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Evaluation of Nutrient Content in Human Urine and Conversion of Ammonia from Urine into Nonvolatile Compound for Its Fertilizer Use

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Abstract

Human urine contains many plant nutrients and its composition is found to be different according to human diet. The ammonical nitrogen and phosphate concentration of pure vegetarian diet urine sample was found to be 3594.5 mg NH_4-N/l and 449 mg PO_4-P/l after seven months storage. In a mixed diet the concentration of Nitrogen and phosphates was found to be 4261 mg NH_4-N/l and 552 mg PO_4-P/l. Similarly potassium was found to be 1520 mg/l in pure vegetarian diet urine sample and 1595 mg/l in mixed diet urine samples. The fertilizer value of urine is mainly dependent upon its nitrogen content as phosphates and potassium in human urine is low. Literature shows high volatilization of ammonia at very high pH. The aim of this treatment is lowering the pH or transforming ammonia into non-volatile nitrogen compound so that the product can be used as fertilizer. Product formed is mixed with suitable adsorbent so that handling is easy. This paper deals with the evaluation of nutrient of human urine with pure vegetarian Indian diet and mixed diet and unconventional technique used to prevent volatilization of ammonia by neutralizing the urine with single super phosphate. Single superphosphate is mixture of mono calcium phosphate and gypsum which is extensively used in India as a fertilizer. It was observed that 2.50 g of single super phosphate is required for 100ml of urine sample to bring the pH of 9.25 to pH of 7.02. In this reaction ammonium sulphate and tri calcium phosphate is formed, which does not react with each other which prevents the loss of ammonia and product can be easily handled and used as a fertilizer even in high temperature during summer.

Keywords: Human Urine; Fertilizer; Nonvolatile Compound; Mixed Diet; Pure Vegetarian Diet

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Introduction

Researchers are looking forward for different organic sources which are plenty in nature and available at low cost. Human urine is one of them, and has been gaining popularities as a raw material for organic cultivation. Human urine largely consists of water, approximately 93-96% and large amount of nutrients that are mainly in water-soluble form [1]. The amount of plant nutrients excreted via urine per person and year has been measured at 2.5-4.3 kg Nitrogen (N), 0.4-1.0 kg phosphorus (P) and 0.9-1.0 kg potassium (K) [2] [3] However, effects to derive maximum benefits from human urine ,it is most essential to prevent volatilization of ammonia. Volatilization loss of ammonia from human urine also has adverse effect on environment and human health [4] Therefore, urine treatment might be necessarily needed to produce an adequate fertilizer, but it might also be a suitable method to prevent the pollution of the environment with micro pollutants [5]. However, high pH, high temperature, concentrated form of urine (high N concentration) and long storage periods are favorable for hygienic reasons .Höglund et al and Vinnerås et al recommended that storage period for human urine as of 6 months at 20 ◦C or higher is safe for unrestricted use with respect to pathogens and viable viruses.[6, 7]. During storage of urine, urea content in urine is rapidly degraded by urease to ammonium and water, which may elevate pH values up to a pH of 9 [8] .literature survey shows that ammonia in urine removed from the urine through air stripping and subsequently neutralized with sulfuric acid to form ammonium sulfate,a liquid fertilizer [9].

$H2SO4 + 2NH3 \rightarrow (NH4)2SO4\downarrow$

Current paper deals with the conversion of ammonia from urine into non volatile compound for its fertilizer use

Materials and Methods:

Author has collected self-urine samples after taking pure vegetarian diet and mixed diet (vegetarian and non vegetarian diet) for 15 days each in plastic air tight container and analyzed the same on a daily basis. Urine storage for one day is termed as “fresh urine sample”. Each Urine sample was analyzed on a daily basis for 41 days and urine sample was stored for 212 days (07months) counted from the first collection day. Two types of urine was stored for seven months and a detailed analysis was carried out, this was termed as “stored Urine sample”. The available phosphorus in the alkaline soil/fly ash was estimated as per the method given by Olsen, Cole, Watanabe, Dean [10]. Phosphorus in water or urine samples were analyzed by vanadomolybdo-phosphoric acid method [11]. Yellow coloured vanado-molybdophosphoric acid was formed and it was measured on HACH model no DR 2800 spectrophotometer at 470 nm which was proportional to P concentration, minimum detectable concentration being 200μg P/l. Available nitrogen was estimated as per the method given by Subbiah, Asija, [12]. Available sulphur in soil/fly ash was estimated as per the method given by Williams and Steinbergs Williams, Steinberg [13]. The method used for available Boron was hot water extraction of soil as developed by Berger, Truog, [14]. The pH was determined as per the method given by Jackson [15] in a soil-water and fly ash water suspension of 1:2 ratio. Electrical conductivity was measured in μS/cm as per the method given by Jackson, [15] Ammoniac nitrogen in liquid samples was determined titrimetrically after distilling NH_3 in boric acid which was then directly titrated with standard sulphuric acid.

Results and Discussion

Undiluted urine, freshly drawn, contains about 5-6 % nitrogen as total ammonia and 85 % of nitrogen is fixed as urea. The rest of the nitrogen compounds are mainly creatinine, aminoacids, uric acid [16]. All urea is degraded and most of the nitrogen is available as total ammonia. Up to 33% of the total ammonia is volatile ammonia. The enzyme urease catalyses the hydrolysis of urea to ammonia and bicarbonates, which increases the pH according to Equation-1 [5].

$$NH_2\,(CO)\,NH_2 + H_2O \longrightarrow NH_3^{+} + NH_4^{+} + HCO_3^{-} \qquad \text{Eq.-1}$$

The urine is alkaline with a pH of around 9. The buffer capacity is so high that acid addition is not economical. Ammonia losses and odour problems will occur during transport and spreading of stored urine [5]. Generally, Nutrient value of urine differs according to monitoring of pH. Total ammonical Nitrogen and Phosphate-phophorus content variation during 41 days study a of vegetarian diet and mixed diet urine samples of an Indian are shown in Table 1. Chemical characteristics of fresh urine sample as well as after storage for seven months is shown in Table -2.

a) Nitrogen

The concentration of ammonical nitrogen in the pure vegetarian diet fresh urine sample is found to be 189.5 mg NH_4-N/l and in the mixed diet fresh urine sample was found to be 243 mg NH_4-N/l. The ammonical nitrogen shows increasing trend during storage because of Urea hydrolysis, reaching its maximum concentration of 4026 mg NH_4-N/l after 52 days of storage. The concentration reduced to 3594.5 mg NH_4-N/l after seven months storage. In a mixed diet sample the maximum concentration reached 4327.5 mg NH_4-N/l in 38 days of storage; then concentration reduced to 4261 mg NH_4-N/l due to volatilizations. The maximum value was reached early in mixed diet sample than vegetarian diet. Mixed diet contains more protein as the diet comprises of egg, chicken, fish and mutton in addition to vegetables whereas vegetarian diet comprises of only vegetables.Nitrogen gets into wastes because proteins contain amino acids and they are constantly being broken down in the body. The amino acids have to break down in order to be excreted. There is an important cycle that regulates this process. When an amino acid breaks down, it turns into an acid and ammonia. Ammonia is a toxic base quickly converted by liver to the less toxic urea along with carbon dioxide, This is excreted in the urine.

b) Phosphorus

Phosphorus is mainly in the form of phosphate ions. Phosphate-phosphorus content in pure vegetarian diet fresh urine sample was found to be 760 mg PO_4-P/l and in mixed diet sample it was found as 920 mg PO_4-P/l. In fresh urine around 95-100 % of phosphorus is bound as dissolved phosphates [16]. The phosphate concentration is strongly influenced by precipitation processes and so is the concentration of calcium and magnesium [5]. The value of phosphate–phosphorus decreases in both the vegetarian and mixed diet samples. The values were found to be 449 mg PO_4-P/l in pure vegetarian diet sample and 552 mg PO_4-P/l in mixed diet sample after seven months of storage. The concentration of soluble phosphate in pure vegetarian diet urine sample reduced by 41% and in mixed diet sample by 40 % from the fresh sample. Measurement and simulation showed that in undiluted urine, about 30 % of the soluble phosphate is incorporated in the solid phase of the precipitates. This fraction varies with the composition of the urine [8]. Dissolved phosphate might be better available for the plants. However, the advantage of phosphate precipitates is that phosphorus is very concentrated and separated from most of the other urine compounds. Struvite and hydroxyapatite make up most of the precipitates in human urine [8]. It was observed that as the pH value increased around pH 9, the value of soluble phosphate–phosphorus decreased which was probably because of struvite and hydroxyapatite formation.

c) pH :

pH of the fresh sample of human urine with pure vegetarian diet sample was found to be 6.6 at 25 ^{0}C and of mixed diet sample was found as 6.4 at 25 ^{0}C. During storage the pH value of the sample increased due to the formation of ammonia and reached a value of 9.25 pH in 36 days.

In both type of samples, pH values were fairly constant, between pH 9.1 to 9.35. Maximum pH values in both type of samples reached up to pH 9.35. pH value observed at the end of seven months storage was 9.25. The degradation of urea to ammonium/ammonia raises the pH to around 9. Ammonia in high concentration is toxic to all living cells and this is utilized to sanitise the urine during storage [17].

d) Potassium, Sodium and Chloride:

Potassium was present in the form of potassium ions. The amount of potassium slightly decreased on storage of fresh sample of urine which was probably due to precipitation with struvite and hydroxyapatite. Potassium in the fresh sample of pure vegetarian diet was found to be 1580 mg/l and mixed diet was 1635 mg/l. At the end of seven months the concentration of potassium in vegetarian diet urine sample was found to be 1520 mg/l and mixed diet urine sample was found to be 1595 mg/l. Sodium in the fresh sample of vegetarian diet was found to be 1810 mg/l and mixed diet was 1820 mg/l. At the end of seven months the concentration of sodium in vegetarian diet urine sample was found to be 1823 mg/l and mixed diet urine sample was found to be 1829 mg/l. Chloride in the fresh sample of pure vegetarian diet was found to be 2600 mg/l and mixed diet was 2605 mg/l. At the end of seven months the concentration of chloride in vegetarian diet urine sample was found to be 2604 mg/l and mixed diet urine sample was found to be 2610 mg/l.

e) Sulphate :

Sulphur in urine is found as sulphates. Other sulphur compounds are esters of sulphuric acid and neutral sulphur compounds [16]. Sulphate content of fresh urine of pure vegetarian diet sample was found to be 1350 mg SO_4/l, where as in mixed diet it was found to be 1380 mg SO_4/l. Sulphate reducing bacteria are widely distributed in nature. They may also invade stored urine and are likely to reduce sulphates [18]. In the current study, it was found to be 1355 mg SO_4/l in pure vegetarian diet and 1383 mg SO_4/l in mixed diet diet samples at the end of seven months

f) Calcium and Magnesium:

Calcium and Magnesium in the fresh urine sample of pure vegetarian diet were found to be 95 mg/l and 65 mg /l respectively, whereas in the mixed diet sample, calcium and magnesium were found to be 110 mg/l and 85 mg/l respectively. The calcium and magnesium content was not found in the stored sample after seven months, indicating its complete precipitation. Chemical reaction of struvite and calcium hydroxyapatite crystallization is explained in equation-2 and equation-3.

$Mg^{2+} + NH^{4+} + PO_4^{3-} + 6\ H_2O \longrightarrow MgNH_4PO_4.6H_2O$ Eq.–2

$5Ca^{2+} + 3PO4^{3-} + OH^- \longrightarrow Ca_5(PO_4)_3.(OH)$ Eq.–3

g) Alkalinity:

The alkalinity or buffer capacity of urine strongly increases during storage due to urea hydrolysis [19]. The present study indicates that alkalinity of urine increases from about 432 to 9600 mg /l in vegetarian diet and in mixed diet from 427 to 9700 mg/l as $CaCO_3$ at pH of 9.25 at 25 ^{0}C (Table 4.3.3). The main buffering compounds are bicarbonate and ammonia; due to high buffer capacity, acid addition is not an economical method to prevent ammonia volatilization [5]. The high buffer capacity may also affect bacterial nitrification and cause nitrite accumulation in soils [20].

h) Transformation of ammonia from urine to non-volatile compound:

The pH of 9.25 in the sample under study was brought down to pH of 7.02 by adding single super phosphate per litre of urine sample. The pH was monitored for fifteen days and it was observed that the pH got stabilized to around 7.1 without addition of any single superphosphate ---- readings are as shown in Table 3. It was observed that 2.5 g of single superphosphate was required for 100ml urine. Single superphosphate is extensively used in India as a fertilizer, which contains mono calcium phosphate and gypsum in 3:2 ratio. The analysis results of single super phosphate used in this experiment is shown in Table.4. Chemical reaction in this neutralization of urine with single super phosphate can be explained in equation-4.

$$Ca(H_2PO_4)_2 + 2CaSO_4 + 2\,(NH_4)_2CO_3 \longrightarrow 2\,(NH_4)_2SO_4 + Ca_3(PO_4)_2 + 2H_2O + 2CO_2 \qquad \text{Eq.-4}$$

In this reaction ammonium sulphate and tricalcium phosphate is formed which prevents the loss of ammonia.

Conclusion

Composition of human urine varies with nature of diet and fertilizer value of mixed diet is slightly higher than pure vegetarian diet. Fertilizer value of Human urine is enhanced when it is neutralized with single superphosphate. Ammonium sulphate is a fertilizer that is readily available to plants; moreover it prevents the volatilization of ammonia. Further research is needed to evaluate the fertilizer value of tricalcium phosphate in Indian climatic conditions.

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Table 1: Urine samples of vegetarian diet and mixed diet

Urine samples of vegetarian diet				**Urine samples of mixed diet**			
Days	**pH at 25 ^{0}C**	**Total NH4-N mg /l**	**Total PO4 mg/lit**	**Days**	**pH at 25 ^{0}C**	**Total NH4-N mg /l**	**Total PO4 mg/lit**
1	6.4	189.5	760	1	6.6	243	920
2	6.96	220	771.5	2	6.9	250.5	911.5
3	7.25	240.5	784	3	7.2	266.5	923
4	7.37	301.5	768.5	4	7.4	278.5	906.5
5	7.45	340	736.5	5	7.45	354	897
6	7.5	402.5	697.5	6	7.5	415.5	843

7	7.6	488.5	672.5	7	7.65	497	827
8	7.6	609	625.5	8	7.57	604	806
9	7.75	680	595	9	7.7	700	773
10	7.85	822.5	590	10	7.85	822.5	742.5
11	7.85	950	556.5	11	7.85	973.5	694
12	8.1	1092	522.5	12	8.05	1105	632
13	8.4	1260	512.5	13	8.2	1256	623.5
14	8.6	1365	511	14	8.55	1400	595
15	8.75	1759	502.5	15	8.75	1759	578.5
16	8.9	2237.5	494.5	16	8.95	2237.5	565
17	9.1	2956	487	17	9.1	3157.5	555
18	9.25	3256	477.5	18	9.25	3593.5	545
19	9.25	3374	467	19	9.25	4259	533
20	9.15	3686	460	20	9.15	4327.5	542

21	9.15	3755	457.5	21	9.1	4217.5	547
22	9.15	3844	436	22	9.15	4151	550
23	9.25	3892.5	443.5	23	9.25	3892.5	541
24	9.15	3925.5	426.5	24	9.2	3925.5	533
25	9.05	3947.5	430	25	9.1	4155	526.5
26	9.10	4012.5	427.5	26	9.1	4254.5	537
27	9.25	4026	432.5	27	9.25	4126	544
28	9.25	3958.5	435	28	9.25	4159	560
29	9.35	3994	442.5	29	9.4	4191	563.5
30	9.35	3816	446	30	9.35	4196.5	555.5
31	9.25	3660.5	456.5	31	9.25	4221.5	547
32	9.25	3615	461.5	32	9.25	4229	544
33	9.1	3607.5	449	33	9.1	4236.5	550.5
34	9.15	3557	450.5	34	9.15	4270.5	554.5
35	9.25	3553.5	435.5	35	9.25	4255.5	561.5

36	9.15	3548.5	434	36	9.15	4244	564
37	9.25	3512.5	422.5	37	9.25	4237.5	563.5
38	9.35	3578	430.5	38	9.35	4214	555.5
39	9.25	3608.5	434	39	9.35	4226.5	552.5
40	9.25	3560.5	438.5	40	9.3	4239.5	553.5
41	9.25	3594.5	449	41	9.25	4252.5	561
	8.65± 0.82	**2556.025± 1474**	**517.82±11 5**		**8.65± 0.82**	**2838.91±1 684**	**633.5 ±134**

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Table 2: Chemical characteristics of fresh and stored urine

Sr. No	Parameters	Vegetarian diet		Mixed diet	
		(fresh urine)	(Stored urine after seven months)	(fresh urine)	(Stored urine after seven months)
1.	pH	6.6	9.25	6.4	9.25
2.	Alkalinity mg/l as $CaCO_3$	432	9600	427	9700
3.	NH4-N mg/l	189.5	3594.5	243	4261
4.	PO4-P mg/l	760	449	920	552
5.	Potassium mg/l	1580	1520	1635	1595
6.	Sulphate mg/l	1350	1355	1380	1383
7.	Chloride mg/l	2600	2604	2605	2610
8.	Sodium mg/l	1810	1823	1820	1829
9.	Calcium mg/l	95	0.0	110	0.0
10.	Magnesium mg/l	65	0.0	85	0.0
11.	Volume of urine l/day	1.2-1.3	--	1.2-1.3	---

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Table 3: Neutralization of Urine sample with single super phosphate