

IV. On-Premise Laundry Facilities

1.0 Background

It has been claimed that commercial laundries may be one of the major contributors to environmental problems in the United States. While this is difficult to evaluate, it does carry an element of truth when one contemplates the vast number of settings in which such laundries are found, including motels, hotels, nursing homes, prisons, universities, hospitals, and so on. Per current estimates, each pound of laundry uses approximately three gallons of water, which ends up in the sewer.

Commercial laundries, often referred to as “On Premise Laundries” (OPLs), or industrial laundries, are operated much the same today as 50 years ago, with little change, and virtually no conservation innovation. The laundry machinery manufacturers have not proven to be innovators of conservation as this industry has not demanded conservation from them. Although laundries consume large amounts of both energy and water, conservation opportunities in this arena are relatively untapped, thus, ripe for the introduction of new technologies that can meet the industry’s reliability and cost-effectiveness expectations. These expectations are high; few of the previously introduced technology innovations have lived up to these expectations, somewhat tarnishing the image of water and energy conservation among OPLs.

1.1 Technology Factors

Several factors must be met for any new technology to be successful in the laundry environment. Not only must the technology meet all of the customer’s financial criteria, it also must meet operational and maintenance requirements, and physical space constraints. The technology must be able to meet the texture standards previously attained, it must be “user friendly” to the laundry workers thus attaining their “buy in”, and the new process must receive the cooperation of the chemical supplier, who has a significant influence on how the laundry equipment is operated. Naturally, the technology must work with very high reliability and it must be maintainable by the “in house” maintenance personnel with minimal additional work or have a low cost program for maintenance available from the manufacturer.

A commercial laundry is like any industrial process. The success of this process within the larger business depends in part upon the laundry to deliver its product in a timely and reliable manner. The product must meet all of the sanitation, appearance and texture requirements of the customer. Clothes, bed linens and towels come into contact with human skin and are therefore highly scrutinized by laundry professionals who constantly monitor the quality of the laundry being processed. Guests, caregivers and others also observe laundry quality and have high expectations in terms of appearance, texture and smell. The process of assuring quality never ends. Although there may be differences of opinion as to what level of quality is acceptable, this is largely dependent upon the expectations of the customer (prison vs. a five star hotel). However, there is always a minimum level of quality that must be achieved on a day-to-day basis.

Reliability of the technology is very important with little tolerance for down time. An OPL that ceases to operate for any length of time can quickly degrade an establishment's ability to conduct its normal business activity.

Because the company selling the new technology often leaves the site after the completion of the start-up and commissioning of the new system, the success of the project is entirely dependent upon the laundry's management and its workers. The technology must be "user friendly" to allow this to happen. Adapting to change is difficult for most people. This is especially true in a workplace like a laundry operation where the process has been in-place for many years. In most cases, the laundry operation has been continuous, stable and successful from the perspective of the laundry management and workers. Introduction of new technology forces management and employees to learn new procedures that may run counter to prior habits. Where conservation applications in OPLs have proven to be successful, the new technology's impact on laundry staff has generally been subtle and minimal.

This also true for the maintenance personnel who service all of the laundry equipment. If the maintenance requirements of the new system technology are minimal, there is a much greater chance of long-term success. The technology must be simple enough to where existing personnel can support trouble-shooting efforts so that repairs can be made efficiently and quickly. Technologies that support remote diagnosis by the manufacturer also minimize expenditures in cost and time associated with trouble-shooting.

The chemical industry, as a whole, has been an influential player in OPL operations and, as such, is a very critical factor in the success of the conservation project. In most cases, the chemical representative actually determines the wash formulas, whose components include the chemical recipe, type of cycle, duration of each cycle, water temperature, amount of water, and when each of these ought to occur for each wash classification and size of wash load. (A wash classification is the type or common grouping of laundry such as towels or "terry", bed linen, uniforms, mats, rags, bedspreads, etc.) The chemical company representative is most often the person who programs the washer controls and the chemical feed equipment that is critical to ensure best results. Naturally, the level of dependence on the chemical representative is very high as no one within the laundry staff is usually able to fulfill this critical task and skill set.

Another requirement is that the chosen conservation technology be readily accepted by the chemical company. If the new technology minimizes chemical changes and ensures high laundry quality, the technology will be perceived as being friendly to the chemical representative. Thus the chemical supplier will be more apt to cooperate, increasing the likelihood of success in the long run.

Although several technologies are available in today's marketplace for OPL water recycling, this discussion focuses only on those technologies that have a proven track record of performance and success in laundry applications.

2.0 Applications

2.1 On-Premise Laundries (OPL's)

A wide range of potential customers exist for OPL conservation technology in California. As mentioned above, hotels and motels constitute the largest group, with approximately 6,500 establishments, each with roughly 150 rooms on average¹. The next largest group includes nursing homes, amounting to approximately 1,600 establishments, each with 100 beds on average². The State Department of Corrections runs 33 prisons in California with a total of 160,000 inmates and staff, or an average of 4,850 per establishment³. The State Corrections Board oversees 560 local county and city jails and other establishments with approximately 87,000 incarcerated on an average day⁴. All of the prisons and most of the jails have an OPL.

There are almost 405,000 enrolled students in the 23 University campuses statewide in the California State University (CSU) system⁵ and almost 417,000 students at the nine campuses (10 now, including University of California, Merced) in the University of California (UC) system⁶. The state also has an additional 127 independent (private) universities⁷, colleges and institutions of higher learning. All laundering of personal clothing and effects at these universities is done in small residential style coin-operated machines. The only laundry processed in an OPL at these universities would include athletic uniforms, work uniforms of staff, and uniforms worn by the marching band. As such, these OPLs experience light usage when compared with OPLs at prisons, for example. Although it is anticipated that all of the State University institutions (UC and CSU) have OPLs, we expect that only about 20 of the non-state affiliated institutions to have OPLs.

Of the 508 hospitals located in California⁸, most hospitals outsource their laundry to large centralized facilities that specialize in laundering for healthcare institutions. The trend to discontinue in-house laundry service in favor of outsourcing has been in-place for several years. The main reasons for this trend are cost containment and the inability of hospitals to stay up with the state's public health regulations governing laundry operation.

Table 1 summarizes the various applications expected to have OPLs in California. Note that only 10 percent of the hospitals and 16 percent of the private colleges and universities are assumed to have laundries due to the reasons noted above.

¹ California Hotel Lodging Association

² California Department of Health Services, Licensing Certification

³ California Department of Corrections, Facilities

⁴ California Board of Corrections

⁵ California State University, Enrollment Facts

⁶ University of California, Statistical Summary

⁷ California Colleges and Universities, Web Site

⁸ California Healthcare Association, Membership Information

Table 1. Existing California On-premise Laundries by Application Type

Commercial- Institutional Application	No. of Facilities	Total Rooms	Institutional Population	OPL Usage		
				High	Low	Percentage with OPLs
Hospitality (hotels/motels)	6,500	975,000		X		100
Nursing Homes	1,600	160,000		X		100
Hospitals	508	88,800			X	10
State Prisons	33		160,000	X		100
City/County Jails	560		87,000	X		100
Universities						
CSU	23				X	100
UC	9				X	100
Private	127				X	16

2.2 Industrial Laundries

Unlike OPLs, industrial laundries contract with and receive and launder stock from a wide variety of customers throughout the community or region. Industrial laundries include uniform companies and those companies that launder materials from industrial firms, schools, and other institutions. This category constitutes a large opportunity for water efficiency. Although some of the largest laundries can process tens of millions of pounds of laundry each year, these operations are usually more process-related and are tailored to specific operations, unlike commercial laundries. As such, we have not included these large types of facilities in this study.

Providing a consistently high quality laundry product at a competitive price in such an environment is a challenging task. Industrial laundries deal with a wide range of laundry products including those with high levels of fats, oils, and grease (FOG), and other soil contaminants. Adding water efficiency into the equation further complicates these already difficult issues.

Several recycling projects have been completed in California’s industrial laundries⁴, designed by engineering firms that specialize in wastewater remediation. These projects represent tailored solutions to an individual laundry’s wastewater problem. First, the opportunity is studied, and the appropriate technological remedies are evaluated. Then these technologies are selected and

⁴ The Metropolitan Water District recently announced the implementation of a major industrial laundry process improvement project for Republic Master Chefs, whose parent company is American Textile Maintenance. According to Metropolitan’s press release (Metrospectives), their Industrial Process Improvement Program (<http://www.mwdh2o.com/mwdh2o/pages/conserv/program02new.html>) provided incentive funding that will yield project savings of as much as 16.5 million gallons of water per year, or 38 percent of the laundry’s current annual water usage.

engineered into a system, with specifications and drawings that are put out to bid for procurement and installation. This entire process is expensive and time-consuming, and is usually undertaken when the local municipality or wastewater agency threatens to shut the laundry down if it does not bring its effluent discharge into compliance with codes and regulations. Although the economic benefit from recycling may not enter these initial decisions, it is conceivable that these benefits could be fruitfully integrated into the marketing message.

Because of the high costs, and lack of currently available “off the shelf” systems, we recommend that the subject of industrial laundries be considered as an industrial process and investigated as a separate PBMP candidate.

2.3 Coin-Operated Laundries

There are approximately 2,500 to 3,000 coin-operated and card-operated laundries in the State of California⁹, presenting a large opportunity for water efficiency. However, similar to industrial laundries, coin-operated laundries handle a wide variety of laundry classifications. It is therefore difficult for any one “off-the-shelf” technology to work in all applications. Other issues involve allocation of responsibility for the results and quality of the laundry product needed to maintain a high degree of customer satisfaction. The general public is not yet friendly to the idea of using recycled water in laundries. Attempts to get the public to accept recycled water for laundering has thus far received limited success. Education of the public will be required as there is a general lack of understanding of the capability of water cleaning and disinfection technology. It is recommended that water efficiency opportunities within coin-operated laundries be considered as a separate PBMP candidate for future investigation.

3.0 Washer Equipment and Facilities

3.1 Equipment

Most OPL’s are typically very small in terms of available space. Not only do they contain the washers, but also dryers, varying assortments of flatwork ironers, folders, steam cabinets, and so on, for processing the laundry. Free space for new washer systems is difficult to find.

The typical OPL utilizes a washer technology called washer-extractors. This type of machine ranges in size from about 35 pounds up to 800 pounds in the largest laundries (a typical washer found in the home is a 12 pound to 14 pound machine). The name washer-extractor is used because after each portion of the wash cycle (soak, suds, pre-wash, wash, rinse or finish) an extraction imparting centrifugal force removes the liquid contents from the wash wheel to the drain.

Other types of washers, called tunnel washers, are also encountered. These units are very expensive and are only used in the largest OPLs and in industrial laundries with very high production rates. Tunnel washers are inherently water-efficient and are highly automated to maximize the throughput of the laundry. Tunnel washers are very different than washer

⁹ Golden State Coin-Op Laundry Association (Estimate)

extractors. They are constructed with a series of compartments, called “pockets”, through which a large internal “auger” moves the laundry product. The initial pockets are soak and wash related, while the trailing pockets are dedicated to rinse functions. Water moves in a counter flow direction to the laundry and is therefore used several times before being sent to the drain. At the end of the tunnel the product is removed automatically in the form of a cake, mechanically compressed before being fed into the line of dryers. Water consumption rates typically found in these washers are approximately 2.0 gallons per pound of wash, or about two-thirds that of the typical washer-extractors.

3.2 Facilities and Facility Operation

OPLs range in size from a single 35 pounds washer, which one might find in a small motel, up to combinations of several larger washers ranging in sizes from 200 pounds, 400 pounds, 600 pounds up to 800 pounds (nominal). Laundries are typically located in the basement of the hotel or institution with minimal space dedicated to this vital operation.

Typical laundries work at least one 8-hour shift, usually beginning operation early in the morning and ending in mid-afternoon. The laundry will generally operate five, six or seven days per week depending upon laundry load, number of laundry replacement sets, and total laundry throughput capability. Many laundries must operate two or three shifts per day, again depending upon these three criteria. These same factors influence the size and cost of the technology needed to accommodate the throughput demand upon the laundry. The hours of operation and total throughput of a given laundry has a significant influence on the financial payback of any water efficiency project.

4.0 Wash Classifications and Washer Operation

Smaller establishments, such as motels, will use three to five wash classifications and corresponding wash cycles. A typical grouping of five classifications would include terry (towels), bed linens, blankets, bedspreads, and mops. A small motel laundry sees very little variation of soil classification or classification mix. Because the laundry is consistent over time and has little variation in content or in the percentages between classifications, it is relatively easy to devise a strategy to recycle the wastewater or apply ozone technology. Larger hotels and hospitals may have as many as 10 to 12 different wash classifications with matching wash cycles devoted to each one. Obviously, this adds to the complexity of any project and technology by having to deal with a multitude of laundry classifications.

A typical wash formula in a smaller motel laundry operation will include a wash cycle and possibly as little as two or three rinse cycles. During each portion of the cycles, different water levels are programmed into the on-board computer in the washer and the chemicals are added in exact amounts during successive points in the wash cycle. For instance, the “brake” or alkali is added in the initial wash, “builder” or surfactant and detergent in a subsequent wash cycle. Bleach and softener are added into the rinse cycles, usually one per rinse. “Sour” (phosphoric acid) is utilized to neutralize any remaining alkali and is usually added in the final rinse cycle. These functions are all controlled by the washer’s on-board computer, typically programmed by the chemical supplier’s representative. Table 2 provides an example of what a typical wash strategy might look like.

Table 2. Typical Heavy Wash Formula (400 lb. Braun)

Cycle	Water temperature (deg F)	Chemical additive	Gallons of water
Flush	100		290
Wash	170	Alkali (Brake)	94
Wash	170	Detergent/Surfactant	94
Rinse	150	Bleach	134
Rinse	140		134
Rinse	120		134
Rinse	100		134
Final Wash	100	Sour/Softener	114
Total			1,128

As noted above, temperatures vary significantly through the different portions of the wash cycle. Typical pre-wash and wash cycles are performed at approximately 160°F to 170°F while successive rinses are reduced to the 130°F to 150°F range, then reducing down to the 100°F to 110°F range for the final rinses.

The volume of water consumed by each of the cycles varies greatly. The initial wash cycle uses the most water because it must saturate the material and fill the wash wheel. These larger volumes also help to carry away the larger proportions of contaminants encountered in the initial wash phases. Rinse cycles use the least amount of water, sometimes as little as 35-60 percent of the amount used in the initial wash. Water is extracted between each step of the wash cycle before clean water is injected into the wash wheel.

Liquid chemicals are usually preferred because of the ease of administration through a series of peristaltic metering pumps. These pumps are programmed to deliver precise amounts of chemical during the appropriate phase of the wash and take their signal from the washer controls.

5.0 Wash System Technologies

5.1 AquaRecycle

AquaRecycle¹⁰ is a comprehensive wastewater recycling system designed and sold only in commercial laundry applications by EMI Water Recycling Systems since 1998. It is considered a **full recycle** system and is designed to recycle 100 percent of the wastewater from the wash and rinse cycles and it reapplies this water throughout the entire array of succeeding wash and rinse cycles. However, the recycled water must be supplemented with about 15 percent make-up water in order to maintain total dissolved solids (TDS) at an acceptable level.

¹⁰ Aquarecycle Sales Literature, EMI Water recycle Systems, Marietta, GA

Theoretical hot water heating energy savings could be as high as 60 percent of current usage. However, in most applications, approximately 40 percent to 50 percent energy savings will be realized. This is due to seasonal changes in municipal water temperatures and other factors that change the process' energy requirements.

Approximately 25 AquaRecycle systems have been successfully installed throughout the United States, including at Ritz Carlton Hotels and large centralized hospital laundries. Economics for AquaRecycle systems become favorable where water and sewer charges exceed \$4.00 per 1,000 gallons, and where laundry loads exceed 8,000 lbs per day. However, the company is willing to sell to any customer large or small as long as there is a good economic return on investment for the client. Their smallest system handles 2,400 lbs. per day for a single shift laundry.

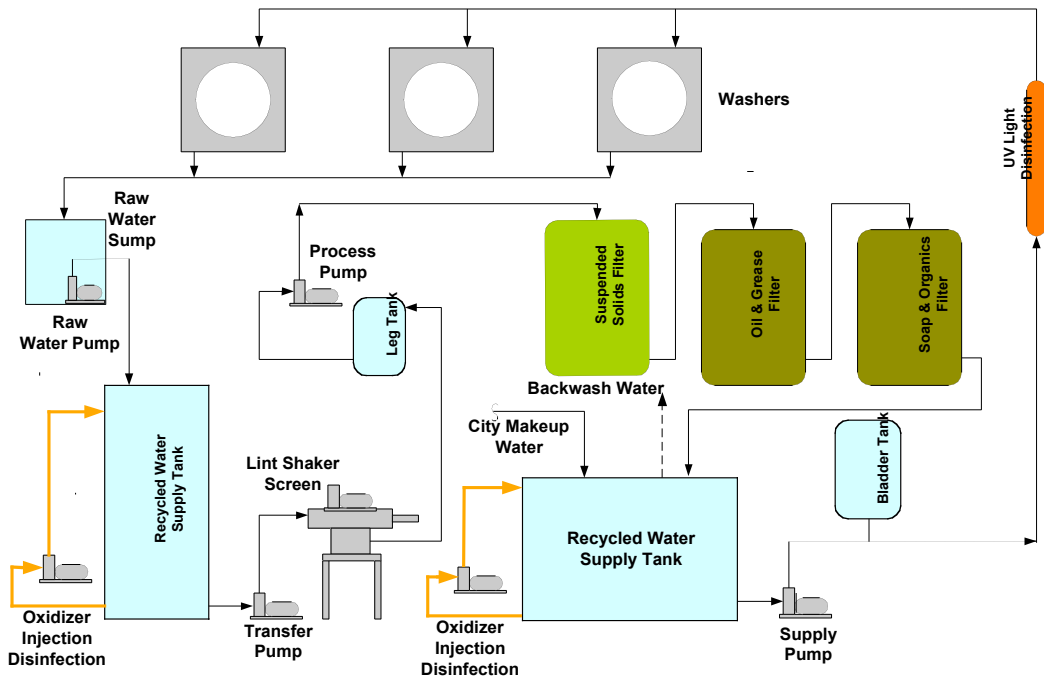
The system operates by recovering wastewater from the "trench" or wastewater sump (pit), which is then pumped into the initial holding tank where ozone is injected into the water. Oxidizing gasses serve as a preliminary disinfectant and deodorizer, keeping the process water bacteria-free and odor-free. In some systems containing high levels of fats, oils, and grease (FOG) and/or other organic matter, a second bypass discharge valve can be attached to each washer; this valve is programmed to open at the completion of the flush or initial wash cycle for certain wash classifications, sending this highly contaminated water directly to the sewer. This strategy lengthens the life of the filter media in the downstream oil and grease filter and in the soap and organics filter, thus reducing the annual maintenance expense.

The process water is then pumped to a vibrating lint removal system called a lint shaker table where the water is "screened" of lint and large solids. Solids larger than 70 microns are removed. (As a point of reference, note that a human hair is about 40 microns in diameter.) The lint is separated from the process water which is then sent to a "leg" tank that holds the water until there is a call for more recycled water in the pressurized portion of the filtration system.

Process water is then sent to pressurized suspended solids filters with filtration media that sometimes including layers of sand, gravel, garnet, and anthracite to trap remaining solids still in the water circuit. Each successive bed along the path has a higher level of filtration that enables an increasing amount of filtration and removes suspended solids down to approximately three (3) microns. This filter automatically backwashes to remove trapped solids from the filter bed at a predetermined pressure drop across the filter or at a programmed time interval. Backwash water is sent to the sanitary sewer. When complete, particles three (3) microns and larger are removed by this filtration method.

Next in sequence are the oil and grease filters and the soap and organics filters, mentioned earlier, that are also pressurized. These filters remove all remaining FOG in the water as well as other organic compounds, remaining hydrocarbons, surfactants, toxins, and other chemicals accumulated in the wash process. Most chlorides and odors are removed as well. These filters are designed to backwash once each day, essentially redistributing the media to prevent channeling. All backwash water is sent to the sanitary sewer. The filter media works through the process of adsorption and therefore has a limited life. The media beds are sized to last approximately one year at which time the media is removed and replaced.

Diagram 1: AquaRecycle Process



A final holding tank is then utilized to store all of the process water until it is needed for the next wash or rinse cycle. A powerful oxidizer is continually sent to this tank for additional disinfection. Water demand at the washers is determined by a pressurized bladder tank whose pump is controlled by a pressure switch. When the pressure in the bladder tank falls, the pump runs, delivering water to the washers and when the pressure reaches the upper limit, it turns off. Ultraviolet (UV) disinfection is utilized as the final method of disinfection to kill any remaining bacteria and viruses in the water before sending it back to the washers. Water from the final holding tank is also used as the backwash water for the filter vessels. Diagram 1 shows the process in graphic form.

The system requires space for holding and filtration tanks and storage tanks which vary in size and capacity depending upon the throughput requirements. Space requirements vary from 100 square feet for a small 15 gallon-per-minute system to approximately 343 square feet for the largest system capable of processing 250 gallons per minute (gpm). The AquaRecycle system lends itself to limited-space applications as components can be placed in several locations within the building and connected by piping and any control wiring. If space is at a real premium, as it usually is in most laundries, the filtration and storage tanks are made of durable, weather resistant plastic and fiberglass and can even be located outside the building. In northern latitudes, freeze protection is provided by AquaRecycle for all outdoor components. Only certain modularized core components, which are factory assembled on a single skid, such as the pumps, control panel, and UV unit, need be protected and located inside the building.

Aside from the obvious savings of water, sewer and energy costs; the system has other operational advantages as well. Because the water returning to the washers is at a slightly elevated pH (10 - 10.5 versus municipal water at 7.5 – 8.4), lesser amounts of alkali are needed to elevate the pH to the normal 11 to 11.5 range in the wash cycles. Slightly higher levels of sour (phosphoric acid) are needed in the final rinse, however. But since alkali is much more expensive than sour, the operator realizes net cost savings. No chemical savings are considered in this analysis.

From the perspective of the operating personnel, the incorporation of this system into an existing laundry operation does not change any of the normal or “historical” procedures within the laundry or of the laundry personnel. Chemical formulas are changed very slightly thus making the recycling system “invisible” to the operational personnel, one of the key aspects of a successful technology.

Pricing of the small 15-gpm system ranges from \$75,000, plus \$10,000 to \$15,000 for shipping and installation, to as much as \$300,000, plus \$15,000 to \$25,000 for shipping and installation, for a large 250-gpm system.

The AquaRecycle system utilizes pneumatic valve operators and very simple programming technology to run the system. Every system is sold with a communication link to the factory’s engineering staff to facilitate rapid and remote trouble shooting.

Table 3 summarizes system operating ranges, area requirements and basic capacities of the nine system sizes offered.

Table 3. AquaRecycle General Characteristics

Model Number	Capacity (gpm)	Area (sq.ft.)	Nominal Laundry Capacity (pounds/8-hr day)
15	0-15	100	2,400
30	15-30	105	4,800
50	30-50	125	8,000
75	50-75	140	12,000
100	75-100	260	16,000
125	100-125	260	20,000
150	125-150	280	24,000
200	150-200	336	32,000
250	200-250	343	40,000

5.2 Aquatex 360 - Wastewater Resources, Inc. (WRI)

WRI¹¹ has developed a system called Aquatex 360, specifically designed for recycling water in commercial laundries. They have been selling these systems since 1988 and currently have over 37 systems installed throughout the United States, of which 24 are owned and operated by

¹¹ Wastewater Resources, Inc. website and conversations with Randal Jones, principal owner of WRI.

the company. WRI sells metered recycled water back to the customer. In these applications, the customer has no initial investment and the savings accrue to the customer through lower water, sewer and energy costs when compared to those imposed by the local utilities companies for the equivalent amount. WRI is incentivized to save as much water as possible because it increases its return with greater amounts of saleable utilities. One major drawback is that the present WRI system cannot be used on tunnel washer systems.

Although this savings analysis is based upon the Aquatex 360, it is important to note that WRI planned to introduce a new product line in mid-2005. All of its sales and marketing efforts will be geared toward larger, centralized (100,000 gallons per day and over) laundries. Centralized laundries, discussed earlier in this report, are non-industrial laundries that combine into a single facility the individual laundry operations of several hotels or hospitals in order to reduce costs and comply with increasingly stringent government regulations. The new, larger WRI system will not be sold to medium and smaller laundry customers.

Unlike AquaRecycle, the Aquatex 360 system is considered a *partial recycle* system. Although it recycles 100 percent of the water in the "trench", reapplication of the recycled water only takes place during hot water calls by the washers. Because the blended temperature in the trench is approximately 100°F, a boiler or steam heat exchanger raises water temperature up to the desired 160°F -170°F level before sending it back to the washers. When it is necessary to temper the water in the wash wheel to the desired temperature below the 160°F - 170°F level, cold water is fed from the municipal supply make-up line directly into the washers and is mixed with the hot recycled water until the desired wash or rinse temperature is reached. WRI literature states that water savings up to 65 percent of the current usage are possible. The WRI literature also states that the system can save up to 50 percent of the energy needed to heat the water.

The system operation starts with wastewater discharged to the trench from the wastewater discharge valves in the washers. The wastewater (raw water) gravitates to the sump or pit from where the raw water pump moves the wastewater to a lint shaker screen. The lint shaker screen removes most lint and particulate matter exceeding 70 microns.

Wastewater from the shaker screen is discharged into a shaker or holding tank. From here, the wastewater is sent to the tubular backwashable pressure filter located on the tube filter skid. This filter is completely automated in operation. Backwash frequency is determined by a pressure differential of 10-20 psi across the filter. The reusable filter elements are capable of removing particulate matter down to one to three microns but is considered totally effective in the 5-micron range for suspended but no dissolved matter. Backwash is accomplished with filtered water that is stored in the backwash tank. A backwash valve opens to replenish the water in this tank as necessary. Backwash water is sent to the sanitary sewer after passing through the filter elements that are being backwashed.

Diagram 2: Aquatex 360 Process

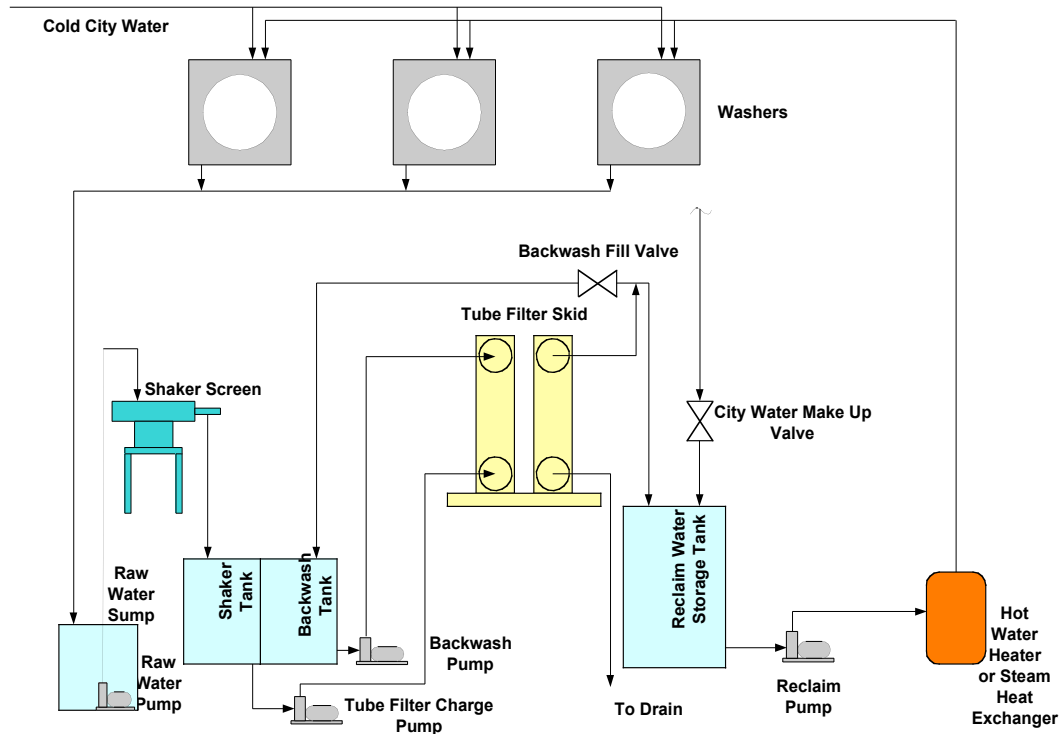


Diagram 2 shows the WRI laundry wastewater recycling process schematic. WRI's process is unique insofar as it utilizes recycled water only for hot water applications. This water is used in all portions of a wash cycle but not in all rinse cycles. The final two rinses must be performed with cold municipal water. The means of disinfection in this process is the reheating of the recycled water to 160°F to 170°F, a process that kills bacteria and virus contaminants. It is important to note that the recycled water still contains all suspended solids below five microns and all dissolved solids. The total dissolved solids (TDS) level is constantly monitored and controlled within allowable limits by introducing fresh municipal water (of lower TDS) to dilute the recycled loop. Because the final rinses and finish cycle are performed in cold water, extra energy is expended in the drying process.

The pH of the process water returning to the washers is between 9.5 to 10.5 (versus municipal water at 7.0 – 8.4). Lesser amounts of alkali are needed to elevate the pH to the normal 11 – 11.5 pH range in the wash cycles. Slightly higher levels of sour (phosphoric acid) are needed in the final rinse. As discussed earlier, alkali is much more expensive than sour so there is a net savings to the operator. No chemical savings are considered in this analysis.

Again, from the perspective of the operating personnel, the incorporation of this system into an existing laundry operation does not change any of the normal laundry procedures of the laundry personnel and the system modification is therefore 'invisible' to them. Chemical formulas are changed very slightly thus making the recycling system non-threatening to the chemical supplier. These are two of the key aspects of a successful technology.

The WRI system lends itself to numerous layout configurations when available space is limited. The tubular filter, controls and valves are factory packaged on a single skid to minimize space and field-related installation labor and associated costs. Other components can be located in available space away from the filter skid. WRI makes eight system sizes ranging from 10 GPM (2,400 lbs/day) up to 150 GPM (32,000 lbs/day). The system is very compact. Table 4 shows the various system sizes by GPM, required floor area and nominal cost.

Table 4. Aquatex 360 General Characteristics

Model Number	Capacity (gpm)	Area (sq.ft.)	Nominal Laundry Capacity (pounds/8-hr day)
10	10	60	2,400
20	20	70	4,800
30	30	80	8,000
50	50	100	12,000
70	70	120	16,000
80	80	140	20,000
100	100	160	24,000
150	150	200	32,000

The Aquatex 360 system is completely automated and can be interrogated through phone modem technology from WRI's offices in Scottsdale, Arizona. This capability allows for remote diagnosis, which, in turn, facilitates trouble-shooting.

5.3 Ozone Laundry Systems

Ozone laundry systems can be used in a large variety of OPLs. They are especially attractive where water/sewer costs are less than \$4.00 per thousand gallons, and where annual laundry volume is relatively small.

The manufacturers all seem to agree that a minimum of 15 percent to 20 percent water and sewer savings can be achieved in many applications. Isolated opportunities may yield 30 percent to 35 percent savings in water consumption and sewer discharges. Some manufacturers claim savings up to the 50 percent - 60 percent range. Caution must be practiced when estimating savings with ozone laundry systems.

Since ozone works best in ambient water temperatures, the water is not heated. Therefore, the water heating energy savings over conventional laundry systems is approximately 80 percent in most applications. Actual energy savings realized will depend upon the proportion of loads that must be washed with standard chemistry in high temperature, such as food and beverage linen, mop heads and bar rags. Other benefits include chemical savings, less wear and tear on linens, shorter wash cycles and potential labor savings. None of these claims are evaluated in our savings analyses; only water, sewer and energy savings are considered.

Over the past 15 to 20 years, many of the companies selling ozone systems have gone out of business. While owners of these businesses may have understood ozone technology, they probably did not understand commercial laundry business or laundry chemistry, and did not have the appropriate financial backing. These companies overstated potential savings to the customer and did not always understand the importance of working with the chemical supplier. Unlike the two recycling technologies discussed earlier, ozone systems require a much greater effort in developing the correct wash formulas, because the ozone laundry process represents a dramatic change from conventional laundry processes.

At least three manufacturers are known to have survived and succeeded, showing both longevity and a serious level of commitment to ozone laundering systems. These are IndustrOzone Tech Inc., Wet-Tech, Inc., and WaterEnergy Tech, Inc. Each manufacturer uses a slightly different approach for enhancing ozone effectiveness, but for the most part they achieve similar savings, laundry quality and customer satisfaction. Although all three manufacturers have completed projects that included heavy soil classifications, this technology is most easily and safely applied to applications with medium and light soil classifications such as hotels, motels, prisons, universities, and some nursing home applications.

Ozone is a very strong oxidant that works well in cold water thereby saving a great deal of water heating energy when compared to conventional laundry processes. Additionally, because of the unique oxidation properties of ozone, there is a theoretical lowering of the quantity of selected chemicals when compared to the same wash being done conventionally. As a direct result of the lowering of chemical content in the wash and subsequent rinse water, the need for multiple rinse cycles can often be reduced, thus saving a portion of the total water demand per wash load. Nonetheless, ozone application may not be viable in many situations. For example, in smaller OPLs, the operator has already reduced wash and rinse cycles to the absolute minimum in the existing operation. Little or no water savings are obtainable from such sites. While manufacturers contend realistic savings of up to 30 percent to 35 percent are obtainable, it is important that each individual project be evaluated for its specific savings opportunity. Often, the system does not yield much water or wastewater savings, but instead may generate considerable energy savings, making the latter the primary justification for the purchase of such a system by the end-user.

Many ozone equipment manufacturers also contend that their systems reduce chemical costs. ECOLAB, the largest supplier of laundry chemicals in the United States, has recently introduced a new product line of chemicals specifically designed for ozone laundries¹². Although ECOLAB acknowledges a decrease in total chemical quantity, they state that the new product is more expensive than the older, more conventional chemical products currently in use. It is their belief that the cost of converting to the new ozone-friendly chemical line will be cost neutral to the customer. As such, no chemical savings estimated by the ozone equipment manufacturers should be considered in the savings calculations.

¹² Personal communication, Mr. Ken Jensen, ECOLAB, Atlanta, GA

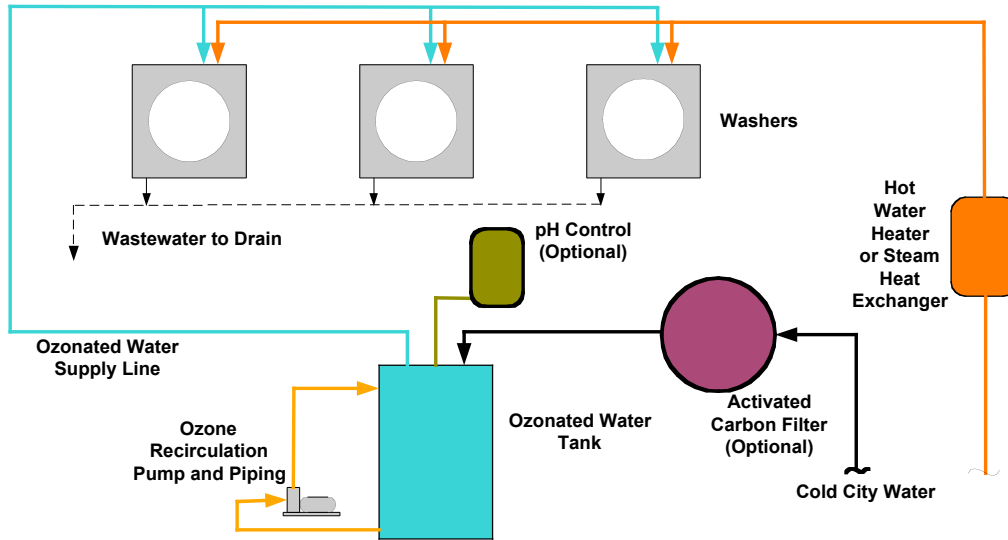
In general, recycling of rinse water in conjunction with ozone laundry systems has not been attempted to any large extent. Only one such system has been completed; it is not located in California. The system achieved 90 percent water savings. Costs and other metrics of this project have not been made available, however.

Ozone systems work because of the extremely high oxidation potential of ozone. Ozone is a powerful oxidant that works 3,000 times faster and is 150 percent more effective than chlorine, but without chlorine's dangerous properties. The ozone molecule is composed of three oxygen atoms that are very unstable (very reactive). Ozone (O₃) ranks second in oxidizing potential (fluorine gas is number one but is extremely toxic), whereas chlorine (bleach) is number 16 on the scale of oxidizing potential. Oxygen is most stable in its diatomic state of two oxygen atoms, so when ozone is allowed to react, the third atom in its molecule quickly breaks away during the oxidation reaction. As mentioned earlier, ozone displaces some of the alkali, bleach, softener and possibly detergent because the ozone does much of the cleaning work by itself and in conjunction with chemical additives. Ozone can thus attain similar results without the need for the same quantities of chemicals as are necessary with conventional high temperature washing. Moreover, unlike chemicals, ozone leaves no residue. Thus, the number of rinse cycles can be reduced.

Ozone is also excellent for destroying bacteria, viruses and controlling odors. When properly applied, ozone laundering attains between 99.5 percent to 99.7 percent bacterial and viral kill count. Ozone decomposes and emulsifies FOG, in addition to purifying and disinfecting the water.

Since ozone is so unstable and cannot be shipped or stored, it must be made at the point of use. The ozone unit takes in ambient air to produce the ozone through a corona discharge or UV (ultraviolet) process. The ozone gas is mass-transferred to a pressurized water supply tank until the washer-extractor requires it for the wash cycles or it is directly fed as a gas from the ozone generator directly into the wash wheels of the washers. The equipment is not extremely large or bulky and easily fits in a corner of a room with many of the components mounted to the wall behind the wash line. Optimally, the ozone equipment is located as near to the washer-extractors as possible for maximum effect of the ozone. Diagram 3 illustrates a basic ozone system schematic. One of the manufacturers, Wet-Tech, Inc., injects gaseous ozone directly into the washers so the schematic does not apply to their technology.

Diagram 3: Ozone Laundry Systems



The manufacturers offer these systems in several sizes. Costs range from \$10,000 to \$12,000, plus \$5,000 for shipping and installation for the smallest systems; the largest systems cost up to \$45,000, plus approximately \$10,000 for shipping and installation.

5.4 Membrane Technologies

Several attempts have been made over the years to introduce membrane technologies into the laundry business - unsuccessfully. There are four levels of membrane technology:

<u>Technology</u>	<u>Particle classification</u>
Microfiltration.....	1.0 – 0.1 Microns
Ultrafiltration.....	0.001 – 0.1 Microns
Nanofiltration.....	0.005 – 0.0001 Microns
Reverse Osmosis (RO).....	1 angstrom* – 0.001 Micron

*1 hundred-millionth of a centimeter

Micro and ultrafiltration are able to eliminate suspended solids whereas nanofiltration and RO are able to eliminate most dissolved solids in their respective particle classifications and all suspended solids. Solids are removed by forcing the smallest molecules through small holes in the membrane media under pressure. Finer membranes require greater pressure. Generally, the waste stream (called brine or concentrate) will account for between 40 – 50 percent of the throughput, leaving 50 – 60 percent as the recovered permeate or useable water.

The initial cost of this technology is very high, and the membranes require constant cleaning, as well as replacement about every two to three years. Although Nano and RO technologies do an

excellent job of cleaning the laundry water waste stream, these technologies are not currently considered as economically viable for this application. There are no known manufacturers utilizing membrane technology in OPLs today. Membrane technology will not be discussed further and will not be considered as a PBMP candidate.

5.5 Rinse Water Recovery Technologies

One of the concepts utilized in laundries in the past has been rinse water recovery. This type of system works by diverting water recovered from rinse-only cycles into a large holding tank near the laundry wash line. Whenever a washer calls for water in a soak, suds or wash cycle, the water stored in the rinse water holding tank is pumped into the washers. One manufacturer, Thermal Engineering of Arizona (TEA), has been successful in installing their system in several institutional properties, such as Veterans Administration hospitals and state prisons, but these systems are not found in typical commercial laundry applications. They involve high initial cost, and very long payback periods, making them often unattractive in commercial settings.

Observation of many of these systems has shown that most have degenerated after several years of operation. The piping and control systems, which direct the flow of water, are extremely complex and are entirely dependent upon the microprocessor controls in the washers. Although the controls were seemingly simple enough for onsite maintenance personnel to deal with, the systems were allowed to fall into disrepair. The reasons are not clearly understood.

Since these systems are yet to be proven as feasible for laundry applications, they are not considered as a PBMP candidate.

6.0 Technology Risks

The major risk with any of the laundering system technologies discussed in the preceding paragraphs is the ability to keep the technology functioning properly over the long-term, such that expected savings are actually achieved. Most manufacturers offer a one-year parts and labor warranty, which protects the owner for the first 12 months after the system is installed and commissioned. Not only must the manufacturer be able to repair or replace defective parts in a relatively short period of time to keep the laundry operational, the technology partner must be able to resolve changes in the laundering chemistry that may be made without the knowledge of the laundry manager and operating personnel. The most important factor in keeping all of these system technologies viable is the cooperation of the chemical supplier. Therefore, the system should have the ability to be interrogated remotely by the equipment manufacturer for monitoring and trouble-shooting. Done correctly, properly operated systems can work well for many years.

As is the case with any mechanical system, maintenance is critical for achieving expected water and energy savings. Inadequate maintenance can occur for several reasons, including poor training of onsite operating and maintenance personnel, personnel turnover, and technology requirements far above the level of understanding of onsite personnel. To overcome these obstacles, the supplier of the given technology must be able to offer an ongoing maintenance and

service program that takes over after the first-year warranty has expired. No system should be installed without such support in place. Therefore, an ongoing service and maintenance program must be included in any contract documents and the cost for such a program must be deducted from the savings stream analysis.

Finally, another risk often overlooked is whether or not the magnitude of potential water and energy savings claimed by the seller of the technology can actually be realized. Following the initial commissioning of the system, a one-time measurement to verify savings against the calculated amounts can be performed. However, most systems go through an initial break-in period where frequent adjustments are made to the technology equipment and to the laundry chemistry to improve wash quality results. True long-term savings may thus differ considerably from the manufacturer's promises.

To reduce or eliminate this risk, it is strongly recommended that each manufacturer provide a system for measuring results and verifying that the savings used in the economic analyses are actually being achieved. The measurement of actual savings must be performed on an ongoing basis so that the owner fully understands the value of the savings being generated. If the technology falls short of expectations, penalty clauses can be imposed to "true up" the differential. This will keep technology suppliers honest and realistic about their savings claims.

7.0 Water Savings Estimates and California Potential

Several steps are required to estimate the statewide conservation opportunity associated with the technologies considered in this analysis. The first step is to realistically approximate the actual savings for each of the three technologies under consideration by estimating wash formulas for heavy, medium and light wash classifications and then calculating likely water and energy savings.

7.1 AquaRecycle

AquaRecycle's versatility makes it useful in a diverse set of applications, and therefore it perhaps has the greatest water savings potential. It can be utilized in all sized applications and has no restriction on soil classifications. Tables 5.1, 5.2 and 5.3 display AquaRecycle's wash characteristics in typical heavy, medium and light soil scenarios. These tables show estimates of water and energy consumption before and after the installation of an AquaRecycle system working in conjunction with a Braun 400-pound water-extractor.

Table 5.1. AquaRecycle - Heavy Soil

AquaRecycle System Results - 400# Braun - Bed Pads (Heavy Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE" Conventional Washing - Baseline			"AFTER" Recycled Washing - AquaRecycle		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Flush	100	290	105	185	138,206	193	97	115,171
Wash	170	94	94	0	123,194	94	0	55,997
Wash`	170	94	94	0	123,194	94	0	55,997
Bleach/Rinse	150	134	110	24	143,686	134	0	47,895
Rinse	140	134	97	37	127,721	134	0	79,826
Rinse	120	134	73	61	95,791	134	0	0
Rinse	110	134	61	73	79,826	112	22	66,521
Finish	110	114	52	62	67,911	52	62	30,869
TOTAL GALLONS & BTUs		1128	686	442	899,529	947	181	452,277
Savings percent						84%		50%

Table 5.2. AquaRecycle - Medium Soil

AquaRecycle System Results - 400# Braun - Terry Cloth (Medium Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE" Conventional Washing - Baseline			"AFTER" Recycled Washing - AquaRecycle		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Flush	100	290	105	185	138,206	193	97	0
Wash	170	94	94	0	123,194	94	0	55,997
Wash`								
Bleach/Rinse	150	134	110	24	143,686	134	0	79,826
Rinse	140	134	97	37	127,721	134	0	79,826
Rinse	120	134	73	61	95,791	134	0	0
Rinse								
Finish	110	114	52	62	67,911	0	114	81,494
TOTAL GALLONS & BTUs		900	531	369	696,509	689	211	297,142
Savings percent						77%		57%

Table 5.3. AquaRecycle - Light Soil

AquaRecycle System Results - 400# Braun - Bed Linens (Light Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE" Conventional Washing - Baseline			"AFTER" Recycled Washing - AquaRecycle		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Suds	100	94	34	60	44,798	63	31	0
Wash	170	114	114	0	149,405	114	0	67,911
Wash`								
Bleach/Rinse	150	134	110	24	143,686	134	0	79,826
Rinse	140	134	97	37	127,721	134	0	79,826
Rinse	120	134	73	61	95,791	134	0	0
Rinse								
Finish	110	114	52	62	67,911	0	114	81,494
TOTAL GALLONS & BTUs		724	480	244	629,313	579	145	309,057
Savings percent						80%		51%

The savings claims of the manufacturer appear to be attainable. The average water savings range between 77 percent and 84 percent and the energy savings between 50 percent and 57 percent, all within the range of claims found in the AquaRecycle sales literature and on their web site⁵

7.2 WRI Aquatex 360

As noted earlier, the Aquatex 360 is now sold only for larger centralized commercial laundries processing about 32,000 pounds (100,000 gallons) of laundry product a day and more. Tables 6.1, 6.2, and 6.3 show a Braun 400-pound washer-extractor, typical of larger laundries, with programs for heavy, medium, and light soil loads. The tables include quantities of hot and cold water and the energy consumption, showing both the baseline and post installation consumptions of these utilities. Typically, a laundry would have more than one 400-pound machine to accomplish 30,000 pounds of laundry a day and the laundry would most likely be working 16 hours or more per day to meet this large quota. However, the results from these three wash examples can be scaled up or down to provide a reasonable estimate of potential savings no matter what the size of the machine and laundry.

Table 6.1. Aquatex 360 - Heavy Soil

Aquatex 360 (WRI) System Results - 400# Braun - Bed Pads (Heavy Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE"			"AFTER"		
			Conventional Washing - Baseline			Recycled Washing - Aquatex		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Flush	100	290	105	185	138,206	105	185	0
Wash	170	94	94	0	123,194	94	0	78,396
Wash	170	94	94	0	123,194	94	0	78,396
Bleach/Rinse	150	134	110	24	143,686	110	24	65,312
Rinse	140	134	97	37	127,721		134	127,721
Rinse	120	134	73	61	95,791		134	95,791
Rinse	110	134	61	73	79,826		134	79,826
Finish	110	114	52	62	67,911		114	67,911
TOTAL GALLONS & BTUs		1128	686	442	899,529	403	725	593,353
						Savings percent	36%	34%

⁵ www.aquarecycle.com

Table 6.2. Aquatex 360 - Medium Soil

Aquatex 360 (WRI) System Results - 400# Braun - Terry (Medium Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE"			"AFTER"		
			Conventional Washing - Baseline			Recycled Washing - Aquatex		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Flush	100	290	105	185	138,206	105	185	28,508
Wash	170	94	94	0	123,194	94	0	78,396
Wash								
Bleach/Rinse	150	134	110	24	143,686	110	24	91,437
Rinse	140	134	97	37	127,721		134	127,721
Rinse	120	134	73	61	95,791		134	95,791
Rinse								
Finish	110	114	52	62	67,911		114	67,911
TOTAL GALLONS & BTUs		900	531	369	696,509	309	591	489,764
Savings percent						34%		30%

Table 6.3. Aquatex 360 - Light Soil

Aquatex 360 (WRI) System Results - 400# Braun - Bed Linens (Light Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE"			"AFTER"		
			Conventional Washing - Baseline			Recycled Washing - Aquatex		
			Hot water - gallons	Cold water - gallons	Hot water energy - Btu's	Recycled hot (120F) water = Saved water (gallons)	Make-up (municipal) cold water - gallons	Hot water energy - Btu's
Suds	100	94	34	60	44,798	34	60	28,508
Wash	170	114	114	0	149,405	114	0	95,076
Wash								
Bleach/Rinse	150	134	110	24	143,686	110	24	91,437
Rinse	140	134	97	37	127,721		134	127,721
Rinse	120	134	73	61	95,791		134	95,791
Rinse								
Finish	110	114	52	62	67,911		114	67,911
TOTAL GALLONS & BTUs		724	480	244	629,313	258	466	506,444
Savings percent						36%		20%

The preceding tables assume that the baseline water levels and temperatures are chosen by the chemical supplier and are typical for the given laundry classification (i.e., heavy, medium, and light). The water quantities in the table are typical for the washes shown. A decrease in water use is achieved whenever the recycled hot water can be used in a portion of the load, typically in a suds, soak or wash cycle. No wash or rinse cycles are eliminated. The energy to heat this water in the baseline case is calculated as follows:

$$\text{Btu's} = \text{Gallons} \times 8.34 \text{ lb/gallon} \times 1 \text{ Btu/pound/degree F} \times (\text{Temperature delta of } 170^\circ - 60^\circ) / \text{Boiler Efficiency of 70 percent}$$

Note: The temperature delta is determined by the wash temperature called for in that portion of the wash cycle as recommended by the chemical supplier.

In the case of Aquatex, an average 35 percent water savings is achieved, while energy savings varied between 20 percent and 34 percent. It is important to remember that all of the recycled water is reheated up to the required 170°F hot water temperature, the same as with the conventional or “baseline” system, the only difference being that the recycled water enters the hot water heater or boiler at approximately 100°F. Although the savings expectations were not as high as stated in the company literature, these savings levels are substantial, especially if WRI provides the capital funds for the equipment. This means that WRI assumes all of the savings risk, rather than the customer. As a result, this technology will look very attractive to potential customers, because no initial capital investment is required.

7.3 Ozone Laundry

Ozone laundry systems are best suited for wash classifications in the medium and light range, generally not for heavy soil. Although the manufacturers claim that satisfactory results have been obtained in heavy soil laundering, most manufacturers will not venture into applications with large percentages of heavy soil or they exclude the mix of heavy soil from their savings calculations. Care must be taken at the laundry not to attempt to treat the heavy soil portion with ozone, as it must be laundered with conventional chemistry and high-temperature water.

As a result of the above, this study is confined to those laundry classifications where a proven track record of success exists with ozone. Many manufacturers claim water savings of up to 50 percent, with typical savings in the 25 percent to 30 percent range. Although this may be true in isolated applications, potential savings cannot be modeled on these claims. The savings estimates that follow are representative of known installation successes and are not based upon manufacturer claims. This tends to make any savings estimates shown in this study conservative.

Tables 7.1 and 7.2 assume an ozone system retrofit installation with one of the leading technology suppliers mentioned earlier. The baseline (conventional washing) water levels and temperatures are chosen by the chemical supplier and are typical for the given laundry classification. The water quantities in the table are typical for the washes shown. Unlike the recycling systems previously discussed, any decrease in water use comes from the elimination of a rinse cycle and/or decreases in the water consumption within selected rinse cycles. The energy to heat the water in the baseline case is calculated according to the formula noted earlier.

Table 7.1. Ozone Laundering System - Medium Soil

Ozone System Results - 400# Braun - Terry Cloth (Medium Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE" Conventional Washing - Baseline			"AFTER" Ozone Washing		
			Hot water (municipal) - gallons	Cold water (municipal) - gallons	Hot water energy - Btu's	Hot water (municipal) - gallons	Cold water (municipal) - gallons	Hot water energy - Btu's
Flush	100	290	105	185	138,206	0	290	0
Wash	170	94	94	0	123,194	0	94	0
Wash`								
Bleach/Rinse	150	134	110	24	143,686	134	0	175,617
Rinse	140	134	97	37	127,721	0	114	0
Rinse	120	134	73	61	95,791	0	94	0
Finish	100	114	52	62	67,911	0	94	0
TOTAL GALLONS & BTUs		900	531	369	696,509	134	686	175,617
					Total water used	820		
					Savings percent	9%		75%

Table 7.2. Ozone Laundering System - Light Soil

Ozone System Results - 400# Braun - Bed Linens (Light Soil)								
Cycle	Water temperature (degrees F)	Total water volume required for cycle - gallons	"BEFORE" Conventional Washing - Baseline			"AFTER" Ozone Washing		
			Hot water (municipal) - gallons	Cold water (municipal) - gallons	Hot water energy - Btu's	Hot water (municipal) - gallons	Cold water (municipal) - gallons	Hot water energy - Btu's
Suds	100	94	34	60	44,798	0	94	0
Wash	170	114	114	0	149,405	0	114	0
Wash`								
Bleach/Rinse	150	134	110	24	143,686	114	20	149,405
Rinse	130	134	85	49	111,756	0	114	0
Rinse	120	134	73	61	95,791	0	94	0
Finish	110	114	62	52	81,494	0	94	0
TOTAL GALLONS & BTUs		724	478	246	626,930	114	530	149,405
					Total water used	644		
					Savings percent	11%		76%

Although representations of larger and smaller washing machines have not been shown, the gallons per pound and Btu's per pound for other machines would be similar to that of the Braun machine. The baseline and the ozone results are scalable and, as such, the savings in water and energy consumption would also be proportionately the same.

Tables 7.1 and 7.2 show a 9 percent and 11 percent reduction in water use. However, these tables do not make any reference to, or allowance for, the quantity of heavy soil loads that must be laundered with standard chemistry and high-temperature water. In many of the applications where ozone would normally be the system of choice, a percentage of the laundry will be classified as heavy soil. This eventuality would make the average 10 percent savings estimate

somewhat excessive. Depending upon the application type, the percentage of garments with heavy soil might be as high as 15 to 20 percent of the total laundry load (e.g., for a hotel with a restaurant, where table linens, dishrags, aprons and other cloth materials used in restaurant activities would be classified as heavy soil). To offset those applications where 25 percent to 35 percent water savings are attainable, it is believed that an overall 10 percent water savings is justified.

7.4 Savings Summary

Savings for all three technologies are summarized in Table 8. It can be seen that the greatest overall water savings and the relatively high energy savings are achieved with the AquaRecycle system applications. Overall, the highest energy savings come from the ozone system applications.

Table 8. Summary of Savings by Technology & Wash Classification

Technology	Soil Classification	"BEFORE"		Savings percentage (Tables 5, 6, and 7)		"AFTER"		UNIT SAVINGS	
		Baseline - gallons per pound	Baseline - Btu's per pound	Water Savings - % of baseline	Energy Savings - % of baseline	Post-installation - gallons per pound	Post installation - Btu's per pound	Savings - gallons per pound	Savings - Btu's per pound
Aquatex 360	Heavy	3.22	2570	36%	34%	2.07	1695	1.15	875
Aquatex 360	Medium	2.57	1990	34%	30%	1.69	1399	0.88	591
Aquatex 360	Light	2.07	1798	36%	20%	1.33	1447	0.74	351
AquaRecycle	Heavy	3.22	2570	84%	50%	0.52	1292	2.70	1278
AquaRecycle	Medium	2.57	1990	77%	57%	0.60	849	1.97	1141
AquaRecycle	Light	2.02	1798	80%	51%	0.41	883	1.61	915
Ozone	Medium	2.57	1990	9%	75%	2.34	502	0.23	1488
Ozone	Light	2.02	1791	11%	76%	1.80	427	0.22	1364

Notes:

Gallons: Determined jointly by the chemical supplier and ozone manufacturer and adjusted over time to obtain the best laundry quality results. Percent savings is determined by calculating the new total gallons (hot plus cold) and dividing by the baseline gallons.

Energy: It is assumed that the bleach/rinse cycle will be performed at standard temperature, 150°F in the example, to maximize whitening and minimizing "rejects" which must be laundered a second time. This is the only portion of the wash cycle where heating energy is used.

Btu's = gallons x 8.34 lbs/gal x 1 btu/pound (water)/degree F x delta T / boiler efficiency.

Baseline gallons per pound are determined (from Tables 5.1 through 7.2) by dividing the total baseline gallons by 350 pounds per wash. A nominal 400-pound washer is rarely loaded to its nameplate capacity. Similarly, baseline Btu's per pound are determined by dividing the total Btu's by 350 pounds.

Post-installation water and energy use are calculated in the same manner from the columns entitled "recycled washing" in Tables 5.1 through 6.3 and "ozone washing" in Tables 7.1 and 7.2. The percent savings is determined by subtracting the post gallons and energy from the corresponding baseline numbers and dividing the result by the baseline figure.

Table 9 summarizes the total estimated poundage of laundry by application type. Note that the total poundage is calculated in two ways. The hospitality and health care sectors calculate use according to the number of rooms and the occupancy rates for those sectors. In other sectors, an industry-wide standard of persons per occupancy was used for calculating total pounds. For example, prisons use the actual number of persons incarcerated with occupancies estimated at or near 100 percent. In the case of universities, laundry use was based upon the approximate number of persons involved in athletic programs and other activities, such as the marching band and activities involving laboratory coats, etc., all of which would be washed in an OPL. An estimate of pounds per day for each occupancy or person must be used in the calculation. Laundry poundage ranges from 10 pounds a day per person in county jails and state prisons to as much as 25 pounds per day per person in hospital and nursing home applications. Hotel poundage was also governed by occupancy rates.

Table 9. Total Laundered Poundage by Application Type

Application	Quantity	Measure					Estimated Occupancy Percent	Total Pounds (in millions)
		Total rooms	Population	Rooms per Establishment	Persons per Facility	Pounds per room/person/day		
Hospitality	6,500	975,000						
Hotels	500	225,000		450		36	70%	2,070
Motels	6,000	750,000		125		23	60%	3,696
Nursing Homes	1,600	160,000		100		25	98%	1,431
Hospitals	508							
Portion w/OPL	25	4,375		175		25	70%	28
State Prisons	33		160,000		4,848	12	100%	701
City/County Jails	560		87,000		155	10	100%	318
Universities								
CSU	23		2,000		2,000	20	75%	252
UC	9		2,000		2,000	20	75%	99
Private	127							
Private w/OPL	20		1,000		1,000	20	75%	110
TOTAL								8,702

Notes:

- (1) Actual operational laundries in hospitals estimated at 25 of the 508 institutions statewide
- (2) University population is based upon the estimated personnel engaged in athletic activities and other activities such as band, where uniform cleaning is required.
- (3) Of the 127 private colleges and universities, it is estimated that approximately 20 will have athletic department laundries
- (4) Occupancies are estimates from each respective industry/activity

Table 10 divides the poundage data shown in Table 9 into the anticipated soil classifications for each application type. The associated gallons per pound and Btu's per pound figures are then multiplied by the appropriate poundage for each wash classification to determine baseline gallons and baseline Btu's for each soil classification and each application type. The gallons and Btu's (now converted to therms) are summarized for each application. Laundry soil classification percentages were estimated based upon industry experience.

10. Annual Baseline Water and Energy Consumption by Technology and Application

Commercial- Institutional Application	Soil Classi- fication	Estimated percent distribution among classi- fications	Pounds of laundry (millions)	Water		Energy	
				Baseline gallons per pound of laundry	Baseline consumption - millions of gallons	Baseline Btu's per pound of laundry	Baseline consump- tion - millions of therms
Hotels	Heavy	15%	310	3.22	1,000	2,570	8
	Medium	30%	621	2.57	1,597	1,990	12
	Light	55%	1,138	2.07	2,355	1,798	20
	TOTAL				4,951		41
Motels	Heavy	5%	185	3.22	595	2,570	5
	Medium	30%	1,109	2.57	2,849	1,990	22
	Light	65%	2,402	2.02	4,852	1,798	43
	TOTAL				8,297		70
Nursing Homes	Heavy	35%	501	3.22	1,613	2,570	13
	Medium	40%	572	2.57	1,471	1,990	11
	Light	25%	358	2.02	723	1,798	6
	TOTAL				3,806		31
Hospitals	Heavy	40%	11	3.22	36	2,570	0
	Medium	40%	11	2.57	29	1,990	0
	Light	20%	6	2.02	11	1,798	0
	TOTAL				76		1
State Prisons	Heavy	15%	105	3.22	338	2,570	3
	Medium	30%	210	2.57	540	1,990	4
	Light	55%	385	2.02	779	1,798	7
	TOTAL				1,657		14
County & City Jails	Heavy	10%	32	3.22	102	2,570	1
	Medium	20%	64	2.57	163	1,990	1
	light	70%	222	2.02	449	1,798	4
	TOTAL				714		6
Universities	Heavy	10%	46	3.22	148	2,570	1
	Medium	25%	115	2.57	295	1,990	2
	Light	65%	299	2.02	604	1,798	5
	TOTAL				1,047		9
TOTAL-ALL APPLICATIONS					20,549		171

Table 11 summarizes all projected water and energy savings by application. This summary takes into account the wash classification poundage from Table 10 and gallons and Btu's per pound savings summarized in Table 8. It also incorporates a predicted penetration of the technology into the various applications covered in this report.

Table 11. Potential Annual Savings of Water and Energy by Application (Penetration Weighted)

Commercial-Institutional Application	Laundry Soil Classification	Laundry Classification - total pounds of laundry in millions (see Table 10)	Technology	Water			Energy		
				Savings - gallons per pound (see Table 8)	Predicted Penetration	Savings - millions of gallons	Savings - Btu's per pound (see Table 8)	Predicted Penetration	Savings - millions of therms
Hotels	Heavy	310	Aquatex	1.15	5%	18	875	5%	0.1
			AquaRecycle	2.70	15%	126	1278	15%	0.6
			Ozone	Not applicable to heavy soil classifications					
	Medium	621	Aquatex	0.88	5%	27	591	5%	0.2
			AquaRecycle	1.97	15%	183	1141	15%	1.1
			Ozone	0.23	10%	14	1488	10%	0.9
	Light	1,138	AquaTex	0.74	5%	42	351	5%	0.2
			AquaRecycle	1.61	15%	276	915	15%	1.6
			Ozone	0.22	10%	25	1364	10%	1.6
	Hotels Total		2,070			712			6.2
Motels	Heavy	185	Aquatex	1.15	0%	0	875	0%	0.0
			AquaRecycle	2.70	15%	75	1278	15%	0.4
			Ozone	Not applicable to heavy soil classifications					
	Medium	1,109	Aquatex	0.88	0%	0	591	0%	0.0
			AquaRecycle	1.97	15%	328	1141	15%	1.9
			Ozone	0.23	25%	64	1488	25%	4.1
	Light	2,402	AquaTex	0.74	0%	0	351	0%	0.0
			AquaRecycle	1.61	15%	580	915	15%	3.3
			Ozone	0.22	25%	132	1364	25%	8.2
	Motels Total		3,696			1,178			17.9
Nursing Homes	Heavy	501	Aquatex	1.15	0%	0	875	0%	0.0
			AquaRecycle	2.70	20%	270	1278	20%	1.3
			Ozone	Not applicable to heavy soil classifications					
	Medium	572	Aquatex	0.88	0%	0	591	0%	0.0
			AquaRecycle	1.97	20%	225	1141	20%	1.3
			Ozone	0.23	10%	13	1488	10%	0.9
	Light	358	AquaTex	0.74	0%	0	351	0%	0.0
			AquaRecycle	1.61	20%	115	915	20%	0.7
			Ozone	0.22	10%	8	1364	10%	0.5
	Nursing Homes Total		1,431			632			4.6
Hospitals	Heavy	11	Aquatex	1.15	5%	1	875	5%	0.0
			AquaRecycle	2.70	15%	5	1278	15%	0.0
			Ozone	Not applicable to heavy soil classifications					
	Medium	11	Aquatex	0.88	5%	0	591	5%	0.0
			AquaRecycle	1.97	15%	3	1141	15%	0.0
			Ozone	0.23	0%	0	1488	0%	0.0
	Light	6	AquaTex	0.74	5%	0	351	5%	0.0
			AquaRecycle	1.61	15%	1	915	15%	0.0
			Ozone	0.22	0%	0	1364	0%	0.0
	Hospitals Total		28			11			0.1
State Prisons	Heavy	105	Aquatex	1.15	0%	0	875	0%	0.0
			AquaRecycle	2.70	20%	57	1278	20%	0.3
			Ozone	Not applicable to heavy soil classifications					
	Medium	210	Aquatex	0.88	0%	0	591	0%	0.0
			AquaRecycle	1.97	20%	83	1141	20%	0.5
			Ozone	0.23	5%	2	1488	5%	0.2
	Light	385	AquaTex	0.74	0%	0	351	0%	0.0
			AquaRecycle	1.61	20%	124	915	20%	0.7
			Ozone	0.22	5%	4	1364	5%	0.3
	State Prisons Total		701			270			1.9
County & City Jails	Heavy	32	Aquatex	1.15	0%	0	875	0%	0.0
			AquaRecycle	2.70	10%	9	1278	10%	0.0
			Ozone	Not applicable to heavy soil classifications					
	Medium	64	Aquatex	0.88	0%	0	591	0%	0.0
			AquaRecycle	1.97	10%	13	1141	10%	0.1
			Ozone	0.23	15%	2	1488	15%	0.1
	Light	222	AquaTex	0.74	0%	0	351	0%	0.0
			AquaRecycle	1.61	10%	36	915	10%	0.2
			Ozone	0.22	15%	7	1364	15%	0.5
	Jails Total		318			66			0.9
Universities	Heavy	46	Aquatex	1.15	0%	0	875	0%	0.0
			AquaRecycle	2.70	10%	12	1278	10%	0.1
			Ozone	Not applicable to heavy soil classifications					
	Medium	115	Aquatex	0.88	0%	0	591	0%	0.0
			AquaRecycle	1.97	10%	23	1141	10%	0.1
			Ozone	0.23	10%	3	1488	10%	0.2
	Light	299	AquaTex	0.74	0%	0	351	0%	0.0
			AquaRecycle	1.61	10%	48	915	10%	0.3
			Ozone	0.22	10%	7	1364	10%	0.4
	Universities Total		460			92			1.0
GRAND TOTAL - ALL APPLICATIONS		8,702 million pounds of laundry			2,962 million gallons			32.5 million therms	

In summary, we estimate that approximately 3 billion gallons (or approximately 9,100 acre-feet) of water savings are available annually by employing these technologies. The assumptions used throughout this study are conservatively low, especially the potential California penetration estimates for each technology. Of the 20 plus billion gallons of water consumed annually by OPL's in California, we are estimating that about 15 percent could be captured through focused water conservation programs.

NOTE: The specifications and performance data used in this report to establish potential water savings was derived largely from manufacturer-supplied information. As such, it is important that scientifically based field verification of the savings estimates be conducted on any technology being considered for BMP status.

8.0 Product Cost

8.1 AquaRecycle

AquaRecycle has an average installed cost of \$12 per nominal pound of daily system capacity. That is, a unit that can supply a laundry producing 16,000 pounds in an 8-hour work shift will cost approximately \$190,000 including equipment, installation, freight and related expenses.

8.2 Aquatex 360

The Aquatex 360 cost can be expressed in the same manner as above. The same 16,000 pounds-per-day (8-hour shift) system will cost about \$9.40 per nominal pound system capacity per day, or approximately \$150,000.

8.3 Ozone Laundry System

The three leading ozone system manufacturers were compared in a similar manner. Although there are small differences in equipment and installation cost, and capacities vary among the manufacturers, the cost per pound of daily capacity starts at about \$15.60 on the smallest sized systems and reduces to about \$4.00 on the largest systems. Although these systems can be ganged into multiple units to serve large laundries, the averaged sized systems are much smaller when compared to the recycling systems. The averaged sized ozone system launders approximately 5,200 pounds per 8-hour day. The approximate cost for this size of system is about \$6.50 per nominal pound system capacity or \$33,800.

9.0 Cost Effectiveness

9.1 AquaRecycle

The average service life of most equipment in a commercial laundry is approximately 20 years. The same will hold true for the AquaRecycle system components. Achieving such longevity, however, requires rigorous ongoing maintenance of the system by qualified technicians.

Considering the 16,000 pounds-per-day system (4,160,000 lbs/year) mentioned earlier, the predicted annual water savings in a typical hotel application would be as shown in Table 12.

Table 12. Typical Lifetime Water Savings - AquaRecyle in Hotel Application

Soil classification		Pounds per classification	Water savings - gallons per pound (see Table 11)	Water savings – total gallons saved
Type	Percentage distribution (see Table 10)			
Heavy	15%	624,000	2.70	1,684,800
Medium	30%	1,248,000	1.97	2,458,560
Light	55%	2,288,000	1.61	3,683,680
			Annual total	7,827,040
			20-year total	156,540,800
			Acre-Feet	480.3

Initial cost of the system per acre-foot of water saved is, therefore, \$396 (\$190,000/480).

9.2 Aquatex 360

The anticipated service life for the Aquatex 360 is 20 years with proper system and component maintenance. Considering the same 16,000 pounds per day system (4,160,000 lbs/year), the predicted annual water savings in a hotel would be as shown in Table 13.

Table 13. Typical Lifetime Water Savings - Aquatex in Hotel Application

Soil classification		Pounds per classification	Water savings - gallons per pound (see Table 11)	Water savings – total gallons saved
Type	Percentage distribution (see Table 10)			
Heavy	15%	624,000	1.15	717,600
Medium	30%	1,248,000	0.88	1,098,240
Light	55%	2,288,000	0.74	1,693,120
			Annual total	3,508,960
			20-year total	70,179,200
			Acre-Feet	215.3

The initial cost of the system per acre-foot of water saved is \$697 (\$150,000/215).

9.3 Ozone laundry Systems

The anticipated life for an ozone system is considerably shorter than the AquaRecycle and Aquatex 360 systems. Although components can be changed out relatively quickly and inexpensively, it is the major components of these systems that will usually fail (the oxygen concentrators and corona discharge units). Therefore, a 15-year service life is assumed for these systems. Using the 5,200 pound capacity per day system (1,352,000 pounds/year), the estimated savings are as shown in Table 14.

Table 14. Typical Lifetime Water Savings - Ozone System in Hotel Application

Soil classification		Pounds per classification	Water savings -	
Type	Percentage distribution (see Table 10)		gallons per pound (see Table 11)	Water savings – total gallons saved
Heavy	15%	202,800	<i>Ozone not applicable to heavy soil classifications</i>	
Medium	30%	405,600	0.23	93,288
Light	55%	743,600	0.22	163,592
			Annual total	256,880
			15-year total	3,853,200
			Acre-Feet	11.8

The initial cost of the system on a per acre-foot basis is \$2,864 (\$33,800/11.8).

It is important to keep in mind that this analysis does not take into account any of the energy savings that accrues with each of these technologies. In many cases, it is the avoided energy costs that drive the decision to replace conventional laundry equipment with the more efficient units discussed here.