200 West Pump and Treat: The First Three Years - 16473

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Abstract

The 200 West Pump and Treat (P&T), on the U.S. Department of Energy's Hanford Site, has a 9,464 liters per minute capacity designed to capture and treat an 8 km^2 contaminated groundwater plume and reduce the mass of contaminants of concern (COCs) by 95 percent in 25 years. Treatable contaminants include carbon tetrachloride, trichloroethene, chromium, hexavalent chromium, nitrate, iodine-129 (I-129), and technetium-99 (Tc-99). After 3.5 years of continuous operation, the 200 West P&T treated over 10 billion liters of contaminated groundwater and removed over 190,000 kg of nitrate, 9,000 kg of carbon tetrachloride, nearly 5 curies of technetium-99, and smaller quantities of the remaining contaminants. Twenty three extraction wells strategically installed across the plumes pull contamination in from surrounding areas directing contaminated groundwater to the 200 West P&T for treatment. The 200 West P&T successfully removes all contaminants to below cleanup levels which are at (or lower than) the drinking water standard. Twenty one injection wells return treated water to the aquifer providing flow-path control to mitigate migration of contamination toward the Columbia River, a source of drinking water to the communities downstream. Contaminant concentrations in most monitoring wells are declining and the remedy is on target for accomplishing the mass removal goal ahead of schedule. In 2015, the 200 West P&T was expanded to include treatment for uranium from other operable units. With the uranium treatment expansion, the 200 West P&T is capable of cost-effectively treating contaminated groundwater beneath the 194 km^2 Central Plateau.

Introduction

The U.S. Department of Energy's Hanford Site's location, adjacent to the Columbia River, appeared ideal for plutonium production. However, the site's proximity to the Columbia River poses a potential to impact the ecosystem.

In 2008, the *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* [1] (hereafter referred to as the Record of Decision [ROD]) recommended the installation of a groundwater pump-and-treat system to remediate contaminated groundwater beneath the 200-ZP-1 Operable Unit (OU). The system (designed, constructed and operated by CH2M) has a 9,464 liters per minute capacity designed to capture and treat an 8 km^2 contaminated groundwater plume and reduce the mass of contaminants of concern by 95 percent in 25 years. Treatable COCs are a complex mix of radionuclides, metals, anions, and volatile organic compounds including carbon tetrachloride, trichloroethene, chromium, hexavalent chromium, nitrate, I-129, and Tc-99.

The groundwater treatment approach involves multiple treatment steps to remove the various COCs to below the cleanup levels (Table 1). The relationship between each unit process and the targeted COCs is presented in Fig. 1. Groundwater containing radiological contamination is first treated through an ion exchange system containing Purolite A530E®[1] resin.

Table 1. Final Cleanup Levels for the 200 ZP 1 Groundwater Operating Unit

Contaminant of Concern	Units	Final Cleanup Level	Cleanup Level Basis
Carbon tetrachloride	µg/L	3.4	MTCA, Method B
Chromium (total)	µg/L	100	Federal/State MCL
Hexavalent chromium	µg/L	48	MTCA, Method B
Nitrate-nitrogen	µg/L	10,000	Federal/State MCL
Trichloroethene	µg/L	1	MTCA, Method B
Iodine-129	pCi/L	1	Federal MCL
Technetium-99	pCi/L	900	Federal MCL
Tritium	pCi/L	20,000	Federal MCL

Fig. 2 illustrates the contaminant plumes along with the location of extraction and injection wells. All wells included in the remedy design are installed and operating. Extraction wells strategically installed across the plumes pull contamination in from surrounding areas directing contaminated groundwater to the 200 West P&T for treatment. Injection wells return treated water to the aquifer providing flow-path control to mitigate migration of contamination toward the Columbia River, a source of drinking water to the communities downstream and a critical salmon habitat.

[1] Purolite is a registered trademark of BROTECH CORP., Bala Cynwyd, Pennsylvania

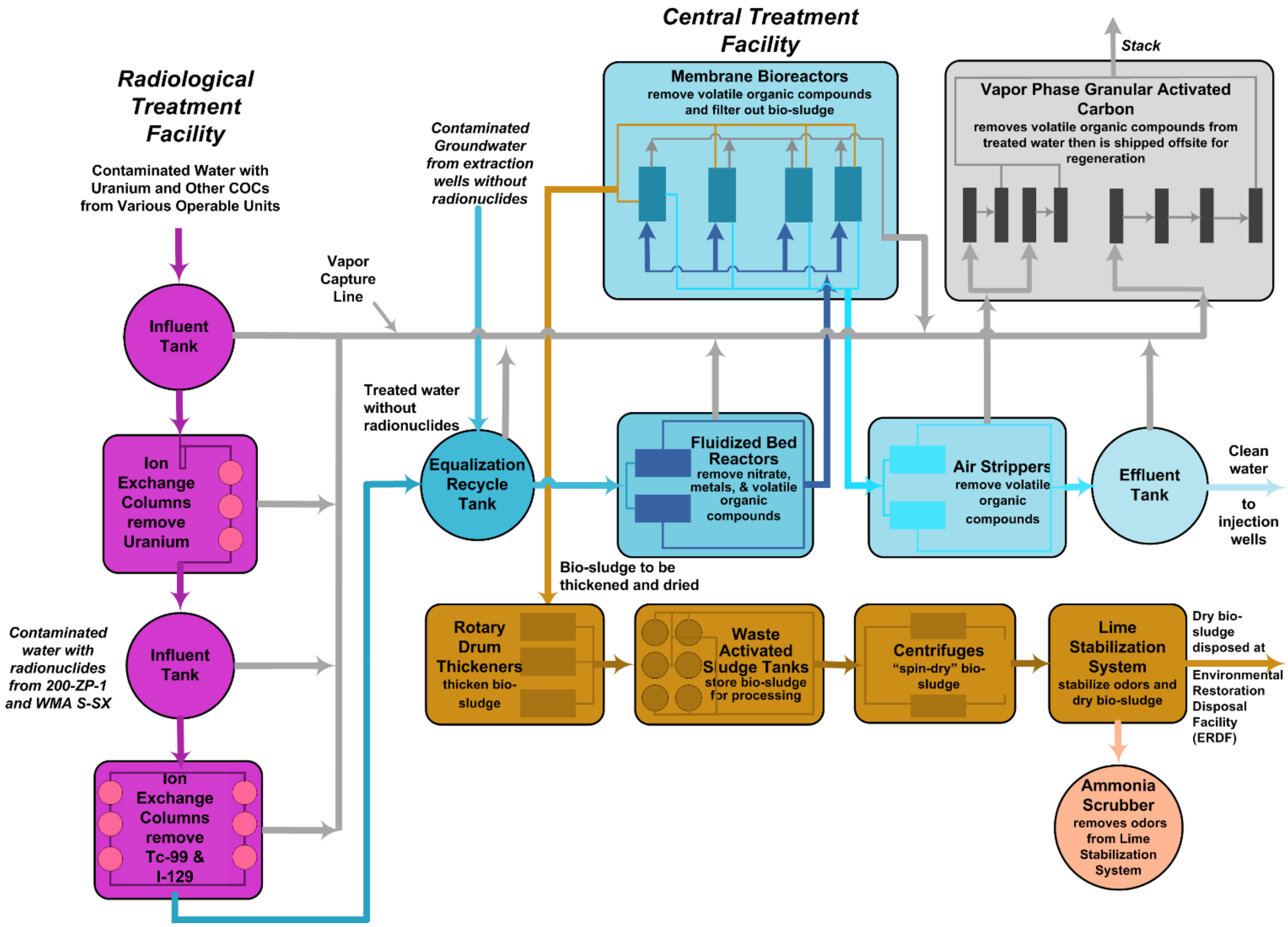


Fig. 1 200 West Pump and Treat Process Flow

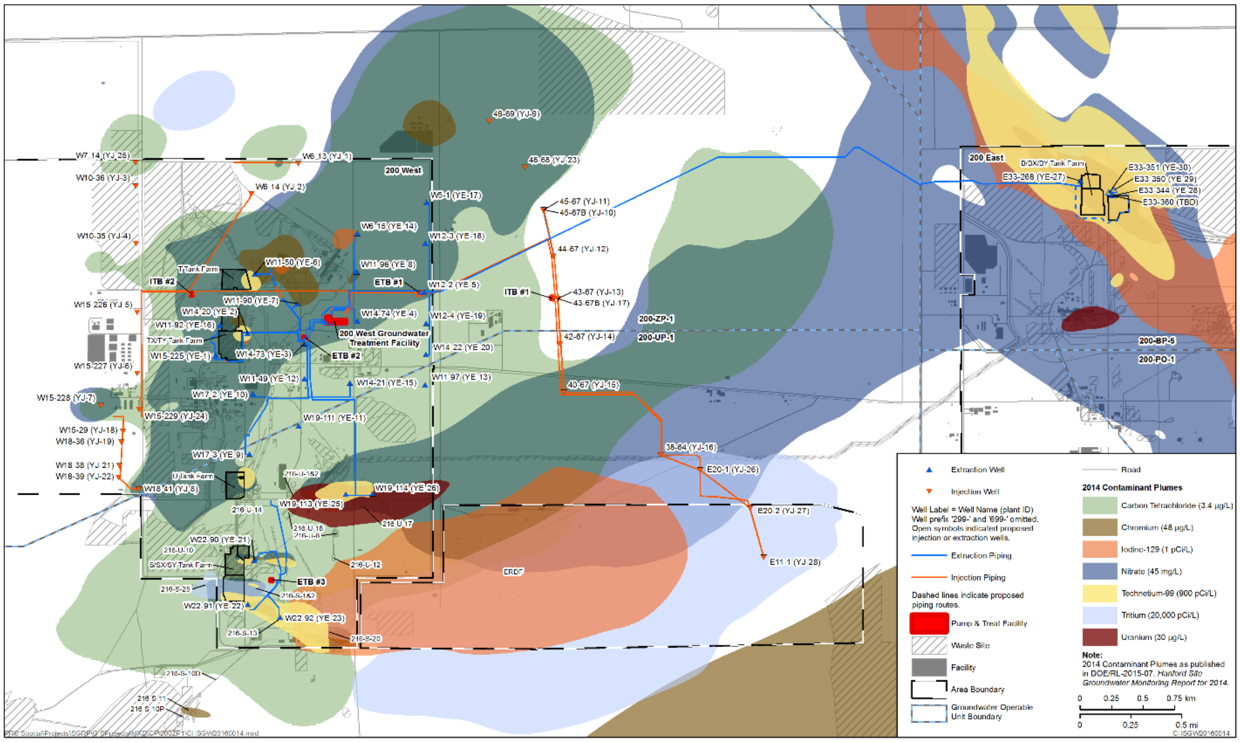


Fig. 2 Contaminant Plumes and Extraction and Injection Well Locations with Conveyance Pipe Routing for the 200 West Pump and Treat

This paper summarizes the progress made in groundwater cleanup at Hanford and some of the more important lessons learned.

200 West Pump and Treat Production

The 200 West P&T began operation in 2012 and since this time the facility has treated over 10 billion liters (2.7 billion gallons) of contaminated groundwater. Table 2 summarizes the production over its history. Each year the facility has increased throughput as issues that limit production are identified and remedied. A summary of lessons learned is provided in a later section.

Table 2. 200 West Pump and Treat Production

Year	Million Gallons	Million Liters
2012	150	569
2013	747	2,826
2014	824	3,118
2015	1,012	3,832
Total	2,733	10,345

All of this water is pumped from the network of extraction wells to the pump and treat facility, treated to drinking water quality, and then injected back into the ground at strategic locations. Some injection well locations encourage migration of the plumes to the extraction wells. Others provide a barrier to mitigate migration of contaminated water toward the Columbia River.

Contaminants of Concern

The contaminants of concern are sampled quarterly in the extraction wells and monthly at key locations through the treatment facility. The monitoring well samples, collected and analyzed annually, are used to provide indications of groundwater cleanup and track plume movements. The well network and volume of water are great enough to impact the size of the plumes and direction of groundwater movement. One of the key features of the well network is to divert contaminated groundwater away from the Columbia River.

Volume of Water Treated

The 200 West P&T radiological system treats only those wells in the proximity of the Tc-99 plume. Table 3 summarizes the influent and effluent concentrations of the radiological contaminants.

Table 3. 200 West Pump and Treat Radiological Treatment System Influent and Effluent Concentrations

	Iodine-129 (pCi/L) Cleanup Level 1 pCi/L		Technetium-99 (pCi/L) Cleanup Level 900 pCi/L	
Year	Influent*	Effluent	Influent*	Effluent
2012	0.48	0.33	1,560	<17
2013	0.32	<0.23	1,584	<17
2014	0.28	0.28	1,281	13
2015	<0.20	<0.20	1,531	22

*Influent to ion exchange system specifically for removal of Technetium-99 and Iodine-129

Radiological Contaminants

The key radiological contaminants are I-129 and Tc-99. The ZP-1 groundwater OU contains trace amounts of uranium, but at concentrations that are a fraction of the drinking water maximum contaminant level (30 µg/L). The I-129 was removed to near detection levels through 2014. Beginning in 2015 the influent concentrations of I-129 are below detection. Additionally, samples from all of the monitoring wells are below detection during the third quarter of 2015 confirming the original plume has been remediated.

During the first three years of operation Tc-99 concentrations in the influent decreased. By 2015 some of the wells no longer had enough Tc-99 to warrant continued treatment for this contaminant and were re-piped to bypass the ion exchange resin and go directly to the biological treatment system. As a result of this change, the Tc-99 concentration in the influent to the ion exchange system increased in 2015.

The Tc-99 concentration in the monitoring wells are shown in Fig. 3. For the most part the concentration of Tc-99 is decreasing over time. In some wells (those with an asterisk), the concentrations increased because these wells are located near the extraction wells that are pulling the plume towards them. It is expected that in time the concentrations will decreased. The concentrations measured in 2015 were slightly less than those measured in 2014.

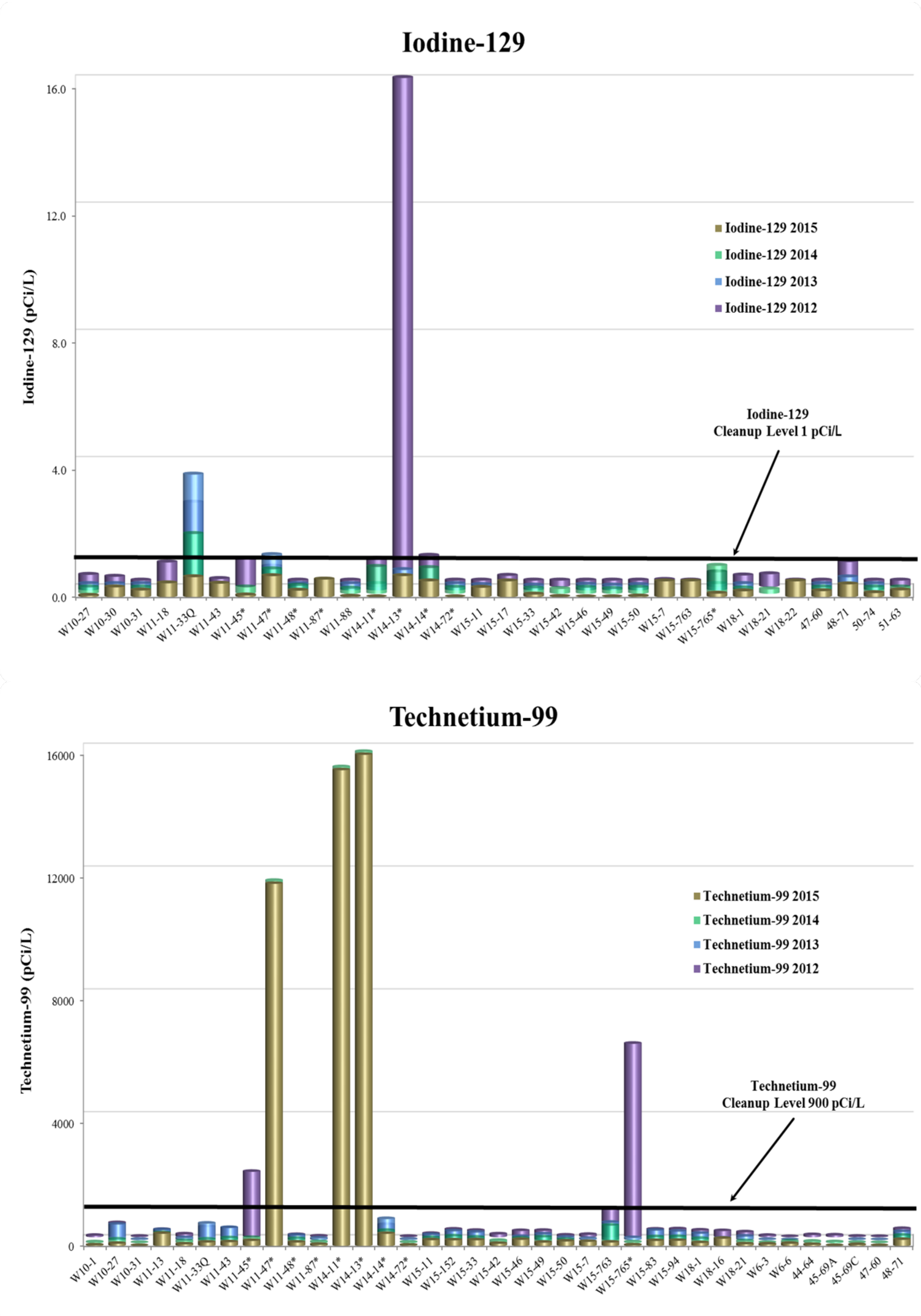


Fig. 3 Iodine-129 and Technetium-99 Concentrations in Monitoring Wells 2012 to 2015. Asterisk notes monitoring well is located near an extraction well.

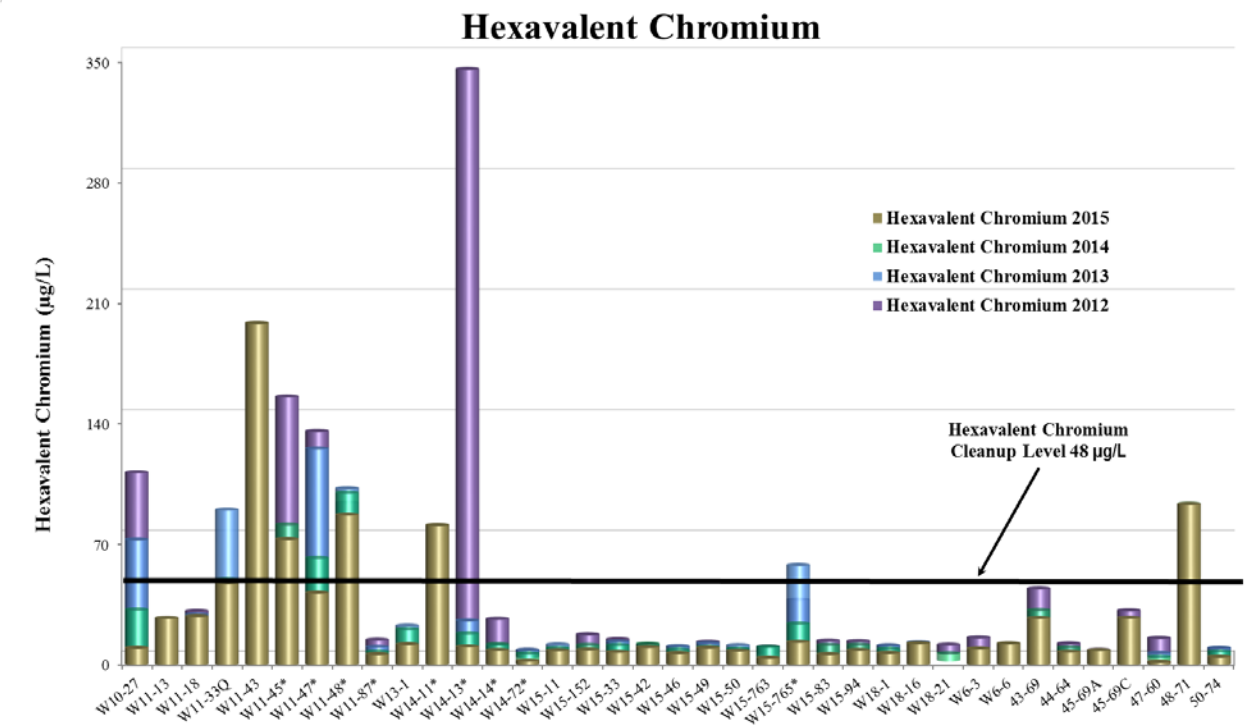
Non-radiological Contaminants

The key non-radiological contaminants include carbon tetrachloride, hexavalent chromium, nitrate, and trichloroethene. These contaminates are removed through biological degradation and, in the cases of carbon tetrachloride and trichloroethene, air stripping. Yearly averages of the influent and effluent concentrations are summarized in Table 4. All contaminants are being removed to below the cleanup levels and some are being removed to below detection. The concentrations of carbon tetrachloride and trichloroethene are steadily decreasing. The concentration of nitrates are increasing as new extractions wells high in nitrate are brought on line and the plant is optimized to take on higher nitrate streams. Optimization steps are covered in a later section.

Table 4. 200 West Pump and Treat Biological Treatment System Influent and Effluent Concentrations

Cleanup Level	Carbon Tetrachloride 3.4 µg/L		Hexavalent Chromium 48 µg/L		Nitrate as N 10 mg/L		Trichloroethene 1 µg/L	
Year	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
2012	663	2.6	15.5	<2.0	19.0	6.3	4.9	<1.0
2013	821	<2.0	22.9	5.6	23.6	8.0	4.5	<1.0
2014	611	<0.7	21.7	6.2	22.9	5.2	3.7	<0.4
2015	488	<0.1	23.2	3.4	26.7	6.1	3.1	<0.3

Figs. 4 and 5 show that the concentrations of the contaminants in most of the monitoring wells are decreasing. The exceptions are those wells that are near the extraction wells. The extraction wells are pulling the plume towards them resulting in increases in concentration.



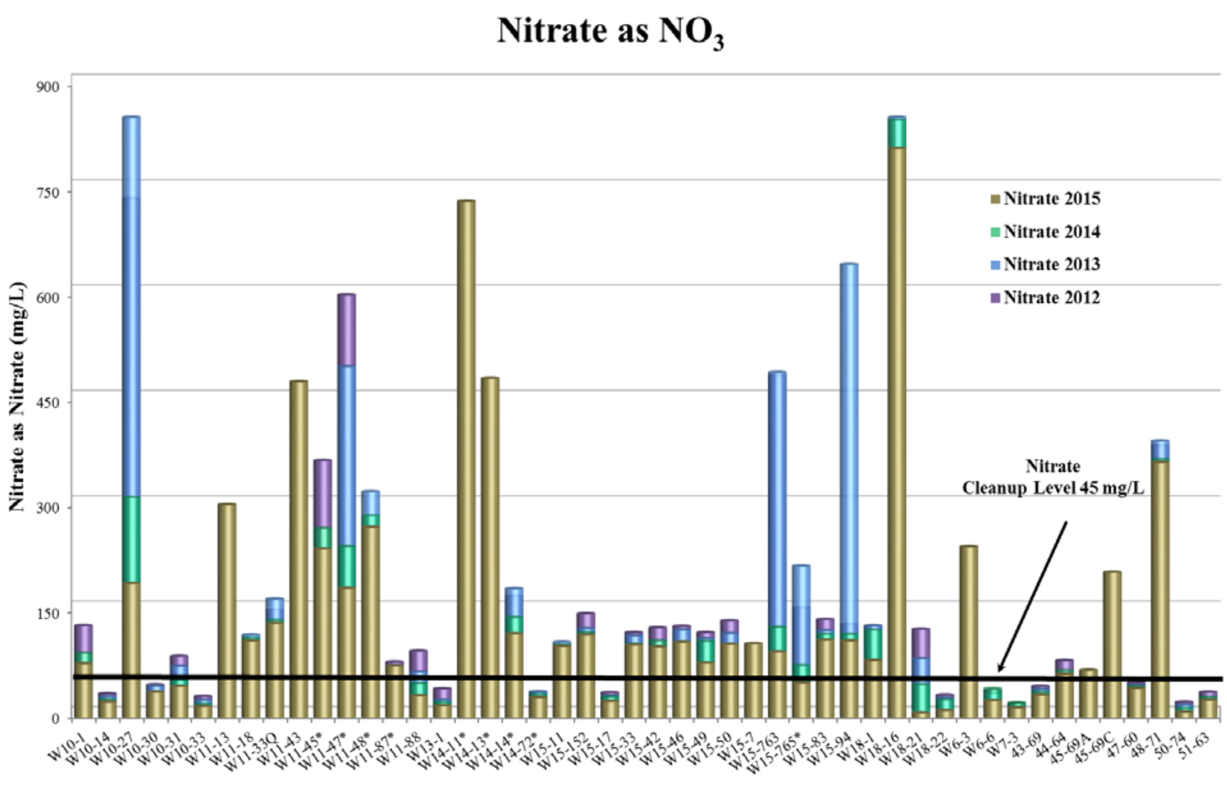


Fig. 4 Hexavalent Chromium and Nitrate Concentrations in Monitoring Wells 2012 to 2015. Asterisk indicates monitoring well is near an extraction well.

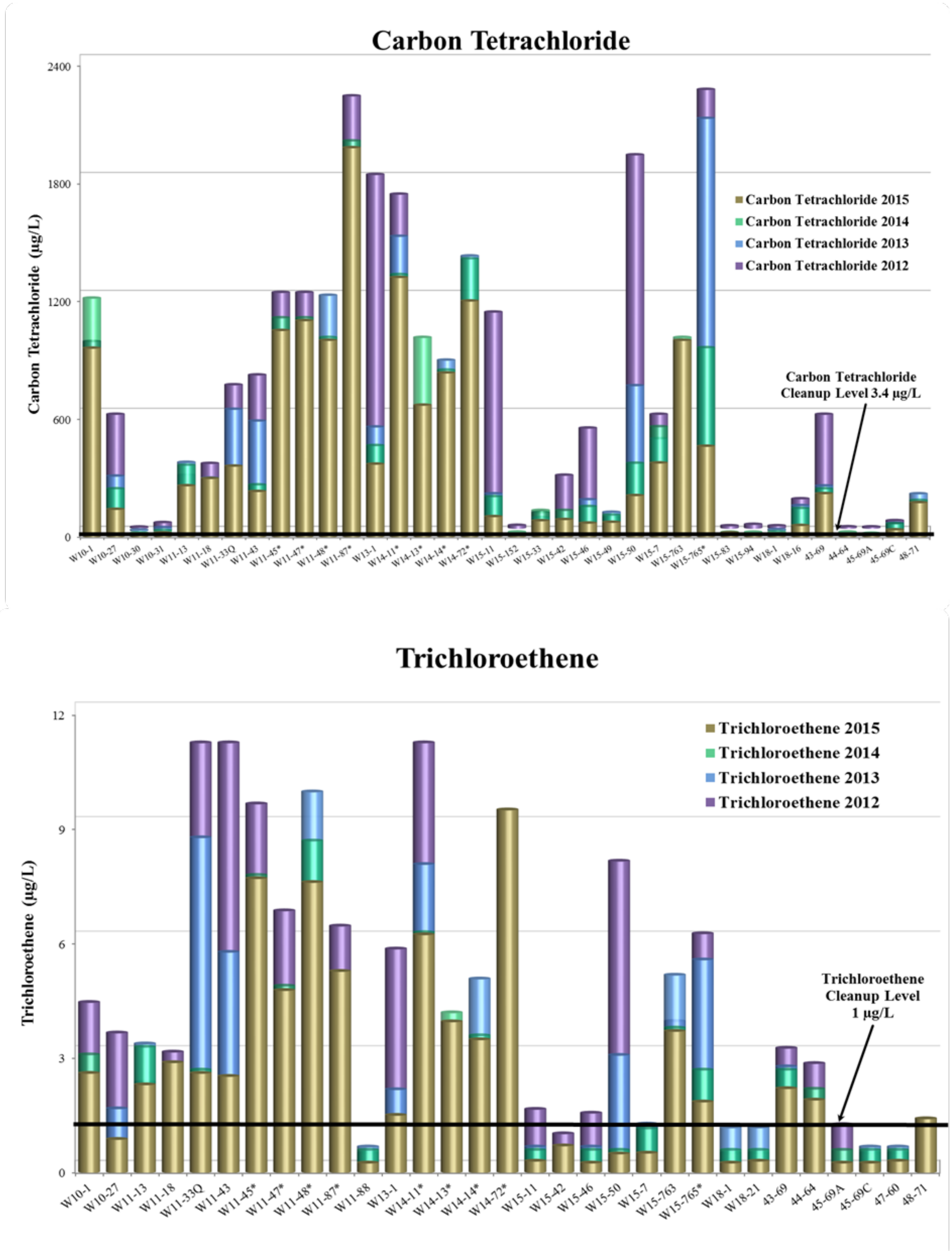


Fig. 5 Carbon Tetrachloride and Trichloroethene Concentrations in Monitoring Wells 2012 to 2015. Asterisk indicates monitoring well is near an extraction well.

Mass Removals

The mass of contaminants removed is carefully tracked by monitoring the concentrations in each of the extraction wells each quarter and continuous measurements of flow. The mass flux to the treatment facility is calculated each minute and stored in a data base. Likewise, the effluent concentrations and flows are used to calculate the mass flux in the plant effluent. Each month the mass removed is totaled and reported. Table 5 summarizes the total mass removed. Each year greater quantities of contaminant are removed with the exception of carbon tetrachloride which is declining in concentration.

Table 5. 200 West Pump and Treat Contaminant Mass Removal and Volume Treated, 2012 to 2015

Year	CCl_4 (kg)	Cr (kg)	I-129 (µCi)	NO_3-N (kg)	Tc-99 (Ci)	TCE (kg)	U (kg)	Liters Treated
2012	531	19.3	83.6	11,053	0.330	2.4	0.6	568,794,204
2013	3,049	71.9	158.4	44,108	1.340	13.1	0.5	2,825,979,014
2014	2,898	75.0	0.0	56,762	1.311	10.2	0.8	3,118,412,520
2015	2,786	83.5	0.0	78,678	1.860	11.1	6.3	3,831,506,172
Cumulative	**9,264**	**249.8**	**242.0**	**190,601**	**4.841**	**36.8**	**8.2**	**10,344,691,910**

Zero Discharge

The 200W P&T is designed to capture all contaminants. The water is treated to cleanup levels that are equal to or less than drinking water standards. All tanks are covered with a slight vacuum pulling the overlying air to a vapor phase granular activated carbon system, and the biosolids are dewatered, stabilized and sent to the on-site landfill for disposal.

The fate of the contaminants is an important consideration. Nitrate is converted to nitrogen gas by biological activity. Some of the carbon tetrachloride is biologically degraded to carbon dioxide and water. The remainder is adsorbed to granular activated carbon that is thermally regenerated where the carbon tetrachloride is thermally oxidized to carbon dioxide and water.

Technetium-99 and uranium are adsorbed to ion exchange resins and will be sent to the on-site landfill when saturated. The landfill is lined and covered and all leachate is collected and treated.

Most of the hexavalent chromium (Cr^{+6}) is removed through the biological processes. It is believed that the hexavalent chromium is converted to the less mobile trivalent chromium (Cr^{+3}) form by chemical and biochemical processes in the FBR and MBR [2]. Bacteria can reduce Cr^{+6} by a number of pathways under both aerobic and anaerobic conditions [3]. Also, non-biologically mediated chemical reduction from Cr^{+6} to Cr^{+3} can occur in reducing conditions that are present in the FBR [4]. Under the oxidation reduction conditions in the MBR, Cr^{+3} is thought to form insoluble precipitates of $Cr(OH)_3$ (s), $FeCr_2O_4$(s) [4] that are filtered out by the membranes. Chromium is then removed from the system with the sludge.

Treatment Optimization and Lessons Learned

Much of the improved performance resulted from a better understanding of the biological treatment process. The biological process was inoculated with micro-organisms capable of converting nitrate to nitrogen. It took less time for this population to become established than originally projected. Once the population was established, the balance of the plant was not ready for operation and it became a challenge to maintain the proper nutrient balance while recycling the water. The microorganism population is dynamic and has been observed to change for better or worse in about a day.

The biomass requires micronutrients which are typically present in waste streams but are lacking in the groundwater being treated. The micronutrient solution had to be carefully blended, be strong enough, and mixed daily to avoid salting out. The problems and solution are documented in Carlson et al. [5].

The injection wells clogged within the first year and diminished the capacity of the system. The nature of the foulant was carefully studied and found to originate from the biological treatment system. The nutrients required to maintain treatment were also causing biological and mineral (manganese) fouling of the wells. This problem and the solutions are documented in Carlson et al [6].

The sequencing of fluidized bed reactors (FBRs) and membrane bioreactors (MBRs) is a relatively new approach and posed unique operational challenges. The microorganisms in the FBR formed extracellular polymeric substances allowing them to form a biofilm on the granular activated carbon media. The biofilm sloughed off the granular activated carbon and was carried to the MBR. The membranes in the MBR have a nominal pore size of 0.04 micron and separates the water from all solids. In this process the biofilm occluded the pores on the membrane fibers, reducing the ability to treat water. A carefully planned cleaning regime was developed and has been implemented to minimize pore occlusion and maintain production.

The food-to-microorganism ratio resulting from this treatment sequence of FBRs followed by MBRs selects for bacteria associated with foaming. Foam in an MBR results in a loss of operational efficiency and can temporarily limit plant throughput until the foam subsides and the affected MBR can be returned to service. Additionally, the foam enters the off-gas handling system which may decrease the life of the activated carbon and increase the maintenance of the off-gas handling equipment. The MBR operation is carefully monitored and controlled. The food to microorganism ratio is maintained within a tight band. The cleaning steps have been adjusted to minimize air. Antifoam agents were screened and selected. And, finally, a foam spray-down system was installed.

The vapor phase granular activated carbon units were optimized by installing insulation. The vapor is heated to limit condensation in the units. Water from condensation reduces the effectiveness of the granular activated carbon. When outside temperatures decreased to less than 4^{o} Celsius, water would condense in the units. With insulation there is little to no condensation.

The air stripper towers downstream of the biological system are subject to bio-fouling. Left unchecked bio-fouling will reduce the effectiveness of the air stripper leaving carbon tetrachloride in the water. In extreme cases on other sites bio fouling has added so much mass to the media that towers have structurally failed requiring replacement. The 200 West P&T air stripper towers are cleaned with a strong chlorine solution once or twice a year to maintain effectiveness.

Items on the Radar

Given the success of the 200 West P&T operation new flow streams are planned. These new streams have a similar mix of contaminants as those currently treated with the addition of uranium. Uranium treatment is provided by ion exchange. In September 2015, the 200 West P&T was expanded to include treatment for uranium from nearby 200-UP-1 OU (also in 200 West) and from 200-DV-1 OU and 200-BP-5 OU in the 200 East area.

Conclusions

After 3.5 years of continuous operation the 200 West P&T is performing as designed, treating over 10 billion liters of contaminated groundwater. To date, over 190,000 kg of nitrate, 9,000 kg of carbon tetrachloride, nearly 5 curies of Tc-99, and smaller quantities of the remaining contaminants have been removed. Additionally, the 200 West P&T successfully removed all contaminants to below cleanup levels, which are at (or lower than) the drinking water standard. Contaminant concentrations in most monitoring wells are declining and the remedy is on target for accomplishing the mass removal goal ahead of schedule. With the uranium treatment expansion in the fall of 2015, the 200 West P&T is capable of cost-effectively treating contaminated groundwater beneath the 194 km^2 Central Plateau.

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