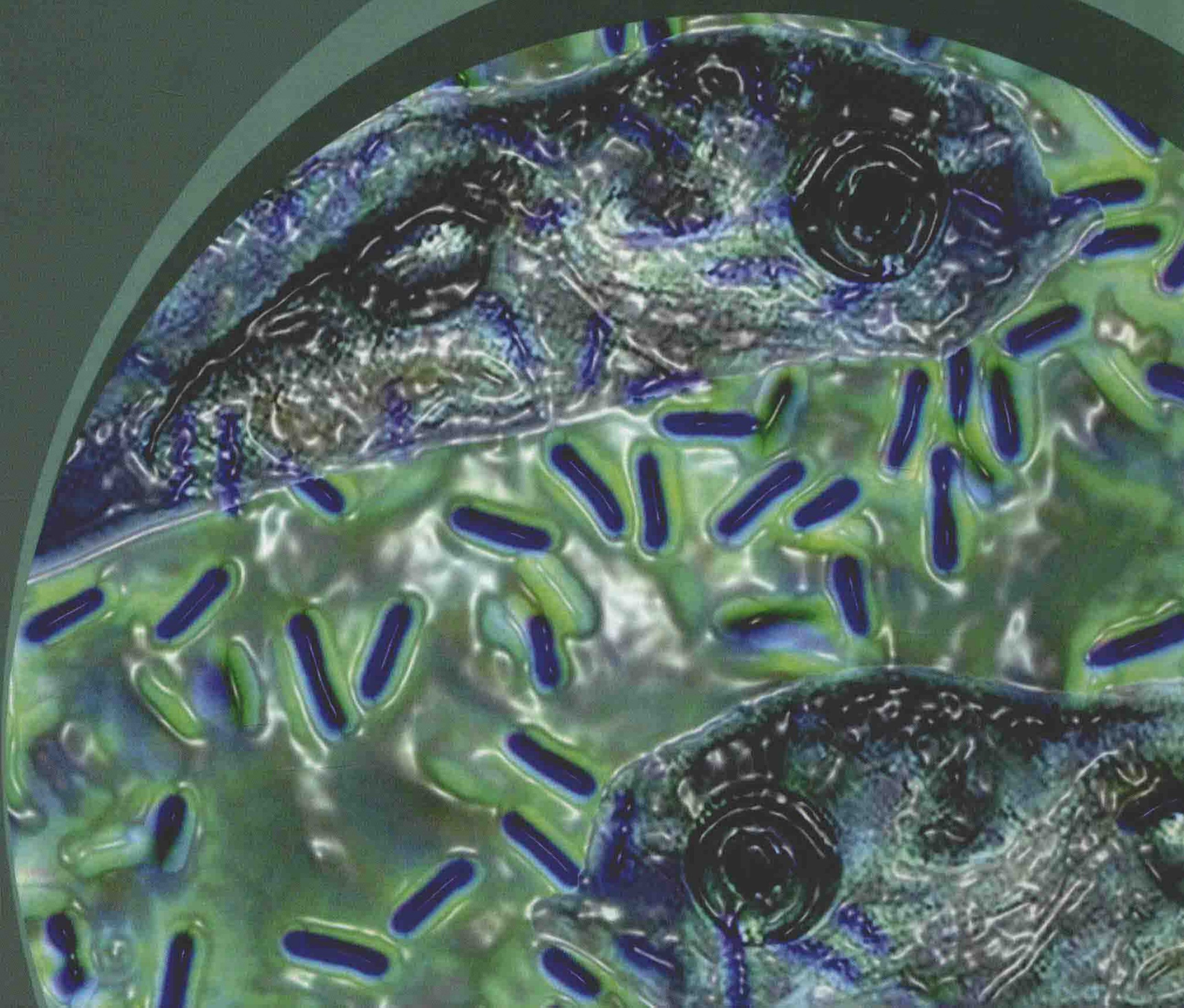
Ecological Principles of Waste-water Microbes

Andres Robinson
Editor



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Preface

Microbiology is the scientific field that is occupied with the study of microscopic organisms, commonly known as microorganisms or microbes. Sometimes microbes that cause health effects can be found in drinking water. However, as drinking water is thoroughly disinfected today, disease caused by microrganisms is rarely caused by drinking water. People that swim in swimming pools will find that the water they swim in is disinfected with either chlorine, ozone, UV or chlorine dioxide. But there are people that swim outside in surface water every year. These are the people that are most susceptible to bacterial infections and infections caused by other microrganisms, because microrganisms often enter surface water through industrial discharge and animal excrements. When you are an outside swimmer, you always have to be careful and read the signs placed by the waterside, because the water you are swimming in may be infected, for example with botulism. There are various bacteria and protozoa that can cause disease when they are present in surface water.

Bacterium in water, also known as pathogens, is a public health hazard with risk factors in nearly all parts of the world. Water borne pathogens can occur in all types of water sources and are particularly rampant in areas where there are large amounts of untreated wastewater. In a large waterway, such as a river or stream that has a continuous flow and a renewable source of fresh water, a small amount of contaminant may not make a considerable impact as there is a natural process of bacteria breakdown if water temperature, dilution and solar radiation are optimal. Streams and rivers, which wind through rocks, pebbles, gravel and sand also have a natural filtration system that can help to break down contaminants. In addition, a certain amount of nutrients is actually helpful in the growth process of aquatic plants, but excessive nutrients can also hasten algae growth which then leads to a decrease in dissolved oxygen. This overgrowth of algae clouds the water and prevents sunlight from permeating, leading to the destruction of important organisms, plant and animal life.

The book 'Ecological Principals of Waste Water Microbes' focuses on microbial contaminants found in wastewater, methods of detection for these contaminants, and methods of cleansing water of microbial contamination. The book features new methods to determine cell viability/activity in environmental samples; a new section on bacterial spores as indicators; new information covering disinfection byproducts, UV disinfection, and photo-reactivation; and much more.

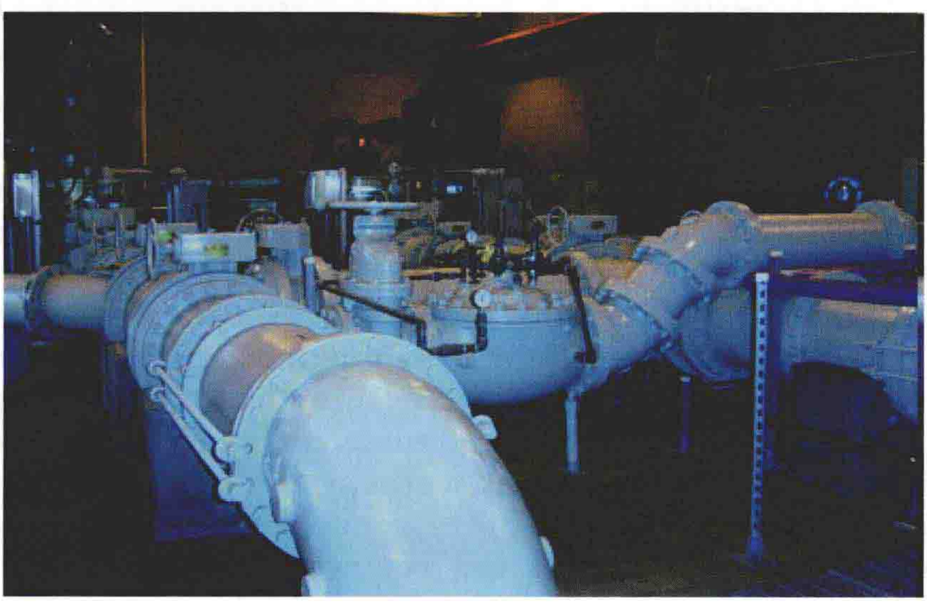
—Editor

Chapter 1

Assessment of Drinking-Water Supplies

The U.S. Department of Energy's (DOE's) Hanford Site was established in southeastern Washington State in 1943 to house facilities for producing and processing nuclear materials for the U.S. government. Nine plutonium production reactors were constructed on the site between 1944 and 1954, along with facilities to separate and purify reactor products into desirable forms.

Eight of the nine production reactors were shut down by the early 1970s. One remained operational until 1987. Decades-long nuclear-fuel processing activities on the site generated an estimated 1.4 billion cubic metres of chemical and radioactive waste in liquid, gaseous, and solid forms. These materials were released to the air, soil column, and surface water, or stored in 177 underground tanks with capacities ranging up to 3.8 million litres.



The current DOE mission at Hanford emphasizes cleaning up the tank, the former waste disposal locations, and the groundwater underlying the site, with the intent to limit the movement of persistent contaminants from the soil column (vadose zone) to groundwater and to reduce the transfer of groundwater contaminants to the adjacent Hanford Reach of the Columbia River. Numerous groundwater discharges are known to enter the Columbia River along the Hanford Site shoreline, and Hanford-produced contaminants are measurable in river water near and downstream from the site.

Hanford is an EPA Region 10 Superfund site with a cleanup budget that was approximately 1.9 billion dollars in fiscal year 2003. Activities associated with this classification have, in recent years, attracted many new workers to the site.

Anticipated non-DOE uses of cleaned-up Hanford lands may bring in even more workers in future years. Because of the large amount of nuclear and chemical waste still present at Hanford, there is concern about potential health impacts to workers and the public from exposure to remaining contaminants. One area of concern has been the possibility that harmful materials may be present in on-site drinking water.

The objective of the study reported here was to characterise drinking water at Hanford Site DOE facilities and to compare current levels of contaminants to state and federal standards for water quality. This information may be relevant to site workers and to planners involved with determining future use of the site.

Regulatory Oversight

Under the federal Safe Drinking Water Act (SDWA) and its 1986 and 1996 amendments, U.S. EPA set legal limits on the levels of certain contaminants in drinking water. U.S. EPA also established water-testing schedules and methods that water system owners must follow. The state governments, through their health departments and environmental agencies, were expected to accept the major responsibility for the administration and enforcement of the regulations set by U.S. EPA. In the state of Washington, the federal drinking-water laws are implemented by the Washington State Department of Health (WDOH) through state administrative codes (Washington Administrative Codes [WAC]). All water systems on the Hanford Site are designated by Washington State as public water systems and are operated in accordance with the requirements contained in the applicable state codes. Water quality at Hanford is monitored according to written contaminant-specific plans that are in keeping with both state and federal drinking-water laws and are acceptable to WDOH.

Description of Hanford Site Drinking-Water Systems

The Hanford Site historically was divided into operational areas. The six 100 Areas (B/C, KE/KW, N, D, H, and F) on the shore of the Columbia River are where the nine retired plutonium production reactors are located. The 200-East and 200-West areas include facilities that processed the irradiated materials from the reactors. Fuel rods for the reactors were manufactured in the 300 Area, near the city of Richland. The 400 Area is the location of the Fast Flux Test Facility (FFTF), a liquid-sodium-cooled test reactor built by DOE in the 1970s to test equipment and fuel for the Liquid Metal Fast Breeder Reactor Program. The remainder of the site, the 600 Area, houses facilities that serve the entire site or more than one specific production area, and includes several non-DOE commercial and research facilities.

Four principal drinking-water pumping facilities were used on the site in 2001 and 2002. Most site workers were provided with drinking water pumped from the Columbia River. The 100-B Area pump house served as the primary Columbia River pumping station, and the pump house in the 100-D Area functioned as its emergency backup. Together these two facilities potentially supplied water to an average of 4,184 people per workday in the 100, 200-East, 200-West, and 600 areas.

Water for the 100-K Area was obtained via its own river pump house and was potentially served to an average of 631 people per day. Drinking water in the 400 Area was pumped from three wells of varying depths located within the 400 Area complex. Generally, only one of the three wells is operated at a time, but water from more than one well can be commingled in a holding tank prior to dissemination through the distribution system. An estimated 389 people were potentially served each workday from these wells. In the 300 Area, an average of 1,805 people was served each day, but the water for this area was supplied by the city of Richland.

All drinking water obtained from the Columbia River was filtered and chlorinated at treatment plants on the site. Active river water treatment plants were located in the 100-K, 100-N, and 200-West areas. Multiple treatment processes were provided in series to remove turbidity and microorganisms, and then to inactivate or remove a specific percentage of Giardia cysts or other pathogenic organisms. At a minimum, filtration was provided at each river water treatment plant to achieve the required reduction in turbidity. Turbidity was monitored continuously to maintain performance expectations. Water from the 400 Area wells was chlorinated but not filtered. Drinking water in the 300 Area was delivered to consumers via a DOE-owned and -operated distribution system and was chlorinated on site when needed even though the water had already been treated by the city of Richland.

Sampling and Analysis Information

Hanford Site drinking-water systems have been classified by the state of Washington as Group A public water systems. Group A systems can be either community or noncommunity systems.

The systems at Hanford are defined as nontransient, noncommunity systems. State and federal laws requiring the monitoring of radiological contaminants in drinking water apply to community systems and therefore are not directly applicable to the Hanford Site. Radionuclides in DOE systems at Hanford are, however, monitored to community system requirements to comply with the requirements of DOE Order 5400.5, a DOE Directive. Monitoring includes collecting and analysing samples and comparing analytical results with established state and federal drinking-water standards and guidelines.

Radiological Sampling

Drinking-water samples for radiological analysis were collected and analysed quarterly in 2001 and 2002. Untreated river water samples were collected at the pump houses in the 100-B, 100-D, and 100-K areas in 2001. Well water samples collected during 2001 in the 400 Area consisted of treated water collected at a consumer-accessible sink. In 2002, in compliance with recently revised drinking-water regulations, all samples were collected after the water was treated but before it was distributed to the consumer. Collection sites in 2002 included treatment plants in the 100-N, 100-K, 200-West, and 400 areas. A state-certified analytical laboratory in Richland, Washington, analysed all samples during both years for gross alpha, gross beta, tritium, and strontium-90. Gross alpha and gross beta measurements are general indicators of radiological contamination. Tritium (12.3-year half-life) and strontium-90 (28.8-year half-life) are materials that were produced in large quantities at Hanford and are also components of atmospheric fallout from worldwide nuclear-weapons testing. Tritium also is produced naturally in the atmosphere.

To comply with revised regulations, one sample from each water supply in 2002 also was analysed for iodine-131, radium-226, and radium-228. Iodine-131 is a manmade isotope produced by the detonation of nuclear weapons and by nuclear-reactor operations. Because iodine-131 has a short half-life (eight days), it is not likely that it would be measurable in Hanford Site drinking water obtained from either river water or groundwater sources. Both radium-226 (1,599-year half-life) and radium-228 (5.8-year half-life) are isotopes that result from the decay of naturally occurring uranium-238 and thorium-232, respectively. Radium should be measurable in both surface and groundwater at Hanford, but U.S. surface waters such as the Columbia River usually have low radium levels.

A continuing program of internal laboratory quality control, participation in inter-laboratory crosschecks, replicate sampling and analysis, submission of blind standard samples and blanks, and splitting of samples with other laboratories verified the quality of radiological results. These verifications in 2001 and 2002 were summarised and published in the Hanford Site's annual environmental reports.

Radiological Results

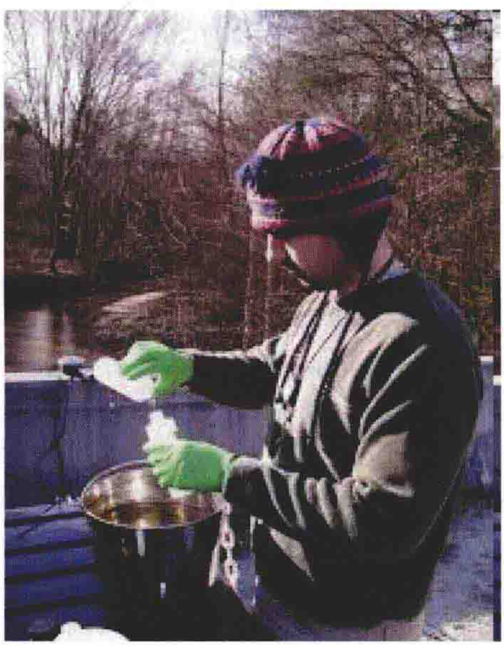
Thirty-two drinking-water samples were analysed for gross alpha in 2001 and 2002 and alpha activity was detected only in one sample. This river water sample was collected in 2001 at the 100-D Area pump house. Gross beta was detected in one of 24 river water samples analysed during 2001 and 2002 and the measured concentration was about 8.4 percent of the U.S. EPA screening level of 1.85 becquerels per litre (Bq/L). This sample was collected at the 100-N Area water treatment plant, which gets water from either the 100-B Area pump house or the 100-D Area pump house. All eight drinking-water samples from the 400 Area (groundwater) analysed during 2001 and 2002 were positive for gross beta, with the highest concentration measured during 2001.

Strontium-90 was measured in 23 of the 24 samples from river water sources analysed during 2001 and 2002. The highest concentration, about 0.7 percent of the U.S. EPA limit of 0.296 Bq/L, was seen in water from the 100-D Area pump house in 2001. The 100-D Area intake is located downstream of the 100-B, 100-K, and 100-N areas, where groundwater containing strontium-90 is found near the river. Strontium-90 was not detected in any of the 400 Area well water samples in either year. Tritium was detected in five of 11 river water samples analysed in 2001 and in two of nine river water samples analysed in 2002. The highest concentration (~1.2 percent of the U.S. EPA annual average limit) was measured in water from the 100-B Area pump house. This drinking-water intake is the one farthest upstream at the site and the one least likely to be influenced by Hanford contaminated effluents entering the river.

The highest tritium concentration measured in drinking water on the site in 2001 and 2002 was found in a groundwater sample from the 400 Area. This concentration was 19 percent of the U.S. EPA annual average limit for tritium in drinking water and was slightly more than 16 times greater than the highest level measured in river water samples. Annual average tritium concentrations in 400 Area drinking water in 2001 and 2002 were 117 Bq/L and 128 Bq/L, respectively. A groundwater tritium plume originating from the former plutonium-processing facilities in the 200 areas is known to affect well water in the 400 Area, and tritium levels in 400 Area drinking water can fluctuate depending on which of three drinking-water wells is being used. Tritium concentrations are usually lowest in the deepest well, which is considered the primary supply well. Tritium concentrations above the annual average U.S. EPA limit of 740 Bq/L have been measured in the two shallowest wells in recent years, and the annual average level in 400 Area drinking water could potentially exceed the U.S. EPA standard if either of these two wells were used as the primary water source for most of the year. Neither of these wells was used in 2001 and 2002, however, and when water from one of these wells is needed, the current DOE policy is to use the well with the lowest tritium level as demonstrated by sampling and analysis. Iodine-131, radium-226, and radium-228 were monitored once at all four sampling locations in 2002. As expected, iodine-131 was not detected in any samples. Radium-226 was, however, found in all four samples analysed during the year. The maximum radium-226 concentration was measured in Columbia River water from the 200-West Area treatment plant.

Radium-228 was found in two of three river water samples but not in the 400 Area well water sample. The highest detectable radium-228 level was found in water sampled at the 100-N Area treatment plant. As stated earlier, both the 100-N Area and 200-West Area treatment plants obtain water from the 100-B Area pump house or from the 100-D Area pump house if the 100-B Area facility is off line. There are no established drinking-water limits for radium-226 and radium-228 individually, but U.S. EPA has established a limit for the two combined. The highest concentration of radium-226 and radium-228 combined was measured in two river water samples and was only 2.2 percent of the MCL of 0.185 Bq/L.

Nonradiological Sampling



Drinking-water samples collected for non-radiological analyses were obtained in accordance with the WDOH-approved plans and procedures of the Hanford Site. Samples for coliform analyses were collected each month at representative locations around the site (primarily building sinks) by qualified personnel and transported to the analytical laboratory at the Benton-Franklin Health District office in Richland, Washington, for analysis. Disinfection requirements for all water sources included ensuring sufficient water and disinfectant contact times, maintaining a free-chlorine residual at each treatment plant prior to supplying consumers, and maintaining a detectable free-chlorine residual within each distribution system. The chlorine residual was monitored continuously at the water treatment plants, and samples were collected daily from each distribution system. Monthly samples were collected in the 100-K, 100-N, 200-East, 200-West, 400, and 300 areas for coliform and total organic carbon analyses (surface-water systems only), and quarterly or annually (400 Area) at several locations within each distribution system to monitor levels of undesirable halogenated organic by-products (trihalomethanes [THMs] and haloacetic acids [HAA5s]).

Inorganic- and organic-chemical monitoring of Hanford water systems was performed in accordance with federal and state monitoring schedules. Samples for a suite of volatile-organic-compound (VOC) analyses were collected annually from the 100-N, 100-K, and 200-West areas, and once every three years from the 400 Area. Semivolatile organic compounds (SOCs) were monitored every year at the 200-West, 100-N, and 100-K areas and every three years in the 400 Area. Both the VOC and SOC samples were monitored for a wide variety of U.S. EPA-regulated and state-unregulated materials. Inorganic contaminants, including nitrate, fluoride, arsenic, and selected metals, were monitored annually in the 100-N, 100-K, 200-West, and 400 areas. Samples for lead and copper analyses were collected every three years at the above locations and in the 300 Area, but were not collected during 2001 and 2002. State-approved site water purveyor procedures were followed for the collection and timely transport of the samples. Chain-of-custody control provided further insurance that the requirements were met for documenting and maintaining custody of the samples from their point of origin to receipt at the laboratory.

Nonradiological Monitoring Results

In 2001 and 2002, all of the river water treatment plants effectively removed or inactivated 99.9 percent of Giardia lamblia and 99.99 percent of viruses. None of the Hanford Site drinking-water samples analysed for total coliform bacteria in 2001 and 2002 were found to be coliform positive. Concentrations of natural organic matter (disinfectant by-product precursors) in drinking-water samples were in compliance with regulatory requirements. Sampling also showed that annual average concentrations of undesirable halogenated organic by-products (HAA5s and THMs) were below their respective MCLs of 60 [micro]g/L and 80 [micro]g/L. No U.S. EPA-regulated VOCs were detected by the analytical lab in either year.

Scans for SOCs in surface water and groundwater systems were conducted in early 2002, and results were reported for 85 regulated and unregulated materials. Only one contaminant (Dalapon [2,2-dichloropropanoic acid]) was detected, and it was seen in water from the Columbia River. The highest amount detected (0.97 [micro]g/L) was far below the MCL of 200 [micro]g/L established by U.S. EPA. Dalapon is a herbicide that is used to control grasses in a wide variety of crops. It is also used in noncrop applications in lawns, in drainage ditches, along railroad tracks, and in industrial areas. This chemical was used on the site in the mid- to late-1990s, but it is believed that the concentration measured in 2002 is related to applications of the chemical to orchards and farmlands located upstream of the site.

Potential inorganic contaminants monitored at the site in 2001 and 2002 included 27 state- and U.S. EPA-regulated materials and parameters. Analytical results indicated that the concentrations of all regulated metals and other inorganic contaminants in site drinking-water samples collected in both years were below their respective maximum concentration limits. Sanitary surveys of Hanford's Group A water systems were performed by the Washington State Department of Health in June 2001. Each survey included an on-site review of the water source, facilities, equipment, operation, and maintenance of the water systems to evaluate their ability to reliably produce and distribute safe drinking water. All systems were found to be well operated and maintained, and monitoring program plans were satisfactory.

Concentrations of all radionuclides in drinking water supplied to Hanford Site facilities by DOE were below state and federal regulatory limits in 2001 and 2002. Tritium and gross beta levels in 400 Area drinking-water wells were elevated relative to other water sources on the site, and tritium concentrations in the two shallowest wells can potentially be high enough to exceed the 740 Bq/L annual average drinking-water standard. DOE's practice of using the two shallow wells only when needed and then using the well with the lowest tritium level as determined by sampling and analysis would, however, keep the annual average concentration below the regulatory limit for community systems.