International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 01-09-2020; Accepted: 15-09-2020; ; Published: 02-10-2020
Volume 2; Issue 4; 2020; Page No. 49-54

Characterization of human urine: An alternative to plant nutrient sources in Sustainable Agriculture

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Abstract
The concentration of nutrients in urine from persons of vegetarian and non-vegetarian diet and of different age groups were conducted with objectives of characterize human urine and to study the changes in nutrient composition when stored under open and closed conditions. Human urine was slightly acidic in reaction (5.73, 5.56 and 5.59, from persons of <20, 20 to 40 and >40 years age group, respectively), and has appreciable amount of salts 6.36, 7.50 and 7.24 dS m^{-1} from <20, 20-40 and >40 years age group). The nitrogen varied slightly with age that is 0.30, 0.33 and 0.33 per cent N whereas, P and K content was almost half of that of nitrogen, 0.19, 0.17 and 0.16 per cent P_2O_5 and 0.16, 0.17 and 0.19 per cent K_2O, in urine from persons of < 20, 20 to 40 and >40 year age group, respectively. The concentration of calcium (11.80, 12.60 and 17.00 $meql^{-1}$) and magnesium (23.70, 29.23 and 36.94 $meqL^{-1}$) was found to be substantial. Human urine had anions like sulphate (0.12, 0.14 and 0.12 per cent), bicarbonate (9.09, 10.37 and 9.60 $meqL^{-1}$) and chloride (28.65, 32.66 and 31.41 $meqL^{-1}$). Human urine also contained appreciable amount of micronutrients. The zinc concentration with an average value of 18.02, 19.70 and 20.90 mgL^{-1}. The iron content with mean value of 120.44, 122.40 and 126.90 mgl^{-1}. The manganese average value of 22.36, 22.42 and 23.26 mgL^{-1}. The copper content with the mean of 44.83, 45.83 and 46.69 mgl^{-1} for samples of <20, 20 to 40 and >40 years age group respectively. Later on 30 and 60 DAI all the samples from different categories recorded alkaline in reaction. The loss of Nitrogen content was recorded in case of openly incubated condition as compared to closed condition.

Keywords: human urine, vegetarian diet, non-vegetarian, nutrients, incubation, etc

1. Introduction
Human urine is a natural resource available in every household. Human urine contains almost all the plant nutrient elements in appreciable quantity. Each individual produces 1 to 1.5 L of urine per day, the chemical composition of which depends on feeding habits, the amount of water consumed, physical activities, body size, and environmental factors. In general, human urine contains very few enteric microorganisms. The nutrient contents in human urine qualities it as a good liquid fertilizer for plants.

Human urine is known to contain appreciable quantity of plant nutrient elements (especially Nitrogen), which may be readily absorbed and assimilated by crops if used properly. There is lot of hesitation amongst people in handling this nutrient rich waste due to lack of knowledge and by consuming the produce grown by using anthropogenic liquid waste one may suffer from various deadly diseases which may not be a reality. Now we are in the midst of the problems in terms of shortage of good quality water, shortage of fertilizers and also problem of proper methods of waste disposal. Hence a study of this kind is very much appropriate and necessary to address such problems being faced by mankind. The scientists in the field of agriculture are therefore deeply concerned about the use of human and cattle urine for agricultural purposes. Proper utilization of anthropogenic liquid waste may improve the soil quality, soil health and crop growth and yield.

Urine is used by the body as a balancing medium for liquids and salts and the amount of urine excreted varies from person to person (Jonsson *et al*., 2004) [7]. Excessive sweating results in concentrated urine, while consumption of large amounts of liquid dilutes the urine. Feachem *et al*. (1983) [4] reported that the urine generation rate for most adults is between 1.0 and 1.3 kg per person per day. Vinneras *et al*. (2006) [8] suggested a design value for urine generation to be 1.5 kg per person per day based on measurements in Sweden. Winblad *et al*. (2004) [18] reported 1.1 to 1.4 kg per person per day.

Ecological sanitation is a term not well defined. In ecosan system, anthropogenic liquid waste from households is considered a resource and not a waste. Urine diverting ecosan toilet consists of a superstructure similar to that of most toilets, the urine and faeces are separated at source using the urine-diverting toilet. The Urine diverting Ecosan toilet fulfil the dual objective of water conservation and also environmental sustainability. If installed indoors, this toilet can help in water conservation as minimum water is used. Diverting nutrient-rich urine to land instead of water bodies can reduce pollution of such water bodies and hence reduces the occurrence of algal blooms. (Winblad *et al*., 2004) [18].

2. Materials and methods
In order to assess the nutritive value of human urine and their changes in composition when incubated in open and closed conditions were conducted. The human urine samples were collected from Swami Vivekananda Kannada Medium School,

Doddaballapur from persons of less than 20 years age group whereas, 20 to 40 years age group and more than 40 years age group urine sample was collected from persons in the P. G. Hostel, College of agriculture, UAS, GKVK Bangalore. The human urine samples from persons of non-vegetarian diet was collected from respective places by feeding chicken for nearly ten days to the individuals who were selected for the same purpose. Human urine samples of different age group and diet namely, Vegetarian diet persons of <20, 20-40 and >40 years age group and Non-Vegetarian diet persons of <20, 20-40 and >40 years age group were collected for the characterisation studies.

After collection, the urine samples were subjected to analyzed for all the quality parameters on the initial day itself, then 50 % sample of the volume of both vegetarian and non-vegetarian diet with different age group were kept in closed containers at room temperature in 1000ml poly propylene screw capped containers and the remaining 50 % of the samples were kept under open condition to monitor the changes in the chemical properties of urine under closed and open conditions. The samples from the containers incubated under both closed and opened condition were drawn on 30 and 60 days after incubation and analyzed the chemical properties.

The pH was determined by potentiometric method using pH meter with glass electrode as described by Manivasakam (1987) [13]. Electrical conductivity was determined by using digital conductivity bridge (Manivasakam, 1987) [13]. The total nitrogen was determined by Kjeldahl digestion and distillation method as described by Piper (1966) [14], the total Phosphorus in urine samples estimated by diacid digestion and vanadomolybdate yellow colour method (Piper, 1966) [14] and the total potassium and sodium by Diacid digestion and flame photometer method (Piper, 1966) [14]. The secondary nutrients like Calcium and Magnesium determined by Versenate titration method where as Sulfur by Turbidimetry (Manivasakam, 1987) [13]. Anionic parameters like Carbonate and bicarbonate by Titration method using phenolphthalein indicator, Chloride by Winkler's method using potassium chromate as indicator as described by Manivasakam, (1987) [13]. The cationic micronutrient like Fe, Zn, Cu and Mn were estimated by Atomic absorption spectrophotometry as described by Manivasakam, (1987) [13].

The analysis and interpretation of the data was done using simple statistical methods like range, average or mean of the data. A repeated measurement analysis of variance was thus performed on the data. The effect of types of diet and age group, duration of incubation, day of collection and their first-order interactions on urine containing plant nutrient concentration were determined. In the single urine collection during 2010-2011, the data were analysed according to a one-way analysis of variance to determine the effect of type of animal on urine containing plant nutrient concentration.

2. Result and Discussion

The chemical composition of human urine samples from ten persons each of vegetarian and non-vegetarian diet belonging to <20, 20 to 40 and >40 years age group was found to vary to some extent.

The pH, soluble salts and nutrient composition of human urine samples from persons of vegetarian diet was found to vary slightly among the age group. The human urine was slightly acidic in reaction (5.73, 5.56 and 5.59, from persons of <20, 20 to 40 and >40 years age group, respectively), and has appreciable amount of salts (6.36, 7.50 and 7.24 dS m^{-1}) in case of samples from <20, 20-40 and >40 years age group. Similar results were reported by Jonsson *et al*. (2004) [8]. Human urine has appreciable quantity of nitrogen and it varied slightly with age (0.30, 0.33 and 0.33 per cent N in urine samples collected from persons of < 20, 20-40 and >40 years age group, respectively). The P and K content was almost half of that of nitrogen and varied slightly with age (0.19, 0.17 and 0.16 per cent P_2O_5 and 0.16, 0.17 and 0.19 per cent K_2O, in urine from persons of < 20, 20 to 40 and >40 year age group, respectively). Similar observations were recorded by Jonsson (1997) [9] and Shayo (2003) [16].

The concentration of calcium (11.80, 12.60 and 17.00 $meql^{-1}$) and magnesium (23.70, 29.23 and 36.94 $meqL^{-1}$) was found to be substantial. This might be due to discharge of salts through urine during purification of the blood in the body. The concentration of magnesium was almost double the concentration of calcium in human urine. This trend of lower calcium may be due to better utilization of calcium by the human body than magnesium. Similar results were reported by Altman and Dittmer (1994). Human urine had anions like sulphate (0.12, 0.14 and 0.12 per cent), bicarbonate (9.09, 10.37 and 9.60 $meqL^{-1}$) and chloride (28.65, 32.66 and 31.41 $meqL^{-1}$). In fresh human urine, the carbonate was absent as the fresh urine is acidic in reaction whereas concentration of bicarbonates varied slightly in the urine samples of different age groups. Similar findings were also reported by Kirchmann and Pettersson (1995) [10].

Human urine also contained appreciable amount of micronutrients (zinc, iron, manganese and copper) and the concentration varied slightly with age. The zinc concentration with an average value of 18.02, 19.70 and 20.90 mgL^{-1}. The iron content with mean value of 120.44, 122.40 and 126.90 mgl^{-1}. The manganese average value of 22.36, 22.42 and 23.26 mgL^{-1}. The copper content with the mean of 44.83, 45.83 and 46.69 mgl^{-1} for samples of <20, 20 to 40 and >40 years age group respectively. This might be due to variation in the intake of salts and minerals through food (Schouwz *et al.*, 2002) [15] (Table 1).

The urine samples from non-vegetarian diet persons of different age groups also had appreciable amount of nutrients. Fresh urine was more acidic than urine samples of vegetarian diet persons. Also the concentration of salts was found to be slightly higher in urine from persons of non-vegetarian diet which may be due to variations in food habit. It also had higher nitrogen content (0.40, 0.39 and 0.40 per cent for samples of <20, 20 to 40 and >40 years age group, respectively) when compared to urine from vegetarian diet persons. This may be due to the fact that non-vegetarian diet has more protein and after assimilation, some quantity of protein will be discharged through urine as nitrogen compound. Phosphorus and potassium contents varied slightly in urine samples of non-vegetarian diet persons compared to vegetarian diet urine samples. Human urine samples from non-vegetarian diet persons also had high amount of sodium and chloride when compared to urine from vegetarian diet persons which may be due to consumption of more salts through food (Table 2).

Table 1: Physico- chemical properties of the red, laterite and black soils.

Sl. No.	Parameters	Red soil	Laterite soil	Black soil
I. Physical properties				
1	Textural class	Sandy Loam	Gravelly sandy loam	Clay
II. Chemical properties				
1	pH (1:2.5)	6.19	4.97	8.43
2	EC (dS m^{-1})	0.18	0.09	0.29
3	Organic Carbon (%)	0.39	0.63	0.57
4	Available N (kg ha^{-1})	225.15	210.09	378.4
5	Available P_2O_5 (kg ha^{-1})	21.01	12.03	18.63
6	Available K_2O (kg ha^{-1})	318.54	115.93	515.30

Table 2: Total volume and quantity of nutrients (kg ha^{-1}) added through human urine, cattle urine and fertilizer to tomato crop as per the treatments.

Treatments	HU/CU (m^3 ha^{-1})	Fertiliser			Human urine			Cattle urine			Balance P and K through fertilizer	
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	P_2O_5	K_2O
T_1	-	250	250	250							-	-
T_2	-	375	375	357							-	-
T_3	-	500	500	500							-	-
T_4	83.3				250.0	141.7	150.0				108.3	100.0
T_5	125.0				375.0	212.5	225.0				162.5	150.0
T_6	166.6				500.0	283.3	300.0				216.7	200.0
T_7	100.0							250.0	120.0	160.0	130.0	90.0
T_8	150.0							375.0	180.0	240.0	195.0	135.0
T_9	200.0							500.0	240.0	320.0	260.0	180.0

3.1 Incubated under open condition

In general an increase in pH, carbonate and bicarbonate content, a decrease in nitrogen and micronutrients content was observed when incubated for 30 and 60 days and the increase or decrease was more with incubation period.

There was an appreciable reduction in the nitrogen concentration of urine kept under open condition compared to closed condition. The nitrogen content varied from 0.16 to 0.32 and 0.16 to 0.31 per cent with mean value of 0.24 per cent at both 30 and 60 days after incubation. The phosphorus content varied from 0.16 to 0.28 and 0.16 to 0.27 per cent with mean value of 0.20 and 0.19 per cent on 30 and 60th day, respectively. The potassium content varied from 0.14 to 0.26 and 0.13 to 0.25 per cent with an average value of 0.18 per cent at 30 and 60 days after incubation. In closed condition the concentration of nitrogen varied from 0.19 to 0.38 and 0.19 to 0.37 per cent with an average value of 0.28 and 0.27 per cent. There was no change in the P and K content of urine samples with incubation.

There was slight variation in the chemical composition of human urine samples from persons of vegetarian diet persons of < 20 years age groups, when incubated under open condition. There was increase in pH of urine with time and had turned to slightly alkaline pH. This might be due to hydrolysis of urea leading to formation of ammonia during incubation (Jonsson, 1997) [9] (Tables 3).

In open condition, the nitrogen content was slightly less compared to initial value which might be due to loss of nitrogen as NH_3 due to volatilization at high pH during incubation. Similar findings were reported by Blouin (1979) [2], Hellstrom *et al*. (1999) [5] and Kirchmann and Pettersson (1995) [10]. There was no variation in the phosphorus and potassium content of urine samples incubated under open condition. Similar results were recorded by Jonsson *et al*. (2004) [7]. The concentration of carbonates and bicarbonates has increased appreciably. Increase in concentration of carbonates and bicarbonates may be because of diffusion of atmospheric carbon dioxide into urine samples and its conversion to carbonates and bicarbonates. The micronutrients like zinc, manganese, iron and copper were found to decrease with time. This may be because of increase of pH of urine to the alkaline range and the conversion of Zn, Fe, Mn and Cu to insoluble carbonate salts (Blouin, 1979, and Kirchmann and Pettersson, 1995) [2, 10].

The urine samples of non-vegetarian diet persons also turned to alkaline side upon incubation. Similar findings were reported by Jensen *et al*. (2009).

The nitrogen content of urine samples from persons of vegetarian and non-vegetarian diet was found to decrease slightly upon incubation under open condition at 30 and it further decreased at 60 days. Similar findings were also observed by Jonsson *et al*. (2005) [8], Lentner *et al*. (1981) and Vinneras *et al*. (2006) [8]. While the phosphorus and potassium content did not change much with incubation and it remained almost same in samples at 30 and 60 days after incubation (Larsen and Gujer (1996) showed more or less similar trend as that of vegetarian diet persons (Carlander *et al*., 2001) [11].

The fresh urine samples from vegetarian and non-vegetarian diet persons were having only bicarbonate not any carbonates. But appreciable amount of carbonate also was found at 30 days after incubation and it increased further at 60 days after incubation under open condition. This might be due to diffusion of carbon dioxide from the atmosphere into incubated urine samples. The conversion of both CO_3 and HCO_3 content were slightly higher when samples were incubated under open condition at 30 and 60 days compared to closed condition.

Micronutrients concentration showed little variation with the diet of the persons and it decreased with time it might be due to conversion of Fe, Mn, Zn and Cu to respective insoluble carbonate compounds at higher pH of incubated samples (Schouwz *et al*., 2002) [15].

Table 3: Plant height (cm), number of branches, number of leaves and total dry matter (g/plant) of tomato at harvest as influenced by graded levels of human urine, cattle urine and fertilizer in three different soils.

Treatments	Red soil				Laterite soil				Black soil			
	Plant height	No. of branches	No. of leaves	Total dry matter	Plant height	No. of branches	No. of leaves	Total dry matter	Plant height	No. of branches	No. of leaves	Total dry matter
T_1	78.1	5.15	29.6	164.5	72.6	4.16	26.3	153.5	87.3	5.43	30.3	194.5
T_2	83.1	5.60	36.7	213.3	76.8	5.15	31.7	200.1	91.9	6.30	38.0	238.7
T_3	84.8	5.74	38.0	227.3	78.0	5.47	34.3	212.3	93.9	6.90	41.5	249.8
T_4	78.3	5.23	31.2	174.0	72.9	4.33	26.8	162.2	86.5	5.17	29.7	191.9
T_5	84.5	5.70	37.3	217.6	77.6	5.35	34.0	201.4	90.8	6.24	37.2	235.7
T_6	87.2	5.90	40.8	236.7	80.2	5.80	36.2	218.6	93.3	6.60	40.3	243.5
T_7	78.2	5.18	30.6	171.6	72.8	4.23	26.4	158.9	85.7	5.13	29.5	188.5
T_8	84.3	5.67	36.5	215.7	77.0	5.27	33.7	201.0	90.1	6.05	36.7	233.0
T_9	85.3	5.82	38.9	234.6	78.8	5.60	36.0	216.4	92.4	6.41	38.3	238.2
S.Em ±	1.11	0.09	1.04	6.02	0.86	0.16	1.10	4.37	1.15	0.25	1.28	4.59
C.D. (P=0.01)	4.57	0.38	4.28	24.68	3.54	0.67	4.52	17.91	4.71	1.04	5.27	18.81

3.2 Incubated under closed condition

The human urine samples with different diet incubated under closed condition recorded slightly lower pH value compared to that the samples under open condition as there was little or no scope for diffusion of carbon dioxide from the atmosphere (Tables 3 and 4)

The loss of nitrogen was found to be slightly less in samples incubated under closed condition than open condition as there was less chance for hydrolysis reactions. There was no much variation in phosphorus and potassium content in urine samples of different age group incubated under both open and closed condition at 30 and 60 days. Similar results observed by Feachem *et al*. (1983) [4].

The carbonates and bicarbonates content was found to increase with time of incubation but the values were less when kept under closed condition compared to open condition as there was less scope for diffusion of carbon dioxide into urine and its conversion to carbonates and bicarbonates.

Table 4: Number of fruits of tomato as influenced by graded levels of human urine, cattle urine and fertilizer in three different soils.

Treatments	Number of fruits per plant								
	Red soil			Laterite soil			Black soil		
	60 DAT	90 DAT	At harvest	60 DAT	90 DAT	At harvest	60 DAT	90 DAT	At harvest
T_1	32.6	39.9	42.6	30.0	36.7	37.5	37.6	45.7	48.3
T_2	42.8	48.1	48.8	39.4	44.3	44.9	46.4	52.9	54.5
T_3	44.4	51.2	52.2	40.8	47.1	48.0	50.3	57.5	57.7
T_4	34.2	41.5	43.9	31.4	38.2	37.9	36.9	44.2	47.8
T_5	43.3	48.5	49.8	40.3	44.9	47.8	47.2	52.4	54.0
T_6	45.9	52.5	52.7	44.4	49.1	51.8	50.1	56.6	56.9
T_7	33.5	40.2	43.4	30.8	37.0	37.7	35.9	43.9	46.9
T_8	42.9	48.4	49.4	39.5	44.5	45.8	47.1	52.2	53.7
T_9	45.5	52.3	52.5	43.8	48.0	49.6	48.8	56.3	55.3
S.Em ±	0.94	1.13	1.49	1.27	1.52	1.74	0.82	1.17	1.21
C.D. (P=0.01)	3.85	4.63	6.13	5.21	6.23	7.15	3.37	4.80	4.94

Where: DAT= Days after transplanting

Table 5: Yield of tomato as influenced by graded levels of human urine, cattle urine and fertilizer in three different soils

Treatments	Red soil		Laterite soil		Black soil	
	Fresh weight (g fruit^{-1})	Fruit yield (kg plant^{-1})	Fresh weight (g fruit^{-1})	Fruit yield (kg plant^{-1})	Fresh weight (g fruit^{-1})	Fruit yield (kg plant^{-1})
T_1	50.8	2.2	50.1	1.97	60.4	2.24
T_2	62.2	3.0	59.8	2.86	66.9	3.36
T_3	66.3	3.5	63.8	3.21	72.2	3.67
T_4	51.8	2.3	50.6	2.17	59.5	2.10
T_5	63.2	3.1	62.6	3.14	68.1	3.30
T_6	68.8	3.6	68.3	3.45	71.9	3.53
T_7	51.0	2.2	50.3	2.01	57.9	2.03
T_8	62.9	3.1	60.5	3.05	67.3	3.27
T_9	68.4	3.6	65.9	3.32	71.5	3.45
S.Em ±	3.24	0.17	2.19	0.15	1.38	0.16
C.D. (P=0.01)	13.29	0.70	8.97	0.62	5.67	0.68

4. Conclusions

In order to assess the nutritive value of human urine and its use as a supplement to fertilizers in crop production, characterization of human urine samples collected from persons of vegetarian and non-vegetarian food habit representing three different age groups (<20, 20-40 and >40 years) was done. The fresh urine from different categories of human urine were acidic in reaction, had appreciable amount of soluble salts, primary and secondary and micronutrients. The pH of urine samples of all categories turned to alkaline reaction with time. The nitrogen content was slightly less compared to initial value under open condition which might be due to loss of nitrogen as NH_3 due to volatilization at high pH during incubation. There was no variation in the phosphorus and potassium content of urine samples during incubated periods.

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