**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST)**

# ANALYSIS OF NPK IN HUMAN MALE AND FEMALE URINE

**By**

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## CERTIFICATION PAGE

I hereby declare that this submission is my own work towards the award of MSc, and that to the best of my knowledge it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.



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## ABSTRACT

This study was to analyze the concentration of Nitrogen, Phosphorus and Potassium in male, female and composite urine stored over six months and its use in agriculture. Urinals were constructed to allow for easy collection of separate urine which was stored in transparent bottles for six months in a greenhouse. Monthly triplicate analysis of male, female and composite urine was done for nitrogen, phosphorus, potassium, temperature, pH and colour change. Bray P1 and Flame photometry methods were used in analyzing phosphorus and potassium contents respectively. Nitrogen content was analysed by Kjeldahl digestion and a non-digestion (direct) methods. The temperature, pH and colour were determined using mercury thermometer, temperature/ pH meter and a colour chart. The results indicated that the digested female urine nitrogen was significantly ($p<0.05$) higher than that of male urine from month 2 to month 5. However, there were no significant differences ($p>0.05$) with respect to the direct method. Contrastingly, male urine phosphorus content was significantly ($p<0.05$) higher than the female on the 2$^{nd}$ and 3$^{rd}$ months, but there were no significant differences in potassium content for all the different urine. Generally the yield of NPK in all the urine sources peaked on the 4$^{th}$ month. There was a moderate positive correlation between the direct female urine N, and the storage time. The phosphorus levels correlated positively to storage time and temperature but weakly negative to pH. Generally, the urine nitrogen strongly correlated positive to potassium but moderately to temperature and pH. The colour of mature urine is yellow for females and brown for males. The NPK contents in both male (30.4(3.4*)-1-43.7) and female (34.4(6.5*)-1-62.8) urine are comparable to chemical fertilizers. However, the digested female urine nitrogen is significantly higher than that of male urine but vice versa for phosphorus for 2$^{nd}$ and 3$^{rd}$ months of storage. Ecosan urinals should be designed to separately collect urine for specific NPK

requirements for crop production. This study will help famers and Governments to save money on the importation of chemical fertilisers.

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# DEDICATION

This thesis is dedicated to my family especially my mother, Madam Mary S. Duncan, my brother, Mr. Peter Foli Kuwornu, my grandfather, Mr. J.B. Mensah, and my supervisor, Professor Kwasi Obiri-Danso.

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# CHAPTER ONE

## 1.0 INTRODUCTION

### Background

According to United Nations projections, world population will reach 7.5 billion in 2020, an increase of 25 percent over the mid-1999 population of 6 billion. This means that, on average, 73 million people, equivalent to the current population of the Philippines, will be added each year. About 98 percent of the projected growth will take place in developing countries (UNPD, 1998; Roy, 2001; Pinstrup-Andersen *et al*., 1999).

By 2020, the number of people living in developing countries will grow from 4.9 billion to 6.8 billion. Ninety percent of this increase will be in rapidly expanding cities and towns. Growth in urban poverty, food insecurity, and malnutrition will accompany urbanisation (Windberg *et al*., 2005; Pinstrup-Andersen *et al*., 1999).

There is likely to be a gap between food production and demand in several parts of the world by 2020. The demand is influenced by population growth and urbanization, as well as income levels and associated changes in dietary preferences (Cohen, 2000; Roy, 2001; IFA, 2008).

This phenomenal population growth has intensified pressures on the natural resource base—land, water, and air—to produce adequate food, fibre, and raw materials to meet the growing demand (Roy, 2001).

Strong meat demands will double developing countries feedgrain demand (Roy, 2001). Demand for maize will overtake demand for rice by 2020. According to Pinstrup-Andersen *et al*. (1999), IFPRI research suggests that developing countries will account for about 85 percent of the increase in the global demand for cereals and meat between 1995 and 2020. To meet the demand increases, the world's farmers will have to produce 40 percent more grain, with 80 percent of the additional grain coming from yield increases rather than farmland expansion (Cohen, 2000; Pinstrup-Andersen *et al*., 1999). By 2010, according to FAO (1996), 70 percent of food insecure people will live in Sub-Saharan Africa and South Asia, with one of every three Africans undernourished.

Fertilizers provide plants with the nutrients they need for their growth and development. According to Roy (2001) the beginning of our dependence on inorganic fertilizer can be traced back to the 19th century when Justus von Liebig articulated the theoretical foundations of crop production and when John Bennett Lawes began producing single superphosphate (Smil, 1997). The economic need for increased yields in order to feed a growing population from limited arable land has caused a significant global fertiliser demand resulting in increasing fertiliser consumption (Richardson, 2007).

The Robobank's senior analyst, Ms Richardson, and IFA (2008) agree that there tends to be a close relationship between high fertiliser prices and high commodity prices as a farmer's demand for inputs is driven by desire to increase yields in a high commodity environment. Roy (2001) noted that recent projections indicate that fertilizer requirements will reach 180 million metric nutrient tons per year by 2030—a 30%

increase from the current 138 million metric tons. However, current research by Tenkorang and Lowenberg-DeBoer (2008) has projected global fertilizer nutrients forecasts at 187.7 million Mt and 223.1 million Mt for 2015 and 2030, respectively.

Richardson (2007) has noted that increasing demand for fertiliser globally will constraint the fertiliser industries' output supply. In the longer-term, with ongoing and ever-increasing demand on a finite resource, prices for phosphate and potash fertilisers could be expected to rise as exploration pushes into more marginal reserves, the report continued.

As the world's population becomes wealthier and the desire for energy increases, natural gas is expected to supply a larger proportion of the world's energy requirements. As a result, nitrogen-based fertiliser production will need to compete with other natural gas end-users. Long-term increases in the prices of natural gas will lead to an increase in the cost of nitrogen fertiliser production and ultimately lead to higher on-farm fertiliser costs (Richardson, 2007; IFA, 2008; Tenkorang and Lowenberg-DeBoer, 2008). Similarly, Guy Robinson, President of the Zambia National Farmers Union (ZNFU), has expressed the same worry in the 2008 IRIN report.

According to Richardson (2007), at the global level little attention has been devoted to investigate fertiliser alternatives, and enumerated the following facts about fertiliser:

• Fertiliser can be divided into three main nutrients: nitrogen, phosphate and potassium.

• Fertilisers derived from these three elements account for 90 per cent of total global fertiliser consumption.

• There is no substitute for these three nutrients and these are essential for plant growth.

• Nitrogen: 97 per cent of the world's nitrogen fertilisers are derived from synthetically-produced ammonia, produced from a reaction commonly using natural gas as a feedstock. With natural gas available in a diverse number of locations, more than 60 countries produce this type of fertiliser.



• Phosphate: almost entirely derived from mined phosphate rock. Three regions extract 77 per cent of the world's phosphate rock – Morocco and Western Sahara, China and the United States.

• Potassium: derived from mined potassium salts. Global potassium supply is limited to five countries – Canada, Russia, Germany, Belarus and Brazil.

• Intensity of agricultural fertiliser use is determined by a number of factors including crop type, soil type, farmer income, governmental policy (including environmental regulations and fertiliser subsidies) and water availability.

In 2005-2006, world consumption of the three main elements in fertilisers - nitrogen, phosphorus and potassium - was 155.4 million tonnes, of which 60 percent was nitrogen, according to the International Fertiliser Industry Association.

Fertilisers provide the nutrients that farmers need to grow plentiful, high-quality crops to meet the growing world demand for food, feed, fibre and biofuels (IFA, 2008; Roy, 2001). However, numerous transaction costs make fertilizers more expensive in Africa – where soil fertility is declining at alarming rates – than anywhere else in the world. This

means that few farmers in the region can afford to replenish the nutrients removed from their fields by each crop and lost to erosion, a major factor in declining agricultural productivity in Africa (IFA, 2008).

**Alternative Fertiliser**

Excreta are important source of nutrients to many farmers. The direct use of excreta and greywater on arable land tends to minimize the environmental impact in both local and global context. Reuse of excreta on arable land secures valuable fertilisers for crop production and limits the negative impact on water bodies (WHO, 2006; Mashauri and Senzia, 2002; Etnier *et al.*, 1997). The environmental impact of excreta will always be less than that of the direct use of water bodies as the primary recipient of excreta and greywater (WHO, 2006).

Most plant nutrients in wastewater originate from arable land and their flow is via food and human excreta into the wastewater system. To preserve its fertility, arable land needs to be compensated for the plant nutrients removed. Today, chemical fertilisers produced by fossil resources do mostly this. In the long-term perspective we cannot securely rely on fossil resources, as the recycling of plant nutrients from human excreta to arable land could be another way of compensating soil fertility (Palmquist and Jönsson, 2003).

Phosphorus, for example, is an essential element for plants growth, and external phosphorus from mined phosphate is usually supplied in agriculture in order to increase productivity. World supplies of accessible mined phosphate are diminishing. Approximately 25% of the mined phosphorus ends up in aquatic environments or is

buried in landfills or other sinks. This discharge into aquatic environments is damaging, as it causes eutrophication of water bodies (WHO, 2006; Gumbo *et al*., 2002). Urine alone contains more than 50% of the phosphorus excreted by humans. Thus, the diversion and use of urine in agriculture can aid crop production and reduce the costs of and need for advanced wastewater treatment processes to remove phosphorus from the treated effluents (WHO, 2006).

Urine has been used as a valuable plant food for centuries in many parts of the world, particularly in the Far East. It is surprising therefore that nearly all the urine produced in the West and in Africa goes to waste and is lost to agriculture. Each of us passes about 1.5 litres of urine every day - and almost to the last drop, it is either flushed down a toilet or enters a deep pit latrine. The fact is that urine is a very valuable product - in several ways. It contains a lot of nitrogen and also phosphorus and potassium in smaller quantities, nutrients which are very valuable to plant growth. Simply put, urine is too valuable to waste (Morgan, 2004).

*Urine* is known to contribute the major proportion of the nutrients (N, P and K) in domestic wastewater as compared to faeces which even poses a greater health risk when reused (Höglund, 2001). Research has shown that 50% to 90% of NPK in municipal wastewater is held in *urine.* In handling municipal wastewater which is the only liquid waste stream with high concentrations of nitrogen are sludge dewatering liquid (digester supernatant), containing about 15% to 20% of the total nitrogen load in wastewater, and human *urine* contain about 80% of the total nitrogen load (Larsen and Gujer, 1996; Maurer *et al.,* 2003). Thus separating the *urine* which account for about 1% of the total wastewater flow, and using it as fertilizer makes it possible to utilize most of the nutrient

content of wastewater (Johansson and Nykvist, 2001). In regions with sensitive surface waters, the costs for wastewater treatment are dominated by the conversion and elimination of nitrogen and phosphorus (Maurer *et al*., 2003).

According to Rheiberger (1936), there are comparable levels of creatine, urea and ammonia nitrogens in urine among primates such as man, mangabeys, baboons and chimpanzees. However, he identified sex differences in ceratinine nitrogen coefficients of the male mangabeys, baboons and chimpanzees to be higher than those in the female counterparts. In small cases there was reversal of magnitude seen in the macaques species precluding an assumption as to the validity of the observation.

## 1.1 PROBLEM STATEMENT

Research on the use of urine in agriculture has been done in Sweden, Germany, Switzerland, Burkina Faso, South Africa and Nigeria. In all the studies, it has been established that urine promotes crop yields comparable to those grown on organo-mineral fertilizer and chemical fertilizer (Sridhar *et al*., 2005).

Unfortunately, there has been little or no detailed analysis of the fertilizer ability (i.e. NPK) of human urine in Ghana. Again the influence of sex (gender) on the level of NPK in human urine has received no attention. There is, therefore, the need to research into this area of Ecological Sanitation (ECOSAN), especially under local conditions.

The gender physiologies are different in humans, but this has received little or no attention by Ecosan experts in the use of urine in agriculture.

## 1.2 JUSTIFICATION

With the advent of industries and Ecosan concept in the developing countries, gender urinals are going to spring up. These gender Ecosan urinals can be designed to be collected as composite urine from a point. It is worthwhile that the male and the female urines be analysed, with respect to NPK level, and compare with that of the composite urine to give a better option of Ecosan urinal designs in such institutions. Furthermore, there are some institutions which are gender dominated, for example mining companies, and this calls for the need to analyse the fertilising ability of such urines to enable us know the type of crops that they can support.

There is the need to switch to cheaper and less energy demanding type of fertiliser, urine. This is necessary because Phosphorous is a finite resource, with present recoverable reserves calculated to last for less than 200 years (Larsson *et al.,* 1997), whereas potassium is assumed to last for 300 years (Crowson, 1992). Production of nitrogen fertilisers requires energy, as does the reduction of nitrogen in sewage treatment plants. Oil and gas, the most important energy resources for production of nitrogen fertilisers, have been calculated to last for 40 and 60 years, respectively (WRI, 1992). Turning blind eye to this fact will lead to low agricultural productivity and subsequently, famine in the very near future.

## 1.3 MAIN OBJECTIVE

This study was to separately analyse the concentration of Nitrogen, Phosphorus and Potassium in male and female and composite urine stored over six months and its use in agriculture.

## 1.4 SPECIFIC OBJECTIVES

- To determine the variations in the concentration of NPK levels in human urine due to gender (sex).
- To determine the maturation date of human (gender) urine for agriculture.
- To determine effect of temperature and pH on the yield of NPK levels on stored urine.
- To monitor colour change of stored urine to determine urine maturation date
- To compare urine NPK with NPK in chemical fertiliser in terms of market value in Ghana.

## 1.5 RESEARCH QUESTIONS

- Whose urine has high NPK level? Male or Female?
- Is NPK level in human urine comparable with the levels in chemical fertiliser?
- What is the maturation date of human urine for agriculture?
- What is the colour of matured urine for agriculture?
- What effect has temperature and pH on stored urine?

## 1.6 HYPOTHESIS

- The level (concentration) of NPK in male urine is higher than that in female.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 WATER SCARCITY

Water is a key to development in all its many dimensions. It is estimated that within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity (WHO, 2006). First and foremost, it is an essential element for human survival, and the combination of safe drinking water, adequate sanitation and hygiene is recognized as fundamental to human well-being (UN Secretary General, 2003). According to WHO and UNICEF report in 2005, young children suffer disproportionately without safe water and sanitation services. The report observed that every year, 1.9 million children under five die from diarrhoeal diseases in the world's poorest countries – over 5000 children each day. Poor water and sanitation contribute to almost 90 per cent of these deaths (1.6 million). A baby born in Sub-Saharan Africa is five hundred times more likely to die from diarrhoeal disease than a baby in the developed world.

### 2.2 EUTROPHICATION

Urine is the urban waste fraction containing the largest amounts of nutrients (Wilsenach, 2007; Jönsson, 2001). According to Wilsenach (2007) **urine** contributes most of the nutrients in domestic wastewater, accounting for about 80% of the nitrogen, 50% of the phosphate and 70% of the potassium. The abundant supply of nitrogen, phosphorus and potassium has a fertilizer effect, leading to excessive growth of riverine reeds, water weeds and algae, with a range of knock-on impacts for freshwater ecosystems. Approximately 90% of the sewage in cities in developing countries is today

discharged untreated, polluting rivers, lakes and coastal areas (Winblad, 1997). Urine from pit latrines and septic tanks, which are often not emptied regularly, has the potential to enter the soil and pollute the groundwater (Barre, 2006; Niemczynowicz, 1996).

Algae blooms occur from a process known as eutrophication, which happens due to the excessive dumping of nutrients which are naturally limited in an aquatic environment; namely nitrogen and phosphorus (Mara and Cairncross, 1989). The work by Carlsson (1997) indicates that if algae bloom, as a result of eutrophication, and is excessive enough, it will block sunlight from penetrating the water, which will kill off the aquatic plant life, leading to the reduction of oxygen and the destruction of the natural fauna. Carlsson (1997) has noted in Sweden that the current anthropogenic load of nitrogen and phosphorus to waterways should be reduced by 50% according to the Swedish EPA to safeguard water bodies.



## 2.3 URINE PRODUCTION

Stone *et al*. (1985) have explained that after digestion, amino acids are carried in the blood plasma to be used to build up proteins, as biological fuel and synthesis of a variety of other compounds in the body. The excess amino acids are deaminated by the liver to produce glycogen for storage. The amine group is converted to urea and, principally, excreted in urine by the kidneys. It has been reported that the synthesis rate of mixed (total) muscle proteins is reduced in elderly people (Welle *et al*., 1993; Welle *et al*., 1994; Yarasheski, 1993; Short *et al*., 2003). The work by Short *et al*. (2003) revealed that the decline with age in whole body protein kinetics was evident in both men and women. Protein metabolism, especially in muscle, can be strongly affected by physical activity (Tipton and Wolfe, 1998).

## 2.4 DEFINITION AND HISTORIC USES OF URINE

Urine is the by-product or fluid excreted by the kidneys, transported by the ureters to the urinary bladder where it is stored until it is voided through the urethra. Urine is made up of a watery solution of metabolic wastes (such as urea), dissolved salts and organic materials. Fluid and materials being filtered by the kidneys, destined to become urine, come from the blood or interstitial fluid.

The yellow colour of urine was previously thought to come from gold. A German alchemist, Henning Brand in 1669, tried extracting this gold by distilling fermented urine which led to the discovery of white phosphorus. In 1773 the French chemist Hilaire Rouelle, also discovered the organic compound urea by boiling urine dry. According to Höglund (2001), during the 19th Century urine was stored and used as a detergent for washing clothes in Denmark (Hansen, 1928; Drangert, 1998). In Sweden urine has been used to smear wounds and dry skin and to some extent to drink as therapy (Frode-Kristensen, 1966). Other historic uses of urine include tanning of hides and production of gunpowder (Stenström, 1996).

Other works together with that of Dahlstrom (2007) categorise the uses of human urine into four:

### i. Immune Booster

In the past and even now, there are some people who regularly drink their morning urine in order to boost their immune system. Such individuals believe that reintroducing the body to agents it has already seen reminds the immune system to be prepared the next time. This urine therapy is believed to have benefited personalities like Mohamadas

Gandhi, Jim Morrison, and Steve McQueen. The medicinal properties of urine have been observed and are also used in China as a part of holistic medicine.

In Siberia, to communicate with the spirits, the Koryak people drank the urine of another who has consumed fly agaric (an entheogenic mushroom that is occasionally fatally poisonous), or of one who has in turn drunk urine of like source.



### ii. Skin Treatment

Using urine for skin treatment is much more common than consuming the liquid. Urine can be used as a topical disinfectant on wounds. It can also be used several times a day on a rash or a blister. Blisters and rashes will heal much faster when using urine than when not using urine. Other people use urine to soften dry skin or to alleviate eczema. There are some that give their tired, dry feet daily urine soak (Dahlstrom, 2007).

### iii. Bleaching Agent

The ancient Romans used urine as a bleaching agent for cleaning clothes and even isolated reports as a teeth whitener. According to Dahlstrom (2007), some people still use urine and consider it much more natural than a chemical bleaching detergent.

### iv Agricultural Fertiliser

For over 4000 years, people in many countries of Eastern Asia and the Western Pacific have been applying human excreta to the land, which has helped to maintain soil fertility (Mara and Cairncross, 1989). Urine is rich in nutrients that can be used in agriculture and

horticulture. Urine contains the major plant nutrients (N, P and K) in proportions suitable for plants and the nutrients are readily available since the major proportion is present in mineral form (Tidåker *et al.*, 2005).

## 2.5 ECOSAN CONCEPT

Urine in all wastewater is less than 1%, yet it contributes the bulk of the nutrients. Diverting and treating urine separately from wastewater streams ensures effective nutrients recovery. This would permit the construction of smaller wastewater treatment plants, designed to optimize the degradation and retention of dissolved and particulate organic matter in wastewater (Larsen and Lienert, 2007; Tidåker *et al*., 2007).

Urine is usually collected in a source separating toilet (Stintzing *et al*., 2001). In urine separating systems, nitrogen discharge into water is reduced by about 60% irrespective of the type of treatment (Johansson and Nykvist, 2001). In the case of phosphorus, the reduction depends on the type of treatment of the wastewater as a whole. Where the treatment plant ensures efficient phosphorus removal the reduction is marginal, but where the plant does not provide phosphorus removal the reduction may be almost 50%.

EFMA (1999) has shown that of the fertilizer consumed in the EU, 12% of N, 6% of P and 10% of K could be recovered from urine maximally. This agricultural nutrient value of urine is embraced by ecological farmers in Sweden (Lindén, 1997; Kirchmann and Pettersson, 1995; Kvarmo, 1998).

There is also the likelihood of cross-contamination of urine with the use of urine separating (ECOSAN) toilets, but pure urine is sterile (Weinmaster, 2007). The World Health Organisation has approved the use of urine in agriculture after sanitising through

storage (Barre, 2006; WHO, 2006). The low risk of transmission of infections through urine further supports the implementation of urine-separation. The higher temperature in many of the developing regions would probably be beneficial for the inactivation of enteric pathogens in the urine (Höglund, 2001).

The present-day treatment of mixed wastewater has several shortcomings: high amounts of resources – including drinking water – are consumed, valuable nutrients such as phosphorus, nitrogen or potassium are lost to the environment and micropollutants are eliminated insufficiently. Source separation of urine, which contributes most of the nutrients to wastewater, is a promising alternative (Larsen *et al.*, 2001; Udert, 2003). However, the nutrients in urine might not be available in a convenient form for fertilisers. Furthermore, urine contains micropollutants such as synthetic hormones, pharmaceuticals and their metabolites. These substances are mainly excreted via urine (Alder, 2002) and may be harmful to the ecosystems and human health (Daughton and Ternes, 1999). Today, many micropollutants reach the aquatic environment, because their degradation in wastewater treatment plants is poor (Ternes, 1998).

Urine from healthy persons is quite stable and hardly contains any microorganisms. This is because according to Schönning and Stenström (2004) undiluted urine provides a harsher environment for micro-organisms, increasing the die-off rate of pathogens. Significant changes in urine composition are slow and affect mainly the organic fraction (Colombo, 1994). The contact with bacteria cannot be prevented in normal NoMix toilets or waterless urinals (Udert *et al.*, 2006). Urea hydrolysing bacteria have the strongest effect on the urine composition. Since they are ubiquitous (Mobley and Hausinger, 1989), it takes little time until they occur in urine collecting systems. Their enzyme urease

catalyses the hydrolysis of urea to ammonia and bicarbonate. This process involves a strong pH increase,

$NH_2$ (CO) $NH_2$ + $2H_2O \rightarrow NH_3$ + $NH_4^+$ + $HCO_3^-$ when stored, urea is subject to chemical hydrolysis and biological decomposition (Hanaeus *et al.*, 1996). The ammonium is in equilibrium with the dissolved ammonia.



## 2.6 NPK CONCENTRATION IN URINE

In fresh urine, about 85% of nitrogen is fixed as urea and about 5% as total ammonia (Udert *et al.*, 2006). The rest of the nitrogen compounds are mainly creatinine, amino acids and uric acid (Ciba-Geigy, 1997). After urea hydrolysis, total ammonia accounts for 90% of the nitrogen in stored urine. Due to the increased pH, the concentration of ammonia ($NH_3$) is very high. Struvite ($MgNH_4PO_4$) precipitation is controlled by pH, the degree of supersaturation, temperature and the presence of other ions in solution (Doyle and Parsons, 2002). Struvite has a low solubility in water (c: a 0. 02 g/100ml water), but highly soluble in dilute acidic solutions and highly insoluble in alkaline solutions (Weast *et al.*, 1981). So the most favorable environment for struvite precipitation occurs at pH intervals around 9-10 (Mohajit *et al.*, 1989). In public facilities, lower concentrations can also be explained by the absence of highly concentrated early morning urine (Udert, 2007).

Metabolism records of dairy cows fed widely on differing types of rations were studied by Harshbarger and Nevens (1938) with reference to the distribution of nitrogen, potassium, and phosphorus between faeces and urine. The distribution was affected by (1) character of the ration; (2) amount of food intake; and (3) level of milk yield. They

observed that expressing in terms of the amounts of faeces and urine, the urine contained one-third to one-half of the nitrogen, three-fourths or more of the potassium, but only 1 to 4 per cent of the phosphorus. In terms of the nitrogen and of the potassium in the feed consumed, the urine contained one-fourth to one-third of the nitrogen and one-half to three-fourths of the potassium (Harshbarger and Nevens, 1938).

According to Jönsson *et al.* (2000) separated urine contains a great part of the total nutrients in normal sewage; 80% of N, 55% of P, and 60% of K in just 1.5% of the volume of the sewage. The studies conducted by Ek e*t al.* (2004) indicate that Reverse Osmosis (RO) treatment of $1m^3$ urine will produce 200 litres of concentrate at pH 7. This will contain 95% of the nitrogen, 90% of the phosphorus (some losses in the pre-filtration), almost all other salts, and also non desired compounds like heavy metals, hormones, and drug residues (Ek *et al.*, 2006). In their method of evaporation and drying, preliminary experiments showed that the value of pH should be kept below 6 to give more than 70% of N in the concentrate of the urine. However, in this treatment, $1m^3$ of urine would give 50 litres of concentrate with 95% of N and almost all other components. An experiment, carried out by Gethke *et al.* (2006), to recover phosphorus from human urine, the decomposition processes during this period were observed. Throughout the storage the pH value and the concentration of ammonia nitrogen increased, whilst the concentration of phosphate phosphorus decreased. They argued that the concentrations of phosphorus and nitrogen in human urine are dependent on the eating habits. Due to this the urine of a European is not always comparable to e.g. the urine of an Asian. In the work of Gethke *et al.* (2006), the proportions of nitrogen and phosphorus in their NOMIX urine sample were >80% and >50% respectively.

Typical values for the major nutrients (NPK) in adult urine had been documented by Ciba Geigy (1977) as 80%, 50-80%, and 80-90% respectively. According to Werner *et al.* (2005) 500 L of urine per capita per year contains NPK level of 87%, 50% and 54% respectively. They have also documented that the estimation of nutrients (NPK) excretion per capita vary from country to country and even within the same region, according to food habits of people, as also found in Jönsson and Vinnerås (2004).



**Table 2.6.1 Estimated excretion of nutrients per capita in different countries**

| Country | Nitrogen Kg/cap/yr | Phosphorus Kg/cap/yr | Potassium Kg/cap/yr |
|---|---|---|---|
| **China, total** | **4.0** | **0.6** | **1.8** |
| Urine | 3.5 | 0.4 | 1.3 |
| Faeces | 0.5 | 0.2 | 0.5 |
| **Haiti, total** | **2.1** | **0.3** | **1.2** |
| Urine | 1.9 | 0.2 | 0.9 |
| Faeces | 0.3 | 0.1 | 0.3 |
| **India, toal** | **2.7** | **0.4** | **1.5** |
| Urine | 2.3 | 0.3 | 1.1 |
| Faeces | 0.3 | 0.1 | 0.4 |
| **South Africa, total** | **3.4** | **0.5** | **1.6** |
| Urine | 3.0 | 0.3 | 1.2 |
| Faeces | 0.4 | 0.2 | 0.4 |
| **Uganda, total** | **2.5** | **0.4** | **1.4** |
| Urine | 2.2 | 0.3 | 1.0 |
| Faeces | 0.3 | 0.1 | 0.4 |

Source: Jönsson and Vinnerås, 2004.

Lennartsson and Ridderstolpe (2001) have observed that the exact nutrient content of urine depends on the food consumption; Swedish researchers have reported that the NPK

ratio in urine is 12 - 1.1 – 3.3. The proportion of useful plant nutrients in urine will vary a little. According to Wolgast (1993), as cited in Morgan and SEI (2004), one litre of urine contains 11 g nitrogen, 0.8 g phosphorus and 2 g potassium. That is a ratio of NPK of about 11:1:2. If 500 litres of urine are produced by each person per year, that amounts to the equivalent of 5.6 kg nitrogen, 0.4 kg phosphorus and 1.0 kg potassium. The actual amounts of these minerals will vary from one person to another and also from country to country depending on the national diet. The more protein consumed, the more nitrogen is excreted. Thus in dealing with urine as a potential supplier of plant nutrients, one must accept that it has a very high, but variable level of nitrogen (and also common salt). The ratio of the main plant nutrients (NPK) is approximately 11:1:2, which is not ideal for growing most plants, especially in the early stages of their growth (Morgan and SEI, 2004).

## 2.7 GENDER DIFFERENCES IN URINE NPK

The studies conducted by Harshbargar and Nevens (1938) revealed that cows fed with different rations excreted a range of NPK percentages in their urines ; 29-72%, 0.5-40%, and 22-89% respectively. The study also showed that dry cows liberally fed and cows milking at a low level of production excreted a large proportion of Nitrogen (N) and Potassium (K) of the feed in the urine than cows producing large amounts of milk. The mammary gland acts as an excretory organ passing through from the blood to the milk end products of protein metabolism (Taylor, 1922). This relates to the work of Cuaron *et al*. (1983) which indicated that gravid gilts retained more nitrogen than did the non-gravid gilts.

Some suggestion of sex difference in the creatinine nitrogen coefficients of primates (Mangabeys, Baboons and Chimpanzees) on controlled diets had been observed by Rheinberger (1936). In these species, the coefficients for the male were higher than those for the female, but there was a reversal of magnitude seen in Macaques. High creatinine nitrogen coefficients as compared with normal range for man were observed in all cases except the gibbon.



In analysing sex difference in urine with respect to lysine and α - amino nitrogen, the mean excretion of α - amino nitrogen whether "total," "free," or "bound," was higher for females than for males ( Thompson and Abdulnabi, 1950). When expressed in mg/day, this difference was not statistically significant at 10% level but differed significantly when expressed in mg/d/kg body weight in each case. The study also revealed that the amount of urinary α - amino nitrogen excreted by females was much more variable than in the case of males. However, a correlation between the body weight and excretion of α - amino nitrogen showed much more significant correlation in the males than in the females. The study did not show marked sex difference in the urinary excretion of total lysine. The mean values for female subjects if expressed as mg/d/kg of body weight was higher than that for males but this difference was not significant at 10% level. Thompson and Abdulnabi (1950) inferred that it was quite unlikely that the observed differences between the male and female subjects could be attributed to diet. This was supported by the work of Thompson and Kirby (1949) covering four amino acids and identifying no significant variation in urinary excretion with change in diet. A related work (Kirsner *et*

*al.*, 1949) indicated no correlation between urinary excretion and diet in the case of six out of eight amino acids studied.

It is, thus, possible that the higher rate of amino acids excretion observed in females might be correlated with the sexual cycle, although no evidence of this was observed in the case of the four amino acids studied by Thompson and Kirby (1949) when samples from the same subjects were taken at various stages of the menstrual cycle.

Volpi *et al*. (1998) reported that Leucine oxidation per unit of fat free mass was 18% higher in young men than young women. Together, according to Short *et al*. (2003), these data suggest that men oxidize a small, but significantly higher, proportion of Leucine at rest although the reason for this difference and the physiological significance is not yet clear.

On a controlled diet and exercise a study by Bodwell *et al*. (1979), revealed that among the young women, contraceptive users had higher values than non-users for total urinary and urea nitrogen, gram urinary Nitrogen per gram creatinine and faecal nitrogen but the differences were not significant. The results also indicated that the total urinary nitrogen and total obligatory nitrogen losses were lower for non- contraceptive users than for the young men. However, the pooled value of users and non- contraceptive users for urinary nitrogen excretion in the young women was not significantly different from the values observed for either older men or young men. The work showed that both young women and young men had significantly higher nitrogen excretion per gram creatinine than the older men.

## 2.8 URINE TEMPERATURE AND pH

The work of Aragundy (2005) showed that urine sample stored in a dark place of constant 18 $^{o}$C and 19.5 $^{o}$C environmental temperature had initial pH of 7. This pH increased to 9 on the 4$^{th}$ month storage period with an associated colour change to orange in the 3$^{rd}$ month but light orange on the 4$^{th}$ month. In another set-up, a full transparent bottle of urine was kept in a bright place of 24 $^{o}$C - 25 $^{o}$C with initial pH of 7.5. The temperature reached 29.5 $^{o}$C in 2 months and the pH was 9. The colour varied very fast as compared to the one in the dark. The final colour at the pH of 9 was red orange colour. Aragundy (2005) also noticed that when a bottle of urine stored in bright place of 18 $^{o}$C temperature, the initial pH was 6.5. The pH of 9 was achieved after 8 months storage with the maximum temperature reaching 21 $^{o}$C. However, the colour changes were imperceptible during the first five months. The colour started turning to orange and finally to orange colour, but after one year the colour was light brown.

# CHAPTER THREE

## 3.0. MATERIALS AND METHODS

### 3.1. URINE HARVESTING SYSTEM

A urine harvesting system was designed and built at the Department of Theoretical and Applied Biology (TAB) premises of the Kwame Nkrumah University of Science and Technology (KNUST) campus in Kumasi, Ghana.

**Plate 1. Front view of the ECOSAN urinal**

The urine harvesting system was built with locally available materials (Bamboo sticks, wood, cement and sand), separately for men and women. Each unit measured 1.50 m x 2.00 m. A roof was provided. A substructure receptacle, each, was built with cement blocks (Shayo, 2003) for both sexes. A 70 cm tall shower rose with 10 cm diameter was erected in the male urinal (plate 2). Connected to the pedestal was a PVC pipe which collects urine into an 8 litre plastic

container situated behind the urinal. The pedestal for the women urinal was lower so they could urinate without difficulty (Plate 3). It was also connected with a PVC pipe which collects the urine into an 8 litre container also situated behind the urinal. The flow of urine was controlled by gravity (Sridhar, *et al.* 2005), (Plates 4 and 5).

**Plate 2. Male urinal receptacle**

**Plate 3. Female urinal pedestal**

**Plate 4. PVC pipe draining male urine into an 8 L container.**

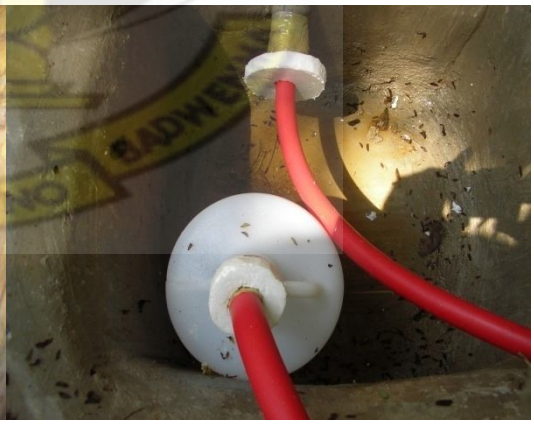

**Plate 5. PVC pipe draining female urine into an 8 L container.**

## 3.2.SAMPLING

### 3.2.1. Collection and Storage of Urine

Urine was collected in well labeled 8 L containers and stored in tightly capped containers (Plates 6 and 7) in a Green-house, located at TAB. Due to the willingness of both students and workers to patronize the urinal and to promote the intended research due to the sensitization campaign amongst the students and workers, about 16 litres of urine was collected at the end of every 48 hour period. The collected urine was stored for periods of 1, 2, 3, 4, 5 and 6 months under normal atmospheric temperature conditions in the Green-house (temperature ranged between 25 $^{o}$C and 33 $^{o}$C). The urine samples were kept in tightly sealed plastic bottles to prevent the escape of nitrogen (in the form of ammonia) and thus reducing its fertilizing capabilities (Winblad *et al*., 2004).

The urine was stored in transparent plastic bottles (Aragundy, 2005) at the green house for six months. The urine was labeled Male-1 and Female-1 for the first sample collected. A similar urine collection was made the following week and also stored. The second sample collected was labeled male-2 and female-2, respectively.

**Plate 6. Urine collection**

**Plate 7. Urine storage**

### 3.3 METHOD OF ANALYSIS

The temperature, colour and pH of the freshly collected urine samples were recorded separately for the male and female before storage. Triplicate freshly collected male and female urine samples were analysed separately for Nitrogen (N), Phosphorus (P) and Potassium (K). These analyses were repeated every month for six months (December, 2007-May, 2008).

The NPK analysis was carried out at the Soil Science Laboratory of the Faculty of Agriculture, KNUST. The total nitrogen in the urine was determined by Kjeldahl method (Kjeldahl, 1883). However, a direct distillation method was also used using Kjeltec System, 1002 Distilling Unit. This was because the digestion of the urine prior to distillation led to a significant loss of nitrogen in the sampled urine.

### 3.3.1 Nitrogen determination

To each of 10 ml triplicate male (M), female (F) and composite (C) (equal volumes of male and female urine) urine samples, a 15 ml 40% NaOH solution was added. Each mixture was distilled against 10 ml of 4% Boric acid in a Kjeltec distilling system for 4 minutes. The NaOH liberated the total nitrogen in the urine into the pink coloured Boric acid till green colour was produced. This green distillate was then titrated against 0.1M HCl until a pink colour was formed (that is the end point). The titre value was multiplied by a factor of 0.713 (plant/animal factor) to obtain %N.

Some of the samples were digested with $H_2SO_4$ in Kjeldhal chamber before distillation was carried out. The corresponding %N values were, however, relatively low. The method employed was as described by Bremner *et al.* (1982), and the protocol followed in the Soil Science laboratory.

### 3.3.2 Phosphorus determination

The stored urine was well shaken before phosphorus analysis was carried out. The Bray P1 method (Bray and Kurtz, 1945) using Bray P1 reagent was employed in this analysis. A few drops (1ml) of a molybdate indicator was each added to a 10 ml each of triplicate urine samples of M, F and C. Distilled water was added to each mixture to a mark of 100 ml and allowed to stand for 15 minutes for colour development. The light intensity of the concentrated sample solution was measured as % transmittance using a Jenway Calorimeter /Spectrophotometer at a wavelength of 600 nm. The % transmittances (T) were then converted to absorbance (2-logT) and the corresponding

concentration values read from the graph readings. The values of graph readings obtained were multiplied by a factor of 0.05 (plant/animal factor) to percentages.

### 3.3.3 Potassium Determination

Potassium was analysed using the Flame Photometry method described by Knudsen *et al*. (1982). The Jenway photometer machine was calibrated by using 5 different concentrations of Na-K standard solution. The values obtained were used to plot a standard graph. The machine readings of the urine samples were converted to part per million (ppm) from the calibrated graph. One millilitre each of the triplicate urine samples of M, F and C was diluted to 500 ml with distilled water. An oxyacetylene gas was turned on to burn to a fine blue flame after standardisation. After stabilizing the machine to 0.00 mark value, 10 ml each of the now 500 ml, triplicate samples was read from the instrument upon aspirating potassium ions ($K^+$) into the device for combustion. The instrument values were read on the said graph as part per million (ppm). Each graph value was divided by a factor of 50 to convert them to percentages.

### 3.3.4 pH determination

The pH of the samples was measured using Suntex pH/mV/ Temp. meter, SP-701. A pH meter probe was immersed in a 20 ml, successively, of each of the triplicate urine samples of M, F and C. The probe was rinsed with distilled water each time it was dipped in a sample. The pH values were recorded from the monitor.

### 3.3.5 Temperature determination

The temperature was measured jointly by mercury thermometer and pH/temp. meter. The thermometer was rinsed each time it was immersed in the samples, and values recorded in degree celcius ($^{o}$C).

### 3.3.6 Colour change

The colour of the stored urines in the transparent bottles was read by dipping paper sticks in the samples and compared with colour chart each time a sample was taken. However, the colour changed when the sample bottles were shaken before samples taken for analysis.

### 3.3.7 Statistical Analysis

The SPSS software was employed for testing if the means on a dependent variable were significantly different among groups. The total % yield of nitrogen, phosphorus and potassium of the stored urine over the 6-month study period were analysed. This gave an idea of when the urine could be used for crops that require proportionally high percentage of nitrogen, phosphorus or potassium. The significant difference of NPK between male and female urines was also established for each month over the 6 months study. If the overall ANOVA is significant and a factor has more than two levels a post-hoc multiple comparisons follow up test was carried out using Least Significance Difference (LSD) or Duncan's Multiple Range Test (DMRT). In all cases, significance was determined at the 95% confidence level. One-way analysis of variance was

performed to assess the differences among means, with a significance level of 5% ($p < 0.05$).

A Pearson correlation was used to establish either positive or negative relationship between maturation period and N, P or K. An association between temperature or pH and the NPK was determined as well.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1.0 Physical parameters of different sources of urine

### 4.1.1 Temperature of the stored urine

Mean temperature of the male urine increased over storage time. The increase was statistically significant from month two to three and also the decrease from month four ($p= 0.00$), (Appendix 1aa). A similar temperature trend was observed for the female urine (Table 4.1). Temperature changes in the composite urine did not follow any defined pattern (Appendix 1cc).

There were strong positive and significant correlations between the male ($r = 0.720$, $p < 0.01$), and female ($r = 0.789$, $p < 0.01$) urine mean temperatures and storage period. The mean temperature of the composite urine, however, moderately correlated positively with storage time ($r = 0.397$, $p < 0.05$), (Appendix 1d, e and f respectively).

### 4.1.2 pH of the stored urine

Mean pH of the male urine remained fairly unchanged until after the fourth month when a significant decrease was observed (Table 4.1). Mean pH of the female urine however increased slightly after month one, but significantly decreased after month four. The mean pH of the composite urine assumed a similar trend and significant patterns as observed in female urine (Table 4.1).

A Pearson correlation analysis indicated that there was a significantly strong negative correlation between mean pH levels of male ($r = -0.807$, $p < 0.01$) and composite ($r = -0.568$, $p < 0.01$) urine over storage time. However, the female mean pH related

moderately negative to storage time, but insignificantly ($r = -0.299$, $p > 0.05$), (Appendix 1d, e and f respectively).

### 4.1.3 Colour of the stored urine

The male urine colour over the storage period changed from light greenish brown through a slight shade of colours to greenish brown (Table 4.1). The colour of female urine, however, changed from light yellowish brown to an intermediary shade of colours and finally to a brownish colour over the 6 -month storage period (Table 4.1). The composite urine colour changed gradually from light greenish brown to brown (Table 4.1).

**Table 4.1 Mean physical properties of human urine over a 6 month storage period**

| Storage time (month) | Male[b] | | | Female[b] | | | Composite[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | T °C[a] | pH[a] | Colour | T °C[a] | pH[a] | Colour | T °C[a] | pH[a] | Colour |
| December | 24.80a | 8.795c | Light greenish brown | 24.70a | 7.59a | Light yellowish brown | 27.80b | 8.12b | Light greenish brown |
| January | 24.45a | 8.80c | Greenish brown | 24.47a | 8.78b | yellow | 24.59a | 8.82c | Light greenish brown |
| February | 27.47b | 8.75c | Dark greenish brown | 27.03b | 8.80b | Orange yellow | 27.55b | 8.67c | Light greenish brown |
| March | 28.92c | 8.78c | Greenish brown | 29.18d | 8.72b | Orange | 29.12c | 8.68c | Light greenish brown |
| April | 28.22bc | 7.45b | Greenish brown | 27.97c | 7.75a | Light brown | 28.15bc | 7.64b | Light brown |
| May | 27.92bc | 7.02a | Greenish brown | 28.40cd | 7.20a | Brown | 27.97b | 7.04a | Brown |

[a]Average of six replications (N=108)
[b]Any two means having a common letter are not significantly different at the 5% level of significance.

### 4.2 .0 Nutrients level in human urine

#### 4.2.1 Nitrogen concentration in urine

The storage of male urine recorded incremental levels of nitrogen. However, the levels decreased after month four. Nevertheless, none of the changes observed was significantly different over the storage period for both digested and direct nitrogen contents (Fig. 4.2.1a).

The female urine nitrogen increased gradually until a decrease was observed after month four. However this decrease was only significant in the digested urine. Secondly, there was a significant increase from month one in both the direct and digested female urine nitrogen. A DMRT analysis, of direct female nitrogen, revealed that there were no significant changes over the storage period except the month one (Table 4.2.1b).

The composite urine nitrogen increased gradually but decreased after month four. None of the changes was, however, significant except the sharp rise from month one of the digested composite urine nitrogen (Table 4.2.1c).

There was a moderately positive relationship between the direct female urine nitrogen content and the storage period($r = 0.390$, $p < 0.05$), (Appendix 1e). However the digested female and composite nitrogen insignificantly correlated weakly to storage time ($r = 0.032$, $p > 0.05$), and ($r = 0.278$, $p > 0.05$) respectively.

#### 4.2.2 Phosphorus content in stored human urine

Phosphorus content in male urine increased gradually until month four when a significant rise was observed but decreased significantly again from month five to six (Table 4.2.1a). Contrastingly, levels in female urine decreased significantly until after

month four when a significant increase was recorded and then decreased again from month five (Table 4.2.1b). Trends in composite urine were as observed for female urine (Table 4.2.1c).

A Pearson correlation analysis revealed that male, female and composite mean phosphorus levels associated significantly positive to the storage time ($r = 0.582$, $p < 0.01$), ($r = 0.631$, $p < 0.01$) and ($r = 0.703$ $p < 0.01$) respectively.



### 4.2.3 Potassium content in stored urine

Potassium levels in all the urine sources, generally, followed a decrease - increase - zigzag fashion successively over the six-month storage period. Among all the three sources of urine, none of the changes in potassium levels was significantly different from succeeding months of storage period (Table 4.2.1a, b and c). A Pearson's correlation analysis revealed no significant relationship between the potassium levels in all the urine sources with the storage time (Appendix 1d, e and f).

**Table 4.2.1a NPK levels in male urine over a six -month storage period**

| Storage period (months) | Digested Nitrogen (%)[x] | Direct Nitrogen (%)[x] | Phosphorus (%)[x] | Potassium (%)[x] |
|---|---|---|---|---|
| **December** | 2.83a | 23.597a | 0.5652a | **49.9000a** |
| **January** | 3.70a | 32.68a | 0.7138a | **44.4167a** |
| **February** | 3.92a | 34.36a | 0.6380a | **45.9467a** |
| **March** | 4.05a | 38.00a | 1.7267c | **42.2500a** |
| **April** | 3.86a | 34.42a | 1.5443c | **46.0617a** |
| **May** | 2.88a | 25.02a | 1.0037b | **42.1833a** |

[x]Average of six replications (n= 36)
Any two means having a common letter are not significantly different at the 5% level of significance.

**Table 4.2.1b NPK levels in female urine over a six -month storage period**

| Storage period (months) | Digested Nitrogen (%)[x] | Direct Nitrogen (%)[x] | Phosphorus (%)[x] | Potassium (%)[x] |
|---|---|---|---|---|
| December | 2.43a | 12.56a | 0.5540b | 58.1333a |
| January | 7.33bc | 34.18b | 0.2050a | 50.0400a |
| February | 7.34bc | 34.33b | 0.3822a | 54.5833a |
| March | 7.80c | 36.32b | 1.5557d | 56.0000a |
| April | 6.04b | 33.29b | 1.5540d | 60.4667a |
| May | 3.42a | 30.93b | 1.0300c | 52.5333a |

[x]Average of six replications ( n= 36)
Any two means having a common letter are not significantly different at the 5% level of significance.

**Table 4.2.1c NPK levels in composite urine over a six -month storage period**

| Storage period (months) | Digested Nitrogen(%)[x] | Direct Nitrogen (%)[x] | Phosphorus (%)[x] | Potassium (%)[x] |
|---|---|---|---|---|
| December | 2.53a | 20.34a | 0.5770b | 46.3333a |
| January | 4.36b | 34.25a | 0.3028a | 45.4333a |
| February | 4.56b | 36.15a | 0.3872a | 52.3000a |
| March | 4.58b | 36.01a | 1.5734d | 46.9333a |
| April | 4.13b | 32.38a | 1.4607d | 52.0000a |
| May | 4.27b | 31.65a | 1.1790c | 55.9667a |

[x]Average of six replications ( n= 36)
Any two means having a common letter are not significantly different at the 5% level of significance

### 4.2.4 N-P-K proportions in different sourced urine

Pooled mean nitrogen concentration in the male urine was 31.35%. In the digested urine, however, the proportion was 3.54%. The phosphorus and potassium contents in male urine were 1.03% and 45.13% respectively. The percentage composition of N-P-K in the male urine was 31.35(3.54)-1.03-45.13. The male urine nitrogen correlated insignificantly to the phosphorus level ($r = 0.161$, $p > 0.05$) but significantly positive to male urine potassium content ($r = 0.831$, $p < 0.01$). The phosphorus level in the male urine insignificantly correlated weakly negative to the potassium content ($r = - 0.118$, $p > 0.05$). The digested male urine nitrogen significantly correlated strongly positive to potassium ($r = 0.838$, $p < 0.01$) but insignificantly to phosphorus ($r = 0.076$, $p > 0.05$).

There was no significant correlation between the male urine phosphorus level and the potassium level ($r = -0.118$, $p > 0.05$), (Appendix 1d).

Pooled mean nitrogen in the female urine was 30.27% and the digested sample was 5.73%. Phosphorus and potassium levels were 0.88% and 55.29%, respectively. The N-P-K composition in the female urine was 30.27(5.73)-0.88-55.29. The nitrogen concentration in the female urine associated insignificantly with the phosphorus ($r = 0.084$, $p > 0.05$) level but significantly with the potassium level ($r = 0.520$, $p < 0.01$). However, the female urine phosphorus content related insignificantly weakly negative to the potassium level ($r = -0.097$, $p > 0.05$). The digested female urine nitrogen had no significant correlation with the phosphorus ($r = 0.024$, $p > 0.05$) and potassium level ($r = -0.081$, $p > 0.05$). The phosphorus correlated insignificantly with the potassium ($r = -0.098$, $p > 0.05$), (Appendix 1e).

The composite urine had a mean pooled nitrogen concentration of 31.80% and the level of nitrogen in the digested composite urine was 4.07%. Mean pooled phosphorus content in the composite urine was 0.91% and mean potassium 49.72 % (Fig 4.2). The percentage composition of N-P-K in the composite urine was 31.80% (4.07) -0.91-49.72. The composite urine nitrogen correlated insignificantly to phosphorus ($r = 0.075$, $p > 0.05$) but strongly positive to potassium level ($r = 0.749$, $p < 0.01$) just as in the digested composite urine ($r = 0.109$, $p > 0.05$), ($r = 0.735$, $p < 0.01$) respectively. However, the composite urine phosphorus level related insignificantly weakly negative to potassium ($r = -0.041$, $p > 0.05$). This was also true in the digested composite urine ($r = -0.048$, $p > 0.05$), (Appendix 1f). The mean pooled NPK level in female urine was higher than was in male urine; however none of the differences was significant (Table 4.4.2).

**Table 4.4.2. Relative percentage ratio of NPK in different sourced urine**

| Urine source | Nutrient level (%) | | |
|---|---|---|---|
| | N | P | K |
| Male | 30.4 | 1.0 | 43.7 |
| Female | 34.4 | 1.0 | 62.8 |
| Composite | 34.8 | 1.0 | 54.4 |

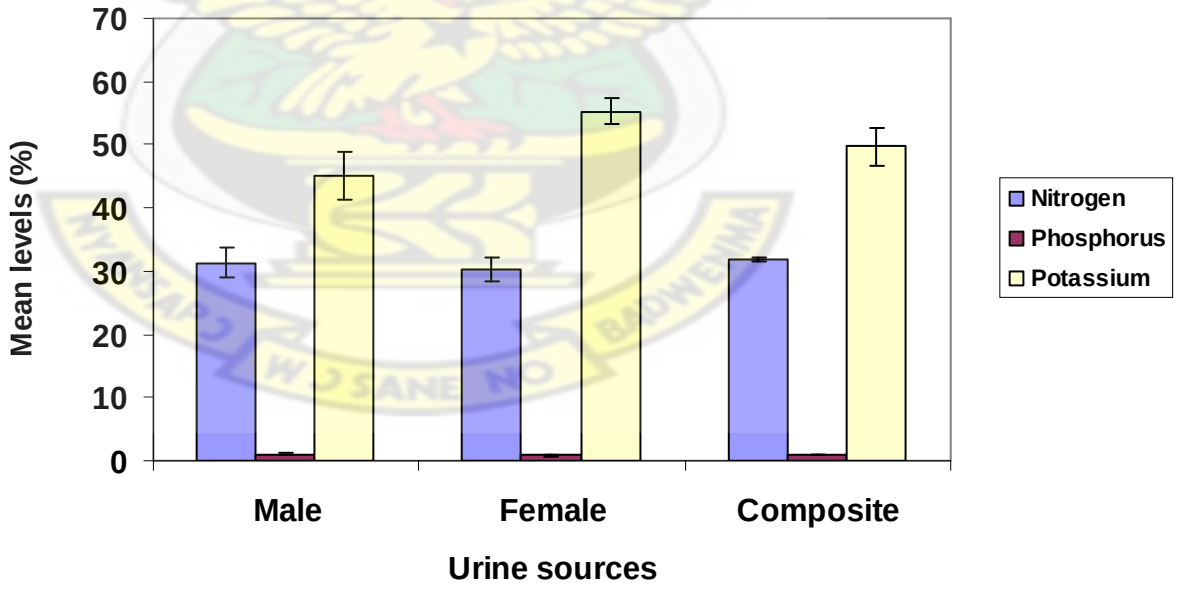


**Fig. 4.2 Nutrients content in different sources of urine**

### 4.3 Gender yield significance

The female digested urine nitrogen was significantly higher than that of the male from month two to month five. However, the male urine phosphorus level was significantly higher than the level in the female urine in month 2 and 3 (Appendix 2a). The pH of the male urine was only significantly higher than the female urine pH in month one. The results also revealed that both digested and direct urine nitrogen correlated strongly positive to potassium throughout the study period.

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 TEMPERATURE OF URINE

The results of the study indicate that mean temperatures for male and female urine were strongly dependent on storage time ($r = 0.720$, $p < 0.01$), ($r = 0.789$, $p < 0.01$) respectively. However, composite urine temperature related moderately to the storage time ($r = 0.397$, $p < 0.05$). This suggests that decomposition of urine or urea produces change in temperature. Secondly, fresh urine has a relatively lower temperature than stored urine. It is likely that the environmental temperature influences the decomposition and maturation of urine (Aragundy, 2005). It may also be that the chemical hydrolysis produces the internal heat change instead of the biological decomposition of urea.

Contrary to what occurred in male urine, both the temperature and urea hydrolysing bacteria may have contributed to the decomposition of female urine. This is likely so since both male and female urine were subjected to the same conditions. It is also possible that the hydrolysing bacteria were more abundant in the female urine than in the male urine. This assumption is made because bacteria urease only speeds up the variance of N, P and pH (Gethke *et al*., 2006), hence by extension associated parameters like temperature.

### 5.2 pH OF STORED HUMAN URINE

Although the pH of the male urine fairly decreased from month 1 to 6 of the storage period, a significant decrease was observed only after month 4. This is in sharp contrast to the work of Gethke *et al.* (2006). Maurer (2007) and Udert (2003) quoted a pH of 6.2

for undiluted fresh urine compared to 8.8 in this study. There is an inference from the work of Aragundy (2005) that the initial pH of urine relates to the location and the environmental temperature of the place of storage. Fresh urine as used in that study was not defined; however, fresh urine in this work was 2 days old. The reason for the relatively high pH in this work may be due to high rate of decomposition within a short storage time. The maturation time of urine, according to Aragundy (2005), is obtained when the pH is 9. This is a suitable pH for struvite precipitation (Mohajit *et al.*, 1989; Gethke *et al.*, 2006). In one of Aragundy's set-ups this pH was achieved on the $4^{th}$ month of storage, which is consistent with the current results at slightly lower pH of 8.78 in male urine.

The mean pH of the female urine of 7.59 increased from the month one to month three, but month four in the composite urine, and then decreased gradually to month six. The drop recorded from the month 3 to 4 was not significant. The increase is consistent with increases in pH over storage period. It appears as though the maximum decomposition of urine, with pH indication, occurred at month four but slowed down later. However the pH, insignificantly, correlated negatively to storage time. This further indicates that the inherent decomposition of the female urine can affect the pH irrespective of the storage time.

## 5.3 COLOUR OF HUMAN URINE

Changes in the colour of urine over the storage period varied from light greenish brown to greenish brown in males, light yellowish brown through yellowish orange to brown in females and light greenish brown to brown in composite urine. The period of

much activity of female urine had orange colour. This is consistent with two of the Aragundy's (2005) set-ups where urine was kept in the dark constantly at 18 $^{o}$C as well as the one kept in a bright place of 18 $^{o}$C over an 8 months storage period. It is important to note that he did not define the urine as male or female. Turbidity increases in stored urine due to the growth of bacteria (Baer, 2002). This may affect the colour of stored urine.

It thus appears that matured male and composite urines have greenish-brown whilst that of the female urine is orange colour at urine maturation.

### 5.4.0 N P K LEVELS IN URINE

#### 5.4.1 Male urine quality

Nitrogen level in male urine over the six month storage period increased from the 1$^{st}$ to the 4$^{th}$ month and decreased thereon to the 6$^{th}$ month. The increase was not significant. This may be ascribed to slow rate with which the male urea hydrolysis or decomposes over the six months storage period due to low level of hydrolysing bacteria.

The results showed that the phosphorus level in the male urine increased significantly from storage month one to four and finally decreased on month six. The pH increase triggers the precipitation of struvite ($MgNH_4PO_4 \cdot 6H_2O$), hydroxyapatite ($Ca_5(PO_4)_3(OH)$) and occasionally calcite ($CaCO_3$) (Udert *et al.*, 2003b; 2003c; Ek *et al.*, 2006). Measurements and simulations showed that in undiluted urine about 30% of the soluble phosphate is incorporated in the solid phase of the precipitates (Udert *et al.*, 2003a; 2003b). However, Gethke *et al.* **(**2006) indicated that increased pH accompanied decreased concentration of phosphate phosphorus in stored urine. The present work,

however has decreasing pH and increasing phosphorus up to month 4, and thus conforms to that of Gethke *et al.* **(**2006). Since there was a significant decrease in the male urine pH and decreased phosphorus level after month four, this is consistent with the opposite of the observation made by Udert *et al*., 2003b; 2003c. This is an indication that the yield of phosphorus is affected by pH, and that urine samples must be thoroughly shaken before phosphorus analysis is carried out. The present work also indicates that the phosphorus yield in stored male urine is affected by storage time ($r = 0.582$, $p < 0.01$) and temperature ($r = 0.674$, $p < 0.01$). The relatively small percentages of phosphorus levels may have been due to the absence of highly concentrated early morning urine (Udert, 2007).

The potassium level in the male urine assumed decreased- increased fashion from month one to month 6. None of the changes were significant. The male urine nitrogen, however, correlated strongly positive to the potassium level ($r = 0.831$, $p < 0.01$). This is likely so as the prevailing factors could not effect any significant changes in the potassium levels.

### 5.4.2 Female urine quality

The nitrogen concentration in the stored female urine significantly increased from month one to month four and then decreased thereafter as observed in the digested urine. However, in the direct method, the significant change occurred only between the first month and the rest of the storage months. The yield of nitrogen peaked at the $4^{th}$ month over a six month storage period. The decrease may be due to the slowdown of the urine hydrolysis. It is also possible that the high pH on the $4^{th}$ month inhibited the bacteria

activity of decomposition or all the organic urea might have been utilized by hydrolysing bacteria (Udert *et al.*, 2003d). It is also likely that chemical hydrolysis coupled with relatively high external temperature may have caused this slowdown process of nitrogen yield. The yield of nitrogen concentration is likely to be influenced by the storage time ($r = 0.390$, $p < 0.05$) and pH ($r = 0.364$, $p < 0.05$) which might in turn affect the urine hydrolysis. The temperature, may equally contribute to the yield of the female urine nitrogen ($r = 0.363$, $p < 0.05$) as explained earlier. The urine nitrogen level correlated significantly to the potassium level ($r = 0.520$, $p < 0.01$). It is likely that similar factors caused the yield of both nitrogen and potassium levels in the urine over the storage period. There was, however, no significant correlation between the nitrogen and the potassium levels in the digested female urine which might be informed by the method of nitrogen analysis. The choice of the two methods was made after realizing that the two were producing different yields of nitrogen in all the sources of urine.

The significant decrease in the phosphorus level from the 1$^{st}$ to the 2$^{nd}$ month storage time might be due to the significant increase in pH over this period (Gethke *et al.,* 2006). The increase in the phosphorus level from the 3$^{rd}$ to the 4$^{th}$ and 5$^{th}$ months' storage time may be due to the storage time ($r = 0.631$, $p < 0.01$) and temperature ($r = 0.741$, $p < 0.01$). This is evident in factors controlling struvite precipitation (Doyle and Parsons, 2002). As the decomposition process started slowing down from month five to six, it is possible that this was also accompanied by a proportional decrease in the phosphorus level in the female urine.

The decreased- increased zigzag fashion of potassium level reached a peaked value on the 5$^{th}$ storage month. All the changes were not significant, and suggestive of the fact that

the exposed factors did not affect significant changes of the potassium levels during a 6-month storage period, though hydrolysis occurred.

### 5.4.3 Quality of composite urine

The nitrogen content of the composite urine increased from month one to four and then decreased gradually to the month six. These changes were, however, not significant indicating that the urine hydrolysis was rather slow, if any. This might be attributed to little or no hydrolysing bacteria to effect significant changes in the yield of urine nitrogen. It is possible that the hydrolyzing bacteria had no time to effect decomposition. On this assumption, it is possible that the insignificant changes in nitrogen levels observed was due to temperature changes. It can also be ascribed to a brief chemical hydrolysis over a short period before analysis was carried out. The nitrogen yield, nevertheless, might have influenced the yield of the composite urine potassium proportion ($r = 0.749$, $p < 0.01$).

The decrease of phosphorus level from the 1$^{st}$ to the 2$^{nd}$ month storage time may be due to increase in pH over this period. It can be deduced from this assumption that the increase observed on the 3$^{rd}$ and 4$^{th}$ months' storage time was as a result of decreased pH ($r = - 0.342$, $p < 0.05$). It appears that after the maturation the decrease pH does not correspond with increased phosphorus level. The yield of composite phosphorus level might have also been influenced by the storage time ($r = 0.705$, $p < 0.01$), and temperature ($r = 0.649$, $p < 0.01$), (Doyle and Parsons, 2002).

The potassium levels in the composite urine also assumed decreased- increased zigzag fashion just as that in the male urine. However, the level increased steadily from the 4$^{th}$ to

the 6th months' of storage time. The non significance of the changes observed might have, once again, been contributed by the slow rate of the process of decomposition. As observed earlier, the yield of potassium level in the composite urine appears to be informed by the same factor(s) responsible for the nitrogen yield ($r = 0.749$, $p < 0.01$).

### 5.5.0 Gender yield significance

The results revealed no significant differences in NPK in all the urine sources but the male urine pH was significantly different from that of the female on month one. This might be due to the fact that other factors other than urine hydrolysis contributed to the increase in urine pH over the storage period. This is likely so since the urine nitrogen from the hydrolysis correlated significantly with the pH ($r = 0.631$, $p < 0.01$) as well as phosphorus level ($r = - 0.776$, $p < 0.01$) and potassium level ($r = 0.860$, $p < 0.01$) Gethke *et al.*, 2006). The significant differences in temperature between the composite urine and that of the male and female, of month one, may be attributed to the chemical interaction of mixing the male and the female urine. The interaction which depends on the respective composition can produce significant or insignificant heat changes.

The significant differences in the female digested urine nitrogen from that of the male and the composite, from the 2nd to 5th months of storage, can be ascribed to the relatively high rate of hydrolysis of female urine. It is also possible that the female physiology allows a relatively higher excretion of urinary nitrogen (Thompson and Abdulnabi,1950). The direct urine nitrogen did not show any significant difference in all the urine sources. This is an indication that the method of analysing the urinary nitrogen influences the significance levels of nitrogen yields. On the other hand, the phosphorus level in the male

urine was significantly different from that of the female and the composite for the 2nd and 3rd months of storage. This might be due to the inherent male metabolic activity of phosphorus that permits relatively higher urinary excretion of phosphate phosphorus than in female, and by extension the composite urine. It may also be argued that the struvite precipitation, at this time, was better in the male urine than in the female urine. In the absence of significant gender pH changes, this might have been influenced by storage time and or temperature for the struvite precipitation (Doyle and Parsons, 2002) which is a chief source of phosphorus recovery from urine. It appears that at equilibrium, pH has little or no influence on the urine phosphorus level. All the parameters appear to have peaked on month 4, indicating higher activity period.

There were no significant differences in all the decreased levels of the parameters studied in all the sources of urine on month 6. This may signal the end of active decomposition or hydrolysis but not the end of the process itself. This is assumed, as Aragundy (2005) observed the process going on after even eight months storage in one of his set-ups.

### 5.6.0 Relative percentage of NPK in different sourced urine

The results showed that the pooled female urine had relatively higher level of N-P-K (34.4(6.5*)-1-62.8), followed by the composite urine N-P-K (34.8(4.5*)-1-54.4) and lastly the male urine N-P-K (30.4(3.4*)-1-43.7). The values with asterisks are for the digested urine nitrogen. These differences in different sources of urine were not significant probably due to the comparable rate of urine hydrolysis in each case. It is also possible that the pooled parameters tend to synergize all the inherent individual errors and

therefore do not present the clear picture of what is happening. According to Lindén (1997) the fertilizer value of pure urine is similar to NPK 18:2:5. However, the NPK level in urine is influenced by eating habits (Gethke *et al.*, 2006; Werner *et al.*, 2005) as well as the environmental temperature of a geographical area (Aragundy, 2005). The relatively high level of female urinary nitrogen can also be influenced by sexual cycle even though no evidence exists to support it (Thompson and Kirby, 1949 cited in Thompson and Abdulnabi, 1950).



According to Morgan and SEI, (2004), a family of 5 can generate 52.5 Kg of urine in a week, since an adult is known to produce 1.5 L of urine every day. By extension 56.0 Kg of urine can be obtained from the site of this work in, roughly, 7 days. This is so because about 16 litres of urine was collected in 2 days. The proportions of NPK in all the sources of urine (male, female and composite) in this work can equally, if not even better, substitute chemical fertilisers quoted from the market survey from the Kumasi Central market, Kejetia. This means that about GHC 128 and GHC 180 respectively can be accrued from ammonia nitrogen and other NPK fertilisers every month from urine harvesting. This amount is huge enough to be saved by a farmer on chemical fertiliser to improve his economic status. This will also ease the burden of subsidy by the Central government on the importation of chemical fertilisers.

# CHAPTER SIX

## 6.1 Conclusion

The study showed that storing male urine for six months will not significantly increase its nitrogen yield irrespective of any of the two methods used and that nitrogen increase peaks at month four of storage time. However, the digested method showed significant variation as opposed to direct method with respect to the female urine. The potassium levels in all the urine sources remained significantly unchanged over a six –month period. The urine phosphorus level increased significantly at least from 2nd to 4th month of all the urine sources. The temperature change caused by both chemical and biological processes was influenced by environmental temperature.

The pH in all the urine sources, except male urine, increased over time to month 4, but both the temperature and pH influence the yield of urine NPK. The colour of the mature male and composite urine is greenish brown while that of female urine is orange

Monthly gender comparison showed that the digested female nitrogen was consistently and significantly higher than that of the male and the composite urines. However, the phosphorus levels in the male urine were relatively higher than they were in either the female or the composite urines on monthly basis. This continues until month four where all the phosphorus levels become significantly the same. The $6^{th}$ month storage time witnessed no significant changes in all the parameters studied. Although insignificant, the potassium levels were high in all the urine sources. In addition, the pooled NPK results for male urine ((30.4(3.4*)-1-43.7)), female urine ((34.4(6.5*)-1-62.8), and the composite urine ((34.8(4.5*)-1-54.4) were significantly the same. The values with asterisks are for

the digested urine nitrogen. Gender urine should be collected separately for specific crop production with respect to a given storage time. In a nutshell, NPK in human urine can give equal or better market value to chemical fertiliser such as 21% N ammonia nitrogen in Kumasi metropolis of Ghana.

### 6.2 Recommendations

This work was based on a real world situation where different people visit public urinals at different times at will. A controlled experimental study should be conducted and compared with the present study. The following recommendations will, however, help shape similar work in the future**:**

1. The diet of the male and female subjects should be controlled and monitored.
2. The selection of the subjects should also take into consideration the age and the body weight**.**
3. Early morning urine must be collected all the time.
4. The NPK requirement of specific crops should be studied in order to know how long urine has to be stored for their use in agriculture.
5. The direct nitrogen method should be studied to establish its reliability and effectiveness.
6. Gender urine from Ecosan urinals should be collected separately and used for specific crop productions in agriculture.

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APPENDIX 1

**a.** QUALITY OF THE STORED MALE URINE



| **Maturation time(month)** | **Digested urine Nitrogen (%)[a]** **DMRT[b]** | **Direct urine Nitrogen (%)[a]** **DMRT[b]** | **Urine Phosphorus level (%)[a]** **DMRT[b]** | **Urine Potassium content (%)[a]** **DMRT[b]** | **Urine Temperature ($^oC$)[a]** **DMRT[b]** | **Urine pH[a]** **DMRT[b]** | **Urine colour** |
|---|---|---|---|---|---|---|---|
| **December** | 2.83a | 23.597a | 0.5652a | 49.9000a | 24.80a | 8.795c | Light greenish brown |
| **January** | 3.70a | 32.68a | 0.7138a | 44.4167a | 24.45a | 8.80c | Greenish brown |
| **February** | 3.92a | 34.36a | 0.6380a | 45.9467a | 27.47b | 8.75c | Greenish dark brown |
| **March** | 4.05a | 38.00a | 1.7267c | 42.2500a | 28.92c | 8.78c | Greenish brown |
| **April** | 3.86a | 34.42a | 1.5443c | 46.0617a | 28.22bc | 7.45b | Greenish brown |
| **May** | 2.88a | 25.02a | 1.0037b | 42.1833a | 27.92bc | 7.02a | Greenish brown |

[a]Average of six replications

[b]Any two means having a common letter are not Significantly different at the 5% level of significance

**aa. One-way Anova of the male urine**

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Male urine nitrogen concentration(%) | Between Groups | 988.388 | 5 | 197.678 | .941 | .469 |
| | Within Groups | 6303.298 | 30 | 210.110 | | |
| | Total | 7291.686 | 35 | | | |
| Male urine phosphorus concentration(%) | Between Groups | 7.321 | 5 | 1.464 | 39.133 | .000 |
| | Within Groups | 1.123 | 30 | .037 | | |
| | Total | 8.444 | 35 | | | |
| Male urine potassium concentration(%) | Between Groups | 250.643 | 5 | 50.129 | .089 | .993 |
| | Within Groups | 16965.929 | 30 | 565.531 | | |
| | Total | 17216.572 | 35 | | | |
| Male urine temperature(oC) | Between Groups | 105.272 | 5 | 21.054 | 22.907 | .000 |
| | Within Groups | 27.573 | 30 | .919 | | |
| | Total | 132.846 | 35 | | | |
| Male urine pH | Between Groups | 19.734 | 5 | 3.947 | 52.823 | .000 |
| | Within Groups | 2.241 | 30 | .075 | | |
| | Total | 21.975 | 35 | | | |
| Male digested urine nitrogen (%) | Between Groups | 8.843 | 5 | 1.769 | .698 | .629 |
| | Within Groups | 75.977 | 30 | 2.533 | | |
| | Total | 84.821 | 35 | | | |

**b.** QUALITY OF THE STORED FEMALE URINE

| Maturation time(month) | Digested urine Nitrogen (%)[a] | Direct urine Nitrogen (%)[a] | Urine Phosphorus level (%)[a] | Urine Potassium content (%)[a] | Urine Temperature ( $^{o}$C)[a] | Urine pH[a] | Urine colour |
|---|---|---|---|---|---|---|---|
| | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | |
| **December** | 2.43a | 12.56a | 0.5540b | 58.1333a | 24.70a | 7.59a | light Yellowish brown |
| **January** | 7.33bc | 34.18b | 0.2050a | 50.0400a | 24.47a | 8.78b | Yellow |
| **February** | 7.34bc | 34.33b | 0.3822a | 54.5833a | 27.03b | 8.80b | Orange yellow |
| **March** | 7.80c | 36.32b | 1.5557d | 56.0000a | 29.18d | 8.72b | Orange |
| **April** | 6.04b | 33.29b | 1.5540d | 60.4667a | 27.97c | 7.75a | Light brown |
| **May** | 3.42a | 30.93b | 1.0300c | 52.5333a | 28.40cd | 7.20a | Brown |

[a]Average of six replications
[b]Any two means having a common letter are not significantly different at the 5% level of significance

**bb. One-way ANOVA of the female urine**

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Female urine nitrogen content(%) | Between Groups | 2349.980 | 5 | 469.996 | 6.036 | .001 |
| | Within Groups | 2336.119 | 30 | 77.871 | | |
| | Total | 4686.099 | 35 | | | |
| Female urine phosphorus content(%) | Between Groups | 10.458 | 5 | 2.092 | 31.725 | .000 |
| | Within Groups | 1.978 | 30 | .066 | | |
| | Total | 12.436 | 35 | | | |
| Female urine potassium content(%) | Between Groups | 426.285 | 5 | 85.257 | .497 | .776 |
| | Within Groups | 5143.404 | 30 | 171.447 | | |
| | Total | 5569.690 | 35 | | | |
| Female urine temperature(oC) | Between Groups | 116.159 | 5 | 23.232 | 39.944 | .000 |
| | Within Groups | 17.448 | 30 | .582 | | |
| | Total | 133.608 | 35 | | | |
| Female urine pH | Between Groups | 15.074 | 5 | 3.015 | 8.784 | .000 |
| | Within Groups | 10.296 | 30 | .343 | | |
| | Total | 25.371 | 35 | | | |
| Female urine digested nitrogen (%) | Between Groups | 154.341 | 5 | 30.868 | 25.192 | .000 |
| | Within Groups | 36.759 | 30 | 1.225 | | |
| | Total | 191.100 | 35 | | | |

**c.** QUALITY OF THE STORED COMPOSITE URINE

| Maturation time(month) | Digested urine Nitrogen (%)[a] | Direct urine Nitrogen (%)[a] | Urine Phosphorus level (%)[a] | Urine Potassium content (%)[a] | Urine Temperature ( $^{o}$C)[a] | Urine pH[a] | Urine colour |
|---|---|---|---|---|---|---|---|
| | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | DMRT[b] | |
| **December** | 2.53a | 20.34a | 0.5770b | 46.3333a | 27.80b | 8.12b | Greenish light brown |
| **January** | 4.36b | 34.25a | 0.3028a | 45.4333a | 24.59a | 8.82c | Light greenish brown |
| **February** | 4.56b | 36.15a | 0.3872a | 52.3000a | 27.55b | 8.67c | Light greenish brown |
| **March** | 4.58b | 36.01a | 1.5734d | 46.9333a | 29.12c | 8.68c | Light greenish brown |
| **April** | 4.13b | 32.38a | 1.4607d | 52.0000a | 28.15bc | 7.64b | Light brown |
| **May** | 4.27b | 31.65a | 1.1790c | 55.9667a | 27.97b | 7.04a | Brown |

[a]Average of six replications

[b]Any two means having a common letter are not significantly different at the 5% level of significance.

**cc. DMRT for comparing all possible pairs of treatment Means of composite urine temperature, from a CRD experiment involving six treatments.**

Duncan[a]

| Maturation period(month) | N | Subset for alpha = .05 | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Jan | 6 | 24.5883 | | |
| Feb | 6 | | 27.5500 | |
| Dec | 6 | | 27.8000 | |
| May | 6 | | 27.9667 | |
| Apr | 6 | | 28.1500 | 28.1500 |
| Mar | 6 | | | 29.1167 |
| Sig. | | 1.000 | .281 | .062 |

Means for groups in homogeneous subsets are displayed.

[a] Uses Harmonic Mean Sample Size = 6.000.

## d. Pearson's correlation results of the stored male urine

**Correlations**

| | | Matturation period(month) | Male urine nitrogen concentration(%) | Male urine phosphorus concentration(%) | Male urine potassium concentration(%) | Male urine temperature(oC) | Male urine pH | Male digested urine nitrogen (%) |
|---|---|---|---|---|---|---|---|---|
| Matturation period(month) | Pearson Correlation | 1 | .055 | .582** | -.083 | .720** | -.807** | .028 |
| | Sig. (2-tailed) | | .751 | .000 | .629 | .000 | .000 | .871 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male urine nitrogen concentration(%) | Pearson Correlation | .055 | 1 | .161 | .831** | .232 | .076 | .956** |
| | Sig. (2-tailed) | .751 | | .349 | .000 | .173 | .658 | .000 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male urine phosphorus concentration(%) | Pearson Correlation | .582** | .161 | 1 | -.118 | .674** | -.280 | .077 |
| | Sig. (2-tailed) | .000 | .349 | | .494 | .000 | .099 | .657 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male urine potassium concentration(%) | Pearson Correlation | -.083 | .831** | -.118 | 1 | -.029 | .009 | .838** |
| | Sig. (2-tailed) | .629 | .000 | .494 | | .864 | .960 | .000 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male urine temperature(oC) | Pearson Correlation | .720** | .232 | .674** | -.029 | 1 | -.397* | .175 |
| | Sig. (2-tailed) | .000 | .173 | .000 | .864 | | .017 | .308 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male urine pH | Pearson Correlation | -.807** | .076 | -.280 | .009 | -.397* | 1 | .078 |
| | Sig. (2-tailed) | .000 | .658 | .099 | .960 | .017 | | .649 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Male digested urine nitrogen (%) | Pearson Correlation | .028 | .956** | .077 | .838** | .175 | .078 | 1 |
| | Sig. (2-tailed) | .871 | .000 | .657 | .000 | .308 | .649 | |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

**e. Pearson's correlation results of the stored female urine**

**Correlations**

| | | Maturation period(month) | Female urine nitrogen content(%) | Female urine phosphorus content(%) | Female urine potassium content(%) | Female urine temperature(oC) | Female urine pH | Female urine digested nitrogen (%) |
|---|---|---|---|---|---|---|---|---|
| Maturation period(month) | Pearson Correlation | 1 | .390* | .631** | .018 | .789** | -.299 | .032 |
| | Sig. (2-tailed) | | .019 | .000 | .915 | .000 | .076 | .851 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine nitrogen content(%) | Pearson Correlation | .390* | 1 | .084 | .520** | .363* | .364* | .500** |
| | Sig. (2-tailed) | .019 | | .626 | .001 | .030 | .029 | .002 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine phosphorus content(%) | Pearson Correlation | .631** | .084 | 1 | -.097 | .741** | -.161 | .023 |
| | Sig. (2-tailed) | .000 | .626 | | .574 | .000 | .349 | .892 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine potassium content(%) | Pearson Correlation | .018 | .520** | -.097 | 1 | .026 | -.100 | -.081 |
| | Sig. (2-tailed) | .915 | .001 | .574 | | .881 | .562 | .638 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine temperature(oC) | Pearson Correlation | .789** | .363* | .741** | .026 | 1 | -.149 | .085 |
| | Sig. (2-tailed) | .000 | .030 | .000 | .881 | | .387 | .621 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine pH | Pearson Correlation | -.299 | .364* | -.161 | -.100 | -.149 | 1 | .785** |
| | Sig. (2-tailed) | .076 | .029 | .349 | .562 | .387 | | .000 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Female urine digested nitrogen (%) | Pearson Correlation | .032 | .500** | .023 | -.081 | .085 | .785** | 1 |
| | Sig. (2-tailed) | .851 | .002 | .892 | .638 | .621 | .000 | |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

**f. Pearson's correlation results of the stored composite urine**

**Correlations**

| | | Maturation period(month) | Composite urine nitrogen level(%) | Composite urine phosphorus level(%) | Composite urine potassium level(%) | Composite urine temperature(oC) | Composite urine pH | Composite urine digested nitrogen (%) |
|---|---|---|---|---|---|---|---|---|
| Maturation period(month) | Pearson Correlation | 1 | .183 | .705** | .170 | .397* | -.568** | .278 |
| | Sig. (2-tailed) | | .285 | .000 | .323 | .017 | .000 | .101 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine nitrogen level(%) | Pearson Correlation | .183 | 1 | .075 | .749** | .185 | .176 | .979** |
| | Sig. (2-tailed) | .285 | | .664 | .000 | .281 | .303 | .000 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine phosphorus level(%) | Pearson Correlation | .705** | .075 | 1 | -.041 | .649** | -.342* | .109 |
| | Sig. (2-tailed) | .000 | .664 | | .811 | .000 | .041 | .527 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine potassium level(%) | Pearson Correlation | .170 | .749** | -.041 | 1 | .114 | -.148 | .736** |
| | Sig. (2-tailed) | .323 | .000 | .811 | | .506 | .388 | .000 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine temperature(oC) | Pearson Correlation | .397* | .185 | .649** | .114 | 1 | -.263 | .166 |
| | Sig. (2-tailed) | .017 | .281 | .000 | .506 | | .121 | .334 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine pH | Pearson Correlation | -.568** | .176 | -.342* | -.148 | -.263 | 1 | .164 |
| | Sig. (2-tailed) | .000 | .303 | .041 | .388 | .121 | | .339 |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Composite urine digested nitrogen (%) | Pearson Correlation | .278 | .979** | .109 | .736** | .166 | .164 | 1 |
| | Sig. (2-tailed) | .101 | .000 | .527 | .000 | .334 | .339 | |
| | N | 36 | 36 | 36 | 36 | 36 | 36 | 36 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

**g. Pearson's correlation results of the combined urine sources**

**Correlations**

| | | gender | urine nitrogen concentration (%) | urine phosphorus concentration(%) | urine potassium concentration(%) | urine temperature(oC) | urine pH | digested urine nitrogen concentration (%) |
|---|---|---|---|---|---|---|---|---|
| gender | Pearson Correlation | 1 | .014 | -.090 | .102 | .066 | -.055 | .107 |
| | Sig. (2-tailed) | | .886 | .355 | .293 | .495 | .572 | .270 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| urine nitrogen concentration(%) | Pearson Correlation | .014 | 1 | .106 | .705** | .329** | .200* | .643** |
| | Sig. (2-tailed) | .886 | | .276 | .000 | .001 | .037 | .000 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| urine phosphorus concentration(%) | Pearson Correlation | -.090 | .106 | 1 | -.107 | .673** | -.240* | .006 |
| | Sig. (2-tailed) | .355 | .276 | | .270 | .000 | .012 | .947 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| urine potassium concentration(%) | Pearson Correlation | .102 | .705** | -.107 | 1 | .067 | -.077 | .502** |
| | Sig. (2-tailed) | .293 | .000 | .270 | | .493 | .430 | .000 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| urine temperature(oC) | Pearson Correlation | .066 | .329** | .673** | .067 | 1 | -.222* | .164 |
| | Sig. (2-tailed) | .495 | .001 | .000 | .493 | | .021 | .090 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| urine pH | Pearson Correlation | -.055 | .200* | -.240* | -.077 | -.222* | 1 | .347** |
| | Sig. (2-tailed) | .572 | .037 | .012 | .430 | .021 | | .000 |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| digested urine nitrogen concentration (%) | Pearson Correlation | .107 | .643** | .006 | .502** | .164 | .347** | 1 |
| | Sig. (2-tailed) | .270 | .000 | .947 | .000 | .090 | .000 | |
| | N | 108 | 108 | 108 | 108 | 108 | 108 | 108 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

**h. A one-way ANOVA of pooled different sources of urine**

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| urine nitrogen concentration(%) | Between Groups | 44.372 | 2 | 22.186 | .125 | .882 |
| | Within Groups | 18572.538 | 105 | 176.881 | | |
| | Total | 18616.910 | 107 | | | |
| urine phosphorus concentration(%) | Between Groups | .457 | 2 | .228 | .773 | .464 |
| | Within Groups | 31.017 | 105 | .295 | | |
| | Total | 31.474 | 107 | | | |
| urine potassium concentration(%) | Between Groups | 1866.230 | 2 | 933.115 | 2.833 | .063 |
| | Within Groups | 34581.632 | 105 | 329.349 | | |
| | Total | 36447.861 | 107 | | | |
| urine temperature(oC) | Between Groups | 2.315 | 2 | 1.157 | .313 | .732 |
| | Within Groups | 387.814 | 105 | 3.693 | | |
| | Total | 390.129 | 107 | | | |
| urine pH | Between Groups | .336 | 2 | .168 | .257 | .774 |
| | Within Groups | 68.656 | 105 | .654 | | |
| | Total | 68.992 | 107 | | | |
| digested urine nitrogen concentration (%) | Between Groups | 93.448 | 2 | 46.724 | 14.120 | .000 |
| | Within Groups | 347.465 | 105 | 3.309 | | |
| | Total | 440.913 | 107 | | | |

APPENDIX 2

**a**.MONTHLY COMPARISON OF DIFFERENT URINE SOURCES

| STORAGE TIME (MONTH) | URINE SOURCE | DIGESTED URINE NITROGEN (%)[a] DMRT[b] | DIRECT URINE NITROGEN (%)[a] DMRT[b] | URINE PHOSPHORUS CONTENT (%)[a] DMRT[b] | URINE POTASSIUM LEVEL (%)[a] DMRT[b] | URINE TEMPERATURE ($^{o}$C) [a] DMRT[b] | URINE pH[a] DMRT[b] |
|---|---|---|---|---|---|---|---|
| | Male | 2.8273a | 23.5968a | 0.5652a | 49.9000a | 24.8000a | 8.7950b |
| **1** | Female | 2.4328a | 12.5583a | 0.5540a | 58.1333a | 24.7000a | 7.5917a |
| | Composite | 2.5293a | 20.3345a | 0.5770a | 46.3333a | 27.8000b | 8.1150ab |
| | Male | 3.7031a | 32.6802a | 0.7138b | 44.4167a | 24.4500a | 8.8000a |
| **2** | Female | 7.3265b | 34.1825a | 0.2050a | 50.0400a | 24.4667a | 8.7767a |
| | Composite | 4.3600a | 34.2468a | 0.3028a | 45.4333a | 24.5883a | 8.8183a |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Male | 3.9234a | 34.3612a | 0.6380b | 45.9467a | 27.4667a | 8.7467a |
| **3** | Female | 7.3363b | 34.3273a | 0.3822a | 54.5833a | 27.0333a | 8.7967a |
| | Composite | 4.5628a | 36.1532a | 0.3872a | 52.3000a | 27.5500a | 8.6683a |
| | Male | 4.0490a | 38.0003a | 1.7267a | 42.2500a | 28.9167a | 8.7767a |
| **4** | Female | 7.8057b | 36.3243a | 1.5557a | 56.0000a | 29.1833a | 8.7150a |
| | Composite | 4.5767a | 36.0125a | 1.5734a | 46.9333a | 29.1167a | 8.6800a |
| | Male | 3.8608a | 34.4217a | 1.5443a | 46.0617a | 28.2167a | 7.4467a |
| **5** | Female | 6.0354b | 33.2878a | 1.5540a | 60.4667a | 27.9667a | 7.7467a |
| | Composite | 4.1336a | 32.3775a | 1.4607a | 52.0000a | 28.1500a | 7.6433a |
| | Male | 2.8840a | 25.0159a | 1.0037a | 42.1833a | 27.9167a | 7.0167a |
| **6** | Female | 3.4198a | 30.9245a | 1.0300a | 52.5333a | 28.4000a | 7.1967a |
| | Composite | 4.1336a | 31.6449a | 1.1790a | 55.9667a | 27.9667a | 7.0417a |

[a]Average of six replications

[b]Any two means having a common letter are not significantly different at the 5% level of significance.

MONTHLY CORRELATION OF PARAMETERS OF DIFFERENT SOURCES OF URINE

## b. Month one

**Correlations**

| | | urine source | digested nitrogen level (%) | direct nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | -.084 | -.106 | .033 | -.107 | .761** | -.335 |
| | Sig. (2-tailed) | | .741 | .675 | .898 | .672 | .000 | .174 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digested nitrogen level (%) | Pearson Correlation | -.084 | 1 | .926** | -.776** | .860** | -.276 | .631** |
| | Sig. (2-tailed) | .741 | | .000 | .000 | .000 | .267 | .005 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| direct nitrogen level (%) | Pearson Correlation | -.106 | .926** | 1 | -.814** | .740** | -.118 | .668** |
| | Sig. (2-tailed) | .675 | .000 | | .000 | .000 | .642 | .002 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | .033 | -.776** | -.814** | 1 | -.844** | .282 | -.220 |
| | Sig. (2-tailed) | .898 | .000 | .000 | | .000 | .257 | .380 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | -.107 | .860** | .740** | -.844** | 1 | -.426 | .262 |
| | Sig. (2-tailed) | .672 | .000 | .000 | .000 | | .078 | .294 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | .761** | -.276 | -.118 | .282 | -.426 | 1 | -.115 |
| | Sig. (2-tailed) | .000 | .267 | .642 | .257 | .078 | | .649 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | -.335 | .631** | .668** | -.220 | .262 | -.115 | 1 |
| | Sig. (2-tailed) | .174 | .005 | .002 | .380 | .294 | .649 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**. Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at 0.05 level (2-tailed)

## c. Month two

**Correlations**

| | | urine source | digest nitrogen level (%) | direct nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | .138 | .054 | -.675** | .028 | .057 | .049 |
| | Sig. (2-tailed) | | .585 | .830 | .002 | .912 | .823 | .846 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digest nitrogen level (%) | Pearson Correlation | .138 | 1 | .449 | -.697** | .572* | .361 | -.138 |
| | Sig. (2-tailed) | .585 | | .062 | .001 | .013 | .141 | .585 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| direct nitrogen level (%) | Pearson Correlation | .054 | .449 | 1 | -.282 | .959** | .906** | -.302 |
| | Sig. (2-tailed) | .830 | .062 | | .258 | .000 | .000 | .222 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | -.675** | -.697** | -.282 | 1 | -.389 | -.356 | .058 |
| | Sig. (2-tailed) | .002 | .001 | .258 | | .111 | .146 | .820 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | .028 | .572* | .959** | -.389 | 1 | .899** | -.350 |
| | Sig. (2-tailed) | .912 | .013 | .000 | .111 | | .000 | .155 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | .057 | .361 | .906** | -.356 | .899** | 1 | -.143 |
| | Sig. (2-tailed) | .823 | .141 | .000 | .146 | .000 | | .573 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | .049 | -.138 | -.302 | .058 | -.350 | -.143 | 1 |
| | Sig. (2-tailed) | .846 | .585 | .222 | .820 | .155 | .573 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

### d. Month three

**Correlations**

| | | urine source | digested nitrogen level (%) | direct nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | .137 | .058 | -.545* | .180 | .042 | -.131 |
| | Sig. (2-tailed) | | .589 | .820 | .019 | .475 | .869 | .606 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digested nitrogen level (%) | Pearson Correlation | .137 | 1 | .464 | -.198 | .591** | .198 | .468 |
| | Sig. (2-tailed) | .589 | | .053 | .430 | .010 | .432 | .050 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| direct nitrogen level (%) | Pearson Correlation | .058 | .464 | 1 | .396 | .827** | .562* | .503* |
| | Sig. (2-tailed) | .820 | .053 | | .104 | .000 | .015 | .033 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | -.545* | -.198 | .396 | 1 | -.009 | .189 | .308 |
| | Sig. (2-tailed) | .019 | .430 | .104 | | .973 | .453 | .214 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | .180 | .591** | .827** | -.009 | 1 | .474* | .356 |
| | Sig. (2-tailed) | .475 | .010 | .000 | .973 | | .047 | .147 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | .042 | .198 | .562* | .189 | .474* | 1 | .246 |
| | Sig. (2-tailed) | .869 | .432 | .015 | .453 | .047 | | .325 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | -.131 | .468 | .503* | .308 | .356 | .246 | 1 |
| | Sig. (2-tailed) | .606 | .050 | .033 | .214 | .147 | .325 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

## e. Month four

**Correlations**

| | | urine source | digest nitrogen level (%) | direct nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | .098 | -.065 | -.390 | .145 | .124 | -.276 |
| | Sig. (2-tailed) | | .700 | .798 | .109 | .565 | .623 | .267 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digest nitrogen level (%) | Pearson Correlation | .098 | 1 | .440 | .041 | .678** | .161 | .198 |
| | Sig. (2-tailed) | .700 | | .068 | .872 | .002 | .524 | .430 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| direct nitrogen level (%) | Pearson Correlation | -.065 | .440 | 1 | .568* | .829** | .491* | .601** |
| | Sig. (2-tailed) | .798 | .068 | | .014 | .000 | .039 | .008 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | -.390 | .041 | .568* | 1 | .186 | .307 | .374 |
| | Sig. (2-tailed) | .109 | .872 | .014 | | .460 | .215 | .127 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | .145 | .678** | .829** | .186 | 1 | .499* | .474* |
| | Sig. (2-tailed) | .565 | .002 | .000 | .460 | | .035 | .047 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | .124 | .161 | .491* | .307 | .499* | 1 | .349 |
| | Sig. (2-tailed) | .623 | .524 | .039 | .215 | .035 | | .156 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | -.276 | .198 | .601** | .374 | .474* | .349 | 1 |
| | Sig. (2-tailed) | .267 | .430 | .008 | .127 | .047 | .156 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

**f. Month five**

**Correlations**

| | | urine source | digest nitrogen level (%) | diecrt nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | .077 | -.076 | -.150 | .116 | -.046 | .115 |
| | Sig. (2-tailed) | | .762 | .765 | .552 | .646 | .856 | .649 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digest nitrogen level (%) | Pearson Correlation | .077 | 1 | .408 | .422 | .585* | .081 | -.006 |
| | Sig. (2-tailed) | .762 | | .093 | .081 | .011 | .748 | .980 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| diecrt nitrogen level (%) | Pearson Correlation | -.076 | .408 | 1 | -.182 | .923** | .543* | -.590* |
| | Sig. (2-tailed) | .765 | .093 | | .470 | .000 | .020 | .010 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | -.150 | .422 | -.182 | 1 | -.118 | -.197 | .348 |
| | Sig. (2-tailed) | .552 | .081 | .470 | | .641 | .434 | .157 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | .116 | .585* | .923** | -.118 | 1 | .411 | -.500* |
| | Sig. (2-tailed) | .646 | .011 | .000 | .641 | | .090 | .035 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | -.046 | .081 | .543* | -.197 | .411 | 1 | -.518* |
| | Sig. (2-tailed) | .856 | .748 | .020 | .434 | .090 | | .028 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | .115 | -.006 | -.590* | .348 | -.500* | -.518* | 1 |
| | Sig. (2-tailed) | .649 | .980 | .010 | .157 | .035 | .028 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

## g. Month six

**Correlations**

| | | urine source | digested nitrogen level (%) | direct nitrogen level (%) | phosphorus level (%) | potassium level (%) | temperature (oC) | pH |
|---|---|---|---|---|---|---|---|---|
| urine source | Pearson Correlation | 1 | .451 | .290 | .235 | .202 | .021 | .061 |
| | Sig. (2-tailed) | | .060 | .244 | .349 | .421 | .933 | .812 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| digested nitrogen level (%) | Pearson Correlation | .451 | 1 | .844** | -.540* | .891** | -.699** | -.051 |
| | Sig. (2-tailed) | .060 | | .000 | .021 | .000 | .001 | .841 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| direct nitrogen level (%) | Pearson Correlation | .290 | .844** | 1 | -.378 | .972** | -.709** | .062 |
| | Sig. (2-tailed) | .244 | .000 | | .122 | .000 | .001 | .805 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| phosphorus level (%) | Pearson Correlation | .235 | -.540* | -.378 | 1 | -.508* | .604** | .215 |
| | Sig. (2-tailed) | .349 | .021 | .122 | | .031 | .008 | .391 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| potassium level (%) | Pearson Correlation | .202 | .891** | .972** | -.508* | 1 | -.783** | .033 |
| | Sig. (2-tailed) | .421 | .000 | .000 | .031 | | .000 | .896 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| temperature (oC) | Pearson Correlation | .021 | -.699** | -.709** | .604** | -.783** | 1 | .013 |
| | Sig. (2-tailed) | .933 | .001 | .001 | .008 | .000 | | .959 |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| pH | Pearson Correlation | .061 | -.051 | .062 | .215 | .033 | .013 | 1 |
| | Sig. (2-tailed) | .812 | .841 | .805 | .391 | .896 | .959 | |
| | N | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

# APPENDIX 3

## Prices of some chemical fertilisers in Kumasi as at March, 2009.



| PROPORTION (%) | CONTENT | WEIGHT (Kg) | PRICE ( GH Cedis) |
|---|---|---|---|
| 46% N | Urea Nitrogen | 50 | 45 |
| 21% N | Ammonia Nitrogen | 50 | 32 |
| 23:10 NPK | NPK | 50 | 45 |
| 15:15:15 NPK | NPK | 50 | 45 |