Nutrient removal by different vegetable plants from source separated urine

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Abstract

In this paper nutrient removal efficiency of different plants were studied. For this purpose source separated urine in varying dilution was treated with different species of vegetable seeds. The growth of the plants was observed for 15 to 20 days experiment cycle. Five experiments were conducted in the batch basis. Results showed that plants Green Pea, Black gram, Broad bean had high nutrient removal efficiency**.** As media solution and effluent still contained traces of nutrients (NPK). Source-separated urine can be further diluted for total nutrient recovery.

Keywords: Nutrient removal, Plant bio-mass growth rate, Source separated urine, vegetable plants.

Introduction

Urine contributes large amount of nutrients to the household wastewater (Esrey et al., 1998; Jönsson et al., 1999; Larsen et al. 1999; Otterpohl, 2001). High levels of these nutrients recovery is possible with separate collection of urine at source. Urine is relatively sterile and can be reused without further treatment (Wolgast, 1993). However, due to faecal contamination, pathogens have been found in urine-collected separately with means of separating toilet; but in low concentration, which will pose low hygienic risk of using urine as a fertilizer, if it is stored at least for 6 months before being used in agriculture (Jönsson et al., 1999, Hellstroem and Johansson, 1999). Moreover, urine has low concentration of heavy metal. Therefore, separate collected urine can be used as fertilizer for growing vegetables. In this paper, nutrient removal efficiency of different plants is presented.

Methods and materials

For the experiment a temporary urinal was constructed, the outlet of which was connected to a collection tank whose outlet was again connected to a mixing tank. The outlet of the mixing tank was connected to culture chambers of 90*60*45 cm size. All the outlet points were installed with valves to control the flow. The chamber was filled with approximately 60 liters of gravel and pebble media of size 5-10 mm size and coarse sand to cover up to 11 centimeters of the chamber. Prior to commencement of the experiment, the medias were washed thoroughly. After the completion of every experiment, the media was washed continuous stirring the media 3-4 times and water drained in each wash. New media was introduced only in the fifth experiment.

Different species of vegetable seeds of cress, spinach, tintel, mustard, 2 varieties of Rayo (rape), green pea (Botanical name Pisum Sativum), black gram (Botanical name Cicer Arietinum) and broad bean (Botanical name Vicia Faba) were allowed to germinate in the laboratory for two days and placed on the plant culture chamber. The seeds which germinated were only taken and rest excluded. The germinated seedlings were planted on the chamber.

The growth of the plant was observed for 15 to 20 days experiment cycle. Five experiments were conducted. The plant species taken for different experiments and climatic condition during the experiment is as shown in the Table 1.

tab 1: Plant species and Climatic condition

Experiment No.	Vegetable Plan Type	Climatic Condition
1	Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black Gram, Broad Bean	Direct sunlight available maximum of 2 hours a day
2	Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black Gram, Broad Bean	Same as in exp. 1
3	Green Pea, Black Gram, Broad Bean	Same as in exp. 1 and 2
4	Black Gram, Broad Bean	No Direct sunlight available at all
5	Broad Bean	Same as in exp. 4

The source-separated urine was collected in the collection tank a day before the experiment and is diluted to required concentration in the mixing chamber. The dilution of urine and nutrient loading were done as shown in Table 2.

tab 2: Dilution and Nutrient Loading Rate

Experiment No.	Urine Volume Loaded (Litre)	Dilution Ratio	Nitrogen Loading Rate (g/m^2)	Phosphorous Loading Rate (g/m^2)	Potassium Loading Rate (g/m^2)
1	12.0	1:10	10.7	2.4	3.7
2	12.0	1: 6	4.2	0.1	3.5
3	14.2	1:15	7.7	0.5	13.7
4	18.0	1:15	6.2	0.3	6.4
5	15.0	1:10	6.2	0.2	1.6

The influent and effluent were analyzed for Nitrogen (N), phosphorous (P) and potassium (K). The effluent sample was drawn in every 5th day–except for experiment 2- for which only final effluent was drawn. At the end of the experiment, the plants were weighed, dried and analyzed for NPK. The process was conducted on batch basis i.e. urine was loaded for one time just before planting of the seedlings.

Results and Discussion

The removal efficiencies of different plants are as shown in Table 3. Nitrogen removal was in the range of 68 - 91 %. Highest removal efficiency was achieved in experiment 3 for broad bean, black gram and green pea with 1:15 dilution. Phosphorous removal was in the range of 63 - 96 %. Highest removal efficiency was achieved in experiment 1 for Cress, Spinach, Tintel, Mustard, Rape, Green Pea, Black gram, Broad bean with 1:10 dilution. Also in experiment 3 phosphorous removal was about 92%. Potassium removal was in the range of 59 - 85 %. Highest potassium removal was in experiment 3 for broad bean, black gram and green pea with 1:15 dilution.

tab 3: Characteristics of Influent and Effluent

Experiment No.	Influent Characteristic (mg/L)			Effluent Characteristic (mg/L)			Removal Efficiency (%)		
	N	P	K	N	P	K	N	P	K
1	479.6	108.8	165	57.3	3.4	n.a	88.1	96.9	n.a
2	197.6	4.6	155.3	59.7	1.7	n.a	68.2	63.0	n.a
3	291.4	19.7	521.2	26.0	1.6	75.0	91.1	91.9	85.6
4	184.8	9.4	191.0	33.5	0.9	72.9	81.9	90.4	61.8
5	222.1	7.1	59.3	61.8	0.9	24	72.2	87.3	59.5

Note: The removal efficiency is based upon initial volume. n.a. means not available.

The NPK content of the dehydrated plant bio-mass is shown in Table 4. Maximum nitrogen recovery was made in 33.3 % of loading value in the fourth experiment with broad bead and black gram, Maximum Phosphorous recovery was made in 50.0 % of loading value in the third experiment with broad bead, black gram and green pea. Maximum Potassium recovery was made in 45.2 % of loading value in the fifth experiment with broad bead.

tab 4: Plant uptake of nutrient and percentage of loading rate

	Nitrogen		Phosphorous		Potassium	
Experiment No.	Uptake By Plants (mg)	% Of N Loading	Uptake By Plants (mg)	% Of P Loading	Uptake By Plants (mg)	% Of K Loading
1	57.6	1.0	11.1	0.9	77.0	3.9
2	332.8	14.8	15.9	28.8	261.0	14.0
3	192.8	4.7	139.8	50.0	509.9	6.9
4	1107.9	33.3	55.3	32.7	1000.5	29.1
5	991.2	29.8	7.1	6.7	402.1	45.2

In the successive experiments, the plant species were selected depending upon mass of plant growth. Higher growth varieties were retained and low yielding plant in terms of plant bio-mass growth were excluded in the later experiments. In the fifth experiment only one species i.e. Broad bean (Botanical name Vicia Faba) was planted. Maximum plant bio-mass growth was achieved in experiment 4 with broad bean and black gram with 1:15 dilution (Table 5)

tab 5: Plant bio-mass growth rate

Experiment No.	Duration of Experiment (days)	Mass Of Plant Growth (g)	Mass Of Plant Growth Per Unit Area ($g./m^2$)	Mass Of Plant Growth Per Unit Area Per Day (g/m^2 /day)
1	15	12.1	22.3	1.5
2	15	65.2	120.7	8.0
3	15	185.6	343.7	22.9
4	20	234.2	433.7	21.7
5	20	108.2	200.4	10.0

From the results it showed that plants Green Pea, Black gram, Broad bean had high removal efficiency. Results also showed that up to 33 % of influent nutrient Nitrogen, 50 % of phosphorous and 45 % of potassium utilized by vegetable plant.

In all experiments, pH in influent with stronger alkaline state had been changed to lesser one (Table 6). Electrical conductivity values also changed from higher values in influent to lesser one, signifying lesser ion concentration in effluent (table 7).

tab 6: Change in pH and EC in wastewater

Experiment No.	Initial pH	Final pH	Initial EC (mS/cm*)	Final EC (mS/cm)
1	12.4	9.2	2.9	1.9
2	8.6	8.3	2.4	1.5
3	9.0	8.1	3.5	0.3
4	8.7	7.9	0.8	0.2
5	9.3	8.5	1.2	0.6

** Electrical Conductivity (mS/cm) – millie-Siemens per centimetre*

Conclusions

The source-separated urine can be used for the vegetable plants particularly broad bean, black gram and Green Pea. There was still unutilised NPK in the media solution. With the applied dilution, effluent still contains traces of NPK. Therefore, further dilution of source-separated urine can be applied for total nutrient recovery. In future studies, actual nutrient recovery by vegetable plants from source separated urine and chemical fertilizers in soil media with different dilution or loading rate in the same condition can be investigated in terms of bio-mass growth.

The system is based on reuse of valuable nutrients, giving rise to a sustainable treatment process with vegetable plants. It can reduce the dependence on chemical fertilizers, which will save foreign currency needed to import the fertilizers in the developing countries like Nepal.

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