International Journal on Advanced Science Engineering Information Technology

Vol.4 (2014) No. 3
ISSN: 2088-5334

Utilization of Human Urine as Fertilizer with Magnesium Oxide (MgO), Zeolite and Activated Carbon as Absorbent

Hijrah Purnama Putra [#], Bagas Pandu Mursanto [*], Alfitri Handayani [#]

[#] *Faculty of Civil Engineering and Planning, Islamic University of Indonesia*
Jln Kaliurang km. 14,5 Sleman, Yogyakarta Indonesia
E-mail: hijrah@uii.ac.id

***Abstract*— Urine is residual fluid excreted by kidneys through urinary tract to outside of the human body, to maintain homeostasis of fluid in the body. Normally urine still contains high amount of nitrogen, which is 87%, phosphor 50%, potassium 54% and low bacterial content. With these contents urine potentially becomes organic fertilizer rich with nitrogen, phosphor and potassium contents and is beneficial to plants. However, until today the utilization or urine in Indonesia is very low. The urine produced is dispose with feces in toilets. This study aimed to utilize urine as solid organic fertilizer using magnesium oxide (MgO), zeolite, and actived carbon as absorbents of ammonium and phosphor. The study started with collecting urine, time variations of urine storage were 24; 48 and 72 hours, and urine was mixed with water as an assumption that urine mixes with water when flushed in urinals. The result showed effectiveness of optimum urine absorption in urine stored for 48 hours by adding 8 gram MgO, producing ammonium and phosphor contents 56.100 ppm and 3.610 ppm, respectively. From environmental perspective, utilization of urine as organic fertilizer was applicable because it satisfied the ecological principle of sanitation to prevent soil pollution, ground and surface water pollution and its utilization as agricultural resources.**

***Keywords*— urine; organic fertilizer; absorbent**

I. INTRODUCTION

This Urine is residual fluid excreted by kidneys then removed from the body through urinating process. Adults generally released 1,5 liter of urine per day. Urine excretion is required to remove residual molecules in blood which are filtered by kidneys and to maintain homeostasis of body fluid (e.g. [1]). Amount of urine excreted depends on various things, including quantity and quality of nutrients, lifestyle, psychological condition, level of activities, level of development, disease conditions, socio-cultural, habit and even weather influence quantity of urine produced (e.g. [2]).

Normal urine in human consists of water, urea, ammonia, creatine, lactate acid, phosphate acid, sulphate acid, chloride, salt and excessive substances in blood, such as vitamin C and medications. All fluid and materials which form urine come from blood or interstitial fluid. Urine composition changes along reabsorption process when molecules which are important to the body, such as glucose, are reabsorbed into the body through carrier molecules (e.g. [3]). The following is important contents in urine which can be used as soil/plant fertilizer.

TABLE I
NITROGEN, PHOSPHORUS, AND POTASSIUM CONTENT IN HUMAN URINE

Parameters	[4]	[5]	[6]
Nitrogen	215 mg/L/day	26 mg/L	5,6 kg/500 L urine
Phosphorus	12 mg/L/day	1,6 mg/L	0,4 kg/500 L urine
Potassium	34 mg/L/day	75 mg/L	1,0 kg/500 L urine

In daily life, people dispose urine directly in toilets or urinals, then urine will be carried to septic tank and mix with other wastes, whether *greywater* (washing wastewater) or feces. When mixed, urine utilization isn't effective and efficient because the characteristics of the three wastes above (urine, *greywater*, and feces) are different. The differences can be seen in the following table (e.g. [7].

With rather high content of Nitrogen, Phosphorus and Potassium elements, urine has high potential to be used as a fertilizer. Reference [8] shows that one liter of urine can be used to fertilize around one square meter, and it's predicted that the volume of urine in one year can be used to fertilize around 300-400 m^2 of agricultural land.

TABLE II
CHARACTERISTICS OF URINE, GREYWATER AND FECES

Parameter	Urine	Greywater	Feces	Total
Volume (L/cap)	500	25.000-100.000	50	25.000-100.000
Nitrogen	87%	3%	10%	4,5kg/cap
Phosphorus	50%	10%	40%	0,75kg/cap
Potassium	54%	34%	12%	1,8kg/cap
Faecal Coliform	0	10^4-10^6 /100 ml	10^7-10^9 /100 ml	-

Tropical climate and high rainfall in Indonesia requires in-depth processing of urine as fertilizer, because if there is rain liquid urine fertilizer will dissolve with rainwater, therefore urine compaction is required, including by adding Magnesium Oxide (MgO), zeolite and active carbon so urine can be tied and become powder so it won't disappear easily when it rains. Moreover, urine utilization is expected to be more acceptable by the market and efficient, because the urine produced can last longer than normal liquid urine fertilizer.

II. RESEARCH METHODE

This study had various stages as follows:

A. Urine Collection

The urine used in this study was collected from several people, then put into mineral water bottles. This collection was to maintain the stability of urine stock in the study.

B. Urine Storage

Urine which would be used was stored in various storage times, i.e. 24; 48 and 78 hours (pure urine). This was to ease the application in the field. Before being used, the three urine from varying storage times was tested for ammonium and phosphor.

C. Mixing with Water (Mix Urine)

There is one variation of urine mixed with water to describe the condition of urine mixed with washing water or flushing water in urinals.

D. Research Variables

- Addition of MgO (magnesium oxide) = 4; 8; and 12gram
- Addition of zeolite = 4; 8; and 12 gram
- Addition of active carbon = 4; 8; dan 12 gram

E. Testing Ammonium and Phosphorous Levels

By testing ammonium and phosphorous levels, optimal urine conditions with added MgO; zeoliet; active carbon or all three were discovered.

III. RESULT AND DISCUSSION

Various absorbents above were added into urine with different storage times. Total urine used was 5 liters. It's manually stirred using simple reactor. The following is the result of absorption of ammonium and phosphor contents in urine with various absorbent.

A. MgO as Absorbent

MgO served as an absorber of ammonium and phosphor contents in urine. In this study the magnesium used was mechanical type of MgO with Mg level ± 3,7 ppm and the rest was polluter, so it's easy to get with cheap price and was expected to be easy to apply in the future (e.g. [2]). Solids from the reaction magnesium oxide are also called struvite or magnesium ammonium phosphate (MAP). Struvite was deposited according to general reaction:

$$PO_4^{3-} (aq) + NH_4^{+} (aq) + Mg^{2+} (aq) + 6H_2O \rightarrow NH_4MgPO_4\ 6H_2O \quad (1)$$

TABLE III
AMMONIUM AND PHOSPHOR CONTENTS IN SOLIDS WITH MGO AS ABSORBENT

MgO (gram)	Storage Time (hours)	Ammonium (ppm)	Phosphor (ppm)	Weight of Solid (gram)
4	24	18.478	2.591	9,1
8		38.043	1.345	16,68
12		39.130	3.380	26,96
4	48	39.674	3.460	13,47
8		56.500	3.610	13,61
12		42.120	3.985	27
4	72	11.005	6.008	7,37
8		9.239	6.121	21,6
12		6.957	6.215	22,7

The best absorption from the addition of MgO was at 48 hours storage time, because new urine has more nutrient content than those with longer storage time. The best absorption of ammonium and phosphor was at 8 gram MgO addition. There was deposit with ammonium level 56.500 ppm while phosphor was 3.610 ppm. According reference [9] by adding MgO in a small amount into human urine, most phosphor (95-99%) and some nitrogen (20-50%) can be recycled through deposit resulted from absorption.

However, previous studies show that the larger quantity of MgO added, the better the recovery percentage (e.g. [2]). Adding MgO also will influence the weight of the solid produced.

B. MgO and Zeolit as Absorbents

Zeolite has several interesting chemical and physical properties, including absorbing (absorption) organic and inorganic substances, as cation exchanger (ion exchanger), catalyst (catalyst) and filter of fine-sized molecules (molecular sieving) (e.g [10]). It's expected that zeolite addition complete the performance when just adding MgO.

Adding MgO and Zeolite one after another produced maximum ammonium and phosphorous levels of the deposit by adding 12 gram MgO and 8 gram zeolit, amounting to 26.359 ppm ammonium and 4.395 ppm phosphor. In the study in Reference [11] adding zeolite as absorbents will reduce ammonium absorption in urine but will increase phosphorous level in the deposit. Compared with the result of phosphor absorption when adding just MgO (Table 3), the result increased significantly. In the same variation the phosphor produced was 3.610 ppm, while in zeolite addition it increased to 4.395 ppm.

TABLE IV
AMMONIUM AND PHOSPHOR CONTENTS IN SOLIDS
WITH MGO, ZEOLITE AND ACTIVE CARBON AS ABSORBENTS

Absorbents (MgO:Zeolit) (gram)	Storage Time (hours)	Ammonium (ppm)	Phosphor (ppm)	Weight of Solid (gram)
12:4	24	21.739	2.732	27,5
12:8		18.342	3.987	26,3
12:12		4.315	4.328	38,5
12:4	48	20.652	3.757	32,3
12:8		26.359	4.395	33,4
12:12		5.000	4.287	38,5
12:4	72	3.780	3.615	21,9
12:8		16.522	5.859	30,6
12:12		15.815	5.880	30,04

However, generally MgO addition and followed by zeolite had smaller absorption than just adding MgO. This was due to imperfect zeolite activation and because the amount of zeolite was too small.

C. *MgO, Zeolite and Actived Carbon as Absorbents*

Aside from using zeolite, this study also used another natural material which was active carbon. The mechanism of action started from MgO, zeolit and followed by adding actived carbon.

The function of adding active carbon in this study was to increase the process of absorbing ammonium and phosphor in urine. The active carbon used was ± 1 mm, with the hope that smaller size will increase the size of the area owned by active carbon. Similar to zeolite, active carbon also started with activation process to work optimally.

TABLE V
AMMONIUM AND PHOSPHOR CONTENTS IN SOLIDS
WITH MGO, ZEOLITE AND ACTIVE CARBON AS ABSORBENTS

Absorbents (MgO + Zeolite + Active Carbon) (gram)	Storage Time (hours)	Ammonium (ppm)	Phosphor (ppm)	Weight of Solid (gram)
12:12:4	24	20.652	4.152	30,3
12:12:8		28.261	4.210	41,22
12:12:12		22.826	4.390	49
12:12:4	48	21.196	4.409	34,3
12:12:8		30.435	4.812	43,9
12:12:12		32.609	4.822	58,14
12:12:4	72	10.598	5.763	40,4
12:12:8		17.120	5.781	44,4
12:12:12		13.043	4.957	45,8

Adding MgO, zeolite and active carbon didn't yield significant result compared with previous variables, whether by only adding MgO or MgO followed by zeolite. The best ammonium deposit content was at storage time 48 hours with variation 12 gram MgO + 12 gram Zeolite + 12 gram actived carbon, which was 32.609 ppm.

Phosphor in the deposit produced from adding active carbon was better because the absorbed phosphor was more constant and stable than MgO addition. The best deposit content in phosphor was at storage time 72 hours with addition variation 12 gram MgO + 12 gram Zeolite + 8 gram active carbon, which was 5.781 ppm.

Tables 3, 4 and 5 show weight of solids in urine absorption in average produce twice the initial weight of absorbent level. This was in accordance with the study in reference [11] which states that the weight of struvite produced by urine absorption will be twice to three times the previous weight. It's because absorbents absorb ammonium and phosphor so that there's evaporation which ends with the growth of the weight of the absorbents themselves.

D. *Mixing Urine*

This study also used variation with the mixture of water and urine. The water used was 1.5 liter mixed with 5 liters of urine. It's expected that with this variable, urine utilization was more optimal.

TABLE 6.
AMMONIUM AND PHOSPHOR CONTENTS IN SOLIDS
URINE AND WATER MIXTURE

Absorbents (gram)		Storage Time (hours)	Ammonium (ppm)	Phosphor (ppm)	Weight of Solid gram)
MgO	4	24	18.478	2.162	9,72
	8		24.457	1.986	12,95
	12		33.696	1.997	11
MgO : Zeolit	12:4	48	16.848	2.064	26,55
	12:8		26.630	2.481	24,57
	12:12		21.060	2.374	32,64
MgO : Zeolit : Activated Carbon	12:12:4	72	15.217	1.704	30,5
	12:12:8		22.283	1.935	29,1
	12:12:12		17.391	185	32,34

Adding 1,5 liter of water was adjusted with the condition at the field. Toilets and urinals generally need around 1-2 liters for one flushing. So, urine which has been mixed with water can still be used. With the same research stages as previous variables, the mixture of urine and water had the highest ammonium with the addition of 12 gram MgO, which was 33.696 ppm. While the smallest absorption was in the addition of 12 gram MgO + 12 gram zeolite + 4 gram actived carbon, which was only 15.217 ppm.

While phosphor content seemed more stable, only one sample, addition variation 12 gram MgO + 12 gram zeolite + 12 gram actived carbon, showed bad absorption. The highest content of phosphor was in the addition of 12 gram MgO + 8 gram zeolite with a deposit of 2.481 ppm. While the lowest content was in 12 gram MgO + 12 gram zeolite + 12 gram Active carbon, with a deposit of 185 ppm.

E. Influence of Urine Storage Time

There were three time variations used in this study, i.e.: 24, 48 and 72 hours. At those time variations there were physical changes, including urine colour, urine colour at 72 hours storage time was darker than urine at 24 hours storage time. Another difference was smell produced by urine, urine with 72 hours storage time has stronger smell than urine at 24 hours and 48 hours storage times.

Reference [12] shows that before processing, urine is stored for two months at room temperature. Durign storing process, there is color change from clear yellowish color to reddish brown. The smell of the urine which has been stored for 2 months is stronger. To remove microorganism which may be in urine the storing is performed until reaching pH 9 (e.g. [13]). The combination between pH 9 with ammonium content in urine causing negative gram bacteria such as Salmonella and E.coli to die quickly, while positive gram bacteria such as Cryptosporidium parvum to die slowly (e.g. [13]).

IV. Conclusion

Effectiveness of absorption with the addition of MgO was better and more constant than the addition of MgO + zeolite and MgO + Zeolite + Actived carbon. This could be seen in the absorption of Ammonium and phosphor in deposits by adding 8 gram MgO at 48 hours storage time ammonium content of 56.500 ppm and phosphor 3.610 ppm, Ammonium and phosphor absorption was very effective, the values of outlet and resulting deposit were nearly similar.

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