Water Reuse – New York City and Japan

Experience and Future Prospect

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Introduction

All water gets reused eventually, some sooner than later. When rivers and other surface water bodies serve as the source of water supply and means of wastewater disposal for multiple cities, the timeframe between uses can sometimes be measured in days rather than years as a portion of the upstream disposal becomes the downstream supply. In remote rural areas where population density is very low and water is drawn from a protected underground aquifer it is possible that the most recent possessor of the water that comes from the tap today may have been a dinosaur, but as world population increases and luxurious water use spreads to developing nations, it is more likely that your next glass of water was last used by an upstream neighbor rather than a prehistoric species. In the natural cycle of water use, this reuse characteristic is inadvertent, unavoidable and almost entirely unintentional. On the contrary, intentional water reuse which is the subject of this paper is a relatively modern concept whereby water is used once, becomes contaminated to a certain degree, is then subsequently treated in some fashion to improve the quality and then is used again in a well planned and controlled manner. Although it is possible to treat used water adequately for purposes of drinking, the water use-reuse concept discussed herein is almost exclusively intended for nonpotable purposes.

Direct water reuse has been practiced in the United States for many years but only to a very small extent and in highly varied fashions which were the result of specific local conditions and goals. Regardless of a successful history, many newly conceived water reuse projects are still hailed as pilots or demonstrations intended to build understanding and acceptance by a public which remains skeptical. The water industry and the general population remain very comfortable with the current simple perspective which emerged in Roman times and embraces the notion that water supply should come from pure upstream sources, as though there remain such sources, and contaminated wastewater should be disposed of downstream, as though this would somehow keep everyone safe, including those who live downstream. The booming bottled water industry which portrays images of pristine protected sources as part of product marketing campaigns continues to bolster this public perception.

Public concern about the quality of water is increasing. There is also an awakening to the reality that water supply sources are severely limited in many populated locations and that wastewater contaminants are spreading everywhere posing a risk to all living things. This awakening is fueled somewhat by widely published images and facts from undeveloped nations that illustrate the connection between disease and the lack of adequate water supply and appropriate sanitation. But even though public concern is heightened, there is no perceived connection between these more obvious problems in undeveloped nations and the way in which water and wastewater are managed in developed countries. The linear Roman model of consume, use and dispose still prevails in the minds of most people as the preferred approach.

There is recent evidence however that this ancient perception may soon change. Through the successful application of water reuse in a growing number of both commercial and residential development projects the multiple benefits of water recycling are becoming too obvious to ignore. Unfortunately, a dramatic shift towards water reuse will be significantly complicated by a multiplicity of hurdles which must be overcome. Complications associated with existing regulations, short term economics, massive existing infrastructure needs and the fact that water is mostly a local issue will likely make the transition to water reuse much slower than comparable revolutions in the communications, information and renewable energy industries. Even though there is tremendous potential benefits to be gained, without significant policy changes, the shift to water reuse is only likely to occur in a gradual manner and where short term cost effectiveness can be realized or where local conditions are severe.

By its nature, the water resource industry in the United States is slow to innovate and deeply encumbered with massive infrastructure that is all configured in a linear manner whereby water flows toward a use, is used and managed in some fashion and then flows away, generally in a downstream direction taking advantage of the simple fact that water flows downhill. This linear configuration is not generally conducive to cyclical reuse approaches that require return loops for recapture, treatment and ultimate reuse. Lacking any widespread water supply shortages caused by major droughts or severe contamination, economics will still be the primary driver behind how people choose to manage their water resources. As a result, the current status quo "once used and through" linear model is likely to remain for some time. On the positive side, there are signs that public awareness and acceptance of water reuse and the overall importance of better water resource management are gaining momentum in certain key sectors which could escalate this transition. This is evident in the green building industry where sustainable infrastructure models are demanded, in developing arid areas where the risk of water resource depletion is becoming very obvious, in pristine rural areas where the discharge of contaminants must be avoided and in urban redevelopment areas where very old and often failing infrastructure cannot support the demands of redevelopment without significant conservation and reuse. Through a number of successful projects that are leading examples of water reuse, it is now possible that the interest and activity in this new water reuse model could increase dramatically and things could change more quickly than otherwise expected.

Early US Closed Loop Water Reuse

Nationwide in the United States, indirect water reuse for purposes mostly associated with irrigation (open loop) has been steadily increasing, but still remains a relatively small component of water resource management in total. The Water Reuse Association estimates that of 396 billion gallons per day of water extracted for use in the US, 2.6 billion gallons per day (0.7%) is reclaimed for some form of reuse and this reuse quantity is growing at a rate of 15% per year. (Metcalf & Eddie, 2007. pp. 46-47) California, Florida and Arizona are the states with the most water reuse in place and each are leaders in use of nonpotable water for irrigation of lawns, golf courses and crop land and for industrial purposes mostly associated with cooling. In 2004 Florida reported 54 percent of their total wastewater capacity being dedicated to reuse which illustrates the significant role water reuse can serve in the bigger water resource management picture. (Metcalf & Eddie, p. 54)

Early water reuse projects in the United States were generally driven by a particular local environmental concern or lack of adequate water supply. Most early projects did not return treated water directly back to a consumer for direct reuse in indoor building plumbing (closed loop) which would in turn yield new wastewater, but instead used the water for indirect outdoor purposes (open loop) such as irrigation or simply placed the water into the ground as a means of recharging the underground aquifer. Such practices, often referred to as indirect reuse, are almost always considered to be beneficial and were sometimes implemented as an alternate means of waste disposal as opposed to an alternate source of water supply. Whereas, groundwater recharge almost always helps maintain the local water balance by recharging aquifers, consumptive uses of reuse water for irrigation or evaporative cooling purposes convert the water to water vapor which is then subsequently lost from the watershed. Such indirect reuse approaches can have both positive and negative effects which can only be fully understood by completing a detailed water balance evaluation that depicts exactly where and how all local water flows.

Irrigation with treated wastewater effluent is arguably almost always better than irrigation with more precious potable water, but from a water balance perspective is less desirable than having no irrigation at all. Xeriscaping, a landscaping method which requires no irrigation, is the best approach for protecting water balance as would be non-evaporative cooling alternatives. In fact, in some surface water bodies the flow of wastewater effluent is so significant that diverting this flow to reuse for irrigation during low flow periods can actually decrease the water body quality. During drought periods, fish will often choose to reside close to the wastewater treatment plant discharge pipe because this is where the freshest and best water can be found.

Direct water reuse offers more significant benefits because the water is not discharged to the environment, but is instead returned directly to the consumer to be used again. For the purposes of this report, direct reuse of this nature is generally referred to as “closed loop”. The term “closed loop” sometimes is also used to signify the concept of continuous reuse with zero discharge. A zero liquid discharge closed loop system is technically possible, but not practical given the economics of water management that exist today. Only the International Space Station can afford an actual completely closed loop water system, simply due to the extreme cost of bringing fresh water into outer space.

Over the past 30 years we have seen a continuous gradual progression of water-wastewater approaches that begin with the linear “once through and used” traditional model to more creative “use it once then use it again” open loop models to the more significant “use it repeatedly for as many purposes as possible and only release what cannot be used” closed loop approach. Taken together, this represents a continuum of slow but steady progress heading towards a future, completely cyclical, closed loop system; a man-made water cycle if you will.

Beginning in the mid-1980’s there was a series of direct closed loop and indirect open loop water reuse projects developed in the northeast which serve as good models. These projects were driven mostly by lack of sewer capacity in suburban and rural communities. This is a region where rainfall is plentiful and water shortages generally only existed due to growth outpacing infrastructure development and the occasional drought that might occur. Whereas today the water supply picture has changed significantly due to over extraction of groundwater supplies, in the 1980’s, lack of wastewater infrastructure was often the most challenging development hurdle which limited growth in undeveloped areas. To a large extent, such infrastructure hurdles sometimes created convenient roadblocks which helped curtail rampant suburban sprawl as people chose to move out of the cities. In addition, the expansion of expensive regional infrastructure without government subsidies was not cost effective and was not in the best interest of the general public. During this era, creative direct water reuse projects where implemented to allow some development to occur in infill areas and where the economics justified the additional costs. All of these projects were created as on-site decentralized systems with the water reuse systems designed for the specific site characteristics and user needs and all were located on private property.

These northeast-based closed loop water reuse models applied a combination of direct water reuse and indirect beneficial reuse. In the simplest model, wastewater was treated for nonpotable use inside buildings for flushing toilets and excess treated water was recharged into aquifers. Over time, these systems advanced into a multiplicity of building types and the nonpotable reuses inside the buildings expanded to include laundry and cooling in addition to toilet flushing. Nonpotable reuse outside the buildings typically included irrigation and groundwater recharge.

To date these systems are all owned and operated by private interests or as privately held public utilities simply because public entities were not available or were not interested at that time, but there is no reason why they could not just as well have been owned by a public agency. Figure 1 provides an overview of the distributed water reuse systems that were built in the northeast, beginning in 1987 and illustrates the percent water reuse that was achieved.

The amount of water reuse varies from 95% for office uses that have a very high nonpotable consumption characteristic, down to 50% for residential high rise buildings that reuse water for toilet flushing, cooling, laundry and irrigation. The percentage of water reuse varies according to the specific user’s characteristics, plumbing fixture types and the nonpotable uses implemented.

Building Type	Date of 1st System	Water Reuse	Water Uses
Research	1987	95%	Toilet Flushing
Office	1989	95%	Toilet Flushing
School	1990	75%	Toilet Flushing
Commercial Center	1993	70%	Toilet Flushing
Stadium	1996	75%	Toilet Flushing
Urban Residential High Rise	2000	50%	Toilet Flushing, Cooling, Irrigation, Laundry
32 Systems	22 Years	80% Nonresidential 50% Residential	

Figure 1 – Distributed Water Reuse Systems in Northeast U.S.A.

Technology played an important role in the viability of direct water reuse in these facilities. The advent of the membrane bio-reactor (MBR) in the 1980's as a robust, highly automated biological wastewater treatment method helped to provide the dependability and advanced levels of treatment required to produce reuse quality water. Also, the steady improvement of ultraviolet light disinfection and ozone oxidation (ozonation) improved disinfection capability while advancements associated with programmable system controllers improved system automation and operability.

In the grand scheme of water resource management in the US, this pocket of decentralized direct water reuse systems represents a drop in the bucket with regard to the total quantity of water reused nationally. However, these systems represent a significant opportunity for future, lower impact development that actually consumes less and discharges less, therefore having direct water balance and water quality benefits. Whereas, this direct reuse closed loop model is new to the US, it has been used for many years in Japan where the need to conserve water arose earlier.

Water Reuse in Japan

Many countries have adopted water reuse practices which supplement water supply for nonpotable purposes. With an evolution similar to the water reuse systems in the US, the early entries into this arena were focused on irrigation demands and were in very arid locations such as Tunisia, Israel and Australia. Irrigation in these countries was critical to support food crop production and to help stem salt water intrusion from over pumping of groundwater. Thus, these early models were open loop indirect reuse style systems wherein treated wastewater was reused once before being dissipated back into the environment. Japan however stands out as a nation that adopted a mix of water reuse strategies that included closed loop type systems at a very early stage and in a more significant manner. Japan also utilized a blend of reclaimed water sources: municipal wastewater, greywater and rainwater. (Metcalf & Eddie) As a result of concentrated high density growth in post World War II Japan, urban areas that lacked adequate water resource systems were forced to find alternative solutions. As a result, Japan became the leader in urban water reuse, with 8% of the total reclaimed water being used for urban purposes through a number of mechanisms which includes decentralized closed loop and open loop systems. Because of Japan's focus on urban water reuse, it stands as a good model for other developing and developed countries that seek to establish water reuse systems as part of urban development and redevelopment.

The earliest designed wastewater reclamation and reuse project started in Japan in 1951 when reclaimed wastewater from a nearby wastewater plant was utilized to supply industrial water for a paper-manufacturing mill. (Yamagata, et al., 2002) In the 1960's there were severe droughts throughout Japan along with rising economic and population growth in the large cities and corollary contamination of surface water bodies. In 1978, citizens of

Fukuoka City were strained by accepting severe water supply limitations which lasted 283 days. These events eventually led to Japan taking great interest in urban water reuse and to the commissioning of the Water Reuse Promotion Center in 1973. Water reuse was further driven by the urgent situation of having no new source water available for growing cities coupled together with the occurrence of ground surface subsidence in areas where aquifers were being over pumped. The resultant multifaceted water reuse approach that ensued is therefore unique and includes the first indoor closed loop water reuse projects beginning in 1984, in the Shinjuku District of Tokyo.

Since that time, along with expansion of municipal and neighborhood scale systems (referred to as large-area reuse systems), many in-building closed loop wastewater reuse systems have been installed. These in-building systems represent a wide range of configurations with wastewater, greywater and rainwater being captured in the building or from neighboring buildings. Some systems are therefore very small but taken together this entire network of large area systems combined within building systems results in 61% of all nonpotable water demand being met with reuse water in Tokyo. It was reported in 1996 that there were a total of 2,100 buildings using some form of water reuse and that 130 new water reuse systems were being installed each year. (Yamagata)

In addition, of the 1,718 wastewater treatment plants that exist in Japan, 240 plants distribute water for reuse in various forms. Currently it is reported that 4.2 million gallons per day of reuse water for toilet flushing is distributed from the larger plants and 46 smaller plants provide 14.2 million gallons per day of reuse for various in-building uses, including toilet flushing, cooling and plant watering. (Nagasawa, 2009) Individual cities have adopted ordinances requiring all buildings over a certain size to include nonpotable water reuse. In Tokyo the requirement for water reuse is for all buildings over 10,000 square meters and in Osaka and Fukuoma the requirement for water reuse is for all buildings over 5,000 square meters. Additionally, nonpotable reuse water is utilized to supply fire suppression systems, thereby effectively using the fire system piping for dual purposes. Action was also taken to retrofit many existing buildings with dual plumbing, particularly multi-family buildings, commercial buildings and schools. In most cases, MBR technology was utilized as the means of treatment to provide adequate water quality.

In addition to the pressing social aspects of water reuse in Japan, the economics have been shaped to promote conservation and reuse. The national government has generally subsidized 50% of the capital cost for large scale water reuse facilities and the average cost for nonpotable reuse water is \$0.83/m^3 (\$3.14/1,000 gallons) whereas potable water supply ranges between \$1.08/m^3 (\$4.00/1,000 gallons) to \$3.99/m^3 (\$15/1,000 gallons). The economics favor water reuse in all cases.

Japan therefore has created an optimized water reuse model for its specific climate, environment and social needs that includes several approaches and which mandates water reuse systems in many new buildings. The need for water reuse in Japan arose at a time when tremendous urban growth could not be completely supported by expansion of traditional centralized infrastructure that relied solely on natural sources of supply. As is often the case, urgency became the driving force behind innovative solutions and the result is that water reuse has become a basic component of the overall water resource management approach.

Battery Park City, New York

Battery Park City, New York, serves as a very recent urban water reuse model which was created under a different set of circumstances from those which exist in Japan, but which ultimately provides a similar illustration of the benefits of water reuse as a means of achieving growth with less impact on natural sources. Battery Park City is a redevelopment area located at the southwest tip of Manhattan which consists of 92 acres under the control of the Hugh L. Carey Battery Park City Authority (BPCA). This land was created from landfill and demolition of old, deteriorating piers which existed along the Hudson River waterfront, the full build out of which would include 14,000 residential units, 6 million square feet of commercial space and more than 27 acres of parks, plazas and waterfront walkway. Begun initially in the 1970's, the BPCA adopted a mission to demonstrate sustainable urban development for the redevelopment of this land and in 2000 issued its Environmental Residential Guidelines, which set forth goals and standards for environmentally responsible building. This was at the same time that the United States Green Buildings Council launched LEED® (Leadership in Energy and Environmental Design) Version 1. The two programs were closely aligned and both included water conservation objectives. The BPCA Environmental Residential Guidelines also included a water reuse component which was more advanced than the LEED requirements.

In order to win the rights for land lease development in Battery Park City, developers had to submit competitive bids which illustrated how the objectives of the guidelines would be fulfilled while offering their best bid price. The BPCA rated the developer proposals based on price and compliance with the guidelines. The first winning proposal was awarded to Albanese Development for a 27 story residential building to be named The Solaire which included water reuse as a component of a long list of other environmental features. The Solaire was completed in 2003 and it became the first residential project in the US to incorporate direct closed loop water reuse. The project went on to be awarded a LEED Gold certification for new construction and later a LEED Platinum for operation and maintenance.

Whereas, public water and sewer facilities were available in Manhattan, the sustainable development program helped to demonstrate how new construction could have a reduced impact on water resources and existing infrastructure. Sewer overflows are common in New York City during rainfall events and while overall water supply is adequate it lacks capacity for future growth due to limited transmission facilities. Deteriorating and inadequate infrastructure is a common constraint for urban redevelopment and growth in many older cities and the water reuse approach was established as a means of demonstrating how decentralized closed loop approaches could help overcome such barriers.

As a result of this initiative, there are now five existing residential water reuse systems in Battery Park City: The Solaire, Tribeca Green, Millennium Tower, The Visionaire and Riverhouse. One additional system is currently under construction at Liberty Luxe. All of these six projects include wastewater and rain water capture and reuse systems which utilize membrane bioreactor technology. The Solaire being the first, has been the most studied and reported on. It has consistently achieved a 48% water consumption reduction by comparison to a comparable base residential building in NYC and a 56% reduction in wastewater discharge. This water and wastewater reduction is achieved by a combination of wastewater reuse and water conservation where nonpotable water is distributed in closed loop systems for uses that include toilet flushing, cooling tower make-up, laundry and irrigation. Each building is unique and the exact components vary somewhat, but the overall program of wastewater and rainwater reuse remains the same.

The typical configuration for a closed loop direct water reuse system consists of holding tanks for wastewater and rainwater. In some buildings, greywater is used in place of wastewater as a source of supply for the water reuse system. Wastewater and rainwater are treated and placed into storage in a nonpotable water reservoir prior to distribution back to the nonpotable water uses in the building. As discussed earlier in this report, the percentage of nonpotable water varies with the use of the building and can be as high as 95% in dry type office uses. Figure 2 illustrates a typical configuration for a closed loop water reuse system as found in most modern buildings.

In Figure 3, all of the water is treated to the same quality prior to reuse. As water reuse standards evolve, there is likely to be some variability in quality requirements for specific uses and the treatment mechanisms would vary accordingly. The system depicted in Figure 2 is meant to achieve high quality nonpotable water that would generally meet all current standards for "unrestricted urban use". Specifically for New York City, this unrestricted urban use would entail the performance outlined in Figure 4 which is similar to the nonpotable reuse water quality in a number of states in the US and in Japan.

New York City Planning and Economics

Battery Park City provided the groundwork for further water conservation and reuse projects throughout the City. PlaNYC 2030 was put forth in 2009 as a progressive growth planning document which adds 200,000 additional residents to the current residential project pipeline and anticipates adding another 700,000 residents between 2010 and 2030 while reducing total water

Figure 2. Membrane bioreactor in basement of The Solaire

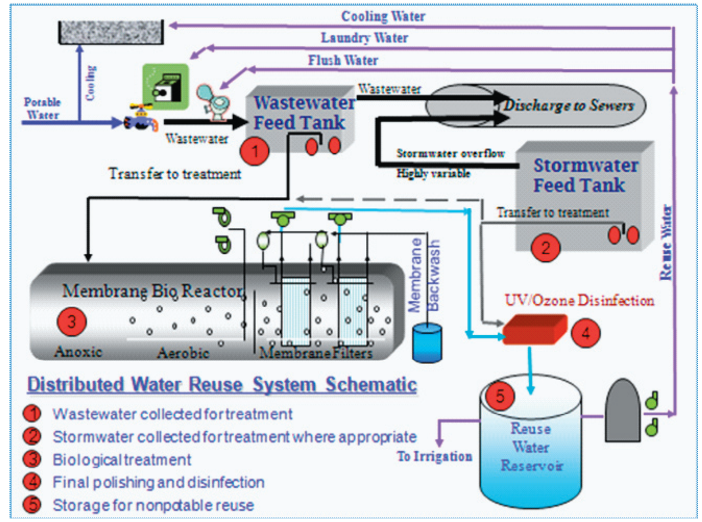

Figure 3. Typical Closed Loop Configuration

consumption by 5% overall. In addition, there are serious combined sewer overflow conditions that must be addressed in this timeframe and major infrastructure upgrades required to correct other existing problems as well as accommodate future demands.

Achieving such aggressive goals will require a multiplicity of approaches that include expanding and upgrading parts of the centralized water, wastewater and stormwater systems, implementing progressive water conservation, adopting best management practices to divert stormwater away from sewers and launching new water reuse efforts. In addition, incentives and rate structure changes may be used to help achieve some of these goals. The City had prior successful experience with incentive programs which offset the customer's cost of high efficiency plumbing fixtures and appliances. Additional incentive programs are anticipated to help achieve a reduction in consumption by approximately 60 million gallons per day over the next 20 years.

In 2004 New York City implemented the Comprehensive Water Reuse Program which provides a 25% reduction in sewer and water charges for buildings that achieve a minimum of 25% water reuse. Such incentives combined with rapidly increasing sewer and water charges provide considerable economic motivation for new developments and are beginning to attract attention within existing buildings as well.

Current water rates are $3.09 per 1,000 gallons and sewer charges are $4.91 per 1,000 gallons for a total water and sewer charge of $8.00 per 1,000 gallons. These rates are projected to increase at 15% per year for the next several years to help fund capital projects that are already under way. The New York City rates are at approximately the median for large cities in the US and similar water and sewer rate increases are occurring in most urban municipalities. It is clear that water and wastewater costs to the consumer are

Nonpotable Reuse Water Quality – Unrestricted Urban Reuse			
Parameter	Abbreviation	Numerical Limit	Units
Biological Oxygen Demand – Five Day	BOD	< 10	mg/l
Total Suspended Solids	TSS	<10	mg/l
Total Coliform Bacteria	TC	< 100	Counts per 100 ml
Escherichia coli	E.Coli	<2.2	Colonies per 100 ml
Acidity (or basicity)	pH	6.5 – 8.0	Standard units
Turbidity	Turb	<2.0 (95% samples) <5.0 (at all times)	NTU

Figure 4. Nonpotable Reuse Water Quality – Unrestricted Urban Reuse

going to increase almost everywhere and that these costs will become a much more significant concern to residents and businesses in the future.

Operating experience from the existing decentralized water reuse systems in New York City indicate that the costs for treating wastewater and producing nonpotable reuse water is in the range of $9.00 to $13.00 per 1,000 gallons depending on system size. The costs for building and operating such systems is very stable, and will probably decrease in the future as technology improves and systems become more efficient. Taking all of this into consideration, nonpotable water reuse is nearly cost competitive today. Considering the pending New York City rate increases and the 25% rate incentive, water reuse is actually a wise choice for all new construction. Certainly, given the life span of a building, not having water reuse capabilities included in the initial plumbing will become a considerable cost detriment in the future. This new age economics for water and wastewater is also spurring some existing buildings to consider retrofitting water reuse when the opportunities are readily available such as in supplying cooling towers or centralized laundries.

The initial pilot water reuse programs in Battery Park City were regulated by the Department of Health. As the need and desire for more water reuse grows, formal regulations are being developed within the building codes which will provide for a more comprehensive management program. Similar to the approach in Japan, the ultimate solutions for New York City water conservation will entail a combination of numerous approaches including rainwater reuse from green roofs, greywater reuse, condensate reuse as well as wastewater reuse. But unlike Japan where the need for reuse was driven by a lack of available resource, the future demand for water reuse in New York City will be more a case of simple economics.

Conclusion

In conclusion, the comparison of New York City and major cities in Japan illustrates how the local demands and drivers with regards to water resource management will make the transition towards water reuse occur at different paces in different places, but the trend will be inevitable and ultimately universal. Water reuse will be a key component for addressing water scarcity and quality issues in the future. There are some barriers to this approach because certain codes may restrict water reuse and the water/wastewater industry is not geared up presently to readily adopt decentralized approaches, but in the relatively short term these barriers will be removed as the economic landscape changes. Water and wastewater services have always been very inexpensive in developed societies and that picture is now changing as both capital and operating costs rise dramatically. The history of water reuse in Japan, one of the world's most densely populated countries, illustrates how mandates for conservation and reuse will come forth as social needs arise. The recent success of decentralized water reuse in New York City illustrates how green building practices and water conservation can play an important role in the US. Taken together, the experience of these water reuse examples provides clear evidence of the rationale that will drive the transition towards water reuse globally.

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