공학석사학위논문

소변 분리 화장실 시스템에서 질소의 운명

Fate of Nitrogen in Urine Separated Toilet Systems

2015년 2월

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위 원 장 김 재 영 (인)

부 위 원 장 한 무 영 (인)

위 원 남 경 필 (인)

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Fate of Nitrogen in Urine Separated Toilet Systems

By:
Shervin Hashemi

Advisor:
Professor Mooyoung Han

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The Graduate School

Seoul National University

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Abstract

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Shervin Hashemi

Department of Civil and Environmental Engineering

The Graduate School

Seoul National University

Present-day treatment of mixed waste water 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 micro pollutants are eliminated insufficiently. Source separation of urine, which contributes most of the nutrients to waste water, is a promising alternative.

However, the nutrients in urine might not be available in a convenient form for fertilizers. Furthermore, urine contains micro pollutants such as synthetic hormones, pharmaceuticals and their metabolites. These substances are mainly excreted via urine and may be harmful to the ecosystems and human health. Today,

many micro pollutants reach the aquatic environment, because their degradation in waste water treatment plants is poor.

Urine treatment might be necessary to produce an adequate fertilizer, but it might also be a suitable method to prevent the pollution of the environment with micro pollutants. Developing a treatment method requires the knowledge about the concentration and behavior of the nitrogen compounds in urine. During separation, storage and transport, urine is subject to several spontaneous processes such as urea hydrolysis, which change the urine composition significantly.

In this research fate of nitrogen in pure urine has been investigated. Also based on a wisdom learned from ancient Persian urine samples have been mixed with acetic acid and sodium bicarbonate and changes in fate of nitrogen and its effect in reducing odor of urine has been studied.

Keywords: Source Separated Human Urine, Nitrogen Compounds, Acetic Acid, Sodium Bicarbonate

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Chapter 1

Introduction

1.1. Introduction

Nutrient overload, or eutrophication, is one of the most serious water quality problems facing the river and its tributaries. Nitrogen and phosphorus are necessary elements for all ecosystems however, too much of these nutrients in natural systems are harmful in the way that happened in The St. Johns River (Fig. 1.1). In other words, the river contains more nutrients than it can "dilute." Excessive nutrients feed uncontrolled algal blooms that deplete oxygen in the water needed by fish, reduce light that is essential to submerged vegetation, and threaten the health of both humans and aquatic life. The river suffers from an excess of nutrients from wastewater treatment plants, industrial discharges, storm water runoff, and fertilizers that regularly wash into the river.

Figure 1.1. The St. Johns River has exceeded its assimilative capacity for nitrogen and phosphorus

The fertilizers we use to grow green crops and lawns are the same fertilizers that grow weeds and algae. As these fertilizers or nutrients enter the lake there's an explosion of weed growth and algal blooms. As weeds and algae die, they sink to the bottom of the lake and begin to decay. As they decay, their decomposition depletes oxygen. Beneficial aerobic bacteria and other microorganisms that depend on oxygen to decompose/digest the phosphorous and nitrogen in the decaying organic matter die.

As aerobic bacteria and muck-eating microorganisms die, anaerobic bacteria take over and the bottom of the lake becomes layered in dead

organic muck. This muck then begins to re-fertilize the lake. This is called internal nutrient overloading. Muck releases phosphorous and nitrogen back into the water column, and continuously fuels further weed and harmful (toxic) algae growth. The lake is fertilizing itself.

Not only in care of environment, but also nutrient overload causes waterborne diseases. Nitrate poisoning affects infants by reducing the oxygen-carrying capacity of the blood. The resulting oxygen starvation can be fatal. Nitrate poisoning, or methemoglobinemia, is commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, US Environmental Protection Agency (EPA) has set a drinking water Maximum Contaminant Level (MCL) of 10 mg/l for Nitrate-nitrogen.

In agriculture, over-fertilizing and poor soil quality can cause imbalances. An excess of nitrogen may make plants look lush and green, but it tends to result in thin, lanky stalks, poor fruit set and an increased risk of blossom-end rot later in the season. This problem occurs more frequently in areas with sandy soil, high salinity or inconsistent moisture levels.

Human urine is the main source of Nitrate. Most of the nutrients in wastewater (about 80% of the nitrogen and 50 % of the phosphorus) derive from urine after it enters the wastewater. However controlling it seems to be

easy as urine accounts for less than 1 % of the total volume of wastewater (Fig. 1.2).

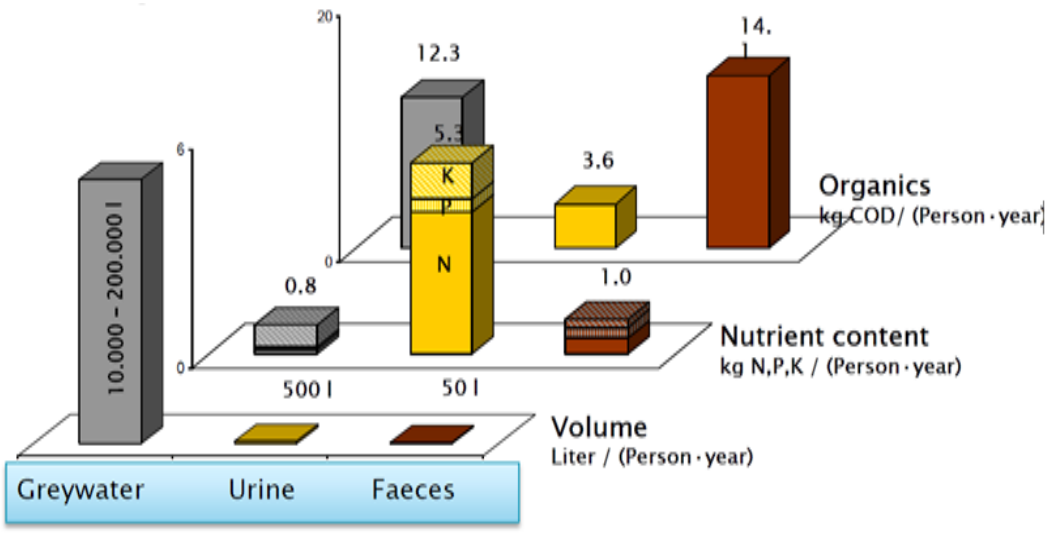

Figure 1.2. Different Parts of Domestic Wastewater and Nutrient Contents

Based on this, the idea of separating urine from the source using urine source separation toilet systems can be a great help in reducing the amount of nutrients in domestic wastewater. Using source separated toilet systems, not only reduces the water consumptions but also as it is shown in figure 1.3, it is able to collect urine, pure and undiluted, so that it can – after sanitisation by storage – be safely used as fertilizer in agriculture (Von Münch & Winker 2011).

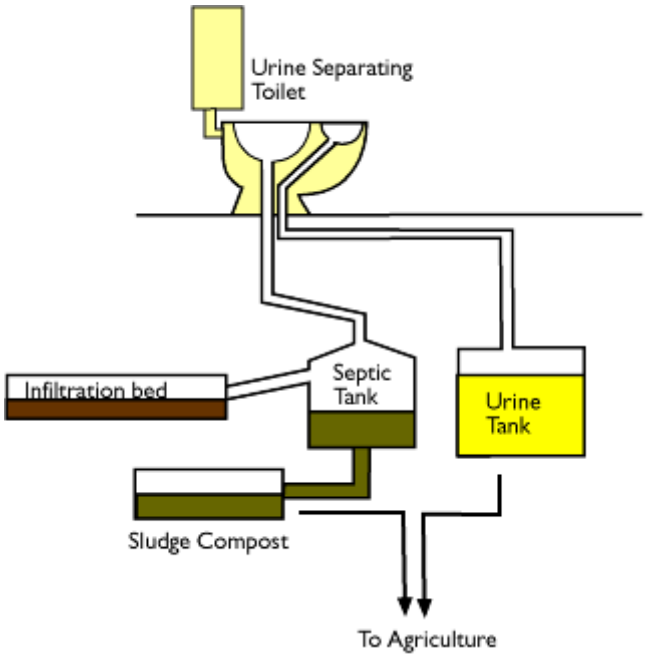

Figure 1.3. Schematic view of Urine Source Separated Toilet Systems and Its Application as Fertilizer

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. Everybody passes about 1.5 liters 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.

The nitrogen found in abundance in urine is good for plant growth because it helps to build protoplasm, protein and other components of plant growth. It certainly promotes leafy growth. Leaves become more numerous, go greener and larger and fleshier with urine application. Phosphorus is important in the root formation, ripening of fruits and germination of seeds, although the percentage of phosphorus compared to nitrogen in urine is low. Potassium is also essential for promoting good fruit (and flower) development. Plants differ in their requirements, but overall plants fed with some urine grow better than plants which never come into contact with urine. Urine is particularly valuable for grasses like maize and leafy green vegetables, and onions, which respond to the high nitrogen content of urine.

1.2. Urine as a Plant Food

When applied to the soil the urea (a small organic molecule) in urine changes into ammonia ions which can be transformed into ammonia gas, which can evaporate and be lost or, in the soil, can be converted by autotrophic bacteria (Nitrosamines) into nitrite ions and then Nitrobacteria into nitrate ions which can be taken up by the plant. The conversion is thus dependent on these bacteria being in the soil. The process takes place in less

than two weeks and often within a few days. It is the nitrogen in the nitrate and the ammonia ions which are available to plants, thus the urea in urine must be transformed before it becomes useful as a “plant food.” The nitrite ions, present during the conversion, can be toxic to plants, but the period is brief and normally there is little effect on plant growth.

The proportion of useful plant nutrients in urine will vary a little. According to Wolgast (1993) one liter of urine contains 11 mg nitrogen, 0.8 mg phosphorus and 2 mg Potassium. That is a ratio of N-P-K of about 11:1:2. If 500 liters 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 (N-P-K) is approximately 11:1:2, which is not ideal for growing most plants, especially in the early stages of their growth.

Most vegetable fertilizers in Southern Africa contain more phosphorus than nitrogen. In an assessment of 10 garden fertilizers available in Zimbabwe, the combined ratios of N-P-K amount to N = 98 points, P =

174 points and K = 125 points a ratio of very approximately 1:2:1. Compound vegetable fertilizers often have a ratio of 2:3:2 for N-P-K. Ammonium nitrate is quite often applied separately as a “top dressing” once the plant is established. The recommended fertilizers for maize provide more phosphorus than nitrogen in the ratio 1:2:1 at the planting or seedling stage and then ammonium nitrate at a later stage once the roots have been established and the plant is secure and meaningful vegetative growth has already taken place. The high phosphorus content of these chemical fertilizers not only reflects the needs of the plant at an early stage of their life, but also that most soils in Africa are very deficient in phosphorus. 70% of natural soils tended by rural farmers in Zimbabwe are very deficient in phosphorus. It is interesting that studies in China show that the daily output of phosphorus in the feces is greater than in the urine.

The balanced array of nutrients present in eco-humus is thus ideal for the early growth of plants with more phosphorus in relation to the other major nutrients, compared to urine. Later on urine can be applied as a liquid plant food during the main vegetative period of growth to supply extra nitrogen. Nitrogen loving plants like maize and green leafy vegetables are particularly responsive.

Also, according to Hill (1997) an excess of nitrogen can reduce the uptake of vital elements like potassium, which is an essential nutrient for healthy plants. Hill also explains that if you fill the plant transpiration stream with a salt and only a fraction gets used, then other more important nutrients may get blocked. The uptake of too much phosphorus may block potassium, whilst excess calcium locks up boron (Hill, 1997). It is not uncommon for magnesium to be deficient where chemical fertilizers provide lots of potassium. The answer to all these problems is to try to accomplish a balance of nutrients in the soil. It is also accepted that unless plants have plenty of humus in the soil, they cannot take up the minerals even if available, especially in drier conditions, a conclusion arrived at by Bromfield (1949) as well as Hill (1997) and many others.

The functions of nitrogen, phosphorus and potassium are interlinked. If large amounts of nitrogen are used, this will cause extra leaf and stem growth, but this growth response will cause the plant to demand extra phosphorus and potassium from the soil. Extra that is to the amount which would have been needed without the nitrogen application. Also nitrogen cannot be efficiently used by the plant unless potassium is there in a proper N/K ratio. Thus deficiencies in phosphorus and potassium show up if too much nitrogen is applied. Nitrogen is a primary growth nutrient, but without the accompaniment of adequate phosphorus and potassium the growth is

unhealthy, more liable to pest attack and disease. Potassium in particular is needed to bring about a balance and ensure that the extensive plant structure is formed of healthy and efficient tissues. This imbalance is perhaps not so serious in short lived plants like lettuce (and green vegetable like spinach). But where the plant has to grow for a full season and eventually produce a seed or fruit crop, these derangements caused by unbalanced nitrogen become serious. Apart from the danger of pest attack and disease, the overstressing of the tissue building function leads to delay in the other functions of the plant and the seed formation or fruit ripening stages are held up.

According to Hopkins (1945) anybody wishing to demonstrate this by personal experience should see how much is lost by giving one or two tomato plants in a row, applications of soluble nitrogen in the late (European) summer. Further leaf and shoot formation will occur but the existing fruit will delay their yellowing and reddening until the autumn sunshine has departed. The fruit yield is thus reduced.

Thus a good balance of nutrients is required for the best plant growth, with generally more phosphorus being required at first in relation to the other major nutrients and then more nitrogen and potassium required later. Adequate amounts of potassium are particularly necessary for crops like

tomato, potato and also fruit trees. Too much nitrogen can block this vital element. So care is required in the overzealous application of urine.

The balance of nutrients available in urine can be influenced by various means. The addition of plants and other materials to form liquor which is allowed to ferment in urine can change the balance. Thus the fermenting of comfrey leaves in urine is known to increase the proportion of potassium in relation to nitrogen (Hill, 1997) – see description in gardening techniques. It is also possible that the peels of fruits like banana, which are known to be high in phosphorus, potassium, calcium, magnesium and sulfur and citrus peels, known to be high in phosphorus and potassium, if allowed to ferment in urine, may readjust the balance of nutrients (a possibility which has yet to be tested). Diluting the lower fraction of urine which has been allowed to sediment out (with the salts containing phosphorus being held in the sediment) may also adjust the balance of nitrogen and phosphorus increasing the phosphorus in relation to nitrogen. But the simplest answer lies in preparing the soil well first with humus and compost, and then feed later with urine in the amount required for specific plants.

1.3. Objectives of Research

This research focuses on managing and controlling the amount of nitrogen compounds in source separated stored human urine in order to reduce the pollutions. Nitrogen compounds have a specific fate in pure stored human urine.

For this matter, as an idea derived from Persian ancient wisdom, fate of nitrogen compounds in urine after adding acetic acid and sodium bicarbonate has been investigated and the effect of this new fate on odor of urine has been studies and based on results, strategies for storing urine and utilizing it for agriculture has been suggested.

1.4. Dissertation Structure

The content of this study is arranged in 6 chapters as shown in figure 1.4. The first chapter deals with general matters on the needs of separating urine from wastewater and utilizing it as a fertilizer. Chapter two contains a detailed literature review on urine treatment and storage in order to be utilized in other aspects. Chapter three contains the initial characteristics of urine, fate of nitrogen compounds in stored pure urine and changes of this fate by adding acetic acid and sodium bicarbonate. Chapter four is a discussion on the bacterial activities of urine on increasing the concentration

of nitrate. Chapter five is discussing on the effect of new fate of nitrogen compounds on the odor of urine. Chapter six is giving suggestions on storage conditions and treatment using acetic acid and sodium bicarbonate for better urine storage. Finally chapter seven is the conclusion of this research.

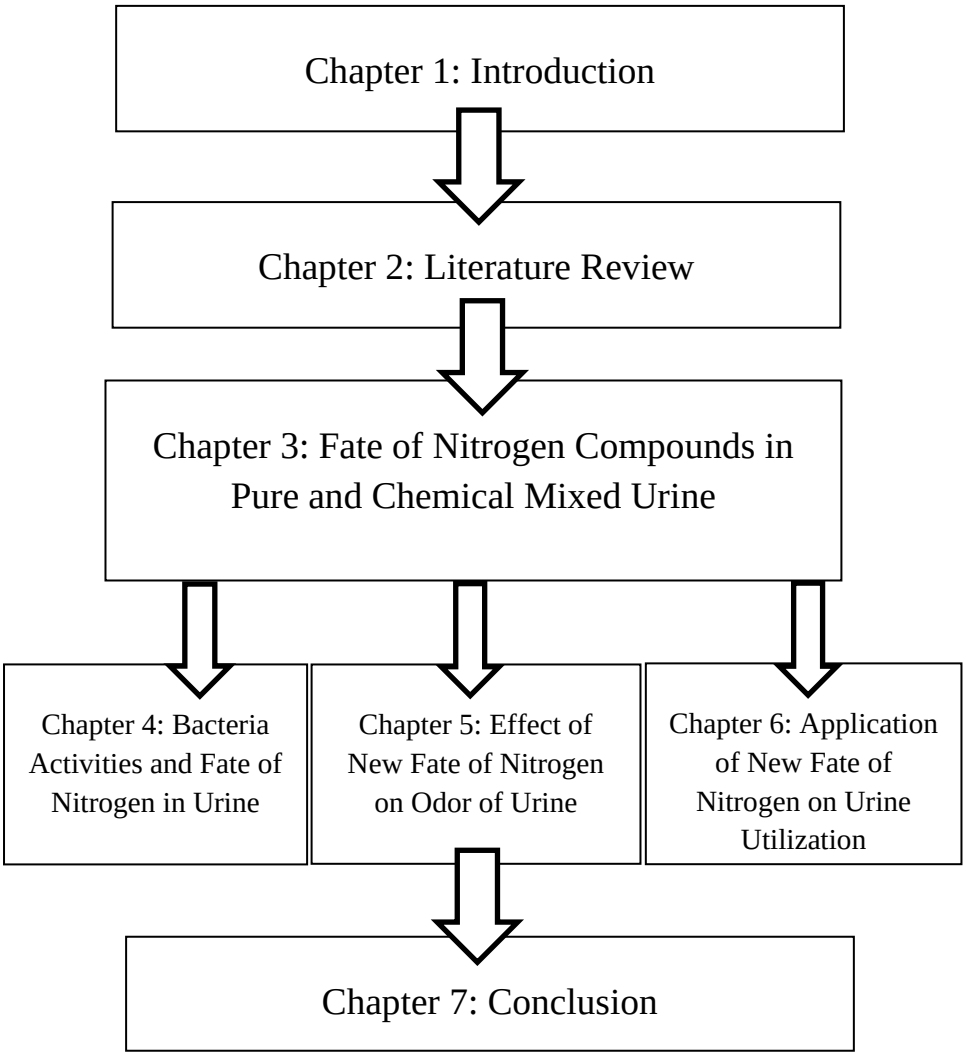

Figure 1.4. Dissertation Structure

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Chapter 2:

Literature Review on Treatment Processes for Source-Separated Urine

2.1. Introduction

In the 1990s, various European groups began working on the same basic idea that separating urine at source could promote the sustainability of wastewater management (Kirchmann and Pettersson, 1995; Larsen and Gujer, 1996). All these approaches are based on the fact that urine contains most of the nutrients in domestic wastewater but makes up less than one percent of the total wastewater volume. Substantial separation of urine at source would thus allow nutrient recycling from a concentrated nutrient solution and at the same time obviate advanced nutrient removal, including nitrification, denitrification and phosphorus elimination (Wilsenach and Van Loosdrecht, 2004).

Urine-source separation presents many advantages, but also leaves many open questions. Besides the obvious advantages mentioned above, it also promises better ways of removing organic micropollutants originating from the human metabolism (Escher et al., 2006) and new ways of more

efficient wastewater management when applied in the rapidly expanding and water-scarce cities in emerging countries (Huang et al., 2006; Medilanski et al., 2006). Furthermore, it offers increased flexibility and a possible shift away from investments in prototypic wastewater treatment plants towards mass-produced market goods (Larsen and Gujer, 2001). Flexibility is well illustrated by the many different treatment options discussed in this paper, ranging from nutrient removal to nutrient recycling, but the potential of mass-producing goods for wastewater treatment is seldom discussed. As an example, household treatment of urine seems inefficient and expensive with today's technology, but nobody has really examined how long it would take a market economy to develop smart mass-produced technology to do exactly that at competitive costs. There are also many challenges in connection with source separation of urine. Once urine has left the body it becomes an unpleasant, smelly and unstable solution. It is locally produced and the present practise of dilution with large amounts of water is actually a perfect way of neutralizing many of the more unpleasant aspects of urine. Furthermore, centralized wastewater management is a system with interdependent actors, and changing even a small part of it is extremely difficult (Larsen and Lienert, 2003). Finally, the question of transportation has not yet been solved. Larsen and Gujer (1996) suggested local storage and transport in sewers over night; the concept developed in Sweden is longterm

local storage followed by truck transport (Hanaeus et al., 1997); in some pilot projects, multiple piping is tested (Peter- Frohlich, 2002) and finally, on-site treatment may be possible in the future, provided that the technical difficulties can be overcome (Wilsenach et al., subm.). In the present paper, we concentrate on the possibilities and difficulties of the process engineering options.

Because the composition of urine reflects the average requirement of nutrients for plant growth (Heinonen-Tanski and van Wijk-Sijbesma, 2005), the use of urine as a fertilizer in agriculture is the most obvious application, but industrial usage or simple nutrient removal are other possible options.

2.2. Nutrient Removal

If the aim of urine treatment is improved control of water pollution, it may be desirable to remove N and P without recovering them. Whereas biological P-removal has never been considered for the treatment of source-separated urine, full nitrification can easily be achieved with an extension to partial nitrification (see above). Denitrification (resulting in N2) may be achieved in a number of ways: biological reduction of nitrate with organic matter as the electron donor; biological oxidation of ammonia with nitrite as

the electron acceptor (the anammox process) or electrochemical oxidation of ammonia (NASA 1977). Of these technologies, the anammox process has been studied in detail for urine.

2.3. Anammox Process

Anaerobic ammonium oxidation (Anammox) is a biological process designed to eliminate nitrogen independently of a carbon source (Strous et al., 1998). Under anaerobic conditions, ammonium and nitrite are converted mainly to nitrogen gas. The formation of nitrite stops halfway through the process, producing a 1:1 ammonium/ nitrite solution. Udert et al. (2003c) added this solution to anammox sludge from a pilot plant treating digester supernatant. At 30 1C they measured a denitrification rate of 1000 $gNm^{-3}d^{-1}$ and the ratio of total ammonia to nitrite elimination was 1:1.18±0.07. The results of these experiments show that nitrogen can be removed from sourceseparated urine with anammox. A combination of nitrification and anammox reactors could eliminate 75–85% of the nitrogen, leaving an ammonium nitrate solution.

2.4. Removal of Micro Pollutants

Increasingly powerful analytical methods mean that a large number of pharmaceuticals and natural hormones from the human metabolism are now detected in the aquatic environment, but their environmental relevance is currently unclear. Most of the effects that can be observed, e.g. the formation of vitellogenin (a precursor of egg yolk proteins) in male trout (Harries et al., 1997), are chronic effects without clear consequences for the affected organism. It is generally recognised that urine contains a significant amount of excreted micropollutants. In general, a distinction must be made between separation and elimination processes. The separation of nutrients and micropollutants is relevant to the production of a urine-based fertilizer, whereas the micropollutants must be eliminated for water-pollution control.

Separation processes are primarily based on membranes or precipitation whereas removal processes are based on oxidation or adsorption (Larsen et al., 2004).

In addition to the processes presented here, it is possible in principle to remove micropollutants by adsorption to active carbon or other adsorbents. It can be expected that the presence of high amounts of COD in urine strongly interfere with the adsorption process (Quinlivan et al., 2005).

2.5. Electro Dialysis

Electro dialysis membranes are ion-exchange membranes made of functionalized polymers with a dense structure (Strathmann 1992) enabling salts to be extracted and concentrated. The apparent pore size is typically around 200Da (Kim et al. 2003) so that these membranes can potentially retain micro pollutants. Investigations showed that electro dialysis may be used to selectively extract the nutrients into a concentrated product stream while retaining the micro pollutants (pharmaceuticals) in the dilute (Pronk et al., 2006a). Experiments with bipolar membranes were carried out (Pronk et al. 2006b) in order to manipulate the pH. Ammonia was transferred across a hydrophobic membrane from the basic into the acid concentrate. Batch experiments confirmed that a pH decrease occurred in the acid concentrate, also known as the product compartment. However, at higher conversions the pH rose again to its original value.

This pH increase can be attributed to carbon dioxide transported from the basic concentrate across the gas-filled membrane into the acid concentrate (Pronk et al. 2006b). The use of an ammonium-selective gas-transfer membrane instead of a hydrophobic gas-transfer membrane should in principle solve this problem, but this has not yet been investigated.

2.6. Nano Filtration

Nan filtration has been tested for the retention of a range of environmentally relevant compounds such as pesticides (Van der Bruggen et al., 2001), disinfection byproducts and pharmaceutical compounds (Kimura et al., 2004), phthalates (Kiso et al. 2001) and natural steroid hormones (Nghiem et al. 2004). For production of an urine based fertilizer, it is important for the micro pollutants to be retained and for mineral salts to be permeated in order to obtain a product free of micro pollutants. The removal of micro pollutants was tested with different nano filtration membranes (Pronk et al. 2006c). The efficiency of the separation process depends strongly on the pH, demonstrating that electrostatic interactions with the membrane play an important role in the separation of micro pollutants. Under optimized conditions, the removal rate of a set of hormones and pharmaceutical compounds in urine exceeds 92% (Pronk et al. 2006c). Furthermore, it was shown that the permeation of urea is almost complete, while 50–80% of the ammonia was retained, depending on the pH. In order to obtain high nitrogen recoveries, therefore, it is important to use non-hydrolysed urine.

2.7. Ozonation and Advanced Oxidation

Micro pollutants can be oxidized with chlorine, chlorine dioxide, ozone (O3), or OH radicals (advanced oxidation processes, AOPs, see Prousek, 1996). In the case of ozone, the reaction can take place directly with ozone or with the secondary oxidants (e.g. OH-radicals) formed during ozonation (Von Gunten 2003a; Von Gunten 2003b). In view of the high COD content of urine (2–10 g/l), oxidants reacting specifically with micro pollutants are preferred. As most of the compounds tested show enhanced reactivity towards ozone (Huber et al. 2003), use of ozone seems to be preferable to advanced oxidation processes because a larger fraction of the oxidant (OH radical) is lost to the matrix in the latter. From recent investigations with urine, it was concluded that complete oxidation of a representative set of micro pollutants including pharmaceuticals and synthetic hormones may be achieved (Pronk et al., 2006d). Despite the quenching of oxidants by the organic matrix in urine, it was shown that all the tested compounds could be transformed completely. At an ozone dose of 1.1 g/l, fast-reacting compounds such as ethinylestradiol were completely removed, while removal of more recalcitrant compound such as ibuprofen was 80% (Pronk et al, 2006d). Analysis of the results showed that oxidation took place directly by ozone as well as by OH radicals. Considering the high

reactivity of the OH radicals with most organic micro pollutants, ozonation can be regarded as a suitable method for removing a wide range of micro pollutants from urine.

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Chapter 3

Fate of Nitrogen Compounds in Urine and Urine Mixed with Acetic Acid and Sodium Bicarbonate

3.1. Introduction

Ancient Persian people knew vinegar and its benefits very well. Vinegar has been valued for its healing properties for thousands of years in Iran, and during that time, it has found its way from the apothecary's shelf to the cook's pot. Today, it can continue to play that dual role, taking the place of less healthful dietary ingredients and helping to regulate blood sugar levels while entertaining our taste buds with its tart flavor.

For centuries, Iranian used different types of vinegar to add flavor and zest to their food. Read about how this tangy condiment was first discovered and then developed into a must-have for kitchens around the world. Learn the key ingredient that gives vinegar its special sour taste and the basic chemical process used to create it.

Persian ancient royal family used white vinegar as a deodorant. They used it in the laundry to whiten, brighten, reduce odor and remove mildew.

Also these days vinegar is known very well as a material that can remove the smell of human or animal urine from the Persian carpets effectively.

In the other hand, Persians knew Baking Soda's deodorization power as a result of its ability to neutralize odors, rather than just covering up odors with perfumes. Most unpleasant odors come from either strong acids (like sour milk) or strong bases (spoiled fish). Baking Soda deodorizes by bringing both acidic and basic odor molecules into a neutral, more odor-free state. Use Baking Soda as a personal deodorant for underarms and feet, and as a household deodorant on carpets, upholstery and in the fridge and freezer. Baking Soda can also deodorize when it's dissolved in water. Recently, in the industry Baking Soda is used for odor control of sewage disposal plants and around barn and feedlots.

As it was mentioned in chapter 1, human urine is the main source of nitrogen in domestic wastewater which improper dumping of it causes nutrient overloads. In this chapter, firstly, characteristics of pure urine and fate of nitrogen compounds in pure urine has been studied and then by adding acetic acid (vinegar) and sodium bicarbonate (baking soda) to urine, the fate of nitrogen compounds has been investigated.

3.2. Chemical Concept

Urea in urine is the source of nitrate due to the chemical reactions below:

$CH_4N_2O+H_2O \rightarrow 2NH_3+CO_2$ ***(Enzyme Urease)***

$2NH_3+3O_2 \rightarrow 2NO_2^-+2H_2O+2H^+$ ***(E-coli Bacteria)***

$2NO_2^-+O_2 \rightarrow 2NO_3^-$

As it is declared in reactions above, the ration of urine and nitrate is 1 to 2. It is notable that average of nitrate ions in urine is around 51 gram (Figure 3.1). Also the ammonium from enzyme urease is the main source of awful odor!

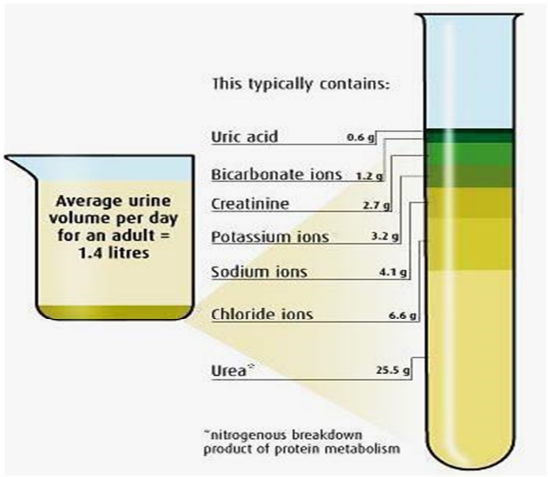

Figure 3.1. Characteristics of Urine

Main nutrients in urine are phosphate, potassium and Nitrate. Nitrate is the majority part of urine (Figure 3.2). As this amount of Nitrate cannot be

tolerated by the root of some immature plants, it is needed to be controlled. Nutrient amounts demanding of some plants are presented in Table 3.1.

Table 3.1. Nitrate Demand of Some Plants

Plant	Nitrate Demand (mg per Kg weight of plant)
Cress, Radish	1500
Spinach, Lettuce	1000
Leeks, Parsley, Cilantro, Basil	500
Cucumbers	250
Potatoes, Onions and Tomatoes	50

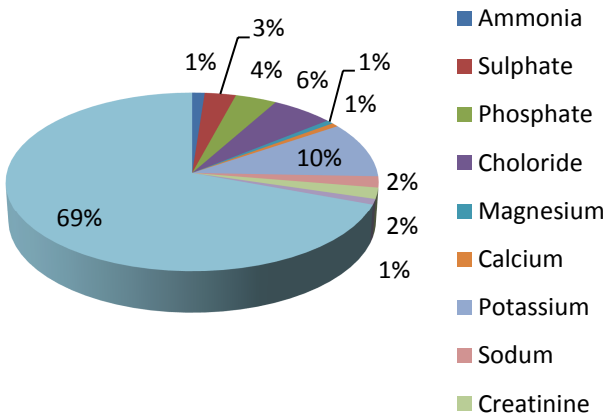

Figure 3.2. Percentage of Nutrients in Urine

3.3. Changes in Urine pH by Time, Temperature and Composition

There are many literature and research on urine characteristics. Based on Cook et.al, 2007 studies on pH change of urine under various conditions, as

the temperature increased the pH of the urine aliquots also increased. At 4°C the pH gradually increased with time to reach a high of pH 8.1 at 14 days. At 25°C the pH jumped dramatically for all conditions by day 1 of incubation. In the second day, the pH for the 25°C incubation aliquots had leveled off to a pH of about 9.2 for the majority of the conditions. The pH in those samples containing glucose never exceeded pH 9.0, with the highest pH values ranging from 8.7 to 9.0 at 25°C At 37°C peak pH values > 9.0 were achieved by 24 hours. Those specimens containing glucose and incubated at 93°C showed an initial increase in pH at day 1 (pH 7.8 - 8.4) followed by decreasing pH values with time. Urine spiked with glucose and incubated at 93°C darkened in color, varying from honey to black, with some of these specimens developing a precipitate. Specimens in the other conditions incubated at 93°C achieved pH values ranging from 8.8 to 9.2 by first 24 hours and leveled off for the duration of the incubation. Graphical representation of the pH changes with time is presented in Fig 3.3.

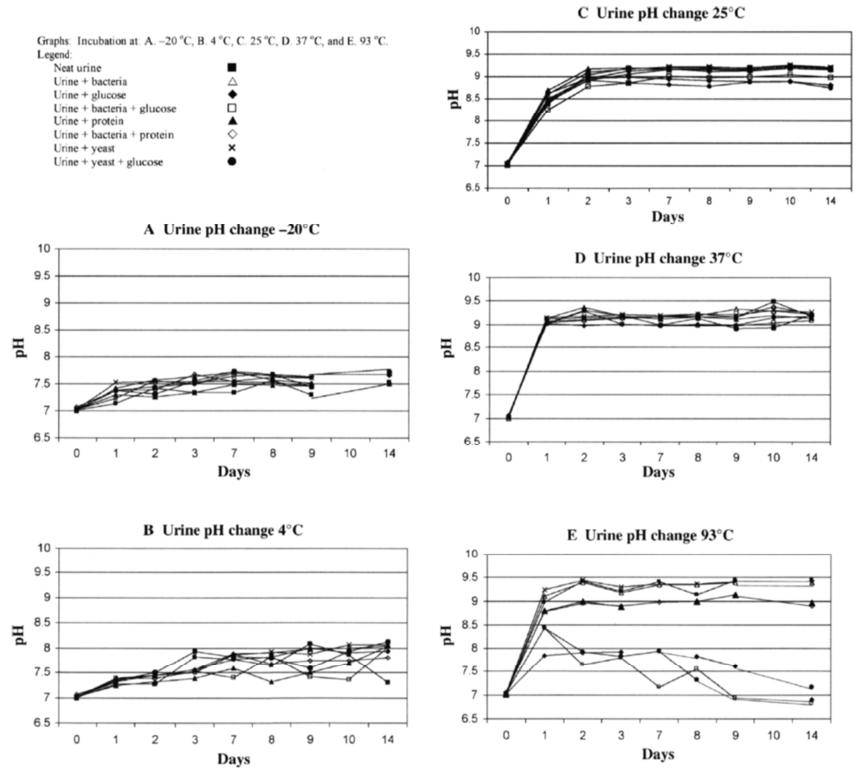

Figure 3.3. The Change in Urine pH With Time at Various Temperature under Various Conditions

As a point of interest, the inclusion of microorganisms (bacteria and yeast) and protein and glucose at pathological levels did not have any significant effect on the changing pH values, excluding the pH decreasing effect of glucose at 93°C after day 1, as evident from the graph that depicts the changes in the neat urine at various temperatures (Figure 3.4).

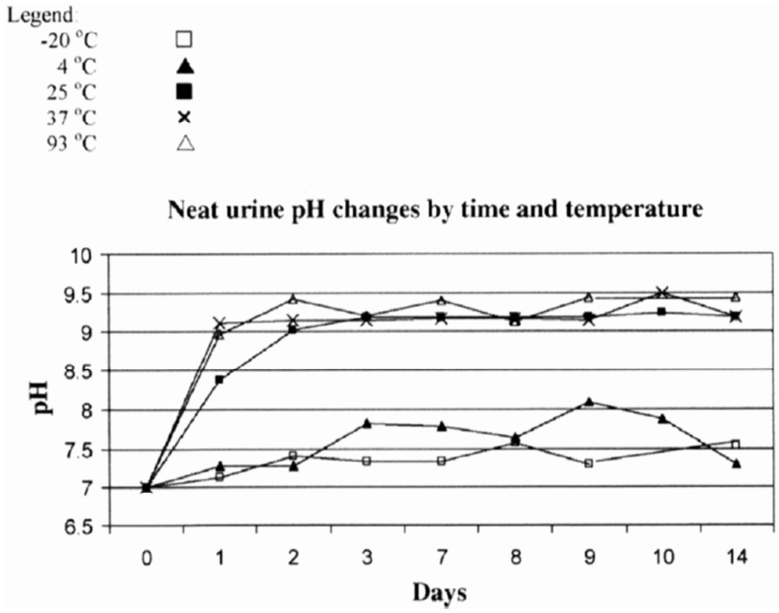

Figure 3.4. The Change of pH With Time and Temperature for the Neat Urine

Temperature and pH have important effects on enzymatic and spontaneous chemical reactions (J. Chen et.al 2005). As temperatures decrease, both enzymatic and spontaneous chemical reactions are significantly slowed (J. Chen et.al 2005). Changing the pH has a tremendous impact on enzymes, which typically have a narrow pH range for catalytic activity (J. Chen et.al 2005). In addition, pH determines protein binding and the stability of pH-sensitive molecules (J. Chen et.al 2005). Thus, it is important to understand the preanalytical effects of post void urine temperature and pH changes and their relationship to the analyze conditions present at sample collection. Urine contains urea and uric acid, non-protein

nitrogenous waste compounds, which are common constituents of urine. The stability of these two molecules is affected by bacterial contamination. Uric acid is degraded by microbial uricase activity to allontoin, hydrogen peroxide, and carbon dioxide while urea is labile to bacterial urease activity with ammonia and carbon dioxide produced as products (Kaplan 1984 and Schultz 1984). To prevent degradation, it is recommended that urine for uric acid and urea determinations be stored at 4°C to inhibit bacterial growth (Kaplan 1984 and Schultz 1984). Optimally, urine for urea analysis is best preserved at pH values < 5.0 (Kaplan 1984).

3.4. Changes in Urine Creatinine, Urea, Uric Acid, Osmolality and Specific Gravity by Temperature

Urine specific gravity was stable at each incubation temperature. The other analyses showed varying stability by temperature. Urine urea was stable only at -20°C uric acid at -20 and 4°C and creatinine at-20, 4, and 25°C Urine osmolality values were stable at -20 and 4°C increased at 25 and 93°C and decreased at 37°C (Figure 3.5).

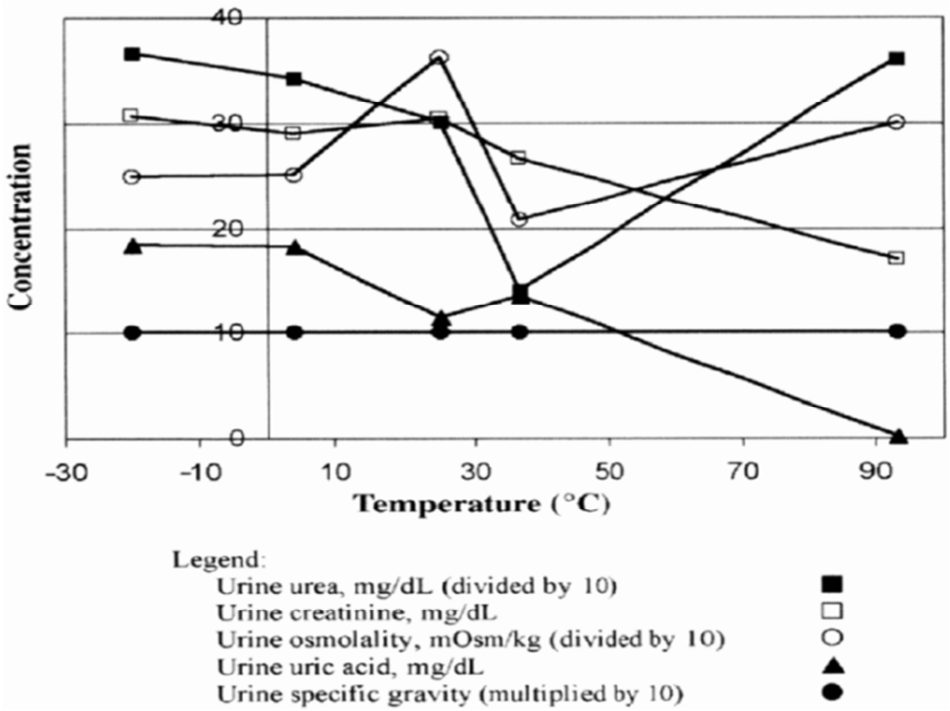

Figure 3.5. Change in Urine pH With Time at Various Temperature under Various Conditions

3.5. New of Fate of Nitrogen Compounds in Urine by Adding Acetic Acid and Sodium Bicarbonate

Amount of urea not only rules the amount of Nitrogen in urine, but also by producing ammonia is the main character for urine odor. Managing the amount of urea can also have effect on removing bad smells. As mentioned before. Persian People from very ancient time till now use vinegar

as a deodorant. Vinegar is symbol of cleanliness in Persian culture. They deodorize and clean urine from carpets by water diluted vinegar.

Adding Sodium Bicarbonate (Baking Soda) and Acetic Acid (Vinegar) can control the odor by deactivating ammonia as below:

$NH_3 + CH_3COOH \rightarrow (NH_4)^+_{(aq)} + CH_3COO^-_{(aq)}$ **(Role of Acetic Acid)**

$2NH_3 + 2NaHCO_3 \rightarrow (NH_4)_2CO_3 + Na_2CO_3$ **(Role of Sodium Bicarbonate)**

In order to study practically on this issue, a series of experiments has been designed as fallows.

3.5.1. Materials and Methods

Urine was provided from water-free urine toilets installed in department of civil and environmental engineering of Seoul national university. Acetic acid with 99.5% purity has been provided from Samchun Chemicals Company and sodium bicarbonate with 99.7% purity has been provided from Sigma-Aldrich Company. Urine solution with additional 1, 5, 10, 30 and 50g/l concentration of each agent has been prepared. Ammonium, nitrate, nitrite and total nitrogen measurement tests have been applied on these solutions as below.

3.5.1.1. Standard Methods for Chemical Measuring

Concentration of ammonia, nitrite and nitrate was measured following the US-EPA standards as mentioned in table 3.2. These methods can be used directly for trace amounts of chemicals, or following distillation when other interfering substances are present.

Table 3.2. Standard Methods of Chemical Measurement

Measuring Objective	Method (US-EPA Standards)
Ammonia (NH3)	Nessler
Nitrite (NO2-)	NED
Nitrate (NO3-)	Brucine
Total Nitrogen	

3.5.2. Results and Discussion

3.5.2.1. Fate of Nitrogen Compounds in Pure Urine

Urine was kept for 30 days and variation of ammonia, nitrite and nitrate has been investigated. Figure 3.6 is showing the variation of ammonia during time.

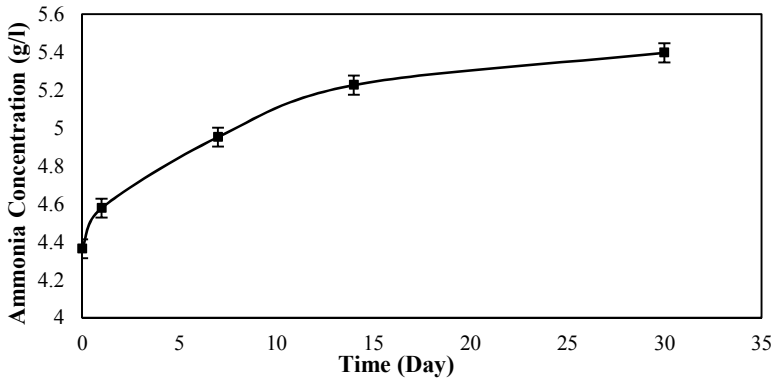

Figure 3.6. Variation of Ammonia Concentration versus Time

Based on mass balance and measured total nitrogen Figure 3.7 shows how urea is changing into ammonia. Numbers in this figure numbers are showing the percentage of nitrogen compounds in total nitrogen on temperature 22 ^{o}C.

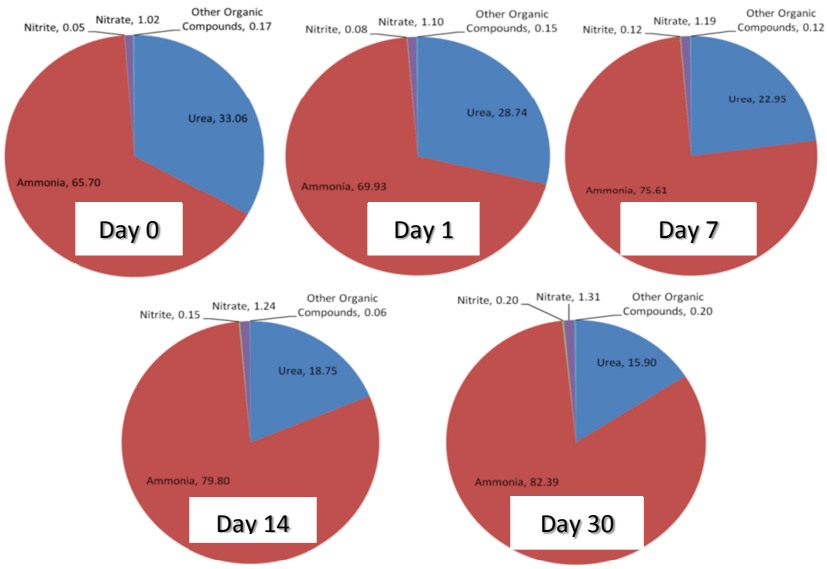

Figure 3.7. Changes of Nitrogen Compounds in Pure Urine versus Time at 22 ^{o}C

Change of pH during time for pure urine is presented in figure 3.8. The pH rises because of chemical reactions which lead the ammonia changes into ammonium as below:

$CH_4N_2O + H_2O \rightarrow 2\ NH_3 + CO_2$

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

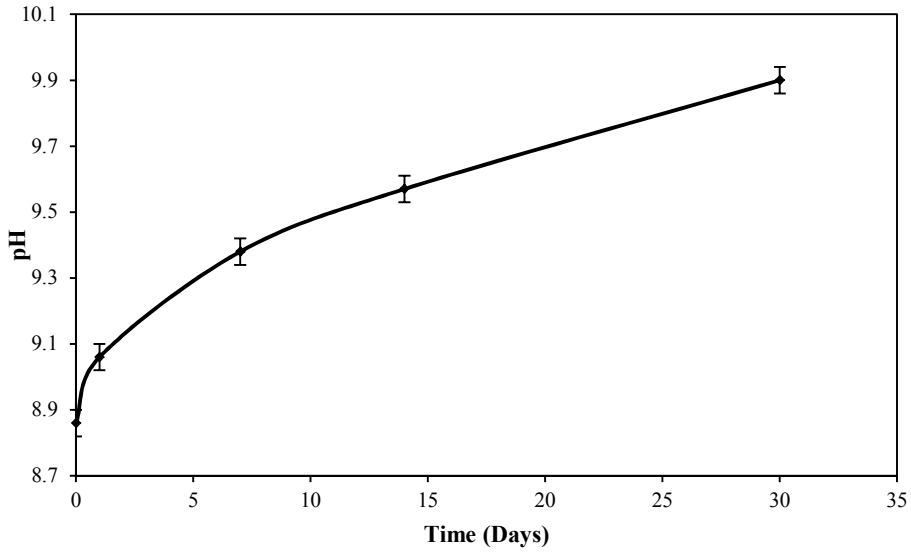

Figure 3.8. Variation of pH in Pure Urine versus Time

Based on these results, the initial concentration of nitrogen compounds in pure urine is presented in table 3.3.

Table 3.3. Urine Initial Concentrations of Nitrogen Compounds

pH	Specific Gravity	Total Nitrogen	Ammonia (NH_3)	Nitrite (NO_2^-)	Nitrate (NO_3^-)	Threshold Odor Number
8.86	1.019 gr/cm^3	4557.21 mg/l	4363.63 mg/l	2.22 mg/l	66.72 mg/l	56

3.5.2.2. Fate of Nitrogen Compounds in Urine Mixed with Sodium Bicarbonate

Chemical reaction of sodium bicarbonate with ammonia appeared from enzyme urease is as below:

$2NH_3 + 2NaHCO_3 \rightarrow (NH_4)_2CO_3 + Na_2CO_3$

Figure 3.9 is showing the changes of ammonia by adding sodium bicarbonate in 4 and 22 ^oC which are common temperature for storing urine. In cold storage condition sodium bicarbonate shows a better efficiency in reducing ammonia.

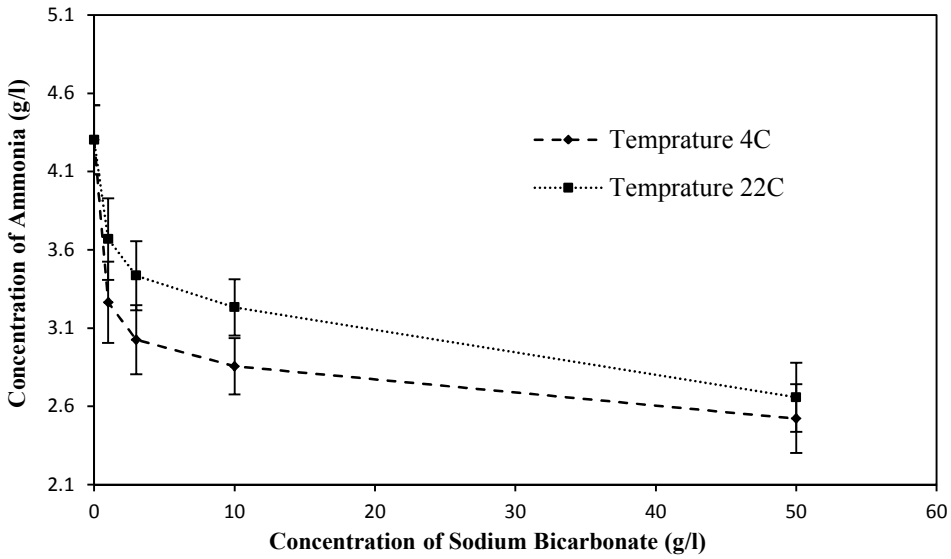

Figure 3.9. Variation of Ammonia in Urine Mixed with Sodium Bicarbonate in Different Temperatures

Figures 3.10 and 3.11 are presenting the fate of nitrogen in urine mixed with sodium bicarbonate in temperature 4 and 22 ^{o}C respectfully. In both cases, ammonia is changing into ammonium carbonate which wakes less odor and pollution.

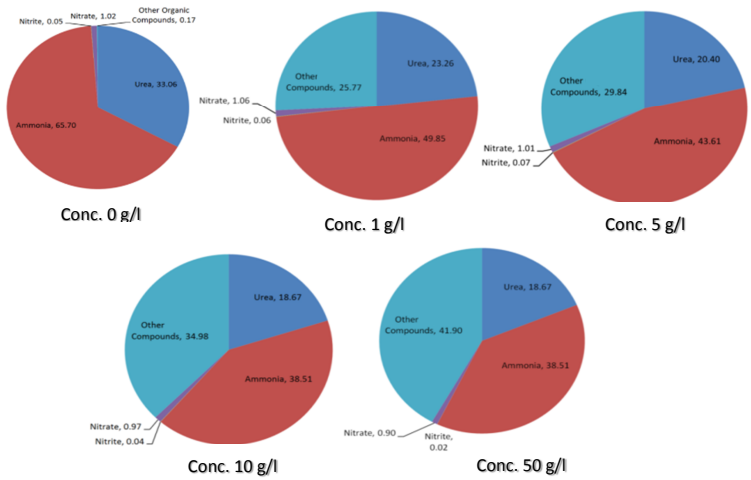

Figure 3.10. Nitrogen Compounds in Urine mixed with Sodium Bicarbonate at 4 ^{o}C

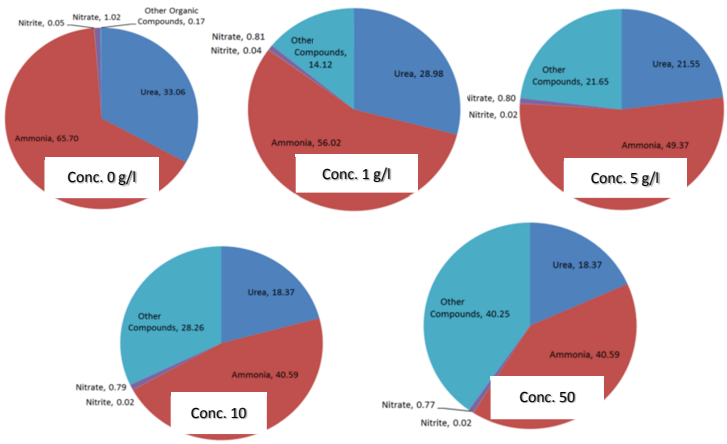

Figure 3.11. Nitrogen Compounds in Urine mixed with Sodium Bicarbonate at 22 ^{o}C

3.5.2.3. Fate of Nitrogen Compounds in Urine Mixed with Acetic Acid

Chemical reaction of acetic acid with ammonia appeared from enzyme urease is as below:

$$NH_3 + CH_3COOH \rightarrow (NH_4)^+_{(aq)} + CH_3COO^-_{(aq)}$$

Figure 3.12 is showing the changes of ammonia by adding acetic acid in 4 and 22 ^oC which are common temperature for storing urine. In cold storage acetic acid is slower in moderating ammonia.

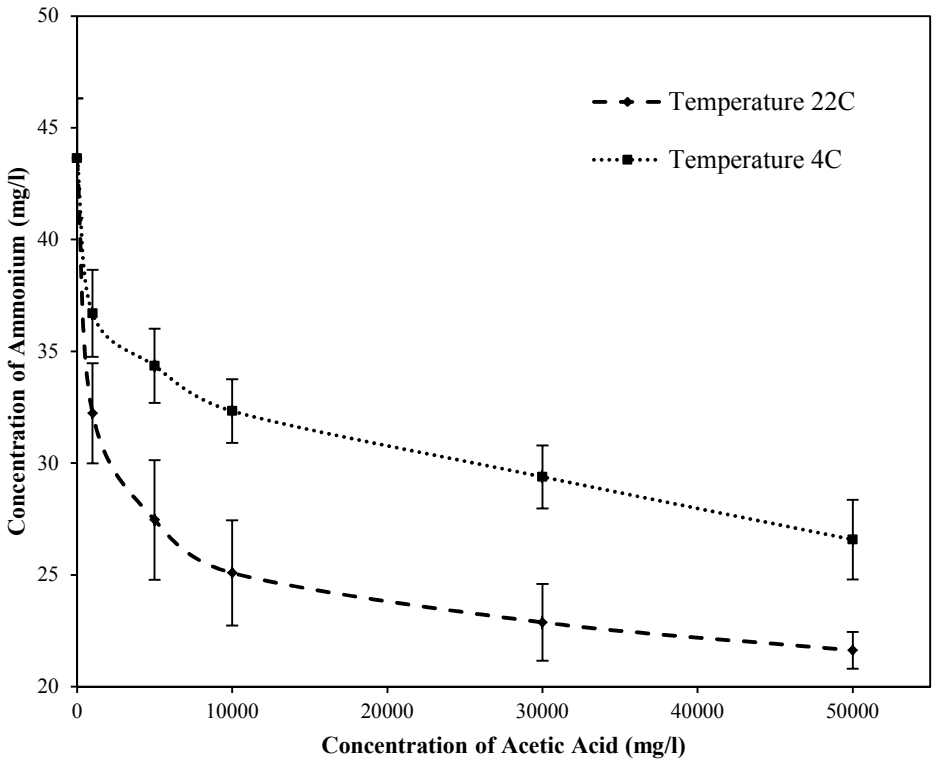

Figure 3.12. Nitrogen Compounds in Urine mixed with Sodium Bicarbonate at 22 ^oC

Figures 3.13 and 3.14 are presenting the fate of nitrogen in urine mixed with acetic in temperature 4 and 22 ^{o}C respectfully. Generally acetic acid shows a better efficiency in comparing with sodium bicarbonate by reducing the percentage of ammonia from 66 to 33 percent.

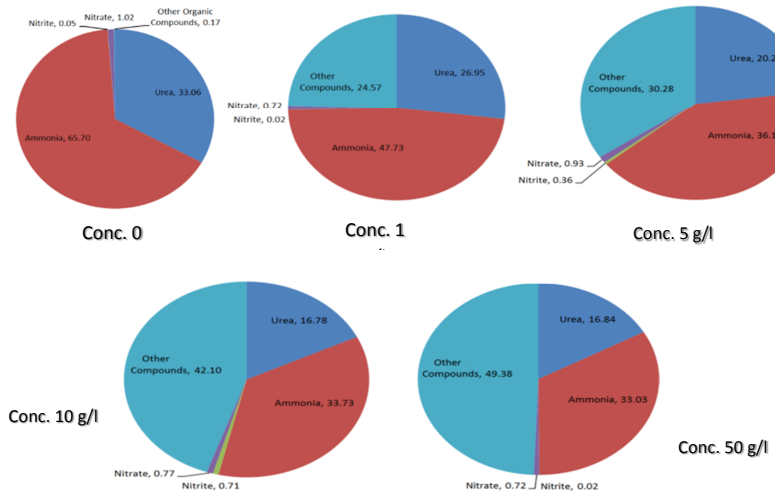

Figure 3.13. Nitrogen Compounds in Urine mixed with Acetic Acid at 4 ^{o}C

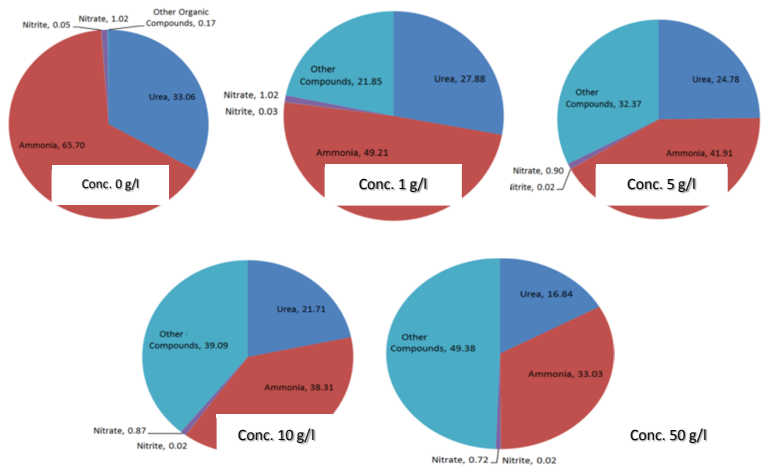

Figure 3.14. Nitrogen Compounds in Urine mixed with Acetic Acid at 22 ^{o}C

Also in 4 ^{o}C adding acetic acid increases the concentration of nitrite dramatically which is shown in figure 3.15. This matter happens due to some bacterial activities such as biological oxidation of ammonium and will be fully studied in chapter 4.

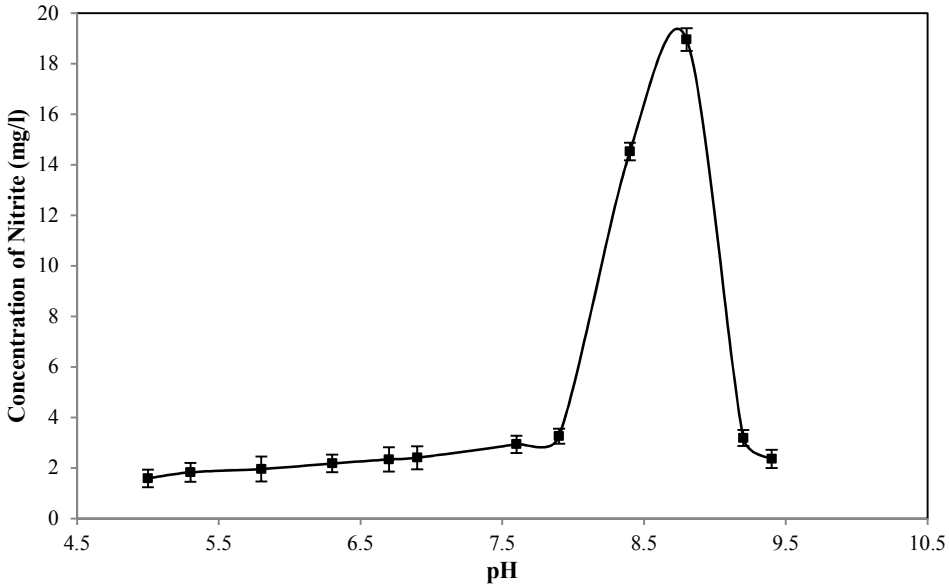

Figure 3.15. Changes in Nitrite Concentration in Urine mixed with Acetic Acid at 4 ^{o}C

3.6. Conclusion

Ammonia in urine appears from enzyme urease reaction which makes odor in urine. After that the oxidation process of ammonia leads to appearance of NO_x compounds which makes pollution.

Mixing urine with acetic acid and sodium bicarbonate can moderate the amount nitrogen compounds up to 55%. The effect of adding these chemicals are appearing in case of ammonia by charging it into other odorless and safe compounds.

The amount of nitrite in adding acetic acid rises dramatically. In this case, using more acid in cold storage is suggested. In chapter 4, the reason of this phenomenon will be investigated. Also in chapter 5, the effect of the new fate of nitrogen compounds in mixing urine with acetic acid and sodium bicarbonate will be investigated.

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Chapter 4

Effect of Bacterial Activities on Fate of Nitrogen Compounds in Urine Mixed with Chemicals

4.1. Introduction

In previous chapter, it is reported that although mixing acetic acid with urine can decrease the concentration of ammonia, it increases the concentration of nitrite if stores at 4 ^{o}C which can make environmental pollutions.

Increasing amount of NO_x compounds has been reported in several literatures and in all of them it is reported that this phenomenon happens because of bacterial activities (Moshagh et al. 1998). Udert et al, mentioned that this phenomenon is because of biological oxidation of ammonium (BOA) (Udert et al, 2005). As ammonium is a main product of chemical reaction between ammonia and acetic acid, the by chemical reactions of BOA are as below:

$$NH_3 + CH_3COOH \rightarrow (NH_4)^+_{(aq)} + CH_3COO^-_{(aq)}$$

$$(NH_4)^+ + 0.5\ O_2 \rightarrow NH_2OH + H^+$$

$NH_2OH + O_2 \rightarrow NO_2^- + H^+ + H_2O$

However in this research this phenomenon has been observed in a low temperature. The objective of this chapter is finding out what kind of bacteria is making this phenomenon in a cold storage case.

Following this objective, by using bacterial DNA tests, the bacterial community of urine has been investigated in urine samples with different pH in different temperature.

4.2. Materials and Methods

Urine samples with different pH have been used for this study. Urine samples derived from men waterless urinals in Seoul National University building number 35 and samples with various pHs have been prepared by adding sodium bicarbonate and acetic acid. To identify the bacteria living in urine, DNA test has been done following standard 16S rD/RNS PCR, using the Polymerase Chain Reaction (PCR).

This technique creates large numbers of copies of the DNA to be tested. This delivers enough DNA to be tested for the presence of the target genetic sequence. This DNA presence has been tested by nucleic acid hybridization technique. Figure 4.1 is showing three-temperature thermal

cycler for PCR. By this method, the bacterial community and number of living bacteria has been identified in different temperatures.

Figure 4.1. Three-Temperature Thermal Cycler Equipment for PCR

4.3. Results and Discussion

4.3.1. Results of Bacterial DNA Test

Bacterial DNA test has been done at different temperatures in samples with different pH. Figure 4.2 is showing the bacterial community at 5 ^{o}C with pH 8.4 which the peak of nitrite concentration happens. In this

community, *C. Pneumonia* has the majority with 10460 cfu/ml which shows that they reproduce more than other kinds of bacteria under this condition.

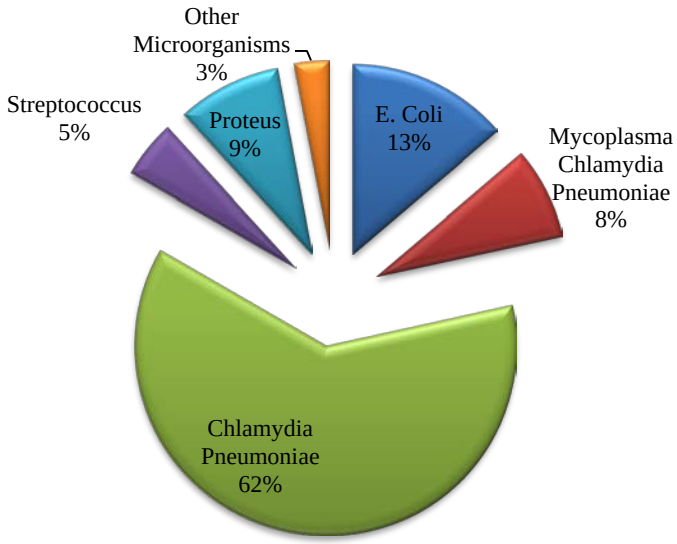

Figure 4.2. Bacterial Community of Urine Sample at 5 ^{o}C with pH 8.4.

Figure 4.3 shows that how the percentage of *C. Pneumoniae* in the whole community changes with pH in 5^{o}C comparing with nitrate concentration.

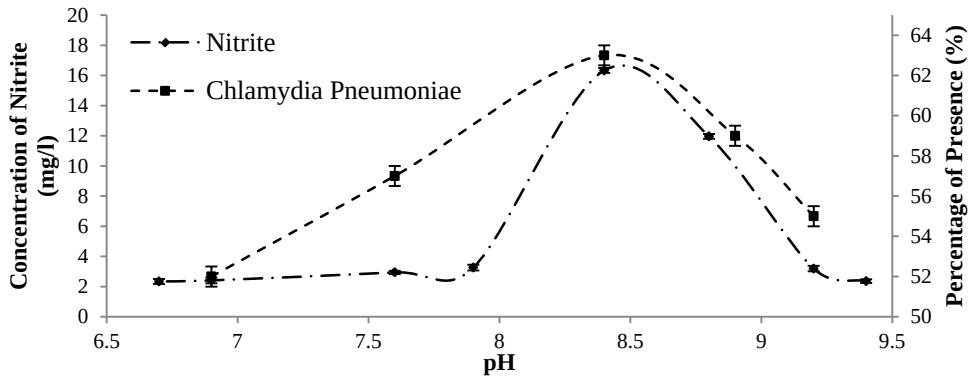

Figure 4.3. Comparing Variation of Percentage of Presence of *C. Pneumoniae* with Concentration of Nitrite versus pH at 5 ^{o}C

By comparing this with results of nitrite concentration, it is obvious that the peak of these parameters is happening in the same pH. This may indicate that *C. Pneumoniae* can be considering as the bacteria that makes this phenomenon happens in low temperature.

However bacterial community changes in higher temperatures. It is observed that in temperature higher than 15 ^{o}C, the majority of the community is *Streptococcus*. Figure 4.4 is showing this fact as an example at 25 ^{o}C in pH 6.2 which *Streptococcus* is the majority with 18200 cfu/ml.

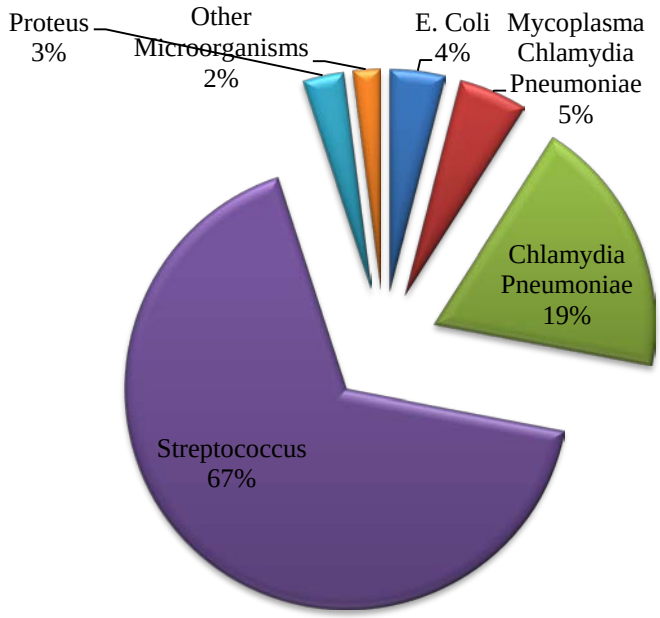

Figure 4.4. Bacterial Community of Urine Sample at 25 ^{o}C with pH 6.2

Figure 4.5 is showing the variety of percentage of presence for *Streptococcus* versus pH at 25 ^{o}C comparing with nitrate concentration.

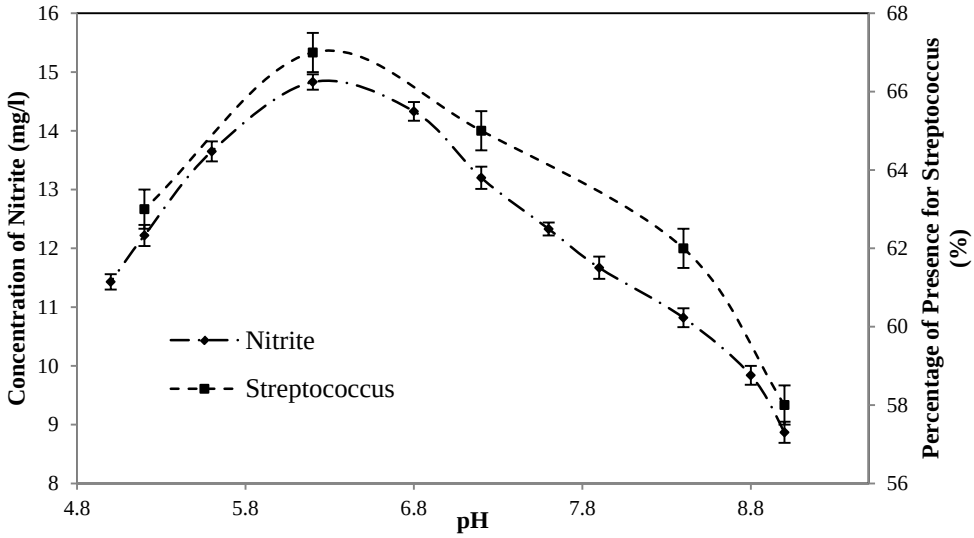

Figure 4.5. Comparing the variety of percentage of presence for Streptococcus with Concentration of Nitrite versus pH at 25 ^{o}C

As it is shown in this graph, the peak of percentage of presence for *Streptococcus* happens in pH 6.2 which is the pH that the peak of nitrite concentration happens. This illustrates that the dramatic rises in concentration of nitrate in temperature higher than 15 ^{o}C may be related to activities of *Streptococcus*. Also results suggest that *C. Pneumoniae* shows stronger ability in nitrification as it can produce more nitrite.

4.4 Conclusion

Increasing nitrite in source separated human urine has been reported in many literatures and most of them assume that biological oxidation of ammonium can be the reason.

Based on observed results in this research it is found that bacterial activities may be the main reason for this phenomenon even in low temperatures. Based on this, bacterial DNA tests have been done to find out what kind of bacteria can make this phenomenon happen.

Based on the results, in lower temperature *Chlamydia* and in higher temperature *Streptococcus* has the majority of bacterial community. The close coverage in trend and peak of changes in amount of these bacteria with the nitrite concentration versus pH may suggest that the sudden raise in nitrite concentration can happen with biological activities of these kinds of bacteria.

References

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Chapter 5

Effect of Changes in Fate of Nitrogen on Odor of Urine

5.1. Introduction

Controlling and managing odor is an important part of urine separation storage. In case of fresh urine, odor can reflect what has been consumed or specific diseases. For example, an individual with diabetes mellitus may present a sweetened urine odor. This can be due to kidney diseases as well, such as kidney stones.

Eating asparagus can cause a strong odor reminiscent of the vegetable caused by the body's breakdown of asparagusic acid (Lison et al. 1980). Likewise consumption of saffron, alcohol, coffee, tuna fish, and onion can result in telltale scents. Particularly spicy foods can have a similar effect, as their compounds pass through the kidneys without being fully broken down before exiting the body (Gates et al. 2006).

However in source separated human urine, the ammonia released from enzyme urease is the main source of odor (Beauchamp et al. 2012 and Zhang et al. 2013). As it is shown in chapter 3, adding sodium bicarbonate

and acetic acid can effect on the fate of nitrogen compounds in source separated human urine by changing ammonia into other compounds. This shows that such changes can effect on urine odor as well. In this chapter, the effect of these changes in nitrogen compounds on odor of urine has been investigated.

5.2. Materials and Methods

Urine samples have been prepared in the way which is explained in chapter 3. Ammonia solution with 1 mol/L concentration has been used from Samchun Chemicals Company for measuring the odor of pure ammonia. Threshold odor number (TON) has been used as an indicator for measuring odor of urine as it is indicated in Standard Method 2150 of US Environmental Protection Agency. Threshold Odor Numbers are whole numbers that indicate how many dilutions it takes to produce odor-free water. As described in Standard Method 2150, the test involves two steps.

Step one is used to determine the range of dilutions for the final test. Amount of 200 ml, 50 ml, 12 ml, and 2.8 ml sample to four 500 ml flasks was added. Enough odor-free water to the flasks added to create a total volume of 200 ml. Also, another flask filled with only odor-free water has been prepared. The flasks were heated up to 40 - 60°C and shake. Starting

with the odor-free water, each flask was being smelled and proceeding from lowest to highest concentration of sample water. Flasks for the final test prepared according to the volume of sample in the jar that first has a detectable odor as mentioned in Table 5.1.

Table 5.1. TON Sampling Method Table

Volume of Sample that First Has a Detectable Odor (ml)	**Volume of Samples for Final Test (ml)**				
2.8	Intermediate Dilution				
12	12	8.3	5.7	4.0	2.8
50	50	35	25	17	12
200	200	140	100	70	50

After adding the amounts of sample water indicated to five 500 ml flasks as mentioned in Table 5.1, odor-free water was added to bring each flask to a total volume of 200 ml. Two blanks (flasks with 200 mL of odor-free water) were included in the series of samples near the expected threshold for a total of seven samples. By have a group of testers or doing the test in different days with same conditions, each flask was smelled, beginning with the smallest concentration of sample water. The volume of sample water in the first flask was recorded an odor is detected. Threshold Odor Numbers (TON) will be computed by using equation below and the final TON will be mentioned by the geometric means of whole recorded data.

$$\text{Threshold Odor Numbers (TON)} = \frac{(\text{The volume of sample water}) - (\text{The volume of odor-free water})}{(\text{The volume of sample water})}$$

5.3. Results and Discussion

5.3.1. Minimum Concentration of Ammonia to be Smelled

Nose of human can start feeling smells with TON between 8 up to 10 (Dietrich, 2003). Figure 5.1 is showing the results TON measurement on pure ammonia. As it is shown in the graph, for concentration around 2.5 g/l of ammonia, the smell can be felt and by increasing the concentration, the smell gets stronger.

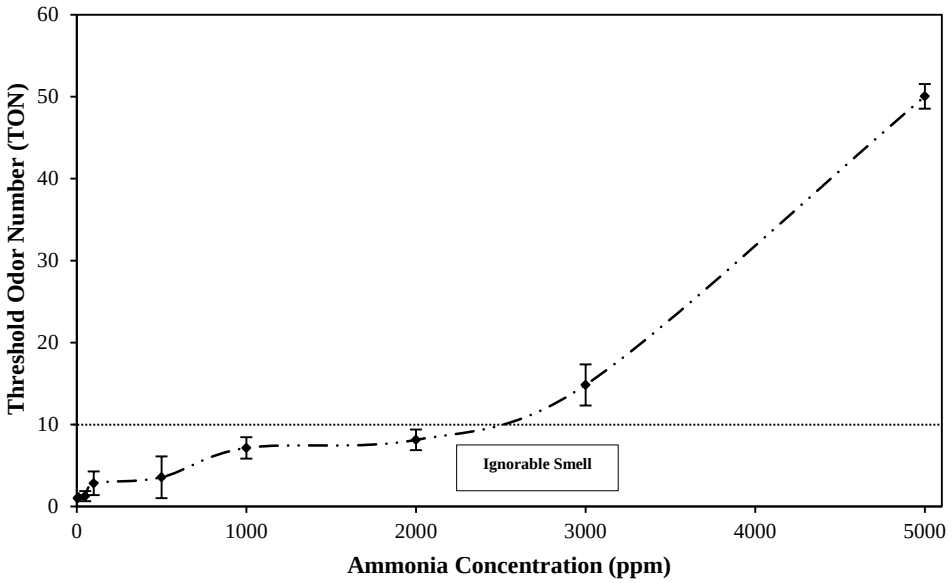

Figure 5.1. Variation of TON versus Concentration for Ammonia under Standard Conditions

Based on this result, the minimum concentration for smelling ammonia is 2.5 g/l which by controlling the amount of ammonia concentration around this amount, it may be possible to remove the smell in an economical way.

5.3.2. Effect of Adding Chemicals on Odor of Urine

Figure 5.2 is presenting the results of TON experiment on pure urine and urine mixed with acetic acid and sodium bicarbonate under standard conditions.

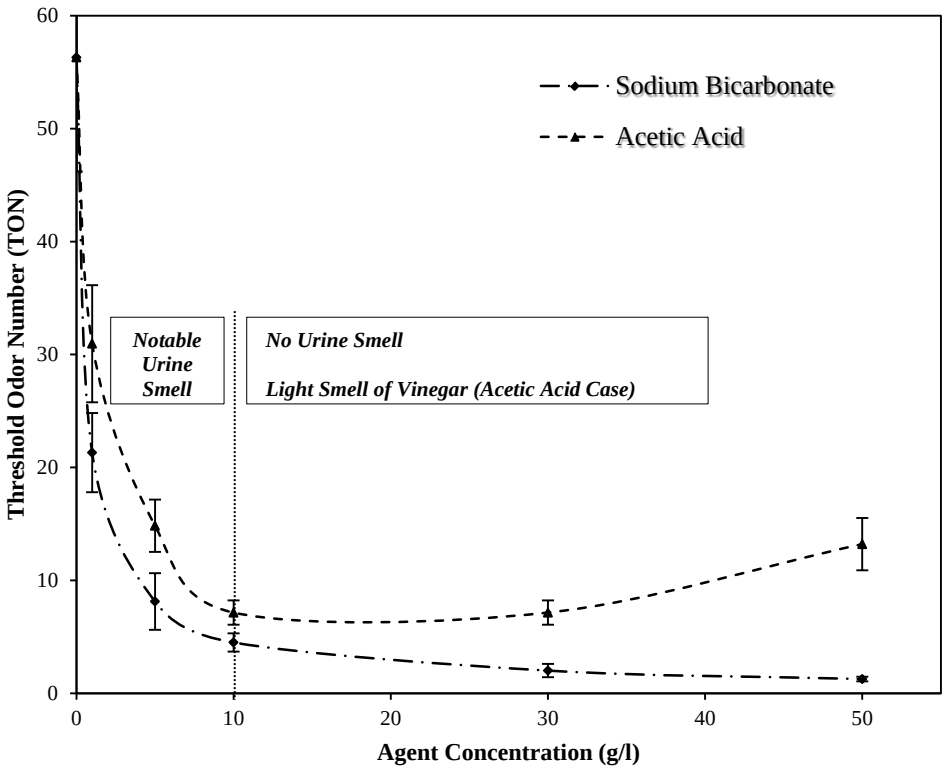

Figure 5.2. Variation of TON versus Concentration of Mixed Chemicals under Standard Conditions

Results indicate that both agents reduce the TON of urine. However in case of acetic acid, the light vinegar odor can be felt in concentration more than 30 g/l which leads to increasing TON in this condition.

5.4 Conclusion

Odor in storing source separated human urine is an important challenge. This research illustrates that by adding acetic acid and sodium bicarbonate can control the amount of ammonia which leads to controlling the smell of urine as well.

Results show that the TON has been reduced up to 75% which is the results of changing the fate of nitrogen compounds by adding acetic acid and sodium bicarbonate. These chemicals can reduce the odor or urine by changing ammonia into other odorless and safe chemicals. This matter used to be practiced by ancient people of Persia as they used to apply vinegar and soda to the urine polluted cloths in order to remove the awful odor.

Furthermore, based on the results it is illustrated that the minimum amount of ammonia for making smell is 2.5 g/l. This fact should be considered in urine treatment as by controlling the amount of ammonia in urine, it is possible to reduce and control odor of stored urine.

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Chapter 6

Application of New Fate of Nitrogen on Urine Utilization

6.1. Introduction

In previous chapters, it was discussed that how nitrogen compounds such as ammonia can rise up in pure urine. Raising ammonia not only can make different pollutions but also it increases the odor of urine which is an important challenge in urine treatment and managements.

However, it was observed that following ancient Persian practice, using acetic acid and sodium bicarbonate can have a positive effect on the fate of nitrogen compounds. Results show that they can reduce the amount of ammonia and keep it constant and by doing this, it is also possible to control the odor of urine. Furthermore, by controlling the pH in different temperatures, we can control condition of bacterial activities in order to control nitrite more effectively.

Now, the question is that when acetic acid and when sodium bicarbonate agent should be used. To find an answer to this question, in this chapter, by taking a closer look to changes of ammonia concentration in

different pH and temperature conditions innovative strategies has been suggested for urine storage treatment. And based on these strategies, a new concept called Urine Storage and Treatment Diagram has been introduced.

6.2. Materials and Methods

Urine samples with different pH have been used for this study. Urine samples derived from men waterless urinals in Seoul National University building number 35 and samples with various pHs have been prepared by adding sodium bicarbonate and acetic acid.

The samples have been made inside plastic tubes to make up 150 ml of volume, and were shaken intensively for 10 seconds. The samples were then left for 30 minutes to react before they were used for sample characterization. Concentration of ammonia was measured following Nessler method as a US-EPA standard for all these samples in 5 ^{o}C up to 30 ^{o}C.

6.3. Results and Discussion

Ammonia concentration has been measured for samples with different pH in temperatures 5 ^{o}C up to 30 ^{o}C. Figure 6.1 is showing simplified results for 5 and 25 ^{o}C.

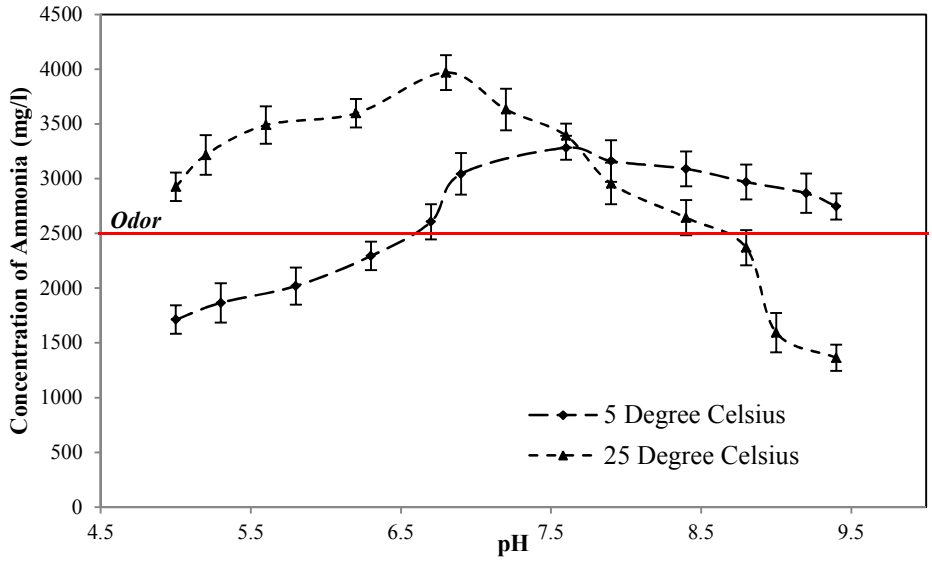

Figure 6.1. Changes of Concentration for Ammonia Versus pH In Different Temperatures

Results presented by figure 6.1 are suggesting that the amount of ammonia in lower temperature (5^{o}C) increases over 2500 mg/l by pH which also means increasing odor. However, in higher temperature, by increasing pH, the amount of ammonia and odor are reducing. This fact can state that in summer time, urine is better to be treated in alkalinity condition, however in winter, acidic storage condition is suggested.

6.4 Conclusion

As it was concluded in chapter 5, while the amount of ammonium in a sample is less than 2500 mg/l, the smell may not be felt as the TON is less than 10.

Based on this idea and the ammonia concentration measurement in urine in different pH and temperatures a new and innovative concept called "Urine Storage and Treatment Diagram" is introduced as figure 6.2.

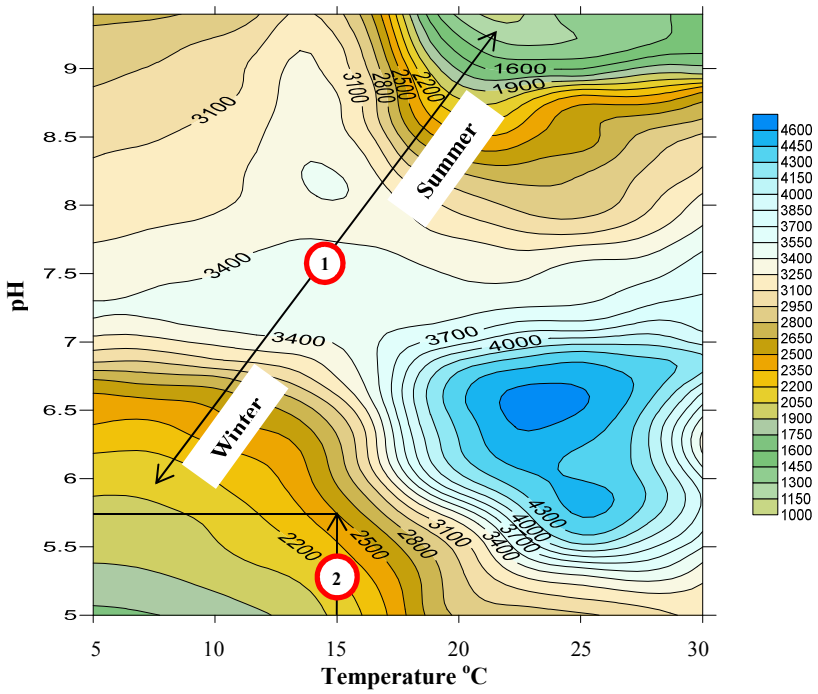

Figure 6.2. Urine Storage and Treatment Diagram

The X- axis of this diagram shows the temperature in ^{o}C and Y- axis is pH and numbers on the diagram are the concentration of ammonia in mg/l. If the temperature of storage is not controlled (arrow number 1), this diagram suggests that during winter, the pH of urine should be reduced during winter, therefore, adding more acetic acid is suggested. Following this discussion,

during summer, the higher pH can keep the ammonia concentration less than 2500 mg/l which can be achieved by adding more sodium bicarbonate.

However, if the storage is being done under a certain temperature, this graph can also suggest the best condition for storage. For example if the storage temperature is 15 ^{o}C (arrow number 2), the best controlled pH is 5.7.

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Chapter 7

Conclusion

The objective of this study was studying on the fate of nitrogen compounds in pure urine and the way this fate changes by adding acetic acid and sodium bicarbonate which is an idea derived from ancient wisdom of Persian people. Also the effect of this change in nitrogen fate on the odor of urine has been investigated. It is illustrated that treating and storing source separated urine should be done under a good condition in order to reduce smell and other pollutions.

Based on this study:

1. Untreated urine has a high concentration of nitrogen compounds which can be moderated by using acetic acid and sodium bicarbonate.

2. By changing the nitrogen fate, adding acetic acid and sodium bicarbonate can moderate the nitrogen concentration up to 55%.

3. There is a dramatic increase of nitrite in each temperature on a certain pH which is related to bacterial activities of *C. Pneumoniae* and *Streptococcus* respectively in low (5-15 ^{o}C) and high (more than 15 ^{o}C) temperature.

4. Changing nitrogen fate can control the amount of ammonia which leads to controlling the smell of urine as well. The TON has been reduced up to 75%.

5. For managing the conditions of storing urine in different temperature, by controlling the pH, it is possible to control the variation of ammonia and odor using urine treatment and storage diagram.

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Appendix 1: Korean Abstract

초 록

소변 분리 화장실에서 질소의 운명

오늘날 대소변의 혼합된 처리는 여러 가지 문제점을 가지고 있다: 음용수를 포함한 많은 자원이 낭비되고 인, 질소, 칼륨과 같은 소중한 영양분들이 환경으로 배출되며, 미세오염물질이 비효율적으로 제거되고 있다. 소변의 대변으로부터의 분리는 효과적인 대안이다.

그러나, 소변이 가지고 있는 영양분들은 비료로 사용하기에 적합한 형태로 존재하지 않을 뿐만 아니라 소변은 인공호르몬, 의약물질, 대사산물과 같은 미세오염물질을 포함하고 있다. 이러한 물질들은 주로 소변을 통해 배출되며 생태계와 인간 건강에 해로울 수 있다. 이 물질들은 하수처리장에서 효율적으로 처리되지 못하고 있기 때문에, 오늘날 많은 미세 오염물질들이 그대로 수계로 배출되고 있다.

소변 처리는 적절한 비료를 생산하는 데에도 필요하며, 미세오염물질로 인한 환경오염을 막는 데에도 적절한 방법이 될 수 있다. 처리방법을 개발하는 것은 소변 내 질소화합물의 농도와 거동에 대한 지식을 필요로 한다. 소변의 분리, 저장과, 이동 동안 소변은 우레아 가수분해와 같이 소변의 구성을 크게 변화시키는 여러가지의 자동적인 공정을 거친다.

이 연구에서는 순수한 소변에서의 질소의 거동에 대해 알아보았다. 또한 과거 고대 페르시아로부터 배운 지식을 기반으로 하여, 소변 샘플들을 아세트산과 중탄산나트륨과 혼합하였을 때의 질소 거동의 변화와 소변의 악취를 제거하는 효과에 대해 연구하였다.

주요어: 소변 분리 화장실, 질소 화합물, 초산, 중탄산 나트륨

학번: 2012-23969

Appendix 2: Award for 2014 International Research Competition

Award

First Prize

Awarded to Shervin Hashemi

Department of Civil and Environmental Eng., College of Engineering

This person above has achieved remarkable results in the "2014 International Research Poster Competition" Thus we present this award in acknowledgment of the contribution followed by your efforts and cooperation in this competition.

College of Engineering, Seoul National University

December 12, 2014

Kunwoo Lee, Ph.D.
Dean
College of Engineering
Seoul National University