ADDIS ABABA UNVERSITY

SCHOOL OF GRADUATE STUDIES

Recovery of Phosphorus and Nitrogen from source-separated urine: process optimization in bench-scale

By:

Johnny Girma Teferra

June, 2018

Addis Ababa University School of Graduate Studies

School of Civil Engineering

Recovery of Phosphorus and Nitrogen from source-separated urine: process optimization in bench-scale

By:

Johnny Girma Teferra

A Thesis Submitted to School of Graduate Studies in Partial Fulfillment of the Requirement for Degree of

Masters of Science

In

Water Supply and Environmental Engineering

Approved by Board of Examiners:

Dr. Agizew Nigussie	_________________	_________________
Advisor	Signature	Date
Zerihun Getaneh(MSc)	________________	_________________
Advisor	Signature	Date
Dr. Adey Desta		
Advisor	Signature	Date
_________________	_________________	_________________
Internal Examiner	Signature	Date
_________________	________________	_________________
External Examiner	Signature	Date
_________________	__________________	_________________
Chair Person	Signature	Date

List of Acronyms

P^H	- Power of Hydrogen
MAP	- Magnesium Ammonium Phosphate
WWTs	- Waste Water Treatment Plants
NH_4-N	- Ammonium Nitrogen
PO_4-P	- Phosphate Phosphorus
Mg^{+2}	- Magnesium Ion
P	- Phosphorus
N	- Nitrogen
SS	- Suspended Solid
DO	- Dissolved Oxygen
DPR	- Denitrifying Phosphate Removal (DPR)
EBPR	- Enhanced Biological Phosphorus Removal
DPAOs	- Denitrifying Phosphorus Accumulating Organisms
PHA	- Polyhydroxyalkanoate
SR	-Short Range
HR	-High Range

ABSTRACT

The main focus of this research is to investigate about the possibility of Nutrient recovery in the form of Magnesium Ammonium Phosphate (Struvite) by determining optimum PH, optimum dosage, suitable mixing time, mixing speed , precipitation time ,and storage time from source separated stored human urine.

A laboratory test was conducted using Jar test for the stored human urine. Struvite formation was PH dependent reaction and the experiment was started with PH optimization having six different pH values from PH 6 to 11.

The experimental result showed that at PH 10 the percentage removal for NH_4^+-N and PO_4-P was 87.07% and 91.55% respectively, which is greater than other PH's which implied that the optimum PH was PH 10.

Using PH 10 as optimum PH, the determination of optimum dosage (P04-p:Mg^{+2})ratio was conducted using six different mass ratios, i.e. 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6.

The result of the experiment showed that, at PH10 and $P0_4$-P:Mg^{+2} dosage of 1:1, the percentage removal of NH_4-N and $P0_4$-P was 90.54% and 77.49% respectively which showed the optimum dosage was 1:1.

Laboratory tests were also done to determine the optimum mixing time and mixing speed and found to be 30minutes and 60rpm respectively .Two samples were tested to determine the optimum incubation period to recover nitrogen and phosphorus for 25 and 30 days and found to be on 20th and 19th day respectively. Furthermore Basaka water was also used as source of Mg^{+2} to recover Nitrogen and Phosphorus and about 36% of Phosphorus was recovered and ultimately struvite was produced by the designed stirred reactor.

Key Words: PH, AMMONIUM NITROGEN (NH_4-N), PHOSPHATE PHOSPHROUS (PO_4-P), MAGNISIUM AMMONIUM PHOSPHATE (MAP), NUTRIENT REMOVAL.

Declaration

I, the undersigned declare that this thesis is my original work performed under the supervision of research advisors Dr. Agizew Nigussie, Zerihun Getaneh and Dr. Adey Desta and has not been presented as a thesis for a degree in any other university in Ethiopia. All sources of materials used for this thesis have also been duly acknowledged.

Name: Johnny Girma Teferra

Signature: ______________________

Place: Addis Ababa institute of Technology, Addis Ababa University

Date: June 2018

Acknowledgement

First of all I would like to express my science gratitude to my advisors Dr. Agizew Nigussie, Zerhiun Getaneh and Dr. Adey Desta for their enormous moral support, patient, continuous guidance and knowledge sharing during my research.

I would like to express my most appreciation to Dr. Adey Desta who bought me all the chemicals and apparatuses which are helpful to conduct the research.

At least but by no means least, I want to give special tanks to my classmates Mireteabe Negash, Dawit Debebe, PH student Nebiyat Mesenbet and staff members Dr. Fisha Behulu, Tadesse Arafayine and Abraham Kedir who closely attended my work and encouraged me.

Contents

List of Tables

List of Figure

1. Introduction

1.1 Nutrients in Urine

Very few studies have been performed to determine the exact nutrient breakdown in urine, and it is compounded by the fact that proportions will depend on the current diet of the person excreting the urine.

Table 1: Nutrient Composition of Urine

Constituents	Amount in g
Uric acid ($C_5H_4N_4O_3$)	0.69
Bicarbonate ions (HCO_3^-)	1.2
Creatinine ($C_4H_7N_3O$)	2.7
Potassium ion (K^+)	3.2
Sodium ion (Na^+)	4.1
Chloride ion (Cl^-)	6.6
Urea $(NH_2)_2CO$	25.5
Phosphorus (P)	1.28

(Source: Walker S. , 2016, Extracting urea from source separated urine)

Table 2: Percentage of Nutrients Found in Urine

Nutrient	Urine [kg/cap/yr]	Feces [kg/cap/yr]	Total [kg/cap/yr]	%of Nutrient Found in Urine
Nitrogen	4.0	0.5	4.5	89%
Phosphorus	0.4	0.2	0.6	67%
Potassium	0.9	0.3	1.2	75%
Source: Swedish Data (Drangert,1998:161)				
Nitrogen	2-4	0.3-0.55	2.3-4.6	87%
Phosphorus	0.2-0.37	0.1-0.21	0.3-0.57	67%
Source:(Kvarnstrom et al.,2006:3)				
Nitrogen	----	---	---	70%
Phosphorus	---	---	---	25-60%
Source :Chines Data (Gao et al.,2006:3)				

Recent studies have reported that rock based phosphorus will be running out in 50-100 years (Cordell et al., 2009). Each year phosphate and Nitrate based fertilizers are applied to the soil to enhance fertility but in the expense of polluting our environment.

The issue with the present fertilizer is that they release the nutrients easily in the soil which lower the retention time in the soil and ultimately reduces their efficiency, which means larger amount of fertilizers are required for plants to get adequate amount of N and P. For example: Urea which is the nitrogen based fertilizer releases nitrogen in the soil from which only 40% is actually recovered by plants and the rest 60% is lost to the environment in the form of N_2O which is a greenhouse gas leading to the global warming (Shalini Guleria, 2016, struvite crystallization).Hence to prevent food shortage, additional nitrogen and phosphorus sources must be exploited such as human urine. (Tilman et al., 2002) justified that the development of slow releasing N and P fertilizer was important for global crop production.(Shuet.et al., 2006) struvite recovery from municipal waste sludge at global scale is expected to reduce about 1.6% of world phosphate rock mining. The average urine volume per day from adult is 1.4-1.5 liters/cap/day (Jonsson et al.,2004:7).In fact humans typically excrete 1.6 to 1.7g of phosphorus per day, most of which (about 60%) is found in the urine (Schouw et al., 2002).It is safe to use wastewater for the recovery of nutrients, WHO states the following concerning the pathogens in the guide line for the safe use of waste water, excreta, and grey water. volume 4.Human Urine rarely sufficiently common to constitute a significant public health problem and are not considered to constitute a health risk in the reuse of human urine in temperate (WHO 2006:36).It is also possible to recover struvite from farm wastes (Cattles, swine, poultry manure urine) but these sources often needs pre-treatment due to presence of limiting interfering ions (Zhang et al., 2010 , Beal et al., 1999 , Lo et al., 2011 and Pastor et al., 2008) again industrial wastes like dye, fertilizer, textile, food, tanning, coking, and from beverage industry to recover P in the form of struvite but it requires the addition of P salts like $NaH_2PO4, KH2PO4$ (Zhang et al., 2010).The disadvantage of nutrients in the Waste water is it contains contaminants that are not desirable for aquatic environment; those elements would arise aquatic problems. The most familiar case is Eutrophication. Eutrophication is an outcome when excess amount of nutrients are released and accumulated in water bodies. It leads to dense growth of plants on rivers affecting the aquatic life and causing water pollution. The other disadvantage of nutrients in wastewater is as wastewater flows through the pipe and incubation period increases the struvite starts to precipitate in the pipes. Hence the accumulation of struvite reduces flow, increase pressure and ultimately breaks pipes in wastewater treatment plants. To deprive these cases for one thing you have to separately recover the nutrients or you have to use struvite removers the so called EF-071 (USA, 2018, Struvite Removal).

Figure 1 Struvite precipitation on pipe

Therefore through appropriate PH, dosage (PO_4-P:Mg^{+2})ratio , velocity, reaction time, and temperature the majority of Nitrogen and Phosphorus in human urine can be crystallized in to white, odorless powder called struvite or Magnesium Ammonium Phosphate hexahydrate (MAP, $MgNH_4PO_4.6H_2O$) (Johnston and Richards, 2004; Romer, 2006). Whenever (MAP, $MgNH_4PO_4.6H_2O$) or struvite is required in large scale as fertilizer it is possible to use reactors.

1.2 Reactor

Reactors are materials (apparatus) in which chemical reactions takes place and produce chemicals by optimizing parameters like PH, dosage, reaction time, velocity, temperature, pressure, amount of dissolved oxygen etc.

The reactor that was produced in our campus was made of stainless steel equipped with two paddles for mixing stored human urine with Mg^{+2}. The designed reactor accommodates 50 liters of human urine .In this research, the struvite forming reactor was built which confirm to the requirement of low cost, and also the materials for construction were available in local market and it was operated mechanically.

To recover nutrients in the form of struvite from source separated urine in reactor physiochemical parameters like PH, dosage, mixing time, mixing speed, precipitation time and incubation period were optimized. Dosage (PO_4-P: Mg^{+2}) is one of the most critical parameter that affects the precipitation of struvite. Since the cost of $MgCl_2$ covers about 75% of the total cost for struvite production, hence in this research Basaka lake water was used as one of the possible source for $MgCl_2$.

1.3 Basaka water

Basaka lake water contains chemical elements like Ammonia, Sodium, Potassium, Calcium, Magnesium, Iron, Manganese, Fluoride, Chloride, Nitrate, Nitrite, Carbonates, Bicarbonate, Sulphates, Phosphates etc. In the experimental research (Soritual adelbertevage, 2017) he used sea water as $MgCl_2$ sources. In his research about 5%, 10%, 15%, and 20% of the volume of respectable jar sea water was used as source of magnesium and he achieved about 68% P.

Table 3: Magnsium content of Basaka water from 1998-2005EC

Month	**Parameter**	**Unit**	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**	**2005**
July	Magnesium	mg/ℓ	1.1	2.92	1.53	1.53	0.96	0.46	8.8
August	Magnesium	mg/ℓ	1.08	18.48	1.53	1.02	1.37	3.65	11.5
September	Magnesium	mg/ℓ	-	-	1.02	-	1.82	0.91	1.92
October	Magnesium	mg/ℓ	-	-	7.65	-	1.82	1.66	0.96
November	Magnesium	mg/ℓ	-	-	2.55	1.22	0.48	1.37	2.28
December	Magnesium	mg/ℓ	1.1	-	1.02	-	0.91	-	0.91
January	Magnesium	mg/ℓ	1.1	-	1.53	1.53	1.82	-	1.44
February	Magnesium	mg/ℓ	1.1	-	1.02	1.02	1.37	1.37	1.92
March	Magnesium	mg/ℓ	-	1.1	-	1.02	1.44	1.82	0.96
April	Magnesium	mg/ℓ	-	-	3.57	1.02	4.32	5.47	1.37
May	Magnesium	mg/ℓ	-	-	1.02	2.55	0.48	2.22	9.6
June	Magnesium	mg/ℓ	1.08	1.08	0.51	1.02	1.92	0.96	10

(Source: Awash River Basin Authority, 1998-2005EC)

1.4 Scope of the research

This research was part of thematic research which was conducted in corporation with Addis Ababa University, College of Natural Science. In this research laboratory based tests were conducted using jar test equipment to precipitate struvite from stored human urine i.e. recovery of nutrient like N and P. Furthermore parameters like PH, dosage (concentration), mixing speed, mixing time, and precipitation time and storage period were optimized, ultimately struvite was produced with designed stirred reactor.

1.5 Statement of the problem

Whenever Nitrogen and Phosphorus are not recovered efficiently from wastewater they would result in the formation of Struvite which ultimately end with reduction of flow ,blockage of pipes, an increase in pressure ,and ultimately resulted in breakage of pipes ,and therefore to deprive this situation N and P have to be recovered from source separated urine .Moreover since there is scarcity of fertilizers in our country Ethiopia , these recovered N and P in the form of struvite can also be used for agriculture to manufacture fertilizers which leads to an increase in yield.

1.6 Objectives

The main objectives of this research is to demonstrate efficient nutrient recovery and reuse in source separated human urine by investigating optimum PH, dosage (concentration), mixing time ,mixing velocity ,precipitation time and storage period. Moreover, design of stirred reactor with optimal conditions.

Main Objective

The main objective of this research is to demonstrate efficient nutrient recovery and reuse in agriculture from source separated urine.

Specific objectives of the research

- To investigate various process parameters on Nitrogen (N) and phosphorus recovery by struvite formation from stored human urine.
- To design the stirred reactor for nutrient recovery from source separated human urine

.

2. Literature Review

2.1 Waste water Treatment Technologies (WWTs)

Waste water is classified as industrial waste water and municipal wastewater. Usually, industrial waste water after pretreatment with compatible characteristics with municipal waste water discharged to municipal sewer and again treated with municipal treatment plant with municipal wastes. The main contaminant in waste water is usually suspended solids (SS), biodegradable organic compound, pathogens, heavy metals, and nutrients. All these components of the waste water have to be reduced to acceptable level in order to diminish the direct or indirect harms and impacts to human and environment before the water and nutrients can be reused or discharged to either surface water or ground water.

Most treatment plants that are found worldwide consists of three steps to make the effluent suitable for human beings, animals and environment. These steps are physical treatment (primary), Biological (secondary) and tertiary treatment.

2.1.1 Physical (primary) treatment

This treatment process is conducted by settling (floating) process which is applied to remove suspended matters, grit, oil and grease. This process usually takes place by the help of gravity to separate the solids from the filtrate. The main use of this treatment process is to remove heavier solids to reduce the loads on the biological treatment and increasing its efficiency.

2.1.2 Biological/ Secondary/ treatment

This process can be carried out by single and/or combined systems of anaerobic or aerobic digestion. The treatment process is determined by intake nutrients and also the target effluent. Now a days, anaerobic digestion and activated sludge are the most widely used processes when treating sludge and municipal waste water respectively.

2.1.3 Tertiary treatment

This treatment method includes odor removal, disinfection, filtration, nitrogen and phosphorus recovery. Excess amount of N and P will result in sever environmental problems like eutrophication, contamination of surface water and ground water.

2.2 Nutrient Removal

2.2.1 Nitrogen removal

2.2.1.1 NH_4-N recovery by precipitation of Magnesium Ammonium Phosphate

Human urine has been studied by applying freezing thawing method and MAP precipitation method (Ganroz, Z., G. Dave, and E.Nilsson, 2007). The experiment result showed that, freezing-thawing could affect the removal of ammonium. In the experimental research of land fill leachetes at molar ratio of ($PO_4^{-3}: Mg^{+2}$) 1:1, they found that the optimal PH was 9.5 to NH_4^+-N removal but the efficiency drops below 9.5 (Zhang, L., et al, 2008). Other research extended that when the molar ratio of ($PO_4^{-3}: Mg^{+2}$) 1:1 was increased from 1:1 to 1:1.25 the removal efficiency of ammonium increased and then decreased, which indicates that theMg^{+2} could affect the removal efficiency of NH_4-N. (Zhang, L., et al., 2008).

There was an experimental research conducted on recovery of N from waste water and they recovered about 95% of NH_4-N in the form of MAP (Mohamad Darwish, AzmiAris, 2015) but (Mi Liang, 2009) showed in his experimental research the amount of Nitrogen recovered in the form of struvite was 57% as NH_4-N.

2.2.2 Phosphorus Removal

2.2.2.1 PO_4-P recovery by precipitation of MAP

Struvite is most suitable where the use of phosphate rock is not suitable because of its low solubility and it's applicability in calcareous soils (Massey et al., 2007). Struvite is also recommended in soils with high Mg and P demands (Gonsaley – ponce et. al., 2009).In struvite treated soil, N leaching losses are remarkably about 1.99% of the total nitrogen compared to chemical fertilizer treated soil (Rahamann, et.al., 2011).

In experimental research conducted on resource conservation recycling, struvite or Ammonium Magnesium Phosphate (MAP) hexahydrate (Mg NH4PO4. 6H2O) recovery is one of the available method of P recovery (de Bashan and Bashan, 2004).In the other experiment, batch experiments were conducted to examine the influence of various process parameters on phosphorus recovery by struvite formation from urine. In their research they concluded that the phosphorus recovery was more than 96.6% when the Mg:P ratio was 1.3 (Xiaoning Liu, Zhengyi Hu, Chunyou Zhu, and GuoqiWen, 2015) but there was a research that reported phosphate removal was 98% at 1:1 molar ratio again Abegglen, 2008 found that the phosphorus removal was about 95% when PO4: Mg^{+2}= 1:1 .

Again the other researchers (Patricia Zamora, Tanya Georgieva, and Inmaculada Salcedo, 2016) concluded that phosphorus was recovered in the form of struvite with purity over 90% at PO4: Mg^{+2}= 1:1 but there is other experimental research which concluded that about 97% of P was recovered (Mi Liang, 2009) with this dosage ratio.

2.3 Factors Affecting struvite formation

2.3.1 PH

PH is a predominant factor which has significant impact on struvite precipitation. It is optimized first because it is used to maximize the struvite formation, It is used for the purity of struvite formed and It is the deriving factor for struvite formation (Evagel-Suritua A Delbert H., 2017).

Based on laboratory report the critical PH value was reported as 5.85, i.e. below this pH no struvite was formed (struvite was first formed above PH 5.85) (Abbona, F., H.E lundager Madsen, and R.Boistelle, 1982).

At PH less than 5.85 a chemical compound new beryite (Mg HPO_4. $3H_2O$) is formed above this pH compound like $Mg_3(PO_4)_2.8H_2O$ [bobierrite], $Mg_3(PO_4)_2.22H_2O$, $Ca_5(PO_4)_3$ OH (hydroxyapatite], $Ca_3(PO_4)_2$ [white lockite], $CaHPO_4.2H_2O$ (Brushite), $CaHPO_4$, $MgCO_3$, $Mg(OH)_2$ may also be precipitated at different pH's (Euagel- Soritua A Delbert H., 2017).

In the experimental research of landfill leachates at molar ratio of PO_4^{-3}: Mg^{+2}= 1:1, they found that the optimum PH for NH_4-N removal was at PH 9.5 but the efficiency drops below 9.5 (Zhang, L., et al, 2008).On the other hand by the research done on effect of PH and PO_4^{-3}:Mg^{+2} dosage ratio on struvite precipitation (Nelson, N.D., R.L. Mikkelsen, 2003) they have compared the results of the two treatment plants, and found that the optimum PH value for struvite precipitation was found at 8.9 and 9.25 respectively.

On the other hand in other experimental research, the influence of process parameters on phosphorus recovery by struvite formation from urine (Xiaoning Liu, Zhengyi Hu, and Chungov Zhu, 2013) they found that an increase of PH from 8.7 to 10 did not significantly affect P removal, but the quality of the crystal formed at PH 10 was poor based on scanning electron microscopy analysis. They also reported that the optimum PH was not affected by the molar ratio of PO_4^{-3}:Mg^{+2} but the struvite production was affected by PH but the other researchers showed that precipitation of struvite, was best at PH 9.6 with the range of 9-10 (El Diwani, G., et al., 2007)

2.3.2 Dosage/ PO_4-P:Mg^{+2} concentration/

The effect ofPO_4^{-3}:Mg^{+2} concentration that was added to the solution plays great role in struvite precipitation because the amount of phosphate found in the urine is directly proportional to the amount of struvite produced. In the experimental research assessment of nutrient removal performance in the integrated constructed wet land(Zhang, L., et al., 2008) when the PO_4^{-3}:Mg^{+2} was increased from 1:1 to 1:1.2 removal efficiency of MAP increased and then decreased which showed that Mg^{+2} concentration could affect the removal efficiency of MAP but another experimental result reported that the removal efficiency can be higher than 80% and would be increased further when the PO_4^{-3}:Mg^{+2} is greater than1:1 ratio(Pastor ,L., et al.,2010; Quintana, M., et al., 2005; Xiaoning Liu, Zhengyi Hu, Chunyou Zhu, 2013)).

2.3.3 Mixing Speed

At optimum PH, dosage, the formation of struvite is also affected by the process of the solution turbulence (Ohlinger et al., 1999) this is because the rate of formation of product depends on effective collision between phosphate ions , ammonium ions and $MgCl_2$.

An experimental research revealed that 160rpm per minute was the good mixing speed for struvite precipitation (Xiaoning Liu, Guoqiwen ,Jia Lu, 2013) but other experimental research conducted (Cifang, Tao Zhang, RongfengJiang and Hisao Ohtake, 2016) concluded that when the agitation rate was increased they determined that larger quantity of struvite was formed with smaller size, but when the agitation rate was decrease smaller quantity of struvite with larger size would be obtained. On the other hand other experimental research revealed that if the stirring speed was higher it may cause the break done of the struvite crystal thus the settle ability of NH_4-N and PO_4-P decreased (M.S. Rahaman, N. Ellies and D.S. Mavinic,2015; effect of various process parameters on struvite precipitation).

2.3.4 Mixing Time

In addition to PH, dosage and mixing speed ,mixing time also plays a great role in struvite precipitation, this is because mixing time gives opportunity for ammonium ion and phosphate ion to react with Magnesium.

There was a research conducted on mixing time that revealed a longer mixing time affects positively struvite formation and compared to without mixing, and they concluded that the P removal efficiency increased from 72.7 to 97.3% after 5 minute mixing: this research further explained the addition of speed materials had no influence on the P removal but contributed to the formation of struvite Clusters (XiaoningLiv, Zhengyi Hu, Chunyou Zhu, 2013) but other experimental research conducted revealed that as reaction time increased from 30 minutes to one hour the diameter of the struvite formed and the amount of struvite formed decreases (CiFang, Tao Zhang, Rongfeng Jiang and Hisao Ohtake, 2016).

2.3.5 Temperature

In the experimental research conducted on phosphate recovery from waste water they showed that reaction temperature had significant effects on thermodynamic parameters such as solubility products of crystals. They set the reaction temperatures at 294k, 301k, 308k, 315k and 322k respectively and concluded that the diameter of the struvite formed was not significantly changed.

In another experimental research conducted (Liu et al., 2014) they found that about 80% phosphorous was recovered at 20-30^{0}c, but below and above this temperature the recovery declines.

The effect of temperature with reaction speed, time and dosage was not considered in this research since the laboratory used for the research was too young, but the effect of temperature on the storage with the concentration of PO_4-P was taken into consideration and the measurement was taken only in the morning from 12Am- 1Am local time regularly.

2.3.6 Duration of Incubation (storage)

Duration of incubation should be optimized because in the urine for one thing there is urease that hydrolysis urea in to ammonium ion which ultimately increase the nitrogen in the struvite and for another thing as incubation period increases the ammonium ion found in the urine becomes toxic for the pathogens that are found in the urine.

In the experimental research long term operation of a pilot-scale reactor for phosphorus recovery as struvite from source separated urine they revealed that 16 days residence time inside the collection tank for urine was enough to hydrolysis urea completely (Patricia Zamora, Tanya Georgieva, Inmaculada Salcedo, 2016) but (Miliang, 2009) conducted 15 days experimental research with their respective dosage and found the maximum phosphorus was recovered in the 14th day and Nitrogen in the 11th day.

In general having an optimum PH, optimum dosage (PO_4:Mg^{+2}) optimum mixing time, and optimum mixing speed the measurement was taken at 11th, 12th, 14th and 16th day to determine the best incubation period for the maximum recovery of P and N but the result coincides to none of the researchers, the test was done twice, one for 25 days and the other sample for 30 days.

2.3.7 Precipitation time

Precipitation time has to be optimized because sufficient time should be given for the struvite crystals that are formed in the solution for precipitation .If too long time were given for precipitation there was a chance for the precipitated struvite crystals to re suspend and reduce the percentage recovery of nutrients and also if too small time was given there were also other struvite crystals that were on the way to settle.

In the experimental research done on influence of process parameters on phosphorus recovery by struvite formation from urine, they concluded that precipitation time of 30 minutes was enough for N and P recovery, beyond this time there might be re -suspension of particulate materials in the solution (XiaoningLiv, Jai Lu, Guoqi when, 2013).

2.4. Acceptability of human urine derived in Africa.

2.4.1. Acceptance of human urine as fertilizer in south Africa

In some African countries, the use of urine and faces for food production has also been accepted. However, there is little or no information of its uses in South Africa because of the lack of urine division toilets which enables the hygienic separation of urine and faces. The recent introduction of urine diversion toilets in South Africa should lead soon increase in the use for urine for agricultural purposes (LL Mugivhisa, Jo olowoyo, 2015)

In the research topic assessment of university students and staff perceptions regarding the use of human urine as a fertilizer as a valuable soil nutrients in South Africa a total of 225 questionnaires were administered to the students and the staff members at the university of Limpopo, Medunsa compus then about 57.3% of them were familiar with manure as fertilizers but about 24.6%, and 18.1 were familiar with chemical fertilizers and composts respectively.(LL Mugivhisa, Jo Olowoyo, 2015)

2.4.2. Acceptance of human urine as fertilizer in Uganda farmers

In Uganda, there was a research done in Jopadhola ethnic group of farmers, and there were few farmers aware of urine as a fertilizer but majority of the farmers were no concept about it. Even there were people that kept themselves away from human urine due to their culture. After two years of their practices the farmers recognized the urine crop fertilizer also acts as pest resistant in addition to an increase in productivity (Elina Andersson, 2015) but the country is not yet producing in the form of struvite.

2.4.3. Acceptance of human urine as fertilizer in Mali (West Africa)

In Mali there were practice of using human urine as fertilizer in the system of “Closed loop” sanitation which turns human waste back in to plants as quickly, efficiently and safely as possible. Rather than just disposal of the waste, closed loop sanitation works helps to kill diseases and change valuable plant building elements back in to a form that can be put into soil to help plants grow.

The nitrogen and phosphorous excreted in one Malian’s urine would therefore equal to 5.8 gram /day and 0.33-0.78grams/day respectively (Rayanshaw, 2010)

In Mali the use of urine as a fertilizer has challenged with respect to cultural, and social conditions.

In this country they have paved a mechanism for the collection of urine and using the urine without diluting as long as the toxicity level is avoided and they apply it to the farrow at little bit far distance from the plant but this technique spreads disease whenever the urine was used as a fertilizer. Generally, even though the Malians are practicing human urine as fertilizer they are not producing human urine as struvite.

2.5 Experience of different countries using human urine based fertilizer

In United States of America under the topic cost – effective end eco-friendly struvite waste water treatment products they are producing struvite and delivering to the market. The company is not only producing struvite but also they are manufacturing struvite remover, vivianite and scale remover, J5- 9325 as well as struvite prevention and vivianite prevention J5- 9310, in which both products are environmentally friendly, non-corrosive, safe to human health and cost effective.

Nepal's have no internal or indigenous production of fertilizers means they are fully dependent on other countries. Now a day they are widely using human urine to produce struvite. They have been constructing mobile toilets, struvite reactors for production of MAP. They have been using $MgCl_2$ as magnesium source and stirring for 10 minutes in the reactor to precipitate struvite.

Netherlands are also the main producers of struvite as commercial fertilizers. Chins, Japan, England and some other countries are producing struvite in large as commercial fertilizer in addition to struvite remover from the pipes.

2.6 Efficiency of struvite in comparison with commercial fertilizers

Table 4: Comparsion of struvite with commercial fertilizer

Advantage of struvite as fertilizer	**Disadvantage of Urea or DAP as fertilizer**
-it is low water soluble	-they are highly soluble in water
-slow release of nutrients	-releases nutrients in faster rate
-longer retention period in the soil	-shorter retention period in the soil
-eliminates soil toxicity	-increase soil toxicity
-no damage to plants	-damages plants
-cost effective ,and relatively simple	-it is costly and has processes to produce
-it enables nutrient recycling	-no nutrient recycling
-it yields a product almost free of most organic micro pollutants and traces of heavy metals	-full of micro pollutants

3. Materials and Methods

3.1 Materials

3.1.1 Photometer

Palintest photometer is made in UK (Unite Kingdom) for water quality and waste water tests.

The instrument has dual light source photometer offering direct reading of pre-programmed test calibrations, absorbance and transmittance. The instrument is working with wave lengths 450nm, 500nm, 550nm, 570nm, 600nm, and 650nm ranges. The accuracy of the measurement is ±1%T.

The fundamental operating technique applied to the photometer 7100 is based on the principles of optical absorbance and scattering of visible light. The optical absorbance techniques are based on the use of Palintest photometric reagent, creating visible colors with specific analytes upon action. The intensity of color produced is measured with the photometer 7100 and the stored calibration data and deliver the final result.

Optical scattering techniques produced small particles to scatter the source beam, the amount of scatter providing a result for the concentration of parameter under test. (www.palintest.com)

Palintest®

Figure 2: Palintest photometer

Even though the instrument was given with the test certification, it was checked for calibration as follows.

Preparation of standard solutions

- Weigh out 1.9095g NH_4Cl and dilute to 500ml in volumetric flask ⇒ 1000mg/l stock solution (appendex-1)

Table 5: preparation of standard solution by the rule of dilution

Concentration (mg/l)	Volume of the stock solution (ml)
1000	500
100	250
2	250
1.4	100
0.8	100
0.2	100
0.1	100

Take 10 $m\ell$ from each beaker and read absorbance by using Palintest photometer ,and the result was tabulated as follows:

Table 6: Concentration against absorbance for calibration of Photometer

Concentration (mg.N/ℓ)	Absorbance	
2	450nm	1.804
	650nm	1.97
1.4	450 nm	1.558
	650 nm	1.417
0.8	450 nm	1.423
	650 nm	0.839
0.2	450 nm	1.212
	650 nm	0.29
0.1	450 nm	1.417
	650 nm	0.191
0	450 nm	1.297
	650 nm	0.02

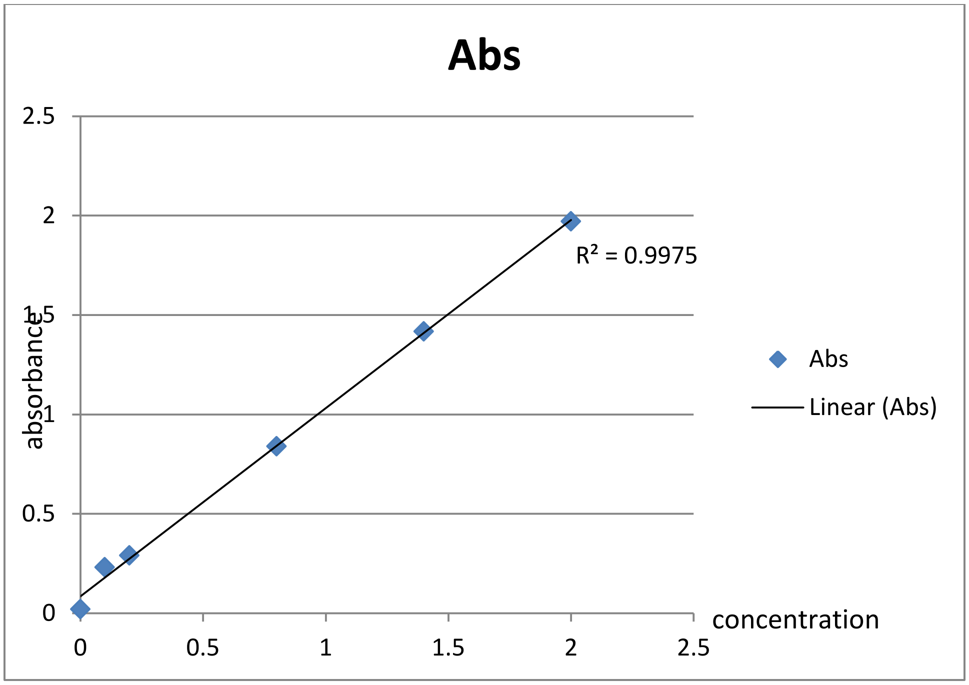

Figure 3: Absorbance against concentration

3.1.1.1 Test for Ammonia /Test for ammonia in natural, drinking and Waste Water/

The palintest ammonia test provides a simple method of measuring ammonia (ammonical nitrogen) over the range of 0 - 1 mg/ℓ N, with automatic wave length selection.

i. Reagents and equipment

-Palintest Ammonia Number -1 Tablets

-Plaintest Ammonia Number -2 Tablets

-Palintest Automatic Wavelength selection photometer

-Round test tubes, 10mℓ glass (PT 595)

3.1.1.2 Test for high level of phosphate

The palintest phosphate HR (high range) test provides a simple method of measuring phosphate levels in boiler waters over the range of 0-100 mg/ℓ PO4.

i. Reagent and Equipment

- Palintest phosphate HR tablets
- Palintest automatic wave length selection photometer
- Round test tubes, 10mℓ glass (PT 595)

3.2 Methods

3.2.1 Measurements of Nitrogen and Phosphorus

3.2.1.1 NH_4-N Measurement

Nitrogen (NH_4-N) measurement was conducted to measure the concentration of N in the stored urine and to investigate the remaining concentration of Nitrogen after struvite formation. For the determination of NH_4-N concentration photometer 7100 test kit was used.

The procedure to measure NH_4-N concentration was started with 10mℓ of stored urine diluted to 100mℓ. Then 10mℓ of the diluted stored urine was added to 10mℓ cuvette and tablet 1 and tablet 2 of ammonia were added one after the other and kept for 10 minutes. It was supposed that at the end of 10 minutes complete reaction occurred. Ultimately after 10 minutes the initial concentration of NH_4-N in stored human urine was measured. The same principle works to measure the final concentration of NH_4-N after struvite formation but the dilution factor was changed to 5.

i. Method

The plaintest Ammonia test is based on indophenols method. Ammonia reacts with alkaline salicylate in the presence of chlorine to form a green blue indophenols complex. Catalysts are provided in the form of two tablets for maximum convenience. The test is simply carried out by adding one of each tablet to a sample of the water.

The intensity of the color produced in the test is proportional to the ammonia concentration and is measured using palintest photometer

ii. Test instructions

1. Fill the tube with sample to the 10mℓ mark
2. Add one ammonia number 1 tablet and one ammonia number 2 tablets, crush and mix to dissolve.
3. Stand for ten minutes to allow color development
4. Select phot 004 on photometer to measure Ammonia mg/ℓ N or select phot 062 on photometer to measure Ammonium mg/ℓ NH_4.

NB: 1. At low temperature the rate of color development in the test may be slower. If the sample temperature is below 20^0c allow 15 minutes for the color to develop.

2. Ammonia concentration can be expressed in a number of different ways.

The following factors may be used for the conversion of readings:

- To convert from N to NH_4 multiply N reading by 1.3
- To convert from N to NH_3 multiply N reading by by 1.2

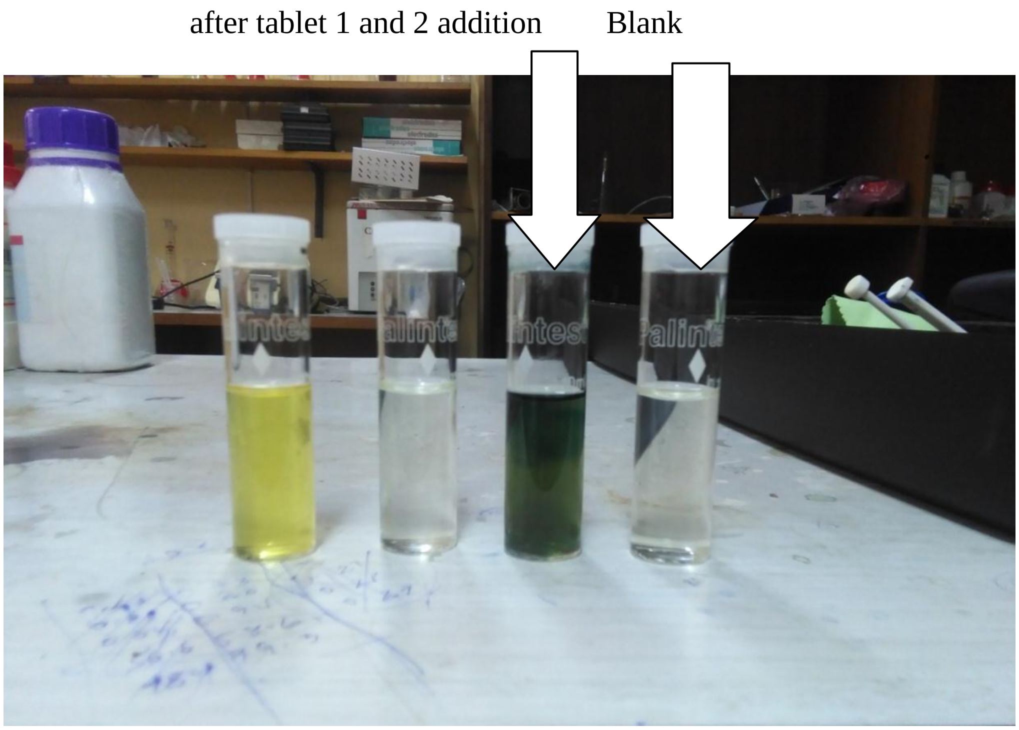

Figure 4: Setting for 10minutes after addition of tablet 1 and 2 for Nitrogen measurement

3.2.1.2 PO_4-P measurement

The procedure to measure PO_4-P concentration was started with 10mℓ of stored urine diluted to 100mℓ. Then 10mℓ of the diluted stored urine was added to 10mℓ cuvette and tablet of phosphate was added and kept for 10 minutes. It was supposed that at the end of 10 minutes complete reaction occurred. Ultimately after 10 minutes the initial concentration of PO_4-P in stored human urine was measured. The same principle works to measure the final concentration of PO_4-P after struvite formation but the dilution factor was changed to 5.

i. Method

The palintest phosphate HR test is based on the Vanadom Olybdate method. In the test phosphate react with ammonium molybdate, in the presence of ammonium vanadate, to form the yellow phosphovanado molybdate. The intensity of the color produced in the test is proportional to the phosphate concentration and is measured using palintest photometer number 029.

ii. Test Instruction

1. Fill test tube with sample to the 10mℓ mark
2. Add one photometer high range tablet, crush and mix to dissolve
3. Stand for 10 minutes to allow full color development
4. Select phot029 on photometer
5. Take photometer reading in usual manner
6. The result is displayed as mg/ℓ PO4

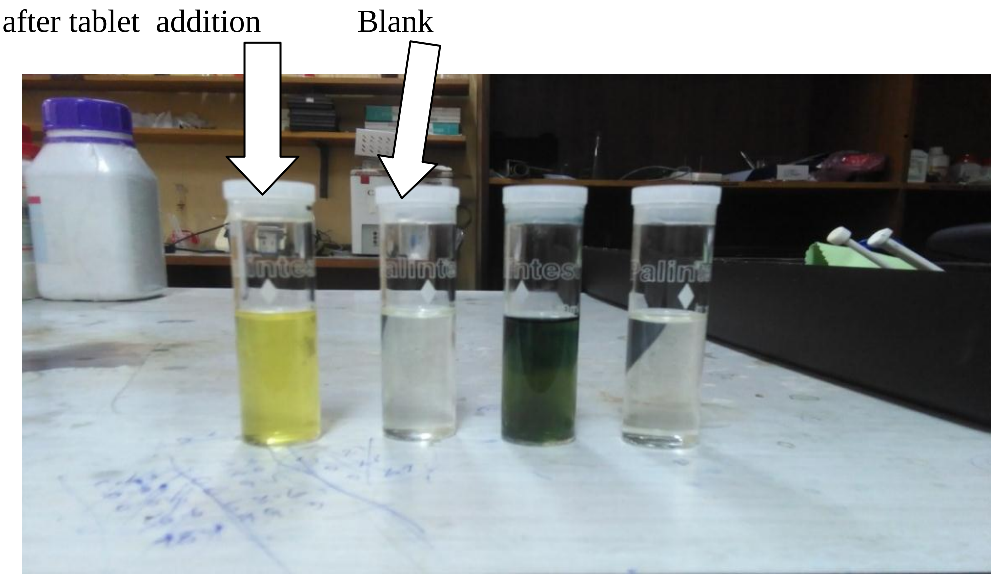

Figure 5: Setting for 10minutes after addition of tablet for Phosphorus measurement

3.3 Optimization of Physiochemical parameters for struvite formation

3.3.1 Optimization of PH

For struvite formation pH was fixed before other physiochemical factors that affects struvite formation for the following reasons:

1. It is used to maximize the struvite formation
2. It is used for the purity of struvite

3.It is the deriving factor for struvite formation (Evagel-suritua A Delbert H., 2017).

To optimize pH the following combinations of (pH, dosage, time, speed) were formed during laboratory session, and their respective percentage recovery of Nitrogen and phosphorus was measured, an optimal PH was the trial with maximum recovery. For optimization of PH five trials were done.

The pH of the solution was adjusted by 5M NaOH and 5M HCl (appendex-1)

Trial -1

Tuesday 14/07/2010 E.C(Collection date)

Test date Wednesday 19/07/2010 E.C

Dilution Factor=100ml/4ml=25

PH of the stored urine before Jar test = 8.15

Amount of PO_4 concentration before Jar test = 905mg/ℓ

Volume of stored urine used = 300mℓ

Amount of $MgCl_2$ added = 0.2715g

$$\%\ \text{Recovery of N} = \left(\frac{\begin{matrix}\text{initial concentration} \\ \text{of N before jar test}\end{matrix} - \begin{matrix}\text{concentration of N} \\ \text{after jar test}\end{matrix}}{\begin{matrix}\text{initial concentration of N before} \\ \text{Jar test}\end{matrix}}\right) * 100$$

$$\%\ \text{Recovery of P} = \left(\frac{\begin{matrix}\text{initial concentration} \\ \text{of p before jar test}\end{matrix} - \begin{matrix}\text{concentration of p} \\ \text{after jar test}\end{matrix}}{\begin{matrix}\text{initial concentration of p before} \\ \text{Jar test}\end{matrix}}\right) * 100$$

Trial -2

Test date Friday 21/07/2010 E.C

Dilution Factor=100ml/4ml=25

PH of the stored urine before Jar test = 9.15

Concentration of PO_4 before jar test= 782.5 mg/ℓ

Amount of $MgCl_2$ added = 0.235g

Volume of stored urine used = 300 m ℓ

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix} \text{initial concentration} \\ \text{of N before jar test} \end{matrix} - \begin{matrix} \text{concentration of N} \\ \text{after jar test} \end{matrix}}{\begin{matrix} \text{initial concentration of N before} \\ \text{Jar test} \end{matrix}}\right) * 100$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix} \text{initial concentration} \\ \text{of p before jar test} \end{matrix} - \begin{matrix} \text{concentration of p} \\ \text{after jar test} \end{matrix}}{\begin{matrix} \text{initial concentration of p before} \\ \text{Jar test} \end{matrix}}\right) * 100$$

Trial-3

Test date Saturday 22/07/2010 E.C

PH of the stored urine before Jar test = 9.10

Concentration of PO_4 before jar test= 623 mg/ℓ

Volume of stored urine used = 300 m ℓ

Dilution Factor=100ml/10ml=10

Amount of $MgCl_2$ added = 0.1869g

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix} \text{initial concentration} \\ \text{of N before jar test} \end{matrix} - \begin{matrix} \text{concentration of N} \\ \text{after jar test} \end{matrix}}{\begin{matrix} \text{initial concentration of N before} \\ \text{Jar test} \end{matrix}}\right) * 100$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix} \text{initial concentration} \\ \text{of p before jar test} \end{matrix} - \begin{matrix} \text{concentration of p} \\ \text{after jar test} \end{matrix}}{\begin{matrix} \text{initial concentration of p before} \\ \text{Jar test} \end{matrix}}\right) * 100$$

Trial-4

Test date Sunday 23/07/2010 E.C

pH of the stored urine before Jar test = 9.13

Dilution Factor=100ml/10ml=10

Volume of stored urine used = 300 m ℓ

Concentration of PO_4 before jar test= 575 mg/ℓ

Amount of $MgCl_2$ added = 0.1725g

$$\text{\% Recovery of N} = \left(\frac{\substack{\mathit{initial\ concentration}\\ \mathit{of\ N\ before\ jar\ test}} - \substack{\mathit{concentration\ of\ N}\\ \mathit{after\ jar\ test}}}{\substack{\mathit{initial\ concentration\ of\ N\ before}\\ \mathit{Jar\ test}}}\right) * 100$$

$$\text{\% Recovery of P} = \left(\frac{\substack{\mathit{initial\ concentration}\\ \mathit{of\ p\ before\ jar\ test}} - \substack{\mathit{concentration\ of\ p}\\ \mathit{after\ jar\ test}}}{\substack{\mathit{initial\ concentration\ of\ p\ before}\\ \mathit{Jar\ test}}}\right) * 100$$

Trial-5

Test date Monday 24/07/2010 E.C

PH of the stored urine before Jar test = 9.06

Concentration of PO_4 before jar test= 665 mg/ℓ

Volume of stored urine used = 300 m ℓ

Amount of $MgCl_2$ added = 0.1995g

$$\text{\% Recovery of N} = \left(\frac{\substack{\mathit{initial\ concentration}\\ \mathit{of\ N\ before\ jar\ test}} - \substack{\mathit{concentration\ of\ N}\\ \mathit{after\ jar\ test}}}{\substack{\mathit{initial\ concentration\ of\ N\ before}\\ \mathit{Jar\ test}}}\right) * 100$$

$$\text{\% Recovery of P} = \left(\frac{\substack{\mathit{initial\ concentration}\\ \mathit{of\ p\ before\ jar\ test}} - \substack{\mathit{concentration\ of\ p}\\ \mathit{after\ jar\ test}}}{\substack{\mathit{initial\ concentration\ of\ p\ before}\\ \mathit{Jar\ test}}}\right) * 100$$

3.3.2 Optimization of dosage for struvite formation

After fixing pH, dosage was optimized based on the concentration of phosphate ion (PO_4^{-3}) measured in stored human urine.

Trial-1

Test date Tuesday 25/07/2010 E.C

PH of the stored urine before jar test = 9.10

Dilution Factor=100ml/10ml=10

Concentration of PO_4 = 771 mg/ℓ

Volume of stored urine used = 300 m ℓ

Amount of $MgCl_2$ added = 0.2313g

Case -1, Dosage 1:1

PH=10, t= 30 min, v=120rpm

Case -2, dosage 1:2

PH=10, t= 30 min, v=120rpm

Case -3, dosage 1:3

PH=10, t= 30 min, v=120rpm

Case -4, dosage 1:4

PH=10, t= 30 min, v=120rpm

Case -5, dosage 1:5

PH=10, t= 30 min, v=120rpm

Case -6, dosage 1:6

PH=10, t= 30 min, v=120rpm

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix}initial\ concentration\\ of\ N\ before\ jar\ test\end{matrix} - \begin{matrix}concentration\ of\ N\\ after\ jar\ test\end{matrix}}{\begin{matrix}initial\ concentration\ of\ N\ before\\ Jar\ test\end{matrix}}\right) * 100$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix}initial\ concentration\\ of\ p\ before\ jar\ test\end{matrix} - \begin{matrix}concentration\ of\ p\\ after\ jar\ test\end{matrix}}{\begin{matrix}initial\ concentration\ of\ p\ before\\ Jar\ test\end{matrix}}\right) * 100$$

Trial-2

Test date Wednesday 26/07/2010 E.C

PH of the stored urine before jar test = 10.03

Concentration of PO_4 = 964 mg/ℓ

Volume of stored urine used = 300 m ℓ

Amount of $MgCl_2$ added = 0.2892g

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix}initial\ concentration\\ of\ N\ before\ jar\ test\end{matrix} - \begin{matrix}concentration\ of\ N\\ after\ jar\ test\end{matrix}}{\begin{matrix}initial\ concentration\ of\ N\ before\\ Jar\ test\end{matrix}}\right) * 100$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix}initial\ concentration\\ of\ p\ before\ jar\ test\end{matrix} - \begin{matrix}concentration\ of\ p\\ after\ jar\ test\end{matrix}}{\begin{matrix}initial\ concentration\ of\ p\ before\\ Jar\ test\end{matrix}}\right) * 100$$

Case -1, Dosage 1:1

PH=10, t= 30 min, v=120rpm

Case -2, dosage 1:2

PH=10, t= 30 min, v=120rpm

Case -3, dosage 1:3

PH=10, t= 30 min, v=120rpm

Case -4, dosage 1:4

PH=10, t= 30 min, v=120rpm

Case -5, dosage 1:5

PH=10, t= 30 min, v=120rpm

Case -6, dosage 1:6

PH=10, t= 30 min, v=120rpm

Trial -3

Initial pH of the stored urine= 10.05

Dilution Factor = $\frac{100m\ell}{10m\ell}$ = 10 mℓ

Concentration of PO_4 before jar test = 10 * 82.0 mg/ℓ = 820 mg/ℓ

Case -1, Dosage 1:1

PH=10, t= 30 min, v=120rpm

Case -2, dosage 1:2

PH=10, t= 30 min, v=120rpm

Case -3, dosage 1:3

PH=10, t= 30 min, v=120rpm

Case -4, dosage 1:4

PH=10, t= 30 min, v=120rpm

Case -5, dosage 1:5

PH=10, t= 30 min, v=120rpm

Case -6, dosage 1:6

PH=10, t= 30 min, v=120rpm

Dosage triplication in 1:1 and 1:2 ratio

Test date Monday1/08/2010 E.C

PH of the stored urine before jar test = 8.82

Dilution Factor=100ml/10ml=10

Concentration of PO_4 = 740 mg/ℓ

Amount of stored urine used = 300 m ℓ

Amount of $MgCl_2$ added = 0.222g

$$\text{\% Recovery of N} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of N before jar test}\end{matrix} - \begin{matrix}\textit{concentration of N} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of N before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

$$\text{\% Recovery of P} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of p before jar test}\end{matrix} - \begin{matrix}\textit{concentration of p} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of p before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

3.3.3 Optimization of speed and time for struvite formation

After optimization of PH and dosage, mixing time and mixing speed were optimized by three trails each with three combinations. Mixing speeds 60rpm,90rpm and 120rpm were selected because if the mixing speed was less than 60rpm there is no complete reaction between phosphate ion ,ammonium ion and magnesium ion again if the mixing speed was greater than 120rpm there was a chance for struvite to re suspend. Mixing time 30min,45min,and 60min were used because if the mixing time was less than 30min the rate of production of struvite was less and other compounds other than struvite was produced again if the mixing time was above 60min for one thing it was not economical and for another thing the precipitated struvite has got chance to re suspend and reduce the percentage recovery of N and P.

Trial-1

Case -1, speed 60rpm

PH=10, dosage 1:1, t= 30 min

Case -2, speed 90rpm

PH=10, dosage 1:1, t= 30 min

Case -3, speed 120rpm

PH=10, dosage 1:1, t= 30 min

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix}\mathit{initial\ concentration} \\ \mathit{of\ N\ before\ jar\ test}\end{matrix} - \begin{matrix}\mathit{concentration\ of\ N} \\ \mathit{after\ jar\ test}\end{matrix}}{\begin{matrix}\mathit{initial\ concentration\ of\ N\ before} \\ \mathit{Jar\ test}\end{matrix}}\right) * 100$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix}\mathit{initial\ concentration} \\ \mathit{of\ p\ before\ jar\ test}\end{matrix} - \begin{matrix}\mathit{concentration\ of\ p} \\ \mathit{after\ jar\ test}\end{matrix}}{\begin{matrix}\mathit{initial\ concentration\ of\ p\ before} \\ \mathit{Jar\ test}\end{matrix}}\right) * 100$$

Trial-2

Case -1, speed 60rpm

PH=10,dosage 1:1 , t= 45 min

Case -2, speed 90rpm

PH=10,dosage 1:1 , t= 45 min

Case -3, speed 120rpm

PH=10,dosage 1:1, t= 45min

$$\%\ \text{Recovery of N} = \left(\frac{\substack{\textit{initial concentration}\\ \textit{of N before jar test}} - \substack{\textit{concentration of N}\\ \textit{after jar test}}}{\substack{\textit{initial concentration of N before}\\ \textit{Jar test}}} \right) * 100$$

$$\%\ \text{Recovery of P} = \left(\frac{\substack{\textit{initial concentration}\\ \textit{of p before jar test}} - \substack{\textit{concentration of p}\\ \textit{after jar test}}}{\substack{\textit{initial concentration of p before}\\ \textit{Jar test}}} \right) * 100$$

Trial-3

Case -1, speed 60rpm

PH=10,dosage 1:1, t= 60min

Case -2, speed 90rpm

PH=10,dosage 1:1 , t= 60 min

Case -3, speed 120rpm

PH=10,dosage 1:1, t= 60 min

$$\%\ \text{Recovery of N} = \left(\frac{\substack{\textit{initial concentration}\\ \textit{of N before jar test}} - \substack{\textit{concentration of N}\\ \textit{after jar test}}}{\substack{\textit{initial concentration of N before}\\ \textit{Jar test}}} \right) * 100$$

$$\%\ \text{Recovery of P} = \left(\frac{\substack{\text{initial concentration}\\ \text{of p before jar test}} - \substack{\text{concentration of p}\\ \text{after jar test}}}{\substack{\text{initial concentration of p before}\\ \text{Jar test}}} \right) * 100$$

3.3.4 Optimization of storage period

For optimization of storage period before struvite formation two samples at different times were collected and tested. The first sample was collected during Hudade (Aiby Fasting) and the second sample was collected after fasting. For both samples the amount of Nitrogen in the form of NH4-N and phosphorus in the form of PO4-P were measured. For optimization 300ml of stored urine was used to produce struvite. The percentage recovery of N and P in the struvite was calculated as follows:

$$\%\ \text{Recovery of N} = \left(\frac{\substack{\textit{initial concentration}\\ \textit{of N before jar test}} - \substack{\textit{concentration of N}\\ \textit{after jar test}}}{\substack{\textit{initial concentration of N before}\\ \textit{Jar test}}} \right) * 100$$

$$\%\ \text{Recovery of P} = \left(\frac{\substack{\text{initial concentration}\\ \text{of p before jar test}} - \substack{\text{concentration of p}\\ \text{after jar test}}}{\substack{\text{initial concentration of p before}\\ \text{Jar test}}} \right) * 100$$

3.3.5 Optimization of precipitation time

To determine the optimal precipitation time, the solution was set for 30min and 45min after jar test. The percentage recovery of N and P were measured by using the following formulas.

$$\%\text{ Recovery of N} = \left(\frac{\begin{matrix}\mathit{initial\ concentration}\\ \mathit{of\ N\ before\ jar\ test}\end{matrix} - \begin{matrix}\mathit{concentration\ of\ N}\\ \mathit{after\ jar\ test}\end{matrix}}{\begin{matrix}\mathit{initial\ concentration\ of\ N\ before}\\ \mathit{Jar\ test}\end{matrix}}\right) * 100$$

$$\%\text{ Recovery of P} = \left(\frac{\begin{matrix}\text{initial concentration}\\ \text{of p before jar test}\end{matrix} - \begin{matrix}\text{concentration of p}\\ \text{after jar test}\end{matrix}}{\begin{matrix}\text{initial concentration of p before}\\ \text{Jar test}\end{matrix}}\right) * 100$$

3.4 Preparation of struvite using Basaka lake water as Mg source

In this research Basaka lake water replaced magnesium chloride as Mg sources in MAP precipitations. The addition of Basaka water was not by mass or molar comparisons to compare the removal effectiveness but it was based on percentage volume.

3.4.1 Percentage recovery of Nitrogen and phosphorus in stored human urine using Basaka lake as source of Mg.

For the recovery of struvite, Basaka water was used as a source of Mg^{+2}. Having optimal PH , dosage, mixing time, mixing speed, and precipitation time, Six different volumes of Basaka water were used to calculate the percentage recovery of N and P.

Volume of the jar=300ml

Volume of Baska water added to stored urine in trail-1=5%*the volume of the jar

=5%*300ml

=15ml

Volume of Baska water added to stored urine in trail-2=10%*the volume of the jar

=10%*300ml

=30ml

Volume of Baska water added to stored urine in trail-3=15%*the volume of the jar

=15%*300ml

=45ml

Volume of Baska water added to stored urine in trail-4=20%*the volume of the jar

=20%*300ml

=60ml

Volume of Baska water added to stored urine in trail-5=25%*the volume of the jar

=25%*300ml

=75ml

Volume of Baska water added to stored urine in trail-6=30%*the volume of the jar

=30%*300ml

=90ml

PH of Basaka water=9.50

Volume of stored human urine=300ml

Concentration of PO4 before jar test=876mg/l

Amount of $MgCl_2$ added=0.2628g

$$\%\ \text{Recovery of N} = \left(\frac{\begin{matrix}\textit{initial concentration}\\ \textit{of N before jar test}\end{matrix} - \begin{matrix}\textit{concentration of N}\\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of N before}\\ \textit{Jar test}\end{matrix}}\right) * 100$$

$$\%\ \text{Recovery of P} = \left(\frac{\begin{matrix}\textit{initial concentration}\\ \textit{of p before jar test}\end{matrix} - \begin{matrix}\textit{concentration of p}\\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of p before}\\ \textit{Jar test}\end{matrix}}\right) * 100$$

3.5 Design of Batch reactor for pilot scale struvite production from human stored urine and Basaka lake

The reactor was designed to accommodate 50ℓ of stored urine. It was proposed to be 50 liters because 20 liters Jarcan's are available in local market and they can manage the volume of urine further to control the foam produced during stirring.

The reaction turbulence in the reactor also depends on the direction of rotation i.e. whenever you rotate only in one direction the chance of collision between phosphate ions, ammonium ions and $MgCl_2$ decreases hence to increase the chance of collision it is advisable to rotate in both ways. Mixing of ions in the solution also depends on the dimensions of the paddles in the reactor i.e. when the paddles have chance of getting the solution the probability of turbulence increases which enhanced the production of struvite. The solution turbulence is also affected by the number of paddles and shape, as the number of paddles increases the rate of collision increases which enhances the formation of struvite.

$V = 50 \text{ liters} = 0.05m^3$

$V = Ah$, $h = 45cm = 0.45m$

$A = \frac{\pi D^2}{4}$

$V = \frac{\pi D^2}{4} h$

$0.05 = \frac{3.14}{4} * D^2 * 0.45$

$D = 0.38 \text{ m} = 38cm$

Figure 6: Mechanically operated reactor

3.6 Production of struvite from human urine using Batch reactor with optimum parameters

The reactor was operated using optimum PH, dosage, mixing time, mixing speed, and precipitation time.

PH of the stored urine=8.68
Dilution Factor=100ml/10ml=10
Initial concentration of PO4=887mg/l
Volume of stored urine used=5000ml
Amount of $MgCl_2$ to be added=4.435g

4. Results

4.1 Physiological nature of the collected human urine

Table 7: Physiological nature of the stored human urine for the first sample

Test date	Concentration of PO_4	Amount of $MgCl_2$ (g)	N concentration before jar test (mg/ℓ)	N concentration after jar test (mg/ℓ)	P concentration before jar test (mg/ℓ)	P concentration after jar test (mg/ℓ)	%RN	%RP
19/07/2010	904	0.2715	17.75	1.15	297.5	46	93.52	84.54
21/07/2010	782.5	0.235	18.75	0.65	257.5	58	96.53	77.48
22/07/2010	623	0.1869	6.6	0.3	206	50	95.38	75.73
23/07/2010	575	0.1725	7.3	0.75	190	49.5	89.73	73.95
24/07/2010	665	0.1995	5.8	0.75	219	18.5	87.07	91.55
25/07/2010	771	0.2313	8	0.65	254	16	91.88	93.70
26/07/2010	964	0.2892	4.1	0.45	318	21	89.02	93.39
27/07/2010	822	0.2466	3.7	0.35	271	61	90.54	77.49
1/08/2010	740	0.222	7.5	0.4	244	28.17	94.67	88.46
7/08/2010	667	0.2031	5.9	0.45	223	13	92.37	94.17
08/08/2010	933	0.2799	2.9	0.35	308	47.5	87.93	84.58
09/08/2010	631	0.1893	6.5	0.15	208	60.5	97.79	70.91
10/08/2010	662	0.1986	7.1	0.7	218	71	90.14	89.27
11/08/2010	699	0.2097	4.7	0.3	231	56.5	93.62	75.54
12/08/2010	833	0.2499	5	No reagent	275	42	-	84.73

Second sample collection date Wednesday 10/08/2010

$$\%\text{ Recovery of N} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of N before jar test}\end{matrix} - \begin{matrix}\textit{concentration of N} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of N before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

$$\%\text{ Recovery of P} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of p before jar test}\end{matrix} - \begin{matrix}\textit{concentration of p} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of p before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

Table 8: Physiological nature of the stored human urine for the second sample

Test date	Concentration of PO4 (mg/l)	Amount of MgCl$_2$ (g)	N concentration before jar test (mg/ℓ)	N concentration after jar test (mg/ℓ)	P concentration before jar test (mg/ℓ)	P concentration after jar test (mg/ℓ)	%RN	%RP
11/08/2010	711	0.2133	3.6	0.2	235	75.5	94.44	67.87
12/08/2010	780	0.2340	2	0.15	257	135	92.5	47.47
21/08/2010	836	0.2508	3.8	0.35	276	116	9.79	57.97
23/08/2010	998	0.2994	2.9	0.58	329	78.33	78.33	76.19
25/08/2010	985	0.2955	3.1	0.4	325	81.5	87.09	74.92
26/08/2010	998	0.2994	3.6	0.33	329	86.8	86.8	74
27/08/2010	899	0.2697	3	0.42	297	42.83	86	85.58
28/08/2010	987	0.2961	4	0.43	326	46.33	89.25	85.79
29/08/2010	767	0.2301	3.7	0.5	253	53.67	86.45	78.79
30/08/2010	721	0.2163	3.1	0.3	238	77.17	90.32	67.58
1/09/2010	744	0.2232	4.2	0.33	246	64.67	92.14	73.71
2/09/2010	735	0.2205	2.5	0.55	243	81.17	78	66.59
3/09/2010	919	0.2757	3.6	055	303	44.5	84.72	85.31
4/09/2010	786	0.2358	4.6	0.43	259	69.17	90.65	73.29
5/09/2010	729	0.2187	7.7	0.63	241	84.67	91.82	64.87
6/09/2010	767	0.2301	4.5	0.7	253	73.33	84.44	71.02
7/09/2010	687	0.2061	6.2	0.52	277	104.5	91.62	53.96
8/09/2010	793	0.2379	4.4	0.45	262	96	89.77	63.36
9/09/2010	842	0.2526	5.3	0.22	278	80	95.85	71.22

4.2 Optimization of physiological conditions for struvite formation.

4.2.1 Optimization of PH for struvite formation

The pH of stored urine was adjusted by using 5MHCl and 5M NaOH. Keeping dosage, time, and speed constant.

PH from 6-11 were varied keeping dosage ,mixing time ,mixing speed , and precipitation time constant then the optimal PH for struvite formation was obtained to be PH 10 for trial -1.

Trial -1

Initial pH of stored urine = 8.15

Dilution Factor =100ml/4ml= 25

concentration of PO_4 before jar test= 905 mg/ℓ

volume of sample used= 300 mℓ

amount of $MgCl_2$ added = 0.2715g

Concentration of N before jar test = 25 * 0.71 mg/ℓ = 17.75 mg/ℓ

Concentration of p after jar test = 25 * 11.9 mg/ℓ = 297.5 mg/ℓ

Concentration after jar test

pH = 6

concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

concentration of p after jar test= 5 * 19.2 mg/ℓ = 96 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of N before jar test}\end{matrix} - \begin{matrix}\textit{concentration of N} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of N before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

$$= \left(\frac{17.75-0.16}{17.75}\right) * 100$$

$$= 96.34\%$$

$$\% \text{ Recovery of P} = \left(\frac{\begin{matrix}\textit{initial concentration} \\ \textit{of p before jar test}\end{matrix} - \begin{matrix}\textit{concentration of p} \\ \textit{after jar test}\end{matrix}}{\begin{matrix}\textit{initial concentration of p before} \\ \textit{Jar test}\end{matrix}}\right) * 100$$

$$= \left(\frac{297.5-96}{297.5}\right) * 100$$

$$= 67.73\%$$

pH = 7

Concentration of N after jar test = 5 * 0.21 mg/ℓ = 1.05 mg/ℓ

Concentration of p after jar test = 5 * 24 mg/ℓ = 120 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{\genfrac{}{}{0pt}{}{initial\ concentration}{of\ N\ before\ jar\ test} - \genfrac{}{}{0pt}{}{concentration\ of\ N}{after\ jar\ test}}{\genfrac{}{}{0pt}{}{initial\ concentration\ of\ N\ before}{Jar\ test}}\right) * 100$$

$$= \left(\frac{17.75-1.05}{17.75}\right) * 100$$

$$= 94.08\%$$

$$\% \text{ Recovery of P} = \left(\frac{\genfrac{}{}{0pt}{}{initial\ concentration}{of\ p\ before\ jar\ test} - \genfrac{}{}{0pt}{}{concentration\ of\ p}{after\ jar\ test}}{\genfrac{}{}{0pt}{}{initial\ concentration\ of\ p\ before}{Jar\ test}}\right) * 100$$

$$= \left(\frac{297.5-120}{297.5}\right) * 100$$

$$= 59.66\%$$

pH = 8

Concentration of N after jar test = 5 * 0.15 mg/ℓ = 0.75 mg/ℓ

Concentration of p after jar test = 5 * 17.3 mg/ℓ = 86.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{17.75-0.75}{17.75}\right) * 100$$

$$= 95.77\%$$

$$\% \text{ Recovery of P} = \left(\frac{297.5-86.5}{297.5}\right) * 100$$

$$= 70.92\%$$

pH = 9

concentration of N after jar test= 5 * 0.17 mg/ℓ = 0.85 mg/ℓ

concentration of p after jar test = 5 * 11.7 mg/ℓ = 58.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{17.75-0.85}{17.75}\right) * 100$$

$$= 95.21\%$$

$$\% \text{ Recovery of P} = \left(\frac{297.5-58.5}{297.5}\right) * 100$$

$$= 80.34\%$$

pH = 10

concentration of N after jar test = 5 * 0.23 mg/ℓ = 1.15 mg/ℓ

concentration of p after jar test = 5 * 9.2 mg/ℓ = 46mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{17.75-1.15}{17.75}\right) * 100$$

$$= 93.52\%$$

$$\% \text{ Recovery of P} = \left(\frac{297.5-46}{297.5}\right) * 100$$

$$= 84.54\%$$

pH = 11

concentration of N after jar test = 5 * 0.41 mg/ℓ = 2.05 mg/ℓ

concentration of p after jar test = 5 * 13.6 mg/ℓ = 68 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{17.75-2.05}{17.75}\right) * 100$$

$$= 88.45\%$$

$$\% \text{ Recovery of P} = \left(\frac{297.5-68}{297.5}\right) * 100$$

$$= 77.14\%$$

Table 9:Summary of the optimization of PH keeping dosage ,speed and time constant for trial -1

pH	**dosage 1:1**	**Time (min)**	**Speed (rpm)**	**% Recovery N**	**% Recovery p**
6	0.2715g	30	120	96.34	67.73
7	0.2715g	30	120	94.08	59.66
8	0.2715g	30	120	95.77	70.92
9	0.2715g	30	120	95.21	80.34
10	0.2715g	30	120	93.52	84.54
11	0.2715g	30	120	88.45	77.14

Trial -2

Again PH from 6-11 were varied keeping dosage ,mixing time ,mixing speed , and precipitation time constant then the optimal PH for struvite formation was obtained to be PH 10 for trial -2.

Initial pH of stored urine = 9.14

Dilution factor = $\frac{100ml}{4ml}$ = 25

Concentration of PO_4 before jar test = 25 * 31.3 mg/ℓ = 782.5 mg/ℓ

Concentration of p before jar test = 25 * 10.3 mg/ℓ = 257.5 mg/ℓ

Concentration of N before jar test = 25 * 0.75 mg/ℓ = 18.75 mg/ℓ

Volume of sample = 300mℓ

Amount of $MgCl_2$ added = 0.23475g

pH= 6

Concentration of N after jar test = 5 * 1.06 mg/ℓ = 5.3 mg/ℓ

Concentration of p after jar test = 5 * 24.4 mg/ℓ =122mg/ℓ

% Recovery of N = $\left(\frac{18.75-5.3}{18.75}\right)$* 100

= 71.73%

% Recovery of P = $\left(\frac{257.5-122}{257.5}\right)$ * 100

= 52.62%

pH = 7

Concentration of N after jar test = 5 * 1.76 mg/ℓ = 8.8 mg/ℓ

Concentration of p after jar test = 5 * 15.6 mg/ℓ = 78 mg/ℓ

% Recovery of N = $\left(\frac{18.75-8.8}{18.75}\right)$* 100

= 53.07%

% Recovery of P = $\left(\frac{257.5-78}{257.5}\right)$ * 100

= 67.91%

pH = 8

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 24.2 mg/ℓ = 121mg/ℓ

% Recovery of N = $\left(\frac{18.75-0.45}{18.75}\right)$* 100

= 97.6%

% Recovery of P = $\left(\frac{257.5-121}{257.5}\right)$ * 100

= 53.01%

pH = 9

Concentration of N after jar test = 5 * 0.08 mg/ℓ = 0.4 mg/ℓ

Concentration of p after jar test = 5 * 11.6 mg/ℓ = 58mg/ℓ

% Recovery of N = $\left(\frac{18.75-0.4}{18.75}\right)$* 100

= 97.87%

% Recovery of P = $\left(\frac{257.5-58}{257.5}\right)$ * 100

= 77.48%

pH = 10

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 11.6 mg/ℓ = 58mg/ℓ

% Recovery of N = $\left(\frac{18.75-0.65}{18.75}\right)$* 100

= 96.53%

% Recovery of P = $\left(\frac{257.5-58}{257.5}\right)$ * 100

= 77.48%

pH= 11

Concentration of N after jar test = 5 * 0.23 mg/ℓ = 1.15 mg/ℓ

Concentration of p after jar test = 5 * 8.4 mg/ℓ = 42 mg/ℓ

% Recovery of N = $\left(\frac{18.75-1.15}{18.75}\right)$* 100

= 93.87%

% Recovery of P = $\left(\frac{257.5-42}{257.5}\right)$ * 100

= 83.69%

Table 10:Summary of the optimization of PH keeping dosage ,speed and time constant for trail -2

pH	Summary (dosage 1:1)	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
6	0.23475g	30	120	71.73	52.62
7	0.23475g	30	120	53.07	67.91
8	0.23475g	30	120	97.6	53.01
9	0.23475g	30	120	97.87	77.48
10	0.23475g	30	120	96.53	77.48
11	0.23475g	30	120	93.87	83.69

Trial -3

For trail-3 as usual PH from 6-11 were varied keeping dosage ,mixing time ,mixing speed, and precipitation time constant then the optimal PH for struvite formation was obtained to be PH 10.

Initial pH of stored urine = 9.10

Dilution factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 62.3 mg/ℓ = 623 mg/ℓ

Concentration of P before jar test = 10 * 20.6 mg/ℓ = 206 mg/ℓ

Concentration of N before jar test = 10 * 0.66 mg/ℓ = 6.6 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.1869g

pH = 6

Concentration of N after jar test = 5 * 0.15 mg/ℓ = 0.75 mg/ℓ

Concentration of p after jar test = 5 * 30.7 mg/ℓ = 153.5 mg/ℓ

% Recovery of N = $\left(\frac{6.6-0.75}{6.6}\right)$* 100
= 88.64%

% Recovery of P = $\left(\frac{206-153.5}{206}\right)$ * 100

= 25.49%

pH = 7

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 29.6 mg/ℓ = 148 mg/ℓ

% Recovery of N = $\left(\frac{6.6-0.55}{6.6}\right)$* 100

= 91.67%

% Recovery of P = $\left(\frac{206-148}{206}\right)$ * 100

= 28.16%

pH= 8

Concentration of N after jar test = 5 * 0.27 mg/ℓ = 1.35 mg/ℓ

Concentration of p after jar test = 5 * 25.8 mg/ℓ = 129 mg/ℓ

% Recovery of N = $\left(\frac{6.6-1.35}{6.6}\right)$* 100

= 79.55%

% Recovery of P = $\left(\frac{206-129}{206}\right)$ * 100

= 37.38%

pH= 9

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 18 mg/ℓ = 90 mg/ℓ

% Recovery of N = $\left(\frac{6.6-0.45}{6.6}\right)$* 100

= 93.18%

% Recovery of P = $\left(\frac{206-90}{206}\right)$ * 100

= 56.31%

pH= 10

Concentration of N after jar test = 5 * 0.06 mg/ℓ = 0.3 mg/ℓ

Concentration of p after jar test = 5 * 5.0 mg/ℓ = 25 mg/ℓ

% Recovery of N = $\left(\frac{6.6-0.3}{6.6}\right)$* 100

= 95.45%

$$\% \text{ Recovery of P} = \left(\frac{206-25}{206}\right) * 100$$

$$= 87.86\%$$

pH= 11

Concentration of N after jar test = 5 * 1.7 mg/ℓ = 8.5 mg/ℓ

Concentration of p after jar test = 5 * 12.6 mg/ℓ = 63 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{6.6-8.5}{6.6}\right) * 100$$

$$=- 28.79\%$$

$$\% \text{ Recovery of P} = \left(\frac{206-63}{206}\right) * 100$$

$$= 69.42\%$$

Table 11: Summary of the optimization of PH keeping dosage ,speed and time constant for trial -3

pH	Summary (dosage 1:1)	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
6	0.1869g	30	120	86.64	25.49
7	0.1869g	30	120	91.67	28.16
8	0.1869g	30	120	79.55	37.38
9	0.1869g	30	120	93.18	56.31
10	0.1869g	30	120	95.45	87.86
11	0.1869g	30	120	-28.79	69.42

Trial -4

Again for trial-4 PH from 6-11 were varied keeping dosage ,mixing time ,mixing speed , and precipitation time constant then the optimal PH for struvite formation was obtained to be PH 10 .

Initial pH of stored urine = 9.13

Dilution factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 57.5 mg/ℓ = 575 mg/ℓ

Concentration of P before jar test = 10 * 19.0 mg/ℓ = 190 mg/ℓ

Concentration of N before jar test = 10 * 0.73 mg/ℓ = 7.3 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.1725g

pH = 6

Concentration of N after jar test = 5 * 1.56 mg/ℓ = 7.8 mg/ℓ

Concentration of p after jar test = 5 * 28.0 mg/ℓ = 140 mg/ℓ

% Recovery of N = $\left(\frac{7.3-7.8}{7.3}\right)$* 100

= -6.85%

% Recovery of P = $\left(\frac{190-140}{190}\right)$ * 100

= 26.32%

pH = 7

Concentration of N after jar test = 5 * 0.36 mg/ℓ = 1.8 mg/ℓ

Concentration of p after jar test = 5 * 25.3 mg/ℓ = 126.5 mg/ℓ

% Recovery of N = $\left(\frac{7.3-1.8}{7.3}\right)$* 100

= 75.34%

% Recovery of P = $\left(\frac{190-126.5}{190}\right)$ * 100

= 33.42%

pH= 8

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 26.3 mg/ℓ = 131.5 mg/ℓ

% Recovery of N = $\left(\frac{7.3-0.55}{7.3}\right)$* 100

= 92.47%

% Recovery of P = $\left(\frac{190-131.5}{190}\right)$ * 100

= 30.79%

pH= 9

Concentration of N after jar test = 5 * 0.15 mg/ℓ = 0.75 mg/ℓ

Concentration of p after jar test = 5 * 13.8 mg/ℓ = 69 mg/ℓ

% Recovery of N = $\left(\frac{7.3-0.75}{7.3}\right)$* 100

= 89.73%

% Recovery of P = $\left(\frac{190-69}{190}\right)$ * 100

= 63.68%

pH= 10

Concentration of N after jar test = 5 * 0.15 mg/ℓ = 0.75 mg/ℓ

Concentration of p after jar test = 5 * 9.9 mg/ℓ = 49.5 mg/ℓ

% Recovery of N = $\left(\frac{7.3-0.75}{7.3}\right)$* 100

= 89.73%

% Recovery of P = $\left(\frac{190-49.5}{190}\right)$ * 100

= 73.95%

pH= 11

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 11.4 mg/ℓ = 57 mg/ℓ

% Recovery of N = $\left(\frac{7.3-0.55}{7.3}\right)$* 100

= 92.47%

% Recovery of P = $\left(\frac{190-57}{190}\right)$ * 100

= 70%

Table 12:Summary of the optimization of PH keeping dosage ,speed and time constant for trial -4

pH	Summary (dosage 1:1)	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
6	0.1725g	30	120	-6.85	26.32
7	0.1725g	30	120	75.34	33.42
8	0.1725g	30	120	92.47	30.79
9	0.1725g	30	120	89.73	63.68
10	0.1725g	30	120	89.73	73.95
11	0.1725g	30	120	92.47	70

Trial -5

For trial -5 again PH from 6-11 were varied keeping dosage ,mixing time ,mixing speed , and precipitation time constant then the optimal PH for struvite formation was obtained to be PH 10 .

Initial pH of stored urine = 9.06

Dilution factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 66.5 mg/ℓ = 665 mg/ℓ

Concentration of P before jar test = 10 * 21.9 mg/ℓ = 219 mg/ℓ

Concentration of N before jar test = 10 * 0.58 mg/ℓ = 5.8 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.1995g

pH = 6

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 31.6 mg/ℓ = 158 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.65}{5.8}\right)$* 100

= 88.79%

% Recovery of P = $\left(\frac{219-158}{219}\right)$ * 100

= 27.85%

pH = 7

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 30.6 mg/ℓ = 153 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.55}{5.8}\right)$* 100

= 90.52%

% Recovery of p = $\left(\frac{219-153}{219}\right)$ * 100

= 30.14%

pH= 8

Concentration of N after jar test = 5 * 0.17 mg/ℓ = 0.85 mg/ℓ

Concentration of p after jar test = 5 * 23.6 mg/ℓ = 118 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.85}{5.8}\right)$* 100

= 85.34%

% Recovery of P = $\left(\frac{219-118}{219}\right)$ * 100

= 46.12%

pH= 9

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 16.6 mg/ℓ = 83 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.55}{5.8}\right)$* 100

= 90.52%

% Recovery of P = $\left(\frac{219-83}{219}\right)$ * 100

= 62.10%

pH= 10

Concentration of N after jar test = 5 * 0.15 mg/ℓ = 0.75 mg/ℓ

Concentration of p after jar test = 5 * 3.7 mg/ℓ = 18.5 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.75}{5.8}\right)$* 100

= 87.07%

% Recovery of P = $\left(\frac{219-18.5}{219}\right)$ * 100

= 91.55%

pH= 11

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 20.2 mg/ℓ = 101 mg/ℓ

% Recovery of N = $\left(\frac{5.8-0.45}{5.8}\right)$* 100

= 92.24%

% Recovery of P = $\left(\frac{219-101}{219}\right)$ * 100

= 53.88%

Table 13:Summary of the optimization of PH keeping dosage ,speed and time constant for trial -5

pH	Summary (dosage 1:1)	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
6	0.1995g	30	120	88.79	27.85
7	0.1995g	30	120	90.52	30.14
8	0.1995g	30	120	85.34	46.12
9	0.1995g	30	120	90.52	62.10
10	0.1995g	30	120	87.07	91.55
11	0.1995g	30	120	92.24	53.88

Therefore, keeping dosage , mixing time ,mixing speed constant since the percentage recovery of N and P were greater at PH10 ,the optimum PH was concluded to be 10.

4.2.2 Optimization of dosage ($MgCl_2$) for struvite formation

The PH was optimized to be 10, time and velocity were kept constant but the dosage was varied as follows from 1:1 to 1:6..

Initial pH of stored urine = 9.10

$$\text{Dilution factor} = \frac{100m\ell}{10m\ell} = 10$$

Concentration of PO_4 before jar test = 10 * 77.1 mg/ℓ = 771 mg/ℓ

Concentration of P before jar test = 10 * 25.4 mg/ℓ = 254 mg/ℓ

Concentration of N before jar test = 10 * 0.8 mg/ℓ = 8 mg/ℓ

Volume of sample used in each trail =300 mℓ

$$\text{Molarity} = \frac{number\ of\ moles\ solute}{volume\ of\ solution} = \frac{n}{v}$$

$$n = \frac{given\ mass}{molar\ mass} = \frac{m}{M_o}$$

$$M = \frac{n}{v} = \frac{m}{M_o * V}$$

$m = M * M_o * V$, but the concentration of PO_4 was in mg/ℓ, to change in to molarity it should be divided by molar mass

$m = \frac{m'}{M_o} * M_o * V$

$m = m' * V*10^{-3}$, where m - was mass of $MgCl_2$ added

m' = concentration of PO4 in mg/ℓ.

V = volume of sample in liter

Therefore, mass of $MgCl_2$ added = $\frac{771}{1000} * 0.3\ell = 0.2313g$

Trial -1

Case -1, Dosage 1:1

pH = 10, t= 30min, v= 120 rpm

dosage (PO4: Mg^{+2}) = 1:1

amount of $MgCl_2$ added = 0.2313g

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 3.2 mg/ℓ = 16 mg/ℓ

% Recovery of N = $\left(\frac{8-0.65}{8}\right) * 100$

= 91.88%

% Recovery of P = $\left(\frac{254-16}{254}\right) * 100$

= 93.70%

Case -2, dosage 1:2

pH=10, t= 30 min, v=120rpm

dosage (PO_4:Mg^{+2})= 1:2

amount of $MgCl_2$ added= 2 * 0.2313g

Concentration of N after jar test = 5 * 0.19 mg/ℓ = 0.95 mg/ℓ

Concentration of p after jar test = 5 * 2.7 mg/ℓ = 13.5 mg/ℓ

% Recovery of N = $\left(\frac{8-0.95}{8}\right) * 100$

= 88.13%

% Recovery of P = $\left(\frac{254-13.5}{254}\right) * 100$

= 94.69%

Case -3, dosage 1:3

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 3 * 0.2313g

Concentration of N after jar test = 5 * 0.31 mg/ℓ = 1.55 mg/ℓ

Concentration of p after jar test = 5 * 6.6 mg/ℓ = 33 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{8-1.55}{8}\right) * 100$$

$$= 80.63\%$$

$$\% \text{ Recovery of P} = \left(\frac{254-33.0}{254}\right) * 100$$

$$= 87.00\%$$

Case -4, dosage 1:4

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 4 * 0.231g

Concentration of N after jar test = 5 * 0.36 mg/ℓ = 1.8 mg/ℓ

Concentration of p after jar test = 5 * 6.7 mg/ℓ = 33.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{8-1.8}{8}\right) * 100$$

$$= 77.50\%$$

$$\% \text{ Recovery of P} = \left(\frac{254-33.5}{254}\right) * 100$$

$$= 86.81\%$$

Case -5, dosage 1:5

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 5 * 0.2313g

Concentration of N after jar test = 5 * 0.3 mg/ℓ = 1.5 mg/ℓ

Concentration of p after jar test = 5 * 7.2 mg/ℓ = 36 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{8-1.5}{8}\right) * 100$$

$$= 81.25\%$$

$$\% \text{ Recovery of P} = \left(\frac{254-36}{254}\right) * 100$$

$$= 85.83\%$$

Case -6, dosage 1:6

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 6 * 0.2313g

Concentration of N after jar test = 5 * 0.48 mg/ℓ = 2.4 mg/ℓ

Concentration of p after jar test = 5 * 5.2 mg/ℓ = 26 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{8-2.4}{8}\right) * 100$$

$$= 70\%$$

$$\% \text{ Recovery of P} = \left(\frac{254-26}{254}\right) * 100$$

$$= 89.76\%$$

The result of Trial -1 shows that keeping PH ,mixing time ,mixing speed and precipitation time constant the percentage recovery of N and P was higher in one to two dosage than the others therefore the optimal dosage was supposed to be 1:2.

Table 14: Summary of the optimization of dosage keeping PH, speed and time constant for trial -1

pH	dosage	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
10	1:1	30	120	91.88	93.70
10	1:2	30	120	88.13	94.69
10	1:3	30	120	80.63	87.00
10	1:4	30	120	77.50	86.81
10	1:5	30	120	81.25	85.83
10	1:6	30	120	70	89.76

Trial -2

Case -1, Dosage 1:1

pH = 10, t= 30min, v= 120 rpm

Amount of $MgCl_2$ added = 0.2892g

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 4.2 mg/ℓ = 21 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{4.1-0.45}{4.1}\right) * 100$$

$$= 89.02\%$$

$$\% \text{ Recovery of P} = \left(\frac{318-21}{318}\right) * 100$$

$$= 93.39\%$$

Case -2, dosage 1:2

pH=10, t= 30 min, v=120rpm

Amount of $MgCl_2$ added= 2 * 0.2892g

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 6.6 mg/ℓ = 33 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{4.1-0.65}{4.1}\right) * 100$$

$$= 84.15\%$$

$$\% \text{ Recovery of P} = \left(\frac{318-33}{318}\right) * 100$$

$$= 89.62\%$$

Case -3, dosage 1:3

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 3 * 0.2892g

Concentration of N after jar test = 5 * 5.8 mg/ℓ = 29 mg/ℓ

Concentration of p after jar test = 5 * 5.2 mg/ℓ = 26 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{4.1-29}{29}\right) * 100$$

$$= -607.32\%$$

$$\% \text{ Recovery of P} = \left(\frac{318-26}{318}\right) * 100$$

$$= 91.82\%$$

Case -4, dosage 1:4

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 4 * 0.2892g

Concentration of N after jar test = 5 * 1.62 mg/ℓ = 8.1 mg/ℓ

Concentration of p after jar test = 5 * 5.2 mg/ℓ = 26 mg/ℓ

% Recovery of N = $\left(\frac{4.1-8.1}{4.1}\right)$* 100

= -97.56%

Case -5, dosage 1:5

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 5 * 0.2892g

Concentration of N after jar test = 4 * 0.25 mg/ℓ = 1 mg/ℓ

Concentration of p after jar test = 4 * 7.8 mg/ℓ = 31.2 mg/ℓ

% Recovery of N = $\left(\frac{4.1-1}{4.1}\right)$* 100

= 75.61%

% Recovery of P = $\left(\frac{318-31.2}{318}\right)$ * 100

= 90.19%

Case -6, dosage 1:6

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 6 * 0.2892g

Concentration of N after jar test = 4 * 0.52 mg/ℓ = 2.08 mg/ℓ

Concentration of p after jar test = 4 * 22.3 mg/ℓ = 89.2 mg/ℓ

% Recovery of N = $\left(\frac{4.1-2.08}{4.1}\right)$* 100

= 49.27%

% Recovery of P = $\left(\frac{318-89.2}{318}\right)$ * 100

= 71.95%

Again the result of Trial -2 shows that keeping PH ,mixing time ,mixing speed and precipitation time constant the percentage recovery of N and P was higher in one to one dosage than the others therefore the optimal dosage was supposed to be 1:1.

Table 15:Summary of the optimization of dosage keeping PH ,speed and time constant for trial -2

pH	dosage	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
10	1:1	30	120	89.02	93.39
10	1:2	30	120	84.15	89.62
10	1:3	30	120	-607.32	91.82
10	1:4	30	120	-97.56	91.82
10	1:5	30	120	75.61	90.19
10	1:6	30	120	49.27	71.95

Trial -3

Case -1, Dosage 1:1

pH = 10, t= 30min, v= 120 rpm

Amount of $MgCl_2$ added = 0.246g

Concentration of N after jar test = 5 * 0.07 mg/ℓ = 0.35 mg/ℓ

Concentration of p after jar test = 5 * 4 mg/ℓ = 20 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-0.35}{3.9}\right) * 100$$

$$= 91.03\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-20}{302}\right) * 100$$

$$= 93.38\%$$

Case -2, dosage 1:2

pH=10, t= 30 min, v=120rpm

Amount of $MgCl_2$ added= 2 *0. 246g

Concentration of N after jar test = 5 * 0.091 mg/ℓ = 0.455 mg/ℓ

Concentration of p after jar test = 5 * 4.6 mg/ℓ = 23 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-0.455}{3.9}\right) * 100$$

$$= 88.33\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-23}{302}\right) * 100$$

$$= 92.38\%$$

Case -3, dosage 1:3

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 3 * 0.246g

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 5.1 mg/ℓ = 25.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-0.55}{3.9}\right) * 100$$

$$= 85.89\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-25.5}{302}\right) * 100$$

$$= 91.56\%$$

Case -4, dosage 1:4

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 4 * 0.246g

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 5.4 mg/ℓ = 27 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-0.65}{3.9}\right) * 100$$

$$= 83.33\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-27}{302}\right) * 100$$

$$= 91.06\%$$

Case -5, dosage 1:5

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 5 * 0.246g

Concentration of N after jar test = 5 * 0.21 mg/ℓ = 1.05 mg/ℓ

Concentration of p after jar test = 5 * 6.1 mg/ℓ = 30.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-1.05}{3.9}\right) * 100$$

$$= 73.08\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-30.5}{302}\right) * 100$$

$$= 89.90\%$$

Case -6, dosage 1:6

pH=10, t= 30 min, v=120rpm

amount of $MgCl_2$ added= 6 * 0.246g

Concentration of N after jar test = 5 * 0.20 mg/ℓ = 1 mg/ℓ

Concentration of p after jar test = 5 * 5.71 mg/ℓ = 28.55 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.9-1}{3.9}\right) * 100$$

$$= 74.36\%$$

$$\% \text{ Recovery of P} = \left(\frac{302-28.55}{302}\right) * 100$$

$$= 90.55\%$$

For trial -3 again keeping PH ,mixing time, mixing speed ,and precipitation time constant the percentage recovery of N and P was higher in one to one dosage than the others therefore the optimal dosage was supposed to be 1:1.

Table 16: Summary of the optimization of dosage keeping PH ,speed and time constant for trial -3

pH	dosage	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
10	1:1	30	120	91.03	93.38
10	1:2	30	120	88.33	92.38
10	1:3	30	120	85.89	91.56
10	1:4	30	120	83.33	91.06
10	1:5	30	120	73.08	89.90
10	1:6	30	120	74.36	90.55

To keep precision and to determine the optimum dosage between 1:1 and 1:2 triplication was performed as follows:

4.2.2.1 Triplication of dosage (PO_4:Mg^{+2}) ratio =1:1

Initial pH of the stored urine = 9.02

Dilution Factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 0.37 mg/ℓ = 3.7 mg/ℓ

Concentration of p before jar test = 10 * 27.1 mg/ℓ = 271 mg/ℓ

Concentration of N before jar test = 10 * 82.2mg/ℓ = 822 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.2470g

Trial -1

Case -1, dosage 1:1

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added= 0.2470g

Concentration of N after jar test = 5 * 0.02 mg/ℓ = 0.1 mg/ℓ

Concentration of p after jar test = 5 * 6.4 mg/ℓ = 32 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.1}{3.7}\right) * 100$$

$$= 97.29\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-32}{271}\right) * 100$$

$$= 88.19\%$$

Trial -2

Case -2, dosage 1:1

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added= 0.2470g

Concentration of N after jar test = 5 * 0.1 mg/ℓ = 0.5 mg/ℓ

Concentration of p after jar test = 5 * 12.1 mg/ℓ = 60.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.5}{3.7}\right) * 100$$

$$= 86.49\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-60.5}{271}\right) * 100$$

$$= 77.68\%$$

Trial -3

Case -3, dosage 1:1

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added= 0.2470g

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 18.1 mg/ℓ = 90.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.45}{3.7}\right) * 100$$

$$= 87.84\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-90.5}{271}\right) * 100$$

$$= 66.61\%$$

$$\therefore \% \text{ Recovery N} = \frac{97.29\%+86.49\%+87.84\%}{3}$$

$$= 90.54\%$$

$$\therefore \% \text{ Recovery P} = \frac{88.19\%+77.68\%+66.61\%}{3}$$

$$= 77.49\%$$

4.2.2.2 Triplication of dosage (PO_4:Mg^{+2}) ratio =1:2

Initial pH of the stored urine= 9.02

Dilution Factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 0.37 mg/ℓ = 3.7 mg/ℓ

Concentration of p before jar test = 10 * 27.1 mg/ℓ = 271 mg/ℓ

Concentration of N before jar test = 10 * 82.2mg/ℓ = 822 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.2470g

Trial -1

Case -1, dosage 1:2

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added= 2*0.2470g

Concentration of N after jar test = 5 * 0.04 mg/ℓ = 0.2 mg/ℓ

Concentration of p after jar test = 5 * 12.7 mg/ℓ = 63.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.2}{3.7}\right) * 100$$

$$= 94.59\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-63.5}{271}\right) * 100$$

$$= 76.57\%$$

Trial -2

Case -2, dosage 1:2

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added= 2*0.2470g

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 12.7 mg/ℓ = 63.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.65}{3.7}\right) * 100$$

$$= 82.43\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-63.5}{271}\right) * 100$$

$$= 76.57\%$$

Trial -3,

Case -3, dosage 1:2

pH=10, t = 30 min, v = 120rpm

Amount of $MgCl_2$ added=2* 0.2470g

Concentration of N after jar test = 5 * 0.18 mg/ℓ = 0.9 mg/ℓ

Concentration of p after jar test = 5 * 11.7 mg/ℓ = 58.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{3.7-0.9}{3.7}\right) * 100$$

$$= 75.68\%$$

$$\% \text{ Recovery of P} = \left(\frac{271-58.5}{271}\right) * 100$$

$$= 78.41\%$$

$$\therefore \% \text{ Recovery N} = \frac{94.59\%+82.43\%+75.68\%}{3}$$

$$= 84.23\%$$

$$\therefore \% \text{ Recovery P} = \frac{76.57\%+76.57\%+78.41\%}{3}$$

$$= 77.18\%$$

Table 17: Summary of the triplication of dosage keeping PH ,speed and time constant

pH	**dosage**	**Time (min)**	**Speed (rpm)**	**% Recovery N**	**% Recovery p**
10	1:1	30	120	97.29	88.19
10	1:1	30	120	86.49	77.68
10	**1:1**	**30**	**120**	**87.84**	**66.61**
	Average			90.54	77.49
10	1:2	30	120	94.59	76.57
10	1:2	30	120	82.43	76.57
10	1:2	30	120	75.68	78.41
	Average			**84.23**	**77.18**

Therefore, keeping PH, mixing time, mixing speed copnstant since the percentage recovery of N and P were greater in 1:1 dosage than1:2, the optimum dosage was concluded to be 1:1.

4.2.3 Optimization of speed at pH= 10, dosage 1:1, t=30,.45,60 min

Initial pH of the stored urine = 8.91

Dilution Factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 67.7 mg/ℓ = 677 mg/ℓ

Concentration of p before jar test = 10 * 22.3 mg/ℓ = 223 mg/ℓ

Concentration of N before jar test = 10 * 0.59mg/ℓ = 5.9 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.2031g

Trial-1

At t=30min, v=60rpm

Concentration of N after jar test = 5 * 0.05 mg/ℓ = 0.25 mg/ℓ

Concentration of p after jar test = 5 * 0.6 mg/ℓ = 3 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.25}{5.9}\right)$* 100

= 95.76%

% Recovery of P = $\left(\frac{223-3}{223}\right)$ * 100

= 98.65%

Trial-2

At t=30min , v=90rpm

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 11.8 mg/ℓ = 59 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.55}{5.9}\right)$* 100

= 90.68%

% Recovery of P = $\left(\frac{223-59}{223}\right)$ * 100

= 73.54%

Trial-3

At t=30min, V=120rpm

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 2.6 mg/ℓ = 13 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.45}{5.9}\right) * 100$$

$$= 92.37\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-13}{223}\right) * 100$$

$$= 94.17\%$$

Trial-4

At t=45min, v=60rpm

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 6.8 mg/ℓ = 34 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.45}{5.9}\right) * 100$$

$$= 92.37\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-34}{223}\right) * 100$$

$$= 84.75\%$$

Trial-5

At t=45min, v=90rpm

Concentration of N after jar test = 5 * 0.1 mg/ℓ = 0.5 mg/ℓ

Concentration of p after jar test = 5 * 6.5 mg/ℓ = 32.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.5}{5.9}\right) * 100$$

$$= 91.53\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-32.5}{223}\right) * 100$$

$$= 85.43\%$$

Trial-6

At t=45min, v=120rpm

Concentration of N after jar test = 5 * 0.3 mg/ℓ = 1.5 mg/ℓ

Concentration of p after jar test = 5 * 3.5 mg/ℓ = 17.5 mg/ℓ

% Recovery of N = $\left(\frac{5.9-1.5}{5.9}\right)$* 100

= 74.58%

% Recovery of P = $\left(\frac{223-17.5}{223}\right)$ * 100

= 92.15%

Trial-7

At t=60min ,v=60rpm

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 16.1 mg/ℓ = 80.5 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.45}{5.9}\right)$* 100

= 92.37%

Trial-8

At t=60min ,v=90rpm

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 5.1 mg/ℓ = 25 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.55}{5.9}\right)$* 100

= 90.68%

% Recovery of P = $\left(\frac{223-25}{223}\right)$ * 100

= 88.79%

Trial-9

At t=60min , v=120rpm

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 2.0 mg/ℓ = 10 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.65}{5.9}\right)$* 100

= 88.98%

% Recovery of P = $\left(\frac{223-10}{223}\right)$ * 100

= 95.52%

Summary

Table 18: Summary of Optimization of speed at, t=30, 45, & 60min at v=60, 90, &120rpm keeping PH, and dosage constant

pH	dosage	Time (min)	Speed (rpm)	% Recovery N	% Recovery p
10	1.1	30	60	95.76	98.65
10	1.1	30	90	90.66	73.54
10	1.1	30	120	92.37	94.17
10	1.1	45	60	92.37	84.75
10	1.1	45	90	91.53	85.43
10	1.1	45	120	74.58	92.15
10	1.1	60	60	92.37	63.90
10	1.1	60	90	90.68	88.79
10	1.1	60	120	88.98	95.52

From the nine different combination for speed optimization, the highest percentage recovery of N and P was obtained at pH=10, dosage 1:1, t= 30 min, V = 60rpm.

4.2.4 Optimization of time at pH=10, dosage 1:1, speed= 60, 90, 120rpm

Initial pH of the stored urine= 8.91

Dilution Factor = $\frac{100m\ell}{10m\ell}$ = 10

Concentration of PO_4 before jar test = 10 * 67.7 mg/ℓ = 677 mg/ℓ

Concentration of p before jar test = 10 * 22.3 mg/ℓ = 223 mg/ℓ

Concentration of N before jar test = 10 * 0.59mg/ℓ = 5.9 mg/ℓ

Volume of sample used = 300 mℓ

Amount of $MgCl_2$ added = 0.2031g

Trial-1

At v=60rpm, t=30min

Concentration of N after jar test = 5 * 0.05 mg/ℓ = 0.25 mg/ℓ

Concentration of p after jar test = 5 * 0.6 mg/ℓ = 3 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.25}{5.9}\right)$* 100

= 95.76%

% Recovery of P = $\left(\frac{223-3}{223}\right)$ * 100

= 98.65%

Trial-2

At v=60rpm, t=45min

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 6.8 mg/ℓ = 34 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.45}{5.9}\right)$* 100

= 92.37%

% Recovery of P = $\left(\frac{223-34}{223}\right)$ * 100

= 84.75%

Trial-3

At v=60rpm, t=60min

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 16.1 mg/ℓ = 80.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.45}{5.9}\right) * 100$$

$$= 92.37\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-80.5}{223}\right) * 100$$

$$= 63.90\%$$

Trial-4

At v=90rpm, t=30min

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 11.8 mg/ℓ = 59 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.55}{5.9}\right) * 100$$

$$= 90.68\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-59}{223}\right) * 100$$

$$= 73.54\%$$

Trail-5

At t=90rpm,t=45min

Concentration of N after jar test = 5 * 0.1 mg/ℓ = 0.5 mg/ℓ

Concentration of p after jar test = 5 * 6.5 mg/ℓ = 32.5 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.5}{5.9}\right) * 100$$

$$= 91.53\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-32.5}{223}\right) * 100$$

$$= 85.43\%$$

Trial-6

At t=90rpm, t=60min

Concentration of N after jar test = 5 * 0.11 mg/ℓ = 0.55 mg/ℓ

Concentration of p after jar test = 5 * 5.1 mg/ℓ = 25 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.55}{5.9}\right)$* 100

= 90.68%

% Recovery of P = $\left(\frac{223-25}{223}\right)$ * 100

= 88.79%

Trial-7

At v=120rpm , t=30min

Concentration of N after jar test = 5 * 0.09 mg/ℓ = 0.45 mg/ℓ

Concentration of p after jar test = 5 * 2.6 mg/ℓ = 13 mg/ℓ

% Recovery of N = $\left(\frac{5.9-0.45}{5.9}\right)$* 100

= 92.37%

% Recovery of P = $\left(\frac{223-13}{223}\right)$ * 100

= 94.17%

Trial-8

At v=120rpm , t=45min

Concentration of N after jar test = 5 * 0.3 mg/ℓ = 1.5 mg/ℓ

Concentration of p after jar test = 5 * 3.5 mg/ℓ = 17.5 mg/ℓ

% Recovery of N = $\left(\frac{5.9-1.5}{5.9}\right)$* 100

= 74.58%

% Recovery of P = $\left(\frac{223-17.5}{223}\right)$ * 100

= 92.15%

Trial-9

At v=120rpm, t=60min

Concentration of N after jar test = 5 * 0.13 mg/ℓ = 0.65 mg/ℓ

Concentration of p after jar test = 5 * 2.0 mg/ℓ = 10 mg/ℓ

$$\% \text{ Recovery of N} = \left(\frac{5.9-0.65}{5.9}\right) * 100$$

$$= 88.98\%$$

$$\% \text{ Recovery of P} = \left(\frac{223-10}{223}\right) * 100$$

$$= 95.52\%$$

Table 19:Summary of Optimization of time at v=60,90,120rpm ,t=30,45,60min keeping PH ,and dosage constant

pH	dosage	Speed (rpm)	Time (min)	% Recovery N	% Recovery p
10	0.2031g	60	30	95.76	98.65
10	0.2031g	60	45	92.37	84.75
10	0.2031g	60	60	92.37	63.90
10	0.2031g	90	30	90.68	73.54
10	0.2031g	90	45	91.53	85.43
10	0.2031g	90	60	90.68	88.79
10	0.2031g	120	30	92.37	94.17
10	0.2031g	120	45	74.58	92.15
10	0.2031g	120	60	88.98	95.52

In general at optimum pH 10, optimum dosage 1:1 , mixing speed 60rpm ,and mixing time 30min the percentage recovery of N and P were 95.76% and 98.65% respectively which was the highest of all combinations which implied that the optimum time was 30 minutes, in which the result was similar to the other experimental researches .

4.2.5 Optimization of Precipitation time

Dilution Factor=600ml/200ml=3

Table 20: Optimization of precipitation time

PH	**Dosage (g)**	**precipitation time(min)**	**Initial conc of N before jar(mg/l)**	**Final conc. of N after jar test (mg/l)**	**Initial conc. of P before jar(mg/l)**	**Final conc. of N after jar test(mg/l)**	**%N**	**%P**
10	**1:1**	**30**	**0.18**	**0.07**	**93.3**	**1.9**	**61.11**	**97.96**
10	**1:1**	**45**	**0.18**	**0.11**	**93.3**	**12.8**	**38.89**	**86.28**

The above table shows that as precipitation time increases the percentage recovery of N and P decreases this is because struvite breaks down and there will be re-suspension of N and P which ultimately reduces the percentage recovery of N and P. Therefore the best precipitation time was 30 minutes**.**

∴ The optimum PH was10, the optimum dosage was 1:1, the optimum mixing time was 30 minutes ,the optimum mixing speed was 60rpm ,the optimum precipitation after jar test was 30minutes and the incubation period was on 19th and 20th day in this research.

4.4 Preparation of struvite using Basaka Lake water as source of Mg^{+2}

Initial pH of baska lake water= 9.50

Initial PH of stored urine =8.94

Concentration of PO4 before jar test =876mg/l

Concentration of N before jar test = 10* 0.45 =4.5 mg/ℓ

Concentration of p before jar test =10 *28.9 = 289 mg/ℓ

Concentration of magnesium ion in basaka lake =10*15=150 mg/ℓ

Amount of $MgCl_2$ added=0.2628g

Six trials were performed to determine the percentage recovery of N and P in urine using Basaka water as source of $MgCl_2$.

Trial -1

Volume of Baska water used as source of MgCl2=5%*the volume of the jar

= 5%*300ml=15ml

Trial -2

Volume of Baska water used as source of MgCl2=10%*the volume of the jar

= 10%*300ml

=30ml

Trial -3

Volume of Baska water used as source of MgCl2=15%*the volume of the jar

=15%*300ml

=45ml

Trial -4

Volume of Baska water used as source of MgCl2=20%*the volume of the jar

= 20%*300ml

=60ml

Trial -5

Volume of Baska water used as source of MgCl2=25%*the volume of the jar

= 25%*300ml

=75ml

Trial -6

Volume of Baska water used as source of MgCl2=30%*the volume of the jar

= 30%*300ml

=90ml

Trail number	**Nitrogen concentration before jartest (mg/ℓ)**	**Nitrogen concentration after jartest (mg/ℓ)**	**P concentration before jartest (mg/ℓ)**	**P concentration after jartest (mg/ℓ)**	**%RN**	**%RP**
1	4.5		289			
2	4.5	4.6	289	214	-2.22	25.95
3	4.5	5.9	289	203	-31.11	29.76
4	4.5	5.1	289	198	-13.33	31.49
5	4.5	6.7	289	182	-48.89	36.68
6	4.5	7.4	289	183	-64.44	36.68

Table 21:summary of the %recovery of N and P using Basaka water as source of Magnesium

Trail number	**pH**	**Dosage**	**Time (min)**	**Speed (rpm)**	**P concentration after jartest (mg/ℓ)**	**%RN**	**%RP**
1	10	1:1	30	120			
2	10	1:1	30	120	214	-2.22	25.95
3	10	1:1	30	120	203	-31.11	29.76
4	10	1:1	30	120	198	-13.33	31.49
5	10	1:1	30	120	182	-48.89	36.68
6	10	1:1	30	120	183	-64.44	36.68

Some of the results were negative for N and P because in addition to N and P in stored human urine there is also N and P in Basaka .In Basaka water N exists in the form of ammonia, nitrate, and nitrite but P is found in the form of phosphate which increases the final concentrations of both, which ultimately result in negative recovery. (Appendex-1)

4.5 Production of struvite from human urine using batch reactor

PH of stored urine=8.68

Dilution Factor=100ml/10ml=10

Initial concentration of PO4=887mg/l

Volume of the sample used=5000ml

Amount of $MgCl_2$ added=4.435g

Having optimal PH ,dosage ,mixing time ,mixing speed ,precipitation time , in the batch reactor which was manufactured in our institute about 80%N and 78.69% P were produced.

4.6 Production of struvite from human urine using Basaka lake water as source of Mg^{+2} using batch reactor.

PH of Basaka water=9.15

PH of stored urine=8.68

Initial concentration of PO4=887mg/l

Volume of the sample used=5000ml

Amount in volume of the added Basaka water=25%*5000ml=1.25liters

Initial concentration of N before jar test =10*0.21mg/l

Final concentration of N after jar test=10*0.16mg/l

Initial concentration of P before jar test =10*29.3mg/l

Final concentration of N after jar test=10*25.4mg/l

Using optimal PH, dosage, mixing speed, mixing time and precipitation time,1250ml Basaka water was added as the source of Mg^{+2} in to 5000ml of stored urine to produce struvite using batch reactor and hence about 13.31% P was recovered.

5. Discussion

In the production of struvite from human urine, PH was the key parameter which affects the precipitation and the quality of struvite formed (Stumm, W. and J.S Morgan, 2013). As precipitation of struvite proceeds, PH would drop because more hydrogen ions are generated due to struvite formation. Based on the experimental results struvite production was occurred at PH 6 - 11 but intensively precipitated at PH 10 which was similar to the results from previous study which found out the optimal PH was 10.

In the experimental research Assessment of nutrient removal performance in the integrated constructed wet land (Zhang, L. et al., 2008; de Bashan and Bashan, 2004;Rahaman et al., 2008) they concluded that increasing the dosage (P04 – P: Mg^{+2}) ratio from 1:1 to 1:1.25 would decrease the percentage recovery of nutrients which was consistent with this research.

The precipitation of struvite from human urine also needs to optimize the mixing time (Ohlinger et al., 1999; M.S Rahaman, N. Ellis and D. S. Mavinic). There was an experiential research that revealed as the reaction time increased from 30 minutes to one hour the diameter of the struvite formed decreases (Ci Fang, Toozhang, Rongfeng Jiang and Hicao Otake, 2016). There is also other experimental research (Ohlinger et al., 1999, M.s.Raheman, N.Ellies and D.S Mavinic, 210; XiaoningLiv, Zhengyi Hu, Chunyou, 2013; Suyunxu, Liwen Loo, Hongtu He, 2015) that Concluded as the mixing time increased above 30minutes the struvite break down and the settle ability of NH4-N and PO_4-P decreases which was similar to this research.

Production of struvite also needs to optimize mixing speed (solution turbulence) (Ohlinger et al., 1999).In the experimental research (Sonia G. Barbosa, Luciana Peixoto, Brendo, 2016) with stirring speed 30 rpm they revealed that 99% P was achieved, but in other experimental researches (Sona g. Barbosa, Luciana Peixoto, Brendo Mewman, 2016) they have achieved 89% P at 30 rpm and the percentage recovery increased to 93% when the speed was 60rpm; this an increase was because, as stirring speed was increased it would result in liberation of CO_2 which in turn increased the PH. In this experimental research the percentage recovery of Pat 60rpm and optimum PH, dosage and time was about 98.56 which was consistent with the others researchers.

In the research conducted by (Xiaoning Liv, Guoqi Wen, Jaia Lu, 2016) for the maximum nutrient recovery the precipitation time after jar test shouldn't be greater than 30 minutes which was identical with this research.

Only few researches were done on the optimization of storage period, but it was the key factor since decomposition of urea took place with time. In the experimental research long term operation of a pilot scale reactor for phosphorus recovery as struvite from source separated urine they concluded that 16 days residence time inside the collection tank for urine was enough to hydrolysis urea completely (Partiricia Zamora, Tanya Georgieva, Inmaculadasalcedo, 2016). Another experimental research did 15 sequential experiments and revealed that the maximum N was obtained at 11th day and P on the 14th day. But in this research two samples at different months were taken and the first sample was tested for 25 days and the second for 30 days , the maximum recovery was obtained on 20th and 19th day respectively .

From JIJE laboratory it was reported that the amount of Total nitrogen and total phosphorus in struvite were 5.66g/100g and 12.2g/100g. Generally, the observed struvite production always deviates from the calculated production, usually the actual production was lower than the calculated. The deviation may be for one thing the optimum process conditions were not achieved and for another thing there were interfering ions (K^+, Ca^{+2}, HCO^{3-}, Cl^- etc) in the urine that inhabits the process.

(Suyun Xu, LiwenLuo, Hongfu He, HonboLiv, 2015; Buchanan, J.R, C.R. Mote, 1994; Stratful, I., M.D. scrimshaw and J.N. Lester, 2001) in their research they concluded that at optimal PH10, PO4: Mg^{+2} dosage 1:1 , mixing time 30min, mixing speed 60rpm and precipitation time 30min they recovered 87.2% N and 92.4% P from the stored human urine. In the other experimental research as well With all parameters (PH, dosage, time, speed) at optimal condition the P removal efficiency was nearly 86% in which the result was similar to those obtained in previous studies on waste water. (Stratful et al., 2001; Von Munch & Barr, 2001). (Mi Liang, 2009) showed in his experimental research that the amount of Nitrogen recovered in the struvite was 57% as NH_4-N.But in this research at optimum parameters 92.37% N and 94.17% P were recovered from the stored human urine.

6. Conclusion and Recommendation

Experimental researchers revealed that N and P recovery from stored human urine was affected by various parameters in the struvite precipitation processes. The parameters optimized in this research were PH, dosage ratio (PO4- P:Mg^{+2}), mixing time, mixing speed, storage (incubation period) and precipitation time.

For optimization of PH, six PH levels, PH 6, 7, 8, 9, 10, 11 where used. The results of the experiment showed that PH10 was the optimum PH to recover N in the form of NH_4 – N and P in the form of PO_4-P.

In the dosage optimization, again six different dosage ratios were used. The dosage (PO4 – P: Mg^{+2}) ratios used were 1:1, 1:2, 1:3, 1:4, 1:5,and 1:6 .The results of the experiments showed that dosage (PO4 – P: Mg^{+2}) ratio 1:1 was the optimum dosage. Further increase of dosage beyond 1:1 showed that decrease in recovery of N and P.

In case of mixing time optimization, three different times 30, 45, 60minutes were used. At optimum PH and optimum dosage, the highest recovery of N and P were obtained when the mixing time was 30 minute.

For optimization of mixing speed, three different speeds were used, i.e. 60rpm, 90rpm, and 120 rpm. Again at optimum PH 10, optimum dosage 1:1, and optimum mixing time 30 minutes, the optimum mixing speed was obtained to be 60 rpm.

The optimum parameters were used in order to determine the incubation period at which maximum percentage recovery of N and P were obtained. Two samples were collected at different times and stored at room temperature in AAiT wastewater treatment laboratory. The first sample was tested starting from the next day of collection for 25 days and the maximum recovery of N and P were 92.37% and 94.17% respectively during 20th day test.

The second sample was again tested from a month at optimum parameters and the maximum percentage recovery was obtained during 19th day test and the percentage recovery of N and P were 89.25 % and 85.79% respectively.

Generally in this experimental research at optimum PH 10, optimum dosage (PO4 –P: Mg^{+2}) ratio 1:1, optimum mixing time 30 minutes, optimum mixing speed 60rpm ,optimum precipitation time 30min, and optimum storage 19 days, 92. 37% N and 94.17% P were recovered in the form of struvite.

Recommendation

In this research even though many parameters were optimized, the incubation period is recommended to be optimized again for more than a month, on top of this there is also difference in concentration of N and P during the fasting time of Orthodox and the other days hence the researcher can extend this research by looking the difference. Further studies can also be done to change the source of Mg from $MgCl_2$ to Moringa seeds, wood ash etc. There is also a possibility of looking the research done by (Sonia G.Barbosa, Lucianna Peixoto, 2016) in which they have recovered 99% of P by using mixing speed 30,45,60rpm. Furthermore, the drain after the recovery of struvite for one thing it can be used for the recovery of nutrients like Potassium etc. and for another thing it can also be used for Urban/ Rural agriculture for the production of fruits, onion ,Cabbage or any other vegetables since it is composed of different nutrients.

Reference

1. Abbona, F., H.E lundager Madsen and R. Boistelle, 1982. N and P recovery from human urine
2. Abegglen, 2008.Nutrient recovery from source separate urine P112-119
3. Amjad, 2010.Optimium nutrient recovery from source separate urine using stirred reactor
4. Antohini et al., 2009. Nitrogen and Phosphorus recovery from human urine by struvite precipitation
5. B. Etter, E. Tilley, R. khadka and K.M. Undert, 2010. Low cost struvite production using source separated urine in Nepal.
6. Beal et al., 1999.Recovery of Phosphorus from human urine by using Moringa
7. Cifang Tao Zhang, Rongfengjiang and Hisao Ohtake, 2016. Phosphate recovery from waste water by mechanism analysis optimization of struvite settle ability in fluidized bed reactor
8. Cordel et al., 2009, 2011. Struvite crystallization
9. D. Ockhorn, 2009.Precipiation of Struvite in the form of MAP
10. De Bashan and Bashan, 2004. Recent advances in removing P from waste water and its future use as fertilizer
11. Desta Beyene, 1982; Tekmlign Mamo, Haque, and C.S kamara, 1995. Phosphorus and Nitrogen status of some Ethiopia highlands
12. Drangert, 1998. Percentage of Nutrients found in urine :P161
13. El Diwani, G., et al., 2007.N and P recovery from source separated urine.
14. Elina Andersson, 2015.Potential nutrient removal from source separated urine.
15. Evagelsuritua A Delbert H., 2017. Potential nutrient removal and/or recovery using controlled struvite precipitation in reject water.
16. Ganroz, Z., G. Dave and E. Nilson, 2007.Chemical kinetics of struvite formation from urine.
17. Gelletal, 2011.Nutrient recovery from source separate urine by anaerobic condition.
18. Gonsaley- Ponce et al., 2009.Potential P removal from human urine.
19. Gregory D. Boardman, Charles B. Bott., John T. Novak, 2016. Struvite recovery from Source separated urine utilizing a fluidizing bed reactor, Alexandria Augusta Gagnon.

20. Jonsson et al., 2004. Guidelines on the use of urine and faces in crop production,P17
21. Jordin and Popel, 1997.Economical fertilizer production from human urine in liquid form
22. Kurtz N. Ohlinger, K.N., T.M. young and E.D Schroeder, 2000. Post digestion struvite precipitation using fluidized bed reactor, P3607-3614.
23. Liv et al, 2014. Effect of contact to the atmosphere and dilution on P recovery from human urine through struvite formation
24. LL Mugiv Aisa, Joolowoyo, 2015.Nutrient recovery from source separated urine in cases of domestic cattle
25. Lo et al., 2011.Precipitation of Struvite in the form of MAP by using $MgCl_2$ as source of magnesium
26. M. Maurer, W. Pronk, T.A Larsen, 2006. Treatment processes for source separated urine
27. M.S Rahaman, N. Ellies and D.S. Mavinic ,2015. Effects of various process parameter on struvite precipitation
28. Massey et al, 2007.Ntrient recovery from source separate urine
29. MC Graw Hill, 2014.Nutrient recovery from source separate urine using fluidized bed reactor
30. Mi Liang, 2009. New possibilities of Mg utilization in waste water treatment and Nutrients Recovery
31. Milliang, 2009.Nutrient recovery from source separate urine using mobile toilets
32. Min Pan, Xiaoming Huang, and Guangxure Wu, 2017.Pand N recovery in the form of Struvite
33. Min Pan, Xiaoming Hung, 2017.Effect of various processes on struvite crystallization.
34. Mohamad Darwish, A ZmiAvis, 2015.Nutrient recovery from source separate urine using stirrper
35. Nalson, N.D., R.L. Mikkelsen, 2003. Struvite precipitation in anaerobic swine lagoon liquid
36. Nalson, N.D., R.L. Mikkelsen, 2003.Effects of PH and Mg:P ratio and determination of rate constant, P 229-236

37. Ohlinger K.N., Young T.M and Schroeder E.D., 1988. Predicting Struvite formation in digestion
38. Ohlinger K.N., Young T.M and Schroeder ED., 2000. Post digestion struvite perception using fluidized bed reactor, England P 126, 361-368
39. Pastor et al., 2008. Pilot scale study of struvite Precipitation in a strived tank reactor
40. Patricia Zamora, Tanya Georgjeva, Inmaculada and Salcedoiong, 2015. Term operation of pilot scale reactor for P recovery as struvite from source separated urine.
41. Patricia Zamoral, and Shalini Guleria, 2016. Struvite crystallization in the form of MAP
42. Quintana, M., et al., 2005. Removal of phosphorus through struvite precipitation using byproduct of MgO.
43. Rahamann, et al., 2011.Effects of various process parameters on struvite precipitation kinetics and subsequent determination of rate constants
44. Rayanshaw, 2010.Recovery of N and P from human urine in the form of MAP by anaerobic condition
45. Romer, 2006. Plant availability of P from recycling products and phosphate fertilizers in a growth chamber trail with seeding
46. Schouw et al., 2002.Efects of PH ,and dosage on struvite precipitation in the form of MAP
47. Shalini Guleria, 2016.Struvite crystallization from human urine
48. Shuet et al., 2006.Precipitation of struvite in the form of MAP
49. Sonia G. Barbosa, Luciana Peixoto, Brendo, 2016. Design of experiments to assess phosphorus removal and crystal properties in struvite precipitation of source separated urine using different Mg source.
50. Soritualadelbertevage, 2017; Potential Nutrient removal and/or recovery using controlled struvite precipitation in Rejection water form IVAR Coroda land.
51. Stumm, W. and J.J Morgan, 2013.Determination of rate constant for production of struvite, Aquatic Chemistry
52. Suyum Xu, Liwen Luo, Hongfu He, Hangbo Liu and Lifeng Cui, 2015.Nitrogen and phosphorous recovery from source separated urine by dosing with Magnesite and Zeolite

53. Tilman et al., 2002.Nutrient recovery from source separate urine
54. Vagel, Hu, J.Y.; Ong, and S.L, 2003.Nutrient recovery from source separate urine using aerobic condition
55. Woods et al., 1999. Cost effectiveness of nitrogen mitigation by alternative household waste water management technologies, P344-354.
56. Xiaoning Liu, Zhengy, HU, Chunyou Zhu, Guoqi Wen, 2015. Influence of process parameters on phosphorus recovery by struvite formation from urine.
57. Zhang et al., 2010. Relating Phosphorus from Calcium for struvite fertilizer production from aerobically digester
58. Zhang, 2008.Nitrogen and Phosphorus recovery from source separate urine using anaerobic condition

Appendex-1

Preparation of standard solution for calibration of the photometer

Dilute 1000mg/l ammonia super stock to 2mg/l

i. M1 = 1000mg/ℓ

Let M2 = 100 mg/ℓ

Let V2 = 250$m\ell$

V1= ?

By rule of dilution M1V1= M2V2

V1= 25 $m\ell \Rightarrow$ take 25 $m\ell$

from 1000 mg/ℓ to prepare 100 mg/ℓ stock solution

ii. M1 = 100 mg/ℓ
V1= ?
Let M2 = 2 mg/ℓ
Let V2= 250 mg/ℓ

By rule of dilution
M1V1= M2V2
V1= 5 $m\ell \Rightarrow$ take 5 $m\ell$ from
100 mg/ℓ to prepare 2 mg/ℓ stock solution

iii. M1 = 2 mg/ℓ
V1= ?
Let M2 = 1.4 mg/ℓ
Let V2= 100 mg/ℓ

By rule of dilution
M1V1= M2V2
V1= 70 $m\ell \Rightarrow$ take 70 $m\ell$ from
2mg/ℓ of stock solution

iv. M1 = 2 mg/ℓ
V1= ?
Let M2 = 0.8 mg/ℓ
Let V2= 100 mg/ℓ

By rule of dilution
M1V1= M2V2
V1= 40 $m\ell \Rightarrow$ take 40 $m\ell$ from
2mg/ ℓ of stock solution

v. M1 = 2 mg/ℓ
V1= ?
M2 = 0.2 mg/ℓ
V2= 100 mg/ℓ

By rule of dilution
M1V1= M2V2
V1= 10 $m\ell \Rightarrow$ take 10 $m\ell$ from
2mg/ $\ell$of stock solution

vi. M1 = 2 mg/ℓ
V1= ?
M2 = 0.1 mg/ℓ
V2= 100 $m\ell$

By rule of dilution
M1V1= M2V2
V1= 5 $m\ell$

NB: Take 70 $m\ell$, 40$m\ell$, 10 $m\ell$, and 5 $m\ell$ from 250 $m\ell$ flask that is 2 mg/ℓ stock solution in separate beaker for each and add 30 $m\ell$, 60 $m\ell$,90 $m\ell$, and 95 $m\ell$ distilled water respectively to make 100 $m\ell$.

2. NaOH solution preparation from NaOH pellet

For pH adjustment 5M of NaOH was used. How to prepare 5M NaOH from NaOH pellet.

M = 5M

Let V= 150mℓ

Mo = 40g/mℓ

M= n/v

n = MV

$\frac{m}{M_o}$ = MV

m = MVMo

m = 5 * 0.15 * 40

m = 30g ⇒30g of NaOH pellet was dissolved in 150mℓ of distrilled water

3. 12M HCl dilution

Again for pH adjustment 5M of HCl was used. How to prepare 5M HCl from 12M HCl

By the rule of dilution:

M1 = 12M

V1= ?

M2= 5M

Let V2 = 250mℓ

M1V1= M2V2

V1= $\frac{M_2V_2}{M_1}$

= $\frac{5*0.250}{12}$

= 105mℓ ⇒ take 105m$\ell$from 12MHCl and dilute to 250mℓ volumetric flask by distilled water.

3. Awash river nutrients composition

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
July	Turbidity	Ntu	12	9	56	71	45.26	68.62	259
	Tolal solids 105^{O}C	mg/l	4648	4226	4320	4240	3504	3320	
	Total dissolved Solid 105^{O}C	mg/l	4602	4200	4210	4102	3860	3238	2110
	P^H		9.5	9.54	9.61	9.23	9.39	9.18	9.07
	Ammonia	mg/l NH_3	0.125	0.185	0.7	0.94	0.62	0.54	-
	Sodium	mg/l Na^+	1640	1450	1500	1580	1360	1300	-
	Potassium	mg/l K^+	65	54	61	59	53	45.5	-
	Total Hardness	mg/l $CaCO_3$	15.5	22	14.7	14.7	18	9.5	24.3
	Calcium	mg/l Ca^{+2}	4.4	7.12	3.36	8.4	5.6	3.04	9.6
	Magnesium	mg/l Mg^{+2}	1.08	1.1	1.53	1.53	0.96	0.46	8.8
	Total Iron	mg/l Fe^{+3}	TRACE	0.02	0.09	0.07	0.18	0.07	-
	Manganese	mg/l Mn^{+2}	0.05	Trace	-	Trace	-	0.72	-
	Fluoride	mg/l F^-	24.8	30.9	34.8	24.64	17.54	14.18	14.2
	Chloride	mg/l Cl^-	572	533.7	556.1	545.9	359.6	512	-
	Nitrite	mg/l NO_2^{-3}	-	-	0.13	-	0.01	0.02	-
	Nitrate	mg/l NO_3^{-2}	3.01	0.1	0.69	0.3	1.12	0.99	-
	Alkalinity	mg/l $CaCO_3$	2373	2350	2280	2310	1615	1568	-
	Carbonate	mg/l CO_3^{-2}	624	600	864	480	570	490.2	-
	Bicarbonate	mg/l HCO_3^-	1626.3	1446	1025	1842	811.3	915.6	-
	Phosphate	mg/l PO_4^{-3}	2.357	4.253	2.75	2.77	2.29	2.44	-

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
August	Turbidity	Ntu	2	4	53	33	34.31	73	29.3
	Tolal solids 105^{O}C	mg/l	4456	4310	4400	4254	3200	2820	-
	Total dissolved Solid 105^{O}C	mg/l	4452	4295	4280	4196	3132	2750	2450
	P^H		9.52	9.51	9.12	9.45	9.97	9.45	9.1
	Ammonia	mg/l NH_3	0.05	1	0.199	0.76	0.91	0.37	-
	Sodium	mg/l Na^+	1690	1600	1700	1500	1175	1150	-
	Potassium	mg/l K^+	70	62	65	53	51	45	-
	Total Hardness	mg/l $CaCO_3$	13.3	26.4	14.7	12.6	15.2	45.6	32
	Calcium	mg/l Ca^{+2}	4.45	8.9	3.36	3.36	3.8	12.16	12.8
	Magnesium	mg/l Mg^{+2}	0.5	1.08	1.53	1.02	1.37	3.65	11.5
	Total Iron	mg/l Fe^{+3}	0.04	0.26	0.03	0.07	0.2	0.01	-
	Manganese	mg/l Mn^{+2}	0.07	0.05	0.05	0.05	-	-	-
	Fluoride	mg/l F^-	40	41.2	32	30.8	15.95	20.85	14.4
	Chloride	mg/l Cl^-	549	576	504.7	536.2	433.2	433.2	-
	Nitrite	mg/l NO_2^{-3}	-	-	0.015	-	Trace	Nill	--
	Nitrate	mg/l NO_3^{-2}	1.7	19.58	0.1	2.5	1.18	0.06	-
	Alkalinity	mg/l $CaCO_3$	2814	2325	2268	2205	15554	1767	-
	Carbonate	mg/l CO_3^{-2}	864	624	624	528	453.6	513	-
	Bicarbonate	mg/l HCO_3^-	1676	1567	1498	1617	973.6	1113	-
	Phosphate	mg/l PO_4^{-3}	3.793	4.25	2.64	3.05	2.33	2.11	

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
September	Turbidity	Ntu	7	-	46	-	31.76	25.92	20.8
	Tolal solids 105^{O}C	mg/l	4470	-	4050	-	3578	3520	3380
	Total dissolved Solid 105OC	mg/l	4450	-	3940	-	3540	3468	3300
	P^H		9.58	-	9.41	-	9.55	9.3	9.19
	Ammonia	mg/l NH_3	0.04	-	0.71	-	0.92	0.94	1.48
	Sodium	mg/l Na^+	1600	-	1460	-	1400	1300	1300
	Potassium	mg/l K^+	65	-	62	-	5.6	48	54
	Total Hardness	mg/l $CaCO_3$	15.5	-	18.9	-	20.9	13.3	20
	Calcium	mg/l Ca^{+2}	4.5	-	5.88	-	5.32	3.8	4.8
	Magnesium	mg/l Mg^{+2}	1.1	-	1.02	-	1.82	0.91	1.92
	Total Iron	mg/l Fe^{+3}	0.04	-	0.21	-	0.29	0.29	0.19
	Manganese	mg/l Mn^{+2}	TRACE	-	-	-	-	-	0.03
	Fluoride	mg/l F^-	40	-	24.2	-	21.61	3.18	20.5
	Chloride	mg/l Cl^-	562	-	621.6	-	419.6	451.4	410
	Nitrite	mg/l NO_2^{-3}	2.2	-	0.13	-	0.12	Trace	0.1
	Nitrate	mg/l NO_3^{-2}	2541	-	-	-	1.23	1.25	1.18
	Alkalinity	mg/l $CaCO_3$	792	-	2142	-	1891	1806	1700
	Carbonate	mg/l CO_3^{-2}	1489	-	552	-	387.6	630	540
	Bicarbonate	mg/l HCO_3^-	440	-	1491	-	1518	922.3	976
	Phosphate	mg/l PO_4^{-3}		-	2.86	-	2.73	2.44	0.57

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
October	Turbidity	Ntu	6	-	21	-	38.3	34.31	22.6
	P^H		9.5	-	9.58	-	9.62	9.4	8.91
	Ammonia	mg/l NH_3	0.1	-	0.64	-	0.77	0.97	1.11
	Sodium	mg/l Na^+	1800	-	1460	-	1420	1320	1240
	Potassium	mg/l K^+	65	-	54	-	5.3	69	56
	Total Hardness	mg/l $CaCO_3$	15.5	-	63	-	22.8	18.4	20
	Calcium	mg/l Ca^{+2}	4.5	-	12.6	-	6.08	4.6	6.4
	Magnesium	mg/l Mg^{+2}	1.1	-	7.65	-	1.82	1.66	0.96
	Total Iron	mg/l Fe^{+3}	0.06	-	0.26	-	0.13	0.22	0.12
	Manganese	mg/l Mn^{+2}	Trace	-	-	-	-	-	0
	Fluoride	mg/l F^-	38	-	23.4	-	21.51	1.42	22.2
	Chloride	mg/l Cl^-	655.7	-	526.3	-	506	469.6	360
	Nitrite	mg/l NO_2^{-3}	-	-	0.145	-	0.12	0.02	0.02
	Nitrate	mg/l NO_3^{-2}	2.2	-	-	-	1.29	1.03	1.22
	Alkalinity	mg/l $CaCO_3$	2688	-	2304	-	1900	1995	1650
	Carbonate	mg/l CO_3^{-2}	648	-	648	-	364.8	604.8	504
	Bicarbonate	mg/l HCO_3^-	1961.8	-	1493	-	1576	1204	988
	Phosphate	mg/l PO_4^{-3}	2.26	-	3.13	-	2.53	2.21	2.34

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
November	Turbidity	Ntu	-	-	34	42	40.52	31.76	31
	Total solids 105^{O}C	mg/l	-	-	4554	4350	4304	3774	3542
	Total dissolved Solid 105^{O}C	mg/l	-	-	4420	4286	3922	3680	3508
	P^{H}		-	-	9.38	9.67	9.07	9.34	9.23
	Ammonia	mg/l NH_3	-	-	0.58	0.39	0.66	1.01	0.43
	Sodium	mg/l Na^+	-	-	1600	1660	1400	1260	1230
	Potassium	mg/l K^+	-	-	56	60	50	53	48
	Total Hardness	mg/l $CaCO_3$	-	-	27.3	17.5	12	15.2	17.1
	Calcium	mg/l Ca^{+2}	-	-	6.72	5	4	3.8	3.04
	Magnesium	mg/l Mg^{+2}	-	-	2.55	1.22	0.48	1.37	2.28
	Total Iron	mg/l Fe^{+3}	-	-	0.11	0.05	0.25	0.03	0.09
	Manganese	mg/l Mn^{+2}	-	-	0.05	0.02	-	-	-
	Fluoride	mg/l F^-	-	-	34.2	36.2	16.16	32.25	21.8
	Chloride	mg/l Cl^-	-	-	546	551	407	246.6	360
	Nitrite	mg/l NO_2^{-3}	-	-	0.1	-	0.01	0.1	Nill
	Nitrate	mg/l NO_3^{-2}	-	-	11.89	2.33	0.71	1.33	0.58
	Alkalinity	mg/l $CaCO_3$	-	-	2358	2100	1878	1406	1600
	Carbonate	mg/l CO_3^{-2}	-	-	720	552	384	638.4	360
	Bicarbonate	mg/l HCO_3^-	-	-	1413	1440	1510	417.2	1220
	Phosphate	mg/l PO_4^{-3}	-	-	2.35	2.8	1.09	2.84	2

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
December	Turbidity	Ntu	10	3	31	-	34		22.3
	Tolal solids 105^{O}C	mg/l	4750	4528	4084	-	3298		3380
	Total dissolved Solid 105OC	mg/l	4700	4514	4020	-	3208		3320
	P^{H}		9.56	9.5	9.53	-	9.45		98
	Ammonia	mg/l NH_3	0.18	0.43	0.54	-	1.19		3.35
	Sodium	mg/l Na^+	1810	1720	1640	-	1200		1200
	Potassium	mg/l K^+	6.4	75	55	-	53		38
	Total Hardness	mg/l $CaCO_3$	15.4	18.2	18.9	-	13.3		13.3
	Calcium	mg/l Ca^{+2}	4.4	5.5	5.88	-	3.8		3.8
	Magnesium	mg/l Mg^{+2}	1.07	1.1	1.02	-	0.91		0.91
	Total Iron	mg/l Fe^{+3}	0.018	0.06	0.07	-	0.16		0.2
	Manganese	mg/l Mn^{+2}	0.2	0.02	0.05	-	-		-
	Fluoride	mg/l F^-	30.8	33.6	42.3	-	45.29		1954
	Chloride	mg/l Cl^-	591.8	562.6	51.6	-	27.3		433
	Nitrite	mg/l NO_2^{-3}	-	-	0.04	-	0.12		Nill
	Nitrate	mg/l NO_3^{-2}	0.2	2.2	24.14	-	1.34		0.96
	Alkalinity	mg/l $CaCO_3$	2845.8	2604	2484	-	1900		1365
	Carbonate	mg/l CO_3^{-2}	1080	792	840	-	456		378
	Bicarbonate	mg/l HCO_3^-	1275.9	1567	1322	-	1391		897
	Phosphate	mg/l PO_4^{-3}	4.1	2.665	3.29	-	2.8		2.06

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
January	Turbidity	Ntu	-	6	29	38	101.5	-	21.9
	Tolal solids 105^{O}C	mg/l	-	4438	4282	4360	3354	-	3320
	Total dissolved Solid 105OC	mg/l	-	4420	4244	4280	3116	-	3280
	P^H		-	9.46	9.38	9.25	9.53	-	9.18
	Ammonia	mg/l NH_3	-	0.45	1.56	0.054	0.76	-	1.91
	Sodium	mg/l Na^+	-	1800	1540	1660	100	-	1200
	Potassium	mg/l K^+	-	65	110	50	64	-	48
	Total Hardness	mg/l $CaCO_3$	-	17.4	58.8	14.7	19	-	20
	Calcium	mg/l Ca^{+2}	-	5.2	21	3.36	4.56	-	5.6
	Magnesium	mg/l Mg^{+2}	-	1.1	1.53	1.53	1.82	-	1.44
	Total Iron	mg/l Fe^{+3}	-	Trace	Trace	0.05	0.25	-	0.17
	Manganese	mg/l Mn^{+2}	-	Trace	0.02	0.02	-	-	-
	Fluoride	mg/l F^-	-	40	34.6	34.6	4.91	-	20.7
	Chloride	mg/l Cl^-	-	668.2	615.7	510.9	296.7	-	392
	Nitrite	mg/l NO_2^{-3}	-	-	Trace	-	Trace	-	0.18
	Nitrate	mg/l NO_3^{-2}	-	12.5	24.47	0.2	1.25	-	1.12
	Alkalinity	mg/l $CaCO_3$	-	2774	2260	2331	1710	-	1800
	Carbonate	mg/l CO_3^{-2}	-	840	624	648	358	-	540
	Bicarbonate	mg/l HCO_3^-	-	1677	1488	1526	1358	-	1098
	Phosphate	mg/l PO_4^{-3}	-	2.35	2.48	2.99	2.37	-	2.77

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
Feburary	Turbidity	Ntu	5	11	36	32	21	19.71	20.1
	Tolal solids 105^{O}C	mg/l	4694	4528	3990	3912	3304	3364	2640
	Total dissolved Solid 105OC	mg/l	4620	4510	3938	3846	3278	3340	2608
	P^{H}		9.4	9.56	9.42	9.28	9.56	9.24	9.04
	Ammonia	mg/l NH_3	0.158	0.42	0.61	0.47	0.97	0.85	0.57
	Sodium	mg/l Na^+	1840	1720	1420	1560	1220	1170	1000
	Potassium	mg/l K^+	67	84	67	62	77	42	45.5
	Total Hardness	mg/l $CaCO_3$	15.5	17.4	21	14.7	15.2	15.2	22
	Calcium	mg/l Ca^{+2}	3.56	5.2	6.72	4.2	3.8	3.8	5.6
	Magnesium	mg/l Mg^{+2}	1.62	1.1	1.02	1.02	1.37	1.37	1.92
	Total Iron	mg/l Fe^{+3}	0.006	0.06	0.27	0.06	0.21	0.32	0.11
	Manganese	mg/l Mn^{+2}	Trace	Trace	0.05	0.05	-	-	0.15
	Fluoride	mg/l F^-	28	38	34.8	36.4	3.57	21.41	17.3
	Chloride	mg/l Cl^-	591.8	581.8	496.5	552.1	496.9	433.2	461
	Nitrite	mg/l NO_2^{-3}	-	-	0.125	-	0.01	Trace	0.08
	Nitrate	mg/l NO_3^{-2}	0.2	2.3	5.1	.0.5	1.09	1.2	1.18
	Alkalinity	mg/l $CaCO_3$	2455.2	2428	1900	1890	1615	1881	1420
	Carbonate	mg/l CO_3^{-2}	768	600	432	408	478.8	399	600
	Bicarbonate	mg/l HCO_3^-	1433.7	1742	1440	1476	996.7	1484	512
	Phosphate	mg/l PO_4^{-3}	4.44	2.08	2.19	2.85	3.95	2.39	2.64

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
March	Turbidity	Ntu	4	-	-	48	23.7	28	20
	Tolal solids 105^{O}C	mg/l	4526	-	-	4792	3552	4360	3616
	Total dissolved Solid 105OC	mg/l	4518	-	-	4692	3102	4160	3568
	P^H		9.38	-	-	9.2	9.69	9.3	9.14
	Ammonia	mg/l NH_3	-	-	-	0.69	0.323	1.41	0.41
	Sodium	mg/l Na^+	1960	-	-		1200	1540	1300
	Potassium	mg/l K^+	65	-	-	65	44	50	58
	Total Hardness	mg/l $CaCO_3$	15.51	-	-	12.6	18	19	20
	Calcium	mg/l Ca^{+2}	4.45	-	-	3.36	4.8	4.56	6.4
	Magnesium	mg/l Mg^{+2}	1.1	-	-	1.02	1.44	1.82	0.96
	Total Iron	mg/l Fe^{+3}	0.02	-	-	0.02	0.31	0.1	0.19
	Manganese	mg/l Mn^{+2}	0.1	-	-	0.05	-	-	0.01
	Fluoride	mg/l F^-	40	-	-	38.4	20.6	20	15.6
	Chloride	mg/l Cl^-	590	-	-	566.5	487.8	465.1	406
	Nitrite	mg/l NO_2^{-3}	-	-	-	-		0.18	0.2
	Nitrate	mg/l NO_3^{-2}	0.4	-	-	0.56	0.9	2.32	1.03
	Alkalinity	mg/l $CaCO_3$	2548	-	-	2100	1663	2200	1470
	Carbonate	mg/l CO_3^{-2}	1008	-	-	576	456	600	605
	Bicarbonate	mg/l HCO_3^-	1059	-	-	1390	1101	1464	564
	Phosphate	mg/l PO_4^{-3}	3.2	-	-	2.75	0.121	2.22	2.24

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
April	Turbidity	Ntu	5	-	9.286	53	25.19	31.39	49
	Tolal solids 105^{O}C	mg/l	4500	-	19022	4164	3628	3304	3224
	Total dissolved Solid 105OC	mg/l	4466	-	246	4092	3320	3278	3154
	P^H		9.52	-	8.01	9.53	9.48	9.25	9.08
	Ammonia	mg/l NH_3	0.13	-	0.31	0.66	0.81	0.52	0.46
	Sodium	mg/l Na^+	1760	-	42	1600	1200	1320	1100
	Potassium	mg/l K^+	55	-	7.1	61	50	8.6	7.1
	Total Hardness	mg/l $CaCO_3$	15.5	-	98.7	14.7	30	47.5	15.2
	Calcium	mg/l Ca^{+2}	4.45	-	33.6	4.2	4.8	9.88	3.8
	Magnesium	mg/l Mg^{+2}	1.1	-	3.57	1.02	4.32	5.47	1.37
	Total Iron	mg/l Fe^{+3}	0.02	-	0.01	0.06	0.26	0.01	0.16
	Manganese	mg/l Mn^{+2}	0.02	-	0.02	0.04	-	-	Nill
	Fluoride	mg/l F^-	51.6	-	1.4	35.4	20.1	24.28	19.6
	Chloride	mg/l Cl^-	566	-	20.85	541.8	416.2	414.1	470
	Nitrite	mg/l NO_2^{-3}	-	-	0.4	-	0.08	0.01	Nill
	Nitrate	mg/l NO_3^{-2}	0.8	-	1.07	0.7	1.24	0.89	0.98
	Alkalinity	mg/l $CaCO_3$	2473.8	-	140	2226	1870	1840	1560
	Carbonate	mg/l CO_3^{-2}	888	-	Trace	625	620	432	504
	Bicarbonate	mg/l HCO_3^-	1212.1	-	170.8	1447	1020	1366	878
	Phosphate	mg/l PO_4^{-3}	2.81	-	0.16	2.59	3.41	2.88	1.98

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
May	Turbidity	Ntu	7	-	42	30	44.17	44.53	-
	Tolal solids 105^{O}C	mg/l	4560	-	4390	4372	3798	3184	-
	Total dissolved Solid 105OC	mg/l	4500	-	4317	4320	3710	3140	-
	P^{H}		9.58	-	9.35	9.36	9.33	9.28	9.24
	Ammonia	mg/l NH_3	0.18	-	0.45	0.043	0.64	0.73	-
	Sodium	mg/l Na^+	1700	-	1620	1680	1420	1200	-
	Potassium	mg/l K^+	74	-	62	55	55	44	-
	Total Hardness	mg/l $CaCO_3$	15.54	-	14.7	21	10	19	26.6
	Calcium	mg/l Ca^{+2}	4.45	-	4.2	4.2	3.2	3.8	10.6
	Magnesium	mg/l Mg^{+2}	1.08	-	1.02	2.55	0.48	2.22	9.6
	Total Iron	mg/l Fe^{+3}	0.03	-	0.06	0.06	0.26	0.2	-
	Manganese	mg/l Mn^{+2}	Trace	-	-	0.05	-	-	-
	Fluoride	mg/l F^-	24.8	-	37.2	31.8	9.39	14.54	14.5
	Chloride	mg/l Cl^-	591.7	-	534.2	556.2	493.1	487.8	-
	Nitrite	mg/l NO_2^{-3}	-	-	0.015	-	Trace	Trace	-
	Nitrate	mg/l NO_3^{-2}	2.2	-	0.45	2.2	0.76	0.33	-
	Alkalinity	mg/l $CaCO_3$	2625	-	2520	2415	1832	1445	1320
	Carbonate	mg/l CO_3^{-2}	612	-	520.6	672	475.2	408	-
	Bicarbonate	mg/l HCO_3^-	1958.1	-	2006	1580	1268	933.3	-
	Phosphate	mg/l PO_4^{-3}	3.6	-	2.39	3	2.22	2.17	-

Month	Parameter	Unit	1997	1998	2000	2001	2003	2004	2005
June	Turbidity	Ntu	23	4	74	50	64.97	383.3	22.9
	Tolal solids 105^OC	mg/l	5010	4490	4690	4326	4316	5200	-
	Total dissolved Solid 105^OC	mg/l	4940	4476	4560	4216	4112	3240	2570
	P^H		9.61	9.55	9.1	9.53	9.47	9.46	9.58
	Ammonia	mg/l NH_3	0.13	0.06	0.43	0.37	0.62	1.18	-
	Sodium	mg/l Na^+	1780	1580	1820	1520	1520	1300	-
	Potassium	mg/l K^+	69	68	71	65	53.5	63.5	-
	Total Hardness	mg/l $CaCO_3$	17.8	17.6	12.6	14.7	20	14	27
	Calcium	mg/l Ca^{+2}	5.34	5.34	4.2	4.2	4.8	4	10.6
	Magnesium	mg/l Mg^{+2}	1.1	1.08	0.51	1.02	1.92	0.96	10
	Total Iron	mg/l Fe^{+3}	0.05	0.22	0.06	0.06	0.24	0.22	-
	Manganese	mg/l Mn^{+2}	TRACE	Trace	-	0.05	-	-	-
	Fluoride	mg/l F^-	24.8	31.4	38	34	43.24	17.51	14.3
	Chloride	mg/l Cl^-	578.1	629.8	566	628.3	906.5	460.5	-
	Nitrite	mg/l NO_2^{-3}	-	-	0.04	-	0.14	0.19	-
	Nitrate	mg/l NO_3^{-2}	1.7	0.2	0.6	1.53	0.87	0.98	-
	Alkalinity	mg/l $CaCO_3$	2562	2331	2360	2268	1758	1634	-
	Carbonate	mg/l CO_3^{-2}	744	600	624	360	513	752.4	
	Bicarbonate	mg/l HCO_3^-	1612.8	1624	1610	2035	2144	463.6	-
	Phosphate	mg/l PO_4^{-3}	2.665	3.465	2.62	2.75	2.01	3.12	-