Conservation and Recycling for Radiological-Contaminated Laundry Applications– 16044

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ABSTRACT

Recovery and reuse of materials exposed to radioactive environments is a critical element for those whom are involved with processing such materials. In order to minimize the disposal of radiological-contaminated Personal Protective Equipment (PPE, laundry, respirators, etc.) the need for environmentally-friendly and cost-effective technologies to provide laundering services is needed for current and future processes. A by-product of the laundry process is contaminated water. In order to reduce waste generation, we developed a radiological water filtration system custom-designed for laundry applications, which is used as both a filtration device as well as a water recycling system. The filtration process utilizes membrane filtration, suspended solids and organic filtration, ion-exchange capture, and ozonation/UV as germicidal reducers. In addition, ultrafiltration is used as a final step in order to return clean water back to the washing process system. The system was originally designed for non-radiological industrial laundry applications (hospitality, healthcare, correctional and governmental settings, etc). This process reduces the water consumption and discharge by up to 75% while retaining heat to minimize energy input costs. Principle components of the system include lint shakers and collection tanks with ozone injection, suspended solids filter, activated charcoal, ultraviolet lamp treatment cell, ion exchange columns, ultrafiltration filters, and final holding tank with ozone injection. Although up-front equipment costs are required, we believe that the reduction in waste generated through recycle and reuse of the water, along with avoiding premature disposal of PPE as radioactive waste, greatly outweighs up-front effort.

INTRODUCTION

The need to treat wastewater contaminated from radiological-laundry operations has persisted for many years. Although most processes to-date use ion-exchange or membrane filtration, it is important to constantly evaluate new technologies for these processes. Gloyna in 1954 published a process using slim (algae) to remove contaminants from water [1]. In order to reduce overall waste streams generated from laundry operations, many groups have connected separate processes to recycle process water or related by-products [2-3]. The current need in this field is precise-controlled water re-use protocols and equipment to further reduce the environmental impact of nuclear-related processes, as well as reduce hands-on time. Smoky Mountain Solutions (SMS) has designed a system that can recycle its laundry process water, and recently reached a milestone of having had recycled over 6800m^3 (1.8 million gal) of laundry wastewater. This represents the prevention of 6800m^3 (1.8 million gal) of water that would have gone into our environment, but instead was cleaned and re-used. The design also allows for the added ability to retain heat in the water process, reducing the need for electricity or gas consumption.

DESCRIPTION

Overall Facility Design and Inputs

SMS's facilities have customized and commercially-available equipment to process Personal Protective Equipment (PPE, radiological and non-radiological laundry and respirators) and general contaminated wastewater for both Government and commercial nuclear customers. As the washers run through their cycles, water is both put-in and taken-out during each processing step. As fabric types and other washables vary (typical anti-C 70:30 cotton/poly blend, anti-static RAD-STAT nylon-carbon blend, shoe scuffs, etc.) this customized system allows for these process parameters to be controlled.

To improve overall process efficiency, all incoming water goes through standard water softening, which extends the life of the equipment, reduces the amount of detergents required, and improves the binding capacity of down-stream resins. SMS has also engineered a baffled-settling system that allows heavier metals to settle and become trapped from water having left the laundry machines.

Choosing the cleansing agent(s) that both remove particulate and act as a disinfectant to reduce biological contamination are critical in designing the laundry and wastewater recycling process. This is also important when designing the downstream recycling system.

AquaRecycle System Equipment and Processes

Although primarily designed for industrial and large-scale non-radiological use, the AquaRecycle (hereafter referred to as AR, Atlanta, GA) system is most commonly used in hospitality, healthcare, correctional and governmental settings [4]. Along with AR, SMS customized and modified the system used to provide water purification for SMS's laundry applications (Figures 1 and 2). Operating at up to 114 liters per minute (LPM, or 30 gal per minute-GPM), the system includes UV and ozonation for sterility, suspended-solids filtration, oil/grease and soap/organics filtration, and multiple storage tanks for providing clean water to the washing system, while allowing purification prior to final discharge. This filtration and treatment process provides clean, disinfected and pre-heated water to the washing machines and tankless on-demand water heaters.

Fig. 1. AR System Sideview at SMS

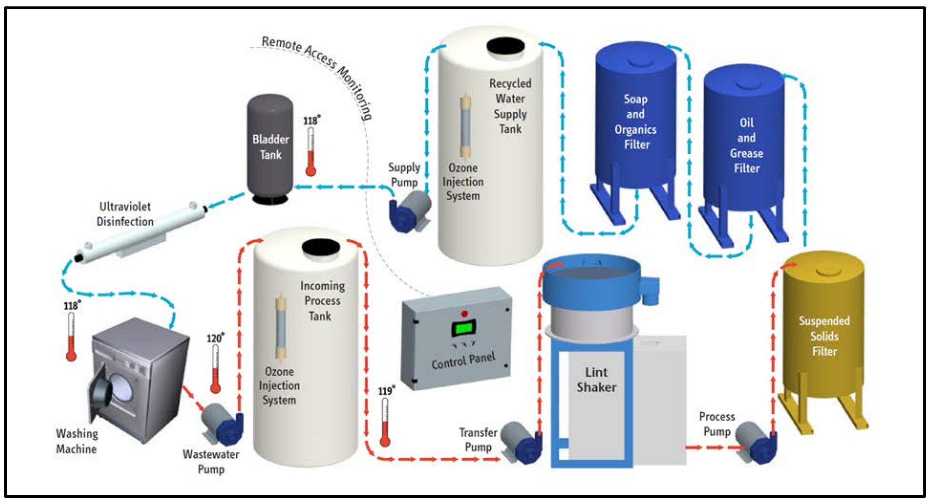

Fig. 2. AR Representative Schematic

The software tracks system performance, monitors recycled water quality and provides complete automation of the system. Total Dissolved Solids (TDS) and pH are continuously monitored by the software on the skid, as well as total flow rates and amount of clean-water added (final rinse in the washers if desired). The system can also measure turbidity (mainly the presence of dyes), and can recognize the change in quality, where fresh water is then added until the final recycled water reaches the appropriate desired quality. TDS and pH have high and low limits that can be changed on the setup screen; outside of these zones, fresh water will be pumped into Final Holding Tank (FHT) until the top float is on and activated. The system is pre-programmed to initiate a backwash to remove retained solids. Backwashes can be set for a specific time of day or liter/gal processed. Remote access allows technicians to monitor system performance, trouble-shoot problems, and perform software modifications to run the system. In-line water quality sensors insure the consistency and quality of the final recycled water. Fail-safe alarms and mechanisms are used for additional quality control. No chemicals are used at any point in this recycle system or filtration process, except during maintenance cleaning.

Lint Shaker, Initial Holding Tank and Ozonation

As water exits the laundry machines, it is sent by a processing pump through a vibrating lint removal system, or shaker. This lint shaker is a metal 200 micrometer screen that collects lint, debris and large suspended solids into a collection bin, while filtered water passes into the Initial Holding Tank (IHT). Within the IHT, ozone is injected, which aids in the disinfection and removal of odors and oxidizes both organic and some inorganic solids. In addition, the bubbles from the ozone injection act as a micro-coagulant to aid the filtration process. When the system calls for recycled water, a process pump sends the pre-filtered water to a series of pressurized tanks (Figure 2) for the media filtration process. Within the main processing skid resides germicidal ultraviolet (UV) bulbs. The use of ozone and UV allows the system to be chlorine-free, further reducing environmental impact.

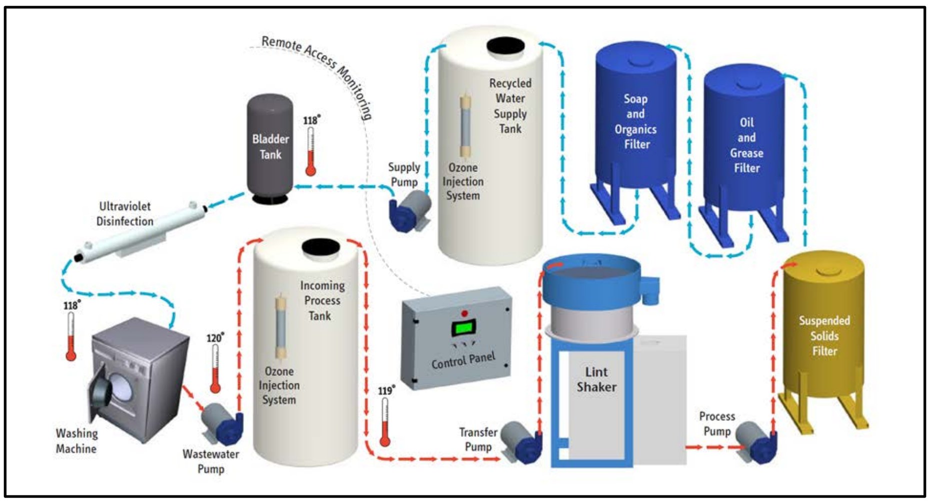

Fig. 2. AR Representative Schematic

Suspended Solids and Oil/Grease/Soaps/Organics Filter

To remove suspended solids, a pressurized-tank containing recycled glass is used. Sand manufactured from recycled glass (soda-lime silicon dioxide glass) is inorganic and insoluble and a good choice for this step in the process. Similar to residential and commercial pools, this step has an automated backwash feature which is sent directly to the discharge tanks. Backwashing is performed by sending recycled water at a high flow-rate through the bottom of the vessel. This high volume lifts the bed approximately 50% and forces the accumulated solids to travel through the top of the vessel and out as backwash water.

Granular Activated Carbon (GAC) is used to remove oil, grease, soaps and organics. Primarily in the form of bituminous/subbituminous coal, activated carbon is extremely porous and attracts and holds organics. Carbon can also remove dyes present in the laundry process. Its porous nature is produced through a series of chemical reactions and extreme heat. Other forms include lignite coal, coconut shell and wood. Once the pores are saturated or “full”, the media can be disposed of properly, or regenerated via acetic acid treatment and washes. All pressure filters are automatically backwashed and have pressure gauges to show blockages within the media beds. The backwashing of the GAC vessel is designed to “fluff up” and redistribute the media bed to prevent channeling.

Membrane Filtration

Depending on the desired TDS and other water quality parameters that are desired, membrane filtration can be used for recycling. These processes range from particle filtration (1 micrometer to gross mesh), microfiltration (0.1-1 micrometer), ultra- and nanofiltration (down to 0.001 micrometer), to reverse osmosis to remove metal ions (RO, down to 0.0001 micrometer). Each has its advantages and disadvantages in the laundry water process. Based on the contaminant input, solid waste generation (membranes) as well as rejected wastewater handling and disposal must be considered. As the AR system typically processes 95-115 liters/minute (25-30 gpm) adding additional membrane filtration steps will affect process output.

Ion Exchange

Ion-exchange is used in this process to remove soluble ionized substances and elements that have an electrical charge. Many different types of polymer-based resins are available for radiological use, and some are customized to specific elements (such as Spherical Resorcinol-Formaldehyde-SRF resin for Cesium). Based on the source contaminant, either a cation, anion, or mixed-bed resin configuration can be designed. For the laundry process, SMS uses A4000 Alamo Brand 8% crosslinked cation, a bead type, cross-linked, polystyrene divinylbenzene resin which is a high purity, premium grade, prewashed, strong acid gel-type cation exchange resin. Different resins have different affinities for specific contaminants, thus small-scale test should be performed to determine the ideal resin for each specific waste stream. Depending on the contaminant load, break-through (or leakage) of the contaminant must be determined so that the resin can either be replaced or regenerated.

Final Holding Tank (FHT)

After leaving the ion exchange or Oil/Grease/Soaps/Organics pressure tanks, the process water is sent to a Final Holding Tank (FHT), where it waits for the washing machines to demand more water. Additional ozone is injected while water is being held in the FHT, constantly disinfecting the water. A pressurized bladder tank and supply pump supplies water demand, and as the washing machines demand more water. The pressure switch turns on the supply pump when the supply line pressure drops below 0.21 MPa (30 psi). As the water is being sent to the machines, it passes through a UV disinfection system, which uses ultra-violet light to kill any remaining bacteria and viruses in the water before sending the final water to the washing machines. A UV monitor verifies the UV intensity in voltage and turns off the process pump when UV treatment is sufficient to disinfect the water supply. The recycled water in the FHT serves primarily as the main supply of water for the washing machines. Its' secondary purpose is to supply the backwash water needed to periodically clean the pressure vessels.

Waste Streams and Liquid Discharge

Radiological laundry generates both liquid and solid waste streams. As the SMS process removes dirt and contamination from the laundered articles, the solid radioactive waste collected is concentrated, requiring planning and consideration. Highly efficient filtration media can become problematic when radioactive solids, especially enriched uranium and Tc-99, are collected in high concentrations in the media. The outlet for these media solids is a Bulk Survey For Release (BSFR) waste stream, through a SMS-Joint Venture company Omega Technical Services (a State of Tennessee licensed outlet for material with very low concentrations of radioactive material). BSFR disposal is far more economical than other alternatives, but concentration and enriched uranium are limiting factors that may preclude BSFR disposal. Resulting radioactive waste concentrations will dictate the path forward. SMS collects real-time data on solid media waste generated and the costs for disposal based on the resulting concentrations. Radioactive discharge concentrations and total activity discharged per month are closely monitored and prescribed by State and Federal law, and the facility Radioactive Materials License (RML) and the local Publicly-Owned Treatment Works (POTW) discharge permit.

AR Maintenance and Rad Survey Program

Maintaining the recycle system is relatively easy. AR remotely monitors recycled and fresh water totals as well as pH and TDS of the final holding tank water, downloading data daily via WiFi or LAN. The ratio of recycled-to-fresh water and pH/TDS of the water produced is a good indication of the overall health of the system. Figure 3 shows how TDS and pH remain relatively constant through the lifetime of the system and the process. Although extensive radiological analysis is performed on all backwash and dischargable water, periodic grab samples from the Final Holding Tank are recommended, as well as analysis of each media used prior to disposal.

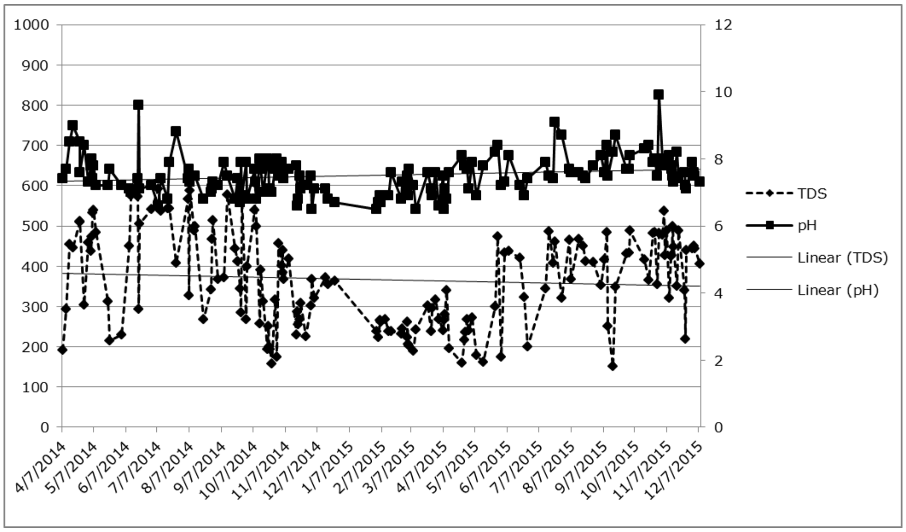

Fig. 3. TDS and pH Values from 2014-2015.

DISCUSSION

Although the combination of these systems developed into a semi-seamless process, there were upfront challenges. Our initial radiological challenge with this project was the recognition by the SMS team and the design engineer that secondary wastes in a laundry application become a primary waste in this radiological use. The design contractor was challenged to accept the concept that backwashing of the filter media columns, required for proper system operation, generated a waste stream that must be captured for sampling prior to discharge. In a routine commercial application, the recycle system would monitor process flows and pressures to determine backwashing cycles. These backwashing cycles routinely discharge to a facility floor drain and thereby would go unmonitored into to the sewer. The use of floor drains in the SMS application was not acceptable. SMS was able to adapt the system by recognizing these limitations. Excess treated water in the system was another challenge for radiological use. With clean potable water additions used for the final rinse cycle in the washing machines, about 76-118 liters (20-30 gal) of wastewater is generated from each load.

The system treats all wastewater leaving the washers for re-use. This water, considered process water, runs a surplus with more additions than system losses (wet clothing). Process water is collected in the final holding tank for reuse in the laundry process. When the final holding tank is full, the level control process of the system was adapted to redirect the “floor drain” discharges into the process holding tanks for eventual sampling and discharge. Depending on the design, only backwashes would go to the floor drain. Since there would be no fresh water used in normal operations, “overflow” would not be an issue, they would constantly be using make-up or fresh water to compensate for water lost in clothing which is about 0.23-0.45 kg (0.5 lb to 1 lb) of cloth.

CONCLUSIONS

Although up-front equipment costs are required, we believe that the reduction in waste generated through recycle and reuse of rad laundry water, along with avoiding premature disposal of radioactive PPE itself into our landfills [5], greatly outweighs up-front efforts. The conservation of water and electrical/gas resources should be a top priority in any radiological PPE and waste processing facility.

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ACKNOWLEDGEMENTS

The Authors would like to thank Jeff Lebedin and Randy Anderson from AquaRecycle for their support and technical expertise.