrer I., Castellnou R. and García J., Sludge dewatering and stabilization in drying reed beds, characterization of three full-scale systems in Catalonia, Spain, *Bioresour Technol*, **100(17)** 3882-90 **(2009)**

Table – 1
Physico –chemical characteristic of reed bed complex after treatment in domestic sludge of Mahananda nagar

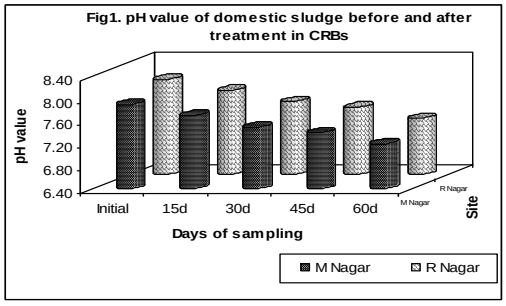
S.No.	Parameters	Initial	15days	%TP	30days	%TP	45days	%TP	60days	*%TP*
1	pH	7.90	7.70	2.53	7.50	5.06	7.40	6.33	7.20	*8.86*
2	Conductivity (mMho)	1.25	1.20	4.00	1.00	20.00	0.80	36.00	0.55	*56.00*
3	Salinity (%)	12.50	12.00	4.00	10.00	20.00	8.00	36.00	5.50	*56.00*
4	% Organic Carbon	38.00	37.00	2.63	33.00	13.16	30.00	21.05	28.00	*26.32*
5	%Organic Matter	65.51	63.79	2.63	56.89	13.16	51.72	21.05	48.27	*26.32*
6	% Moisture content	70.00	58.00	17.14	35.00	50.00	22.00	68.57	11.00	*84.29*
7	Bulk density (%)	1.75	1.71	2.29	1.62	7.43	1.53	12.57	1.41	*19.43*
8	Total Nitrogen (TKN)	37.10	35.70	3.77	25.90	30.19	20.60	44.47	12.17	*67.20*
9	Nitrate Nitrogen (NO_3-N_2)	2.96	2.85	22.58	2.16	49.47	1.95	64.31	1.72	*69.13*
10	Ammonium Nitrogen (NH_4-N_2)	41.00	39.20	4.39	28.60	30.24	19.80	51.71	11.20	*72.68*
11	Organic-Nitrogen	22.40	20.60	8.04	15.40	31.25	9.62	57.05	5.14	*77.05*
12	Available Phosphorus	6.40	5.90	7.81	4.10	35.94	3.50	45.31	2.70	*57.81*
13	*Total Phosphorus*	*7.70*	*7.50*	*2.60*	*5.60*	*27.27*	*3.10*	*59.74*	*1.20*	*84.42*

%TP Treatment performance

Table-2
Physico –chemical characteristic of reed bed complex after treatment in domestic sludge of Ravindera nagar

S.No.	Parameters	Initial	15days	%TP	30days	%TP	45days	%TP	60days	*%TP*
1	pH	8.10	7.90	2.47	7.70	4.94	7.60	6.17	7.40	*8.64*
2	Conductivity(mMho)	1.30	1.20	7.69	1.00	23.08	0.75	42.31	0.60	*53.85*
3	Salinity (%)	13.00	12.00	7.69	10.00	23.08	7.50	42.31	6.00	*53.85*
4	% Organic Carbon	42.50	41.40	2.59	38.50	9.41	30.10	29.18	23.70	*44.24*
5	%Organic Matter	73.27	71.37	2.59	66.37	9.41	51.89	29.18	40.86	*44.24*
6	% Moisture content	80.00	71.00	11.25	58.00	27.50	35.00	56.25	14.00	*82.50*
7	Bulk density (%)	1.95	1.90	2.56	1.65	15.38	1.32	32.31	0.90	*53.85*
8	Total Nitrogen (TKN)	40.60	39.90	1.72	33.10	18.47	21.00	48.28	15.00	*63.05*
9	Nitrate Nitrogen (NO_3-N_2)	3.50	3.30	27.59	2.90	44.44	2.20	51.39	1.90	*60.53*
10	Ammonium Nitrogen (NH_4-N_2)	42.70	41.30	3.28	34.80	18.50	24.90	41.69	13.20	*69.09*
11	Organic-Nitrogen	24.60	22.90	6.91	15.80	35.77	10.10	58.94	4.60	*81.30*
12	Available Phosphorus	6.80	6.60	2.94	5.10	25.00	4.30	36.76	2.70	*60.29*
13	*Total Phosphorus*	*7.50*	*7.20*	*4.00*	*5.10*	*32.00*	*2.50*	*66.67*	*1.00*	*86.67*

%TP Treatment performance



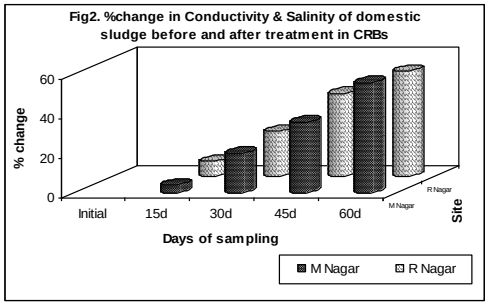
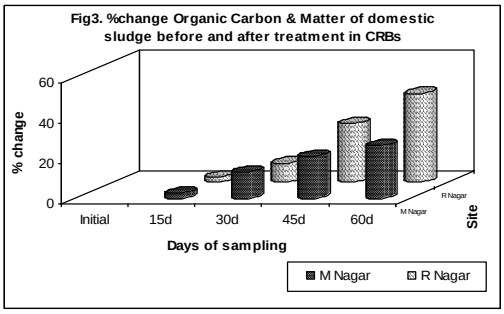
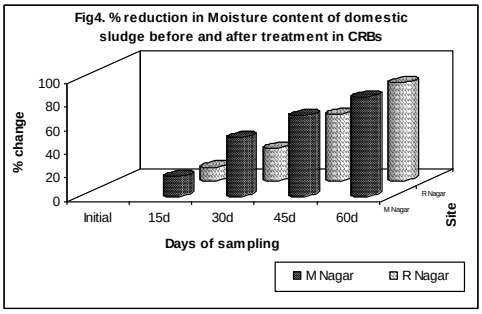


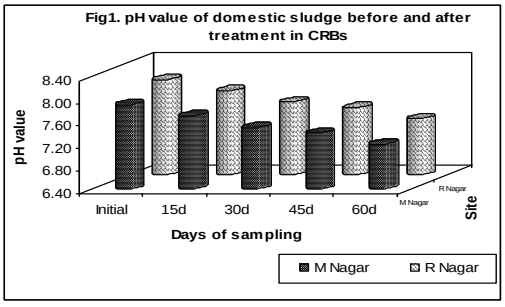
Table-3
Average results of plant growth (Phragmites karka) in CRBs for Mahananda nagar Domestic sludge after three consecutive year

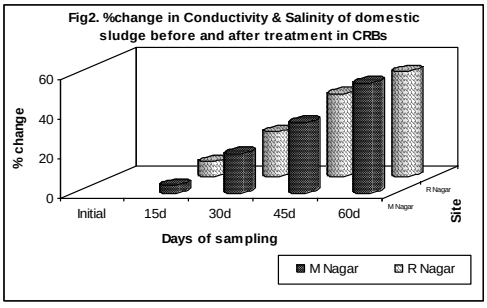
S.No.	Month	Plant Biomass Production (g/m^2)			
		Shoot FW (DW)	Root + Rhizome FW (DW)	Whole plant FW (DW)	TKN g/m^2 ODT
1	January	18.64 (2.79)	6.79 (0.95)	25.43 (3.74)	*0.285*
2	February	31.95 (8.66)	15.20 (2.15)	47.15 (10.81)	*0.863*
3	March	56.81 (14.80)	25.75 (4.50)	82.56 (19.30)	*2.170*
4	April	78.50 (18.25)	33.05(8.20)	111.55 (26.45)	*3.984*
5	May	92.17 (24.50)	42.60 (11.40)	134.77 (35.90)	*6.115*
6	June	125.65 (44.60)	59.87 (15.70)	185.52 (60.30)	*7.953*
7	July	153.86 (63.45)	76.10 (19.20)	229.96 (82.65)	*9.711*
8	August	180.72 (79.23)	93.50 (23.80)	274.22 (103.03)	*10.628*
9	September	195.64 (102.50)	102.75 (30.55)	298.39 (133.05)	*12.109*
10	October	225.79 (110.40)	117.52 (40.90)	343.31 (151.30)	*13.951*
11	November	253.60 (115.80)	129.65(42.85)	383.25 (158.65)	*15.017*
12	*December*	*289.13 (125.15)*	*133.20 (46.80)*	*422.33 (171.95)*	*15.955*

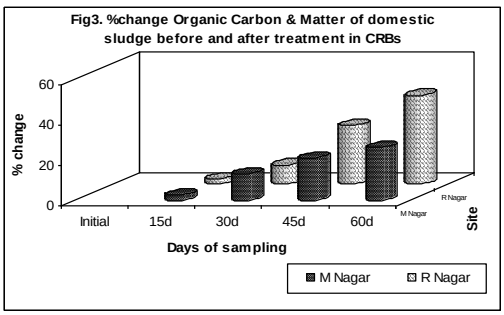
ODT : Oven dry tissue

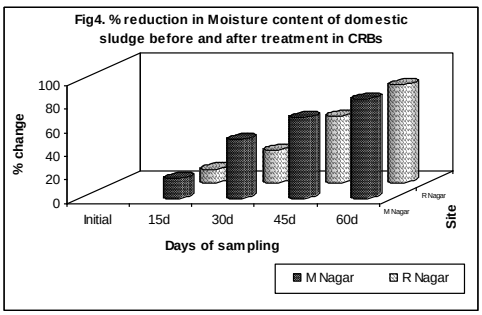


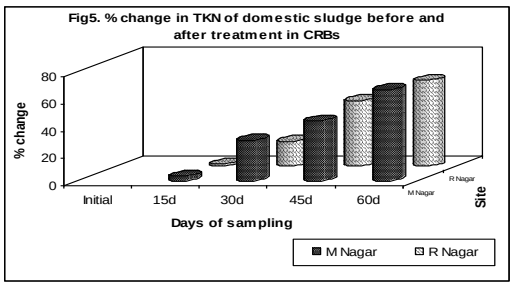


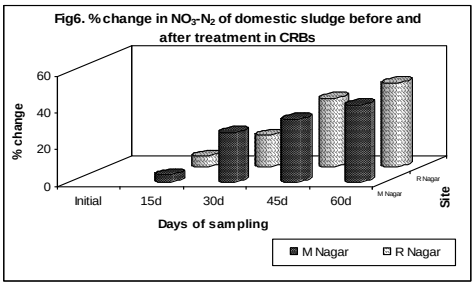


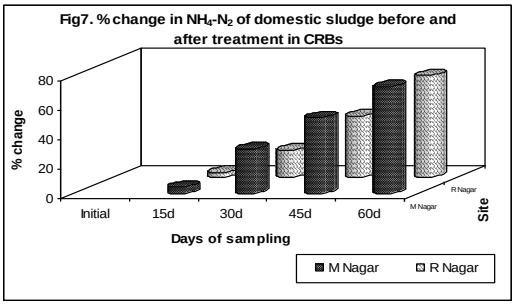


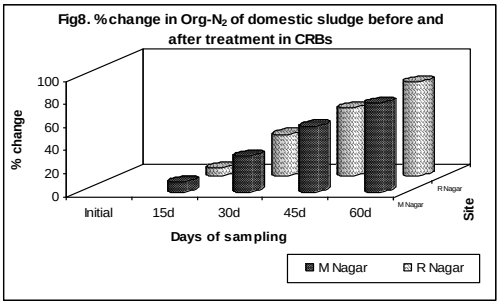


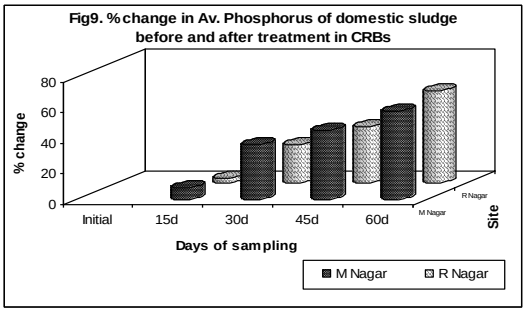












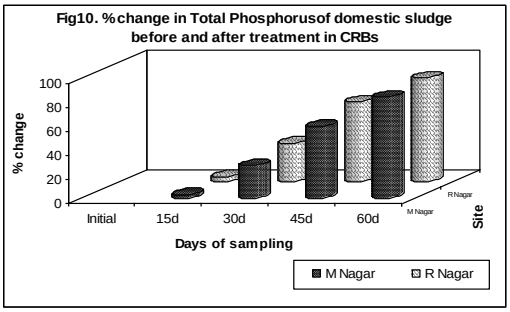


Table-4
Average results of plant growth (Phragmites karka) in CRBs for Ravindera nagar Domestic sludge after three consecutive years

S.No.	Month	Plant Biomass Production (g/m^2)			
		Shoot FW (DW)	Root + Rhizome FW (DW)	Whole plant FW (DW)	TKN g/m^2 ODT
1	January	16.96 (2.41)	6.17 (0.85)	23.13 (3.26)	*0.310*
2	February	33.45 (8.24)	13.45 (2.35)	46.90 (10.59)	*0.952*
3	March	58.70 (13.50)	27.85 (5.15)	86.55 (18.65)	*2.967*
4	April	82.79 (17.12)	36.25 (7.75)	119.04 (24.87)	*4.158*
5	May	95.09 (22.40)	44.56 (9.50)	139.65 (31.90)	*6.439*
6	June	120.36 (41.58)	56.98 (14.37)	177.34 (55.95)	*8.102*
7	July	155.62 (61.05)	79.25 (18.20)	234.87 (79.25)	*9.863*
8	August	183.15 (77.60)	91.45 (22.68)	274.60 (100.28)	*11.052*
9	September	198.00 (89.50)	99.57 (28.15)	297.57 (117.65)	*12.518*
10	October	228.10 (97.20)	115.35 (38.47)	343.45 (135.67)	*14.280*
11	November	243.60 (109.65)	124.70 (43.88)	368.30 (153.53)	*15.488*
12	*December*	*268.90 (122.20)*	*130.90 (44.70)*	*399.80 (166.90)*	*15.870*

ODT: Oven dry tissu