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Fertigation potential of domestic wastewater for tree plantations

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This study analyses feasibility of using domestic wastewater for fertigation of tree crops. Wastewater samples from different sources in domestic sector were analyzed and evaluated in terms of water quality and quantity. Water is rich in plant nutrients. However, due to possible presence of toxic ions and microbial load, it is recommended that direct use of wastewater for fertigation be limited to timber plantation and energy generation from biomass.

Keywords: Domestic wastewater, Fertigation, Irrigation

Introduction

Irrigation of plants with water containing fertilizer is termed fertigation. Liquid fertilizers are best suited for fertigation. However, inadequate availability and high cost of liquid fertilizers could restrict their use. In this regard, use of domestic wastewater for irrigation include benefits of safe and low-cost treatment of wastewater, conservation and recharge of groundwater reserves after phytoremediation by plants, and use of nutrients in wastewater for productive purposes. Suitability of water for irrigation is determined not only by total amount of salt present but also by kind of salts. Potential severity of problems may vary in both kind and degree, depending on type of soil, climate and crop. This study presents evaluation of wastewater from households for fertigation of tree plantation.

Materials and Methods

Wastewater samples (WS), selected in northern India, were as follows: Site 1 (STP), sewage treatment plant at Palwal, Haryana; Site 2 (SS), domestic sullage from a pond in Surajgarh, Rajasthan; Site 3 (SN), sullage from a drain at IIT Delhi, campus; and Site 4 (DS), domestic sullage from a household at IIT Delhi. WS were analyzed according to standard methods for water and wastewater examination[1]. Electrical conductivity (EC), TDS and pH were measured using EC meter TDS meter and pH-meter, respectively. Sodium and potassium were determined by Flame Photometer. Suspended solids (SS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), nitrate nitrogen (NO_3^-N), and total phosphate (TP) were analyzed using APHA methods[1].

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Results and Discussion

Characterisation of Wastewater Samples (WS)

WS were drawn during 2007-08 on different dates and time of the day. WS fall under the category "slight to moderate" in irrigation use (Table 1) and match well with those reported for wastewaters in other parts of the world (Table 2). There are guidelines[2] determining degree of restrictions on the use of wastewater for irrigation. A comparison of characteristics of wastewater from four samples under the study showed that NO_3^-N (0.3-18.5mg/l) and varied in the order SN> DS> STP> SS. This was within permissible limits of irrigation water quality. Total N (28-42.5 mg/l) in the form of Kjeldahl N, which is the estimation of organic and ammonical, also varied in the order SN> DS> STP> SS. So it was found that all N forms were highest in IIT drain (SN) and least in Surajgarh sullage water (SS). This was expected as SN and DS are untreated domestic wastewater while STP water was fully treated and SS is also from a sullage pond exposed to the atmosphere. Phosphate P (2.2-20.8 mg/l) was in the order SN≥ STP> SS>DS.

Table 1—Physicochemical characteristics of wastewaters collected from domestic sources

Parameters	Site 1 (STP)	Site 2 (SS)	Site 3 (SN)	Site 4 (DS)	Irrigation limits[6]
Physical					
pH	8.1-8.3	7.3-7.6	6.8-7.33	6.8-6.9	6.5-8.4
Total solids, mg/l	831-940	975-1152	1986-2431	1261-1291	-
TDS, mg/l	750-845	780-860	540-680	750-810	<2000
TSS, mg/l	81-102	195-312	1346-1751	466-481	-
Chemical					
BOD, mg/l,	32-40	19-47	120-180	105-120	-
COD, mg/l	78-98	57-106	218-295	126-156	-
Phosphate-P, mg/l	6.3-9.5	4.2-6.1	11-21	2-4	0-2
Elemental P, mg/l	2.05-3.09	1.7-2	4-7	1-2	0-2
Nitrate N, mg/l	3.3-3.72	0.3-3.01	8-19	7-14	
Elemental N (from nitrate), mg/l	0.74-0.84	0.18-0.41	1.8-4.2	1.5-3.1	0-10
Kjeldahl N, mg/l	32-36	28-32	40-43	35-37	0-5
K, mg/l	10-13	11-13	12-16	9-11	0-2
Na, mg/l	70-84	145-149	181-201	346-352	920
Chloride, mg/l	310-325	280-345	100-175	92-124.9	1050
Alkalinity, mg/l	342-372	80-90	330-350	315-420	-
Total hardness, mg/l	245-265	160-190	250-270	210-680	-
Ca, mg/l	115-170	90-150	52-68	38-72	400
Mg, mg/l	110-140	20-70	22-34	28-56	0-60
Metals					
Mn, mg/l	0.03-0.05	0.02-0.04	0.07-0.1	0.05-0.08	-
Cu, mg/l	0.11-0.14	0.01-0.03	0.1-0.12	0.11-0.12	0.2
Zn, mg/l	0.04-0.06	0.04-0.06	0.03-0.06	0.03-0.06	2
Ni, mg/l	0.12-0.13	0.04-0.06	0.05-0.07	0.02-0.07	0.2
Biological					
Fecal coliform, CFU/100 ml	3×10^{6}	5×10^{5}	4×10^{6}	3×10^{4}	-

Table 2—Characteristics of treated sewage effluent and allowed standards for irrigation

Parameters	Treated sewage			Irrigation water quality standard, China	Irrigation water quality standards[6]
	China[7]	Palwal, India (STP)	Brazil[9]	GB5084-92[8]	
pH	7.06	8.1-8.3	7.8-8.1	5.5.-8.5	6.5-8.4
BOD, mg/l	83.5	32-40	10-80	150	-
COD, mg/l	782	78-98	30-160	1000	-
Kjeldhal N, mg/l	19.7	32-36	-	30	-
Total N, mg/l	-		10-50	-	-
Total P, mg/l	7.3	1-10	-	10	0-2
K, mg/l	-	10-13	10-40	-	0-2
Chloride, mg/l	152	310-325	-	250	1050
Cu, mg/l	0.7	0.11-0.14	0.04	1.0	0.2
Zn, mg/l	1.3	0.04-0.06	0.04	2.0	2
Fecal coliform, mg/l	0	10^{6}	-	10^{4}	-

Potassium (8.6- 16.1 mg/l) was in the order SN> SS> STP> DS. Sodium (70-352 mg/l) and chloride (92-345 mg/l), which are responsible for causing salinity, were found to be within permissible limit. BOD and COD varied in the order SN> DS>STP =SS. COD: BOD ratio (2.5-1.3) was found to vary in the

Table 3—Wastewater requirement (in litres) for different plants for their nutrient requirement

Common name	N g /tree /yr	N mg / tree / day	WW required (l) @ 30-44 mg/l N	P g / tree / yr	P mg / tree / day	WW required (l) @ 1-5 mg/l P	K g / tree / yr	K mg /tree / day	WW required (l) @ 11-15 mg/l K
Ber (*Zizyphus mauritiana)*	450	1233	28-41	150	411	82-411	150	411	22-31
Mango (*Mangifera indica)*									
1 yr old sapling	100	274	6-9	75	205	41-205	100	274	15-21
5 yr old plant	500	1370	31-46	450	1233	246-1233	400	1096	60-83
Guava (*Psidium guajava)*									8-42
1-2 yr old sapling	50	137	3-5	30	82	16-82	50	137	30-42
5 yr old plant	200	548	12-18	120	329	66-329	200	548	
Orange (*Citrus spp)*									
1 yr old sapling	50	137	3-5	50	137	27-137	50	137	8-12
5 yr old plant	250	685	16-23	250	685	136-685	250	685	37-42
Ardu (*Ailanthus excelsa)*	18	49	1-2	3	8	2-8	-	-	-

Table 4—Approximate wastewater and nutrient availability from urban and rural habitat for 1000 households

	People perHH	Wastewater generation m3/ 1000 HH	N @ 30-44 mg/l kg generated / 1000 HH	P @ 1-5 mg/l kg generated / 1000 HH	K @ 11- 15 mg/ l kg generated / 1000 HH
Urban	5	500	15-22	0.5-2.5	5.5-7.5
Rural	5	100	3-4.4	0.1-0.5	1.1-1.5
	10	200	6-8.8	0.2-1	2.2-3.0

order SS> STP>SN>DS. All four wastewater samples did not contain hazardous ions.

Feasibility of Fertigation with Wastewater

Qualitative Aspects

Plants need suitable light, moisture, temperature, air, and nutrients to grow well. Fertigation potential of wastewater has to be matched with nutrient requirement of crops. NPK requirement varies from crop to crop and its stage of development[3]. N, P and K supplied by four WS were taken to be 30-44 mg/l, 1-5 mg/l and 11-15 mg/l respectively (Table 1). Since wastewater is generated continuously, it is useful to convert amount of nitrogen requirement per tree in milligram per day for daily irrigation regime. This was calculated by dividing per annum requirement by 365 (Table 3). It is seen that nitrogen requirement of a sapling (1 yr old) is fulfilled by a supply of 5-10 l of wastewater per day. A plant (5 yr old) requires almost 5 times this amount of water. To fix daily requirement for delivering full amount of phosphorus and potassium, it would require 5-10 times or more than this water. Nutrient requirement is more for fruit trees as compared to others such as hardy wood plants.

Wastewater Availability: Quantitative Aspects

Wastewater availability would vary depending on the type of habitat and economic status of households.

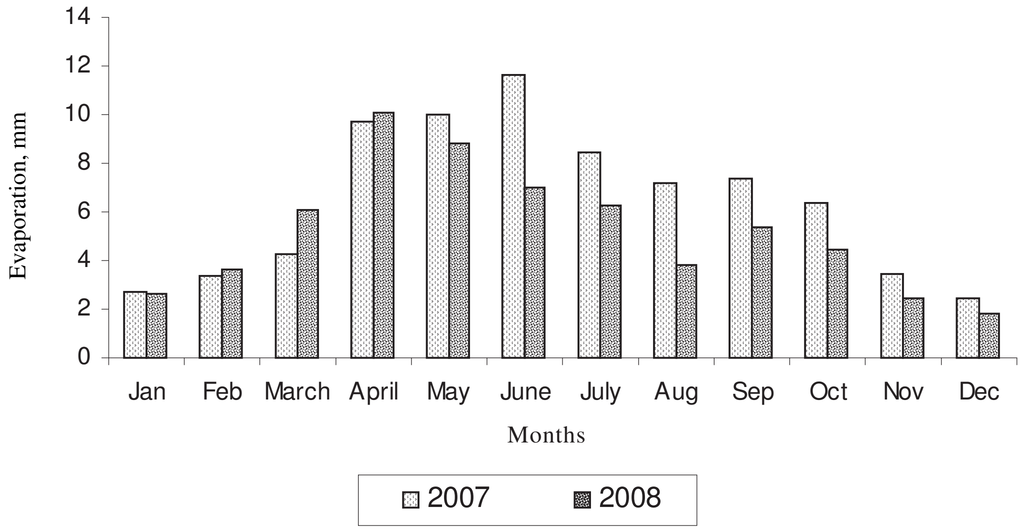

Fig 1—Evaporation in Delhi region during 2007-2008

In urban habitat (cities) consuming 100-200 l/capita/day, a family of 5 may reject up to 500 l/day of wastewater. This goes into sewer lines and reaches sewage treatment plants. Site 1 (a sewage treatment plant) depicts this situation. On the other hand, in a large village or town, wastewater generated may be of the order of 50-100 l/day or less per household. This may be essentially sullage, which goes through open drains reaching a pond situated at low level. Site 2 (Sullage pond in a village) is illustrative of this situation. In this case, fertigation can be attempted at entry point, at which wastewater is flowing into pond. This would also remediate water before it reaches pond, besides fertigating trees. A rough estimate of household water available from 1000 households (HH) (this may correspond to a whole village population or one single colony in an urban area) and nutrient content is shown in Table 4. Application of water (10-100 m^3/ha/day) would roughly correspond to 1-10 mm of water applied fulfilling for nutrient demand. Simultaneously, looking into the amount of wastewater needed for compensating for evaporation (Fig. 1), rate of evaporation in summer months (April- July) of Delhi is around 8-12 mm and only 2 mm in winter months. If each tree occupies a base of 10 m^2, each plant may be watered to 20-100 l for 2-10 mm depth. Choice of crops for irrigation by treated sewage effluents was found to be the principal factor for sustainability of effluent irrigation because certain crops can be irrigated with wastewater without negative yield[4]. Moreover, plants can control N loss in soil plant system by minimizing N leaching[5]. In terms of P and K, water requirement is higher. If more water is available for flooding, space between trees may be used to raise grass. Any extra wastewater, which has not been evaporated may percolate through soil and may be remediated by soil and plant roots by bioleaching.

Conclusions

Systematic studies on wastewater characteristics are needed for deciding on application of wastewater at rates, which ensure a balance between nutrient input and plant uptake. This will promote optimal plant growth while limiting pollution risk. Samples of domestic wastewater are recommended for fertigation of timber plantation and raising plants for energy generation from biomass.

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