City of San José

San José/Santa Clara Water Pollution Control Plant Master Plan

TASK NO. 4
PROJECT MEMORANDUM NO. 10A
URINE SEPARATION

FINAL DRAFT
August 2009

in association with

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CITY OF SAN JOSÉ

SAN JOSÉ/SANTA CLARA WATER POLLUTION CONTROL PLANT MASTER PLAN

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1.0 INTRODUCTION

1.1 Purpose

The Master Plan preparation includes the assessment of potential technologies for waste minimization that could reduce the influent flow and/or loads to the San Jose/Santa Clara Water Pollution Control Plant (WPCP). The Technical Advisory Group (TAG) Workshop No.1 recommended evaluation of the potential for changes in the existing situation of upstream conditions to impact the need and timing of future facilities at the WPCP.

The purpose of this task is to perform a planning-level assessment of urine separation practices and measures which would reduce the per capita wastewater flows and pollutant loadings to the WPCP over the long-term (i.e., over the 30-year planning horizon). Specifically, the focus is on the removal of nutrients (N and P) and associated flow from the plant influent.

1.2 Objectives

The objectives of this project memorandum are listed below:

- Provide a summary description of urine separation, collection, treatment and reuse practices
- Provide a survey of readily available public information on the anticipated reductions in flow volumes, ammonia, nutrients and other trace pollutants consistent with this technology.
- Determine a planning-level project cost (order of magnitude) to implement urine separation, localized storage and trucked collection on a per household basis.
- Present an estimate of potential impact of urine separation on plant flows and loads.

Urine separation generally results in two distinct waste streams; the separated urine stream and the feces stream. This assessment focuses only on the separated urine stream.

2.0 OVERVIEW

According to Jonsson, et al., urine is the urban waste fraction containing the largest amounts of nutrients. It contains approximately 70 percent of the nitrogen and 50 percent of the phosphorus and potassium in all household wastewater fractions. Figure 1 illustrates the relative composition of nutrients and organics in domestic wastewater.

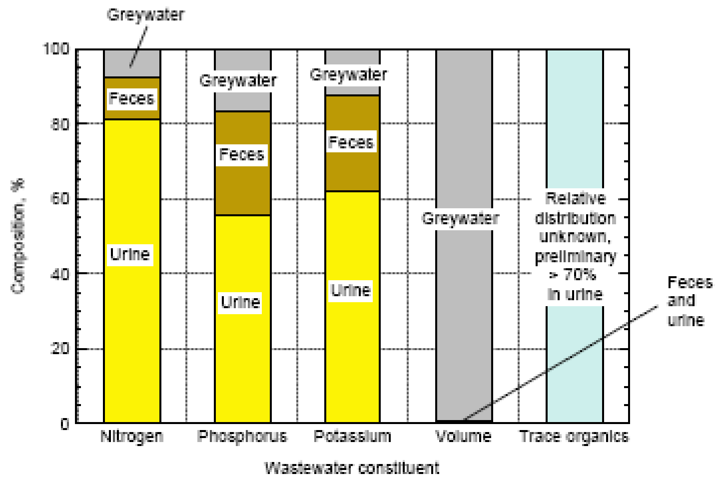

Figure 1 Recycling Source Separated Human Urine
Source: Jonsson et al. 2000

In the past 10 to 15 years new systems for municipal wastewater management, based on separation at the source, have been developed or are under development. At present, these source-separating systems can be divided into two basic approaches:

- Grey water (shower, washing and bathwater) and black water (toilet water) are separated at household level and treated separately.
- Urine is separately collected and treated or used as fertilizer.

The potential advantages of source-separating systems over the traditional wastewater system are (1) reduced use and or recovery of resources (water, nutrients, organic material and energy), (2) reduction of emissions to the environment, and (3) more efficient handling of flows due to less dilution. Figure 2 illustrates the fundamental direction of urine-separating practices in many countries.

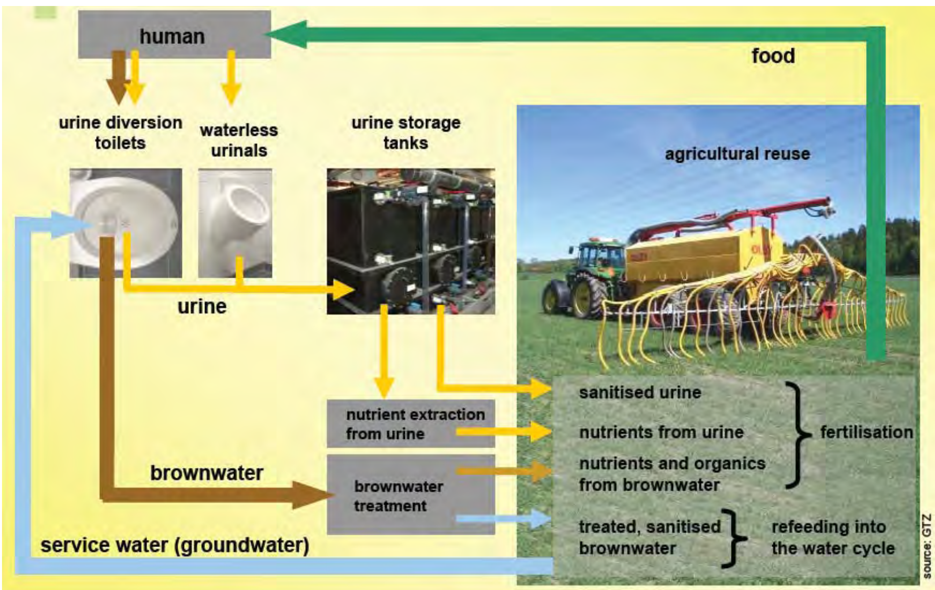

Figure 2 Illustration of Current Urine Separation Practices
Source: Ecosan GTZ, 2008

The practical implementation of source-separating sanitation systems in urban settings has proven to be rather complex due to the involvement of many parties, such as land and project developers, housing corporations, the local community, water authorities and water utilities, and health regulators. Application of urine separation technology is even more challenging in locations where considerable investments have already been made in large scale collection, centralized treatment and disposal infrastructure. Over the past 10 years, urine separation has been practiced in a number of relatively small communities throughout many industrialized nations. While large scale applications are envisioned, none currently exist that can provide performance – related information.

Separated urine has been successfully used as fertilizer for its nutrient-rich content since the days of the Roman Empire and earlier. Literature cites many cases where urine is used for fertilizing, drinking for medicinal purposes and for wool processing. There is considerable concern today about the fate of trace pharmaceuticals, hormones and other compounds that may be found in urine, and the potential detrimental impacts on the receiving water and soil environments. Urine separation provides a means to isolate trace pharmaceuticals from the wastewater stream headed to the treatment plant, and subsequently, receiving waters. While research directed at the detection and treatment of these compounds in urine is increasing, it is likely that considerably more time and effort is required to identify proven treatment techniques and appropriate health regulations in the US. For the most part, the US has not been an active participant in the recent development and application of urine separation technology.

2.1 Driving Forces

The main driving forces for urine separation as reported in literature are:

- Protect receiving water bodies against eutrophication by significantly reducing emission of nitrogen and phosphorus from wastewater treatment plants. For example, Sweden has been developing and deploying urine separation systems since the early 1970s to protect against further eutrophication of the Baltic Sea. In the US, the effluent regulatory limitation for N is typically, 10 mg/l, or lower depending on the receiving water. The power requirement for the nitrification process may result in significant carbon emissions and an increased carbon footprint. Reducing the amount of influent nitrogen (via urine separation) can help treatment plants meet increasingly more stringent effluent nitrogen standards, and reduce the total amount of nitrogen discharged, while reducing their carbon footprint.

- Reduce the consumption of potable water related to disposal of urine into wastewater collection systems. Urine separation can reduce typical flushing volumes by 50 to 80 percent.

- Reduce the cost to small communities for sewage collection, transport and disposal. In locations where urine is collected and used for fertilizer, local treatment of grey water and feces is economical. Significant centralized wastewater system costs required to connect, convey, treat, and dispose of flows from small communities are avoided.

The application of urine separation has demonstrated potential benefits that can be considered as complements to the main driving forces:

- Significant reduction in energy costs associated with the treatment of the urine component of wastewater for Nitrogen and Phosphorus removal (i.e., nitrification). Several studies have shown that up to 80 percent of the total N load and approximately 45 percent of the total P load in municipal wastewater originate from urine (Larsen and Gujer, 1996). Reducing the quantity of influent nitrogen can significantly reduce power demand and carbon footprint of a treatment plant.

- The separation of trace pharmaceuticals, hormones, salts and other trace organics from wastewater typically found in urine. The separation from the municipal wastewater flow can reduce the impacts on receiving waters.

- Direct utilization of the urea and phosphorus in urine as a fertilizer. Natural phosphorus deposits are expected to be fully mined by 2050; therefore, phosphorus is quickly becoming a scarce commodity. Urine separation captures the phosphorus and enables direct reuse, and decreases the demand for mined phosphorus.

- Use of soil for advanced treatment of residual trace organics and pathogens. Trace organics and pathogens can degrade through natural attenuation in the soil subsurface.

2.2 Urine Characteristics

Knowledge of concentrations or loads in wastewater flows is a basic prerequisite for the design of wastewater treatment facilities and the assessment of the environmental impacts associated with each level of treatment. Limited data is available for the characteristics and design values for the various components of source-separated wastewater. The predominant amount of information comes from European and Scandinavian sources, which may not be directly applicable to local conditions.

A desk study of more than 130 references was carried out by F. Meinzinger and M. Oldenburg (2009) to arrive at design values for different source-separated wastewater flows including the fractions urine, feces and grey water. The evaluation was carried out focusing on European data and the different values were analyzed by the use of statistical parameters. To arrive at design values for different parameters, the median as well as minimum-maximum ranges of the available data were calculated. The collected data shown in Table 1 include volumes and characteristics of organic pollution (COD and BOD), nutrients (N, P, K & S) and heavy metals for the different source-separated flows.

Table 1	**Characteristics of Source-Separated Household Wastewater Flows San José/Santa Clara Water Pollution Control Plant Master Plan City of San José**								
		Loading Per Person				**Concentration**			
Category	**Component**	**Units**	**Median**	**Max**	**Min**	**Units**	**Median**	**Max**	**Min**
Volume	-	L/capita/day	1.4	0.5	2.5				
Organic Matter	TSS	g/capita/day	57	11.0	72.0				
	BOD	g/capita/day	5.0	2.0	10.0				
	COD	g/capita/day	10.0	5.0	24.0				
Nutrients	N	g/capita/day	10.4	3.6	16.0	g/l	14.0	14.0	1.8
	S	g/capita/day	1.0	0.4	2.5	g/l	3.8	4.1	2.2
	K	g/capita/day	2.5	1.0	4.9	g/l	3.3	3.4	3.2
	S	g/capita/day	0.7	0.6	1.3	g/l	-	-	-
Heavy Metal	Pb	mg/capita/day	0.0	NR	NR				
	Cd	mg/capita/day	0.0	NR	NR				
	Cu	mg/capita/day	0.1	NR	NR				
	Cr	mg/capita/day	0.0	NR	NR				
	Hg	mg/capita/day	0.0	NR	NR				
	Ni	mg/capita/day	0.0	NR	NR				
	Zn	mg/capita/day	0.0	NR	NR				
Source: Meinzinger and Oldenberg, 2009.									

Table 2 provides a medical estimation of typical urine characteristics.

Table 2 Urine Characteristics Prior to Storage
San José/Santa Clara Water Pollution Control Plant Master Plan
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Category	Component	Loading Per Person Per Day			
		Units	Median	Max	Min
Volume	-	L/capita/day	1.2	2.5	0.6
Organic Matter	TSS	g/capita/day		70	30
	BOD	g/capita/day			
	COD	g/capita/day			
Nutrients	N	g/capita/day			
	S	g/capita/day			
	K	g/capita/day		2.0	1.5
	S	g/capita/day		3.5	0.7
Heavy Metal	Pb	mg/capita/day		Less than 50 mg	
	Cd	mg/capita/day			
	Cu	mg/capita/day			
	Cr	mg/capita/day			
	Hg	mg/capita/day			
	Ni	mg/capita/day			
	Zn	mg/capita/day			
Other	Na	g/capita/day		4	3
	Ca	g/capita/day		0.3	0.1
	P	g/capita/day		1.5	1
	Cl	g/capita/day		16	9
	Mg	g/capita/day		2	0.05
	Ammonia	g/capita/day		1	0.3
	Iodine	g/capita/day		250	50
	Arsenic	g/capita/day		Less than 50 mg	-
	Urea	g/capita/day		30	25

Table 2	**Urine Characteristics Prior to Storage San José/Santa Clara Water Pollution Control Plant Master Plan City of San José**				
Category	**Component**	**Loading Per Person Per Day**			
		Units	**Median**	**Max**	**Min**
	Creatinine	g/capita/day		1.8	1
	Uric Acid	g/capita/day		1	0.3
	Creatine	mg/capita/day		150	60
	Hippuric Acid	g/capita/day		1	0.1
	Purine Bases	mg/capita/day		10	7
	Ketone Bodies	mg/capita/day		15	3
	Oxalic Acid	mg/capita/day		20	15
	Indican	mg/capita/day		4	2
	Allantoin	mg/capita/day		30	20
	Coproporphyins	micrograms		280	60
	Phenols	g/capita/day		0.5	0.2
	Vit, hor, enz	Detection		yes	Yes
Source: http://www.bloodindex.com					

As mentioned earlier, research is continuing on the pharmaceutical drug content in urine. A controlled study was completed in Germany (1996) to determine the residual drug content in urine related to the drug usage in Hamburg and Berlin. The resultant drug concentrations found in the study are provided in Figure 3 below. The researchers emphasized that variation in the type and quantity of drug use among communities should be expected. Therefore, the figure below is presented as a reflection of emerging research on the content of urine, and not necessarily a set of design values.

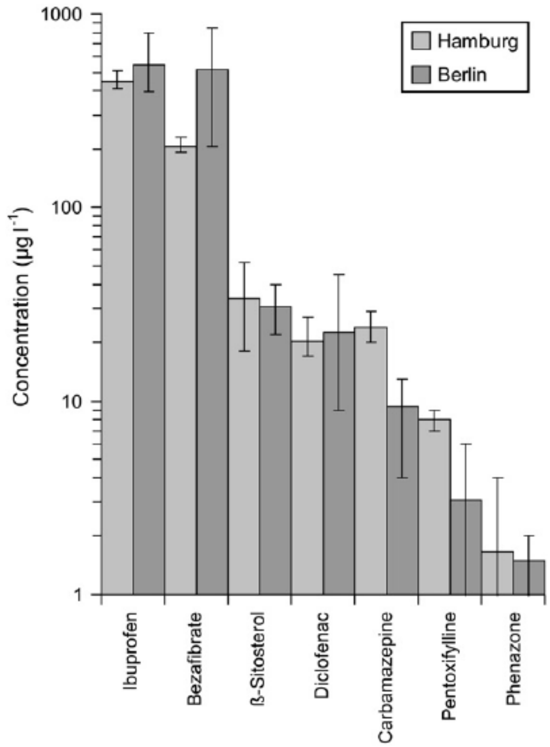

Figure 3 Drug Concentrations from German Study
Source: Tillman et al. 1996

The amount of urine collected at any one location is highly dependent on the life styles of the communities. Figure 4 below presents the findings of a study to assess the typical daily urine distribution in the course of a day.

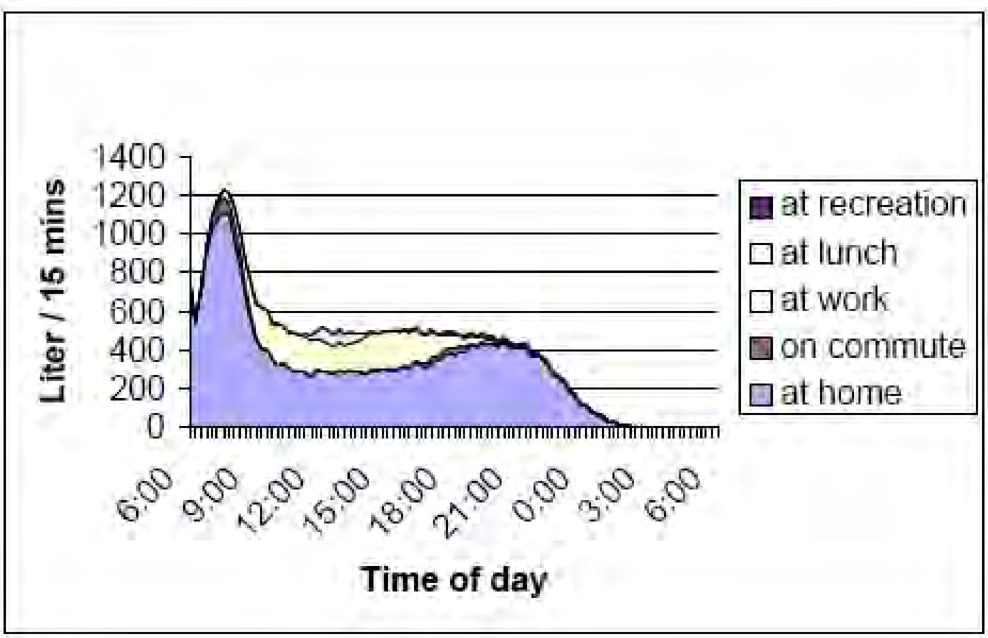

Figure 4 Typical Daily Urine Distribution.

2.3 Urine Production Volumes By Type of Development

Offices. The typical person produces 0.4 gallons of urine a day (Rogalla, 2008). The US General Services Administration (GSA) estimates 230 square feet per employee for general office situations including common space. If you assume that a person sleeps 8 hours in a 24 hour day, then each person distributes their waste during a 16 hour interval. If you assume an 8-hour workday, then you can assume that 50 percent of a person's daily waste is deposited at the office. Using these assumptions, the total daily urine waste from a 100,000 ft^2 office is approximately 87 gallons a day, or 435 gallons a five day work week.

Recreational Facility. A 40,000 seat ballpark filled to capacity could potentially produce 8,000 gallons a day if it is also assumed that 50 percent of their daily waste is deposited at the stadium. This assumption may appear high, however, spectators will produce more waste at events because of an increase in beverage consumption and you can estimate an event to last 6 hours. Using the daily loading data provided in Table 1, the daily nutrient loading from each facility was estimated and is shown in Table 3.

Table 3 Estimated Nutrient Loading from Source Separation at Large Facilities
San José/Santa Clara Water Pollution Control Plant Master Plan
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Facility	Volume gal/day	N lb/day	P lb/day	K lb/day	S lb/day
100,000 ft^2 Office Building	87	4.98	0.48	1.20	0.34
40,000 Seat Ballpark	8000	458.5	44.1	110.2	30.9

2.4 Typical Urine Separation, Collection and Reuse

The literature research conducted for this study revealed there are a considerable number of system configurations for urine, feces and grey water separation, collection, treatment and disposal/reuse. This section focuses on the most typical configuration for urine separation, collection and disposal/reuse. While some mention is made regarding black water (feces), it is not the intent of the following to describe these systems in any detail.

As mentioned earlier, virtually all of the information presented reflects European and Scandinavian research, development, practices and regulations. US technology and practices require further development.

2.4.1 Urine Separation and Collection

A typical urine separation system for a residence is shown in below in Figure 5, and consists of urine separation toilets that provide separate flows of captured urine and feces, and collection piping that conveys the urine to a separate storage tank. Depending on the system chosen, some level of flushing water is required for both streams. Depending on the equipment used and individual habits, potable water consumption for flushing can be reduced 50 to 80 percent. Urine can be collected in a closed tank until collected by a urine collection vehicle.

Urine separation systems have also served clusters of homes and apartment complexes. In most cases, however, the home clusters are in rural environments where centralized wastewater treatment is not available or is too expensive, and therefore onsite treatment is a practical necessity.

Urine separation toilets require changes in habits, learning to use a more complex system, and maintenance to control scale (struvite, hydroxyapatite and calcite) and clogging. Scaling occurs when the urine is exposed to the atmosphere which raises the pH towards 9. The piping from the urine separation toilet to the collection tank is a smaller diameter because of the much lower flow rate. This factor plus natural scaling of urine can lead to increased maintenance. In cases where several homes are served and the small diameter lines are much longer, careful attention must be made to these maintenance concerns.

Figure 5 Typical Urine Separation System

Generally, it is much better to have either a separate storage tank per home, or a single tank for a small cluster of homes. Tanks are usually designed on the basis of 1.5 liters per person per day, and pipes laid at no less than a 1 percent slope. Most Scandinavian countries require a 2 cubic meter tank equivalent for each home. Actual per capita contribution is usually less, and varies with the actual time people spend at home.

It is important to keep the urine piping and tank ventilation-free because urine will undergo a rapid increase in pH and cause scale if exposed to atmosphere. Urine is highly corrosive, and therefore, piping and storage materials must be free of metals or harmful substances than can react with urine. A well-closed system also reduces odor problems. Provisions are needed to facilitate inspection and cleaning.

Likewise, the feces stream can go to a storage tank for hauling, to a septic tank system, or to composting. Toilet systems can be used that provide combined urine separation and feces composting.

2.4.2 Urine Hygienization and Reuse

Special urine tank trucks are used to routinely collect urine collected at the residential source. A typical urine tank truck is shown below in Figure 6.

Figure 6 Typical Urine Tank Truck.
Source: Swedish EPA, 2001

Hygienization. The urine hauler delivers the urine to a centralized storage facility where it is hygienized according to local health regulations. Typical European practices require urine storage for at least 180 days at 20 degrees C, for pathogen kill prior to land application. A typical urine storage tank is presented in Figure 7.

Standards and regulations are in place regarding land application limitations, monitoring and reporting, and proximity to residences and surface water. It is common in many countries for urine to be collected and hygienized in this manner for fertilizing food and other crops, and landscape.

Measurements of fecal sterols in stored urine indicated that transmissible pathogens in source-separated urine are mainly cross-contaminated from feces (Schönning et al., 2002). Many microorganisms die off during urine storage. Höglund and Stenström (1999) stated that a storage time of six months should be sufficient to lower the transmission risk below an acceptable limit. However, not all pathogens are eliminated after this time.

Figure 7 Typical Long-Term Urine Storage Tank.
Source: Follner, 2008

The most important findings regarding the chemical and biological actions that occur during the hygienization of urine (Udert, Larson, and Gujer, 2006) are as follows:

- All urea is degraded and most of the nitrogen is available as total ammonia. Up to 33 percent of the total ammonia is volatile NH_3. Ammonia losses and odor problems will occur during transport and spreading of stored urine.

- The urine is alkaline with a pH around 9. The buffer capacity is so high that acid addition, e.g. to prevent ammonia volatilization, is not economical.

- Practically all calcium and magnesium is precipitated. No more spontaneous precipitation will occur. This is beneficial for the biological treatment of stored urine (Udert et al., 2003d).

- The phosphorus is separated in two phases: at least 30 percent is fixed in precipitates and the rest is dissolved. Supplemental calcium or magnesium addition seems to be a favorable technique to concentrate phosphorus.

- Sulphate may be reduced to H_2S, if sulphate-reducing bacteria grow in the solution.

- The high fraction of biodegradable organic compounds may be a substrate for several aerobic and anaerobic microorganisms.

- Some pathogens may survive or even grow during urine storage, but most of them will be killed during the storage of urine. The occurrence of pathogens is chiefly related to cross-contamination of feces.

Research is also continuing in Europe to investigate the reduction in concentration of trace pharmaceuticals and other organics in the urine curing and treatment process. While a preliminary study published by the Swedish Environmental Protection Agency (1996) indicates that residual medicines do not represent a significant environmental risk in connection with the use of urine as a fertilizer, there is considerable on-going research into the fate of these urine components.

Appropriate health standards and regulations for urine treatment and land application need to be developed and implemented for large scale application in the United States.

3.0 CONCEPT LEVEL COST FOR URINE SEPARATION, COLLECTION AND HYGIENIZATION

Very little data exists on the cost of waste separation implementation because research and pilot testing is still underway. Table 4 presents conceptual level costs for urine separation systems in rural areas. The conceptual cost may provide value if compared to the normal cost of household plumbing installation. However, these costs would be borne primarily by the developer and are provided for information only. When estimating the cost of system installation the entire system of collection, storage, conveyance and treatment should be considered.

The costs presented in Table 4 are conceptual and are based on several assumptions defined below:

- 2.5 restrooms per household
- One urine storage tank per two households
- Small diameter urine piping is additional to normal sewer piping
- Three urine separation toilets per household

Table 4 Current Conceptual Level Costs
San José/Santa Clara Water Pollution Control Plant Master Plan
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Item	Cost	Total per Household	Comments
Urine separation toilet	$2000	$6000	Assume $1000 for normal toilet plus additional $1000 for separation toilet
Urine Storage Tank	$2000	$1000	Assumed below-ground plastic tank
Associated Piping	$3000	$1500	Assumed 50% of household toilet cost
Subtotal	-	$8500	
Contingency	-	$4250	Assumed 50% of subtotal
Total	**-**	**$12750**	

Figure 8 presents a schematic of the conceptualized urine separation system for single family homes. It was assumed that each home contains three separation toilets and one storage tank is provided for every two homes.

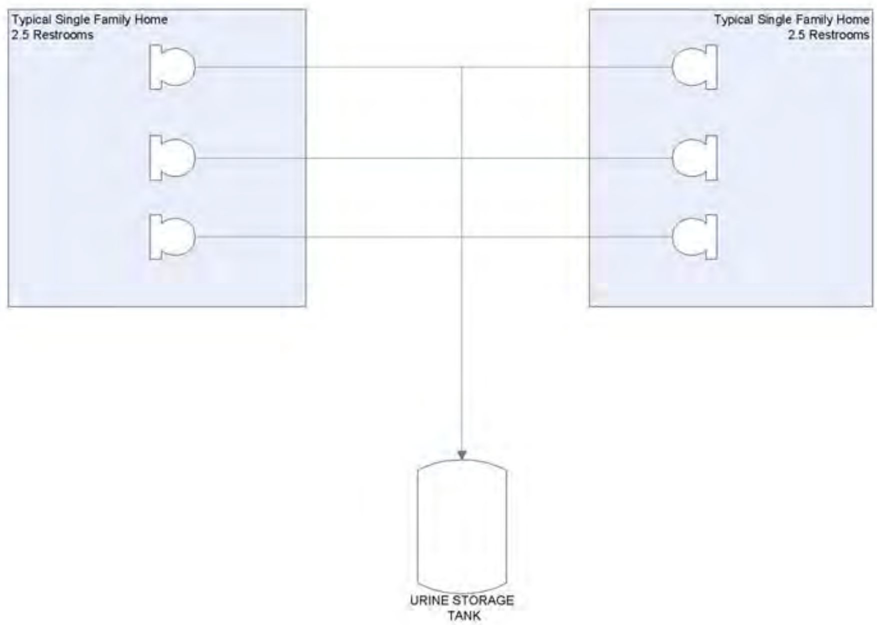

Figure 8 Urine Separation Schematic

An EcoSan 2008 study estimated the cost of installing a separation system is 225 percent more than a traditional system. Maurer et al. (2005) estimated that based on the savings at treatment plants, an approximate benchmark of $260 to $440 per capita for the investment in NoMix installations, assuming a life expectancy of 15 years.

Very little data exists on installation costs and none of the data is from the United States. A valuable conceptual level estimate is not possible at this point because the technology and practice is still in its infancy and what has been developed is mostly foreign. A valuable estimate of costs will require a pilot study in the US, along with the development or estimate of regulatory standards, and these have not been accomplished yet.

4.0 CONCLUSIONS

Research into source separation of waste streams has been performed and continues to develop with the majority of the studies being conducted in European countries. The United States has not conducted a significant amount of research into urine separation and no set of regulations currently exists for this practice. Most applications in Europe are small scale pilot sized samples with no large full-scale applications in operation. While initial study results prove promising, more research and full-scale applications must be demonstrated before urine separation regulations can be formulated in the US. Below is a summary of conclusions reached during the literature review.

- Waste minimization potential: Urine separation has significant potential to appreciably reduce nitrogen and phosphorous loadings to the SJ/SC WPCP. The benefit of urine separation is already recognized by many countries, and is the driving force for continued investment into research and demonstration projects.

- When applied at a significant enough scale, urine separation would reduce electrical demand at the WPCP, as well as lower the mass emissions of nitrogen and phosphorus into the receiving waters. On a much broader scale of benefits, the use of urea and phosphorus from the urine processing also reduces the mineral mining and energy associated with producing commercial fertilizer.

- The success of urine separation depends heavily on development of health and agricultural standards and regulations for use of the urine product, as well as identifying and supporting demand for the product.

- For significant waste minimization, urine separation could be applied to large scale office complexes, shopping malls, convention centers and sports arenas or ball parks. Basically, any location where there would be a relatively high concentration of people during the course of a day would be a candidate for urine separation. The housing developments should be considered candidates as well. The European countries are pouring research money into studying the complexities and solutions for applying urine separation at a large scale. It must be understood that along with urine separation is feces separation and treatment as well.

- Retrofit of existing residential property for urine separation would be very expensive, and would be very difficult to implement.

- San Jose could benefit from the research conducted by other countries into large scale urine separation. However, research must also be initiated by US agencies as well.

Table 5 presents an estimate of the reduction of flow and loads to the WPCP under one implementation scenario: install urine separation in 50 million square feet of buildings. This parallels the San Jose Green Vision goal of building or retrofitting 50 million square feet of green buildings. As described above, this calculation assumes 230 square feet of office space per person. Using this conversion, the 50 million square feet equates to 217,400 people. Also as described above, it is estimated that one half of the urine produced by those people will be deposited at work. The estimate below would be the same if 94,500 new or retrofitted homes had urine separation and collection. (217,400 people at 2.3 per residence).

Table 5	**Potential Reduction in WPCP Influent Flows and Loads Assuming Urine Separation at 50 Million Square Feet of Office Buildings San José/Santa Clara Water Pollution Control Plant Master Plan City of San José**			
Constituent	**Unit Rate of Reduction**	**Total Potential Reduction(1)**	**2050 Projection(2)**	**Potential Percent Decrease**
Flow	2.25(3) gallons/capita/day	0.5 mgd	182 mgd	0.3%
BOD	2.5 g/capita/day(6)	540 kg/day 1,190 lb/day	487,000 lb/day(4)	0.24%
TSS	28 g/capita/day(6)	6,100 kg/day 13,400 lb/day	421,000 lb/day(5)	3%
Nitrogen	0.009 lb/capita/day(6)	1,960 lb/day	34,900 lb/day(7)	6%

Notes:

(1) Based on 1/2 urine production for 217,400 people.
(2) Based on 2040 projected service population of 1,938,577 (PM 3.6, Table 7).
(3) 50% (based on percentage of day person is at work) of the estimated water used for flushing urine, which is approximately 50% of total flushing water.
(4) PM 3.8, Table 8, medium load projection.
(5) PM 3.8, Table 9, medium load projection.
(6) 50% (based on percentage of day person is at work) of the estimated ammonia-nitrogen load, PM 3.8, Table 7 – medium condition.
(7) 0.018 lb/capita/day (PM 3.8) and 2040 projected service population.

REFERENCES

REFERENCES

1. Ecosan GTZ. 2008. Ecosan Demonstration Project. GTZ Headquarter, Germany. Sanitation Challenge. Wageningen, NL.

2. Follner, Steffen. 2008 "Wastewater Separation as a Base for the Safe and Efficient Reuse of Water and Nutrients". Mediterranean Workshop on New Technologies of Recycling Non-Conventional Water and Nutrients. May 1.

3. Gujer et al. 2006. *Fate of Major Compounds in Source Separated Urine*. Water Science and Technology, Vol. 54, No 11-12, pp 413-420. IWA Publishing.

4. Hoglund, C. and Stenstrom, T.A. 1999. *Evaluation of Faecal Contamination and Microbial Die-off in Urine Separating Sewage Systems*. Water Science and Technology.

5. http://www.bloodindex.com/view_learning_master.php?id=21 (1 of 3)6/1/2009 12:25:04 AM

6. Jonsson, Hakan. 2001. "Urine Separation – Swedish Experiences". EcoEng Newsletter 1. October.

7. Larsen, T.A. and Gujer, W. YEAR. Separate Management of Anthropogenic Nutrient Solutions (Human Urine). Water Science and Technology 34(3-4):87-94

8. Meinzinger, F. and Oldenburg, M. 2009. Characteristics of Source-Separated Household Wastewater Flows: A Statistical Assessment. Water and Science Technology.

9. Rogalla et al. 2008. Sustainable Solutions – Much can be Learned from Recent Work in Europe as well as the United States. Water Environment & Technology, April. pp 30-33.

10. Swedish EPA. 2001. Urine Separation – Closing the Nutrient Cycle. Final Report on the Research and Development Project.

11. Tillman et al. 1996. *Life Cycle Analysis of Alternative Sewage Systems in Berlin and Hamberg*. Chalmers Technical University, Gothenburg, Sweden.

12. US General Services Administration. Accessed July 1, 2009. http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_OVERVIEW&contentId=14179&faq=yes&noc=T

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