Analyzing sediments collected during ice pigging projects may help identify causes of water quality concerns and guide maintenance procedures for distribution systems.

**ICE PIGGING CREATES CLEAN MAINS AND WATER QUALITY INSIGHTS**

Ice pigging is a sustainable, powerful cleaning method for potable water distribution mains and wastewater force mains. Suitable for all pipe materials, the ice pigging process involves pumping a slurry of ice into a main through a hydrant or other existing fitting, using system pressure to carry the ice “pig” downstream. The pig scours the pipe and entrains accumulated deposits along the way, then exits the main through a hydrant or similar fitting.

The first step in an ice pigging project is to isolate the section to be cleaned by closing the valves upstream and downstream of the section. The ice slurry is immediately pumped into the pipe through a fire hydrant or similar fitting. Once the upstream valve is opened, the downstream pressure in the pipe is monitored and managed at the outlet point via a hydrant. Flow at the outlet hydrant is used to control the ice pig’s speed.

As the pig nears the outlet point, a temperature drop occurs and alerts an operator that the ice is about to arrive. The sediment-laden ice is discharged via the outlet hydrant and continues on through a flow analysis system (FAS), and the operator collects samples of the discharged ice for later analysis. After passing through the FAS, the slurry finally flows into a sewer.

The pipe is then flushed briefly to ensure all salty water is removed and to allow turbidity levels to return to the appropriate water quality standard. At this point, the system is returned to service without the need to disinfect or take water samples.
A 10-ton ice delivery rig can provide 2,700 gal of ice per day to remove sediment from a distribution system.
A GLACIAL EFFECT

Ice pigging harnesses the characteristics of a semisolid material (an ice slurry) that can be pumped like a liquid but behaves like a solid once the pig is formed in the pipe. As the pig passes through the pipe, the natural glacial effect of the ice causes the pig to scrub the pipe and capture, rather than “bulldoze,” sediment and biofilm. Because of this, ice pigging uses approximately 50 percent less water than standard water flushing and takes significantly less time. Typically, the section of main being cleaned is out of service for no more than 30–60 minutes.

Because the pig is an ice slurry and not a solid object, it can't get stuck in the pipe like traditional hard, mechanical pigs or soft swabs. An ice pig can negotiate pipe bends, diameter changes, partially closed gate valves, and in-line butterfly valves without affecting the cleaning process. Any ice that remains behind simply melts.

By increasing pump efficiency, ice pigging reduces energy costs. Moreover, ice slurry that fills 20–30 percent of a pipe's volume cleans with shear forces up to 1,000 times greater than with water alone. This provides more effective cleaning—while using significantly less water—than traditional flushing methods. In fact, ice pigging has been proven to be between 100 and 1,000 times more effective at removing sediment and debris than water flushing alone. Ice pigging is the lowest-cost option when considering the volume of sediment removed.

SEDIMENT EVALUATION

Ice pigging is the only cleaning technique that enables customers to collect and analyze sediments removed from the pipe during the process. Following the completion of an ice pigging job, a report is delivered to the customer about the amount of sediment removed and the content and chemical analysis of the sediments. This value-added information provides insights into the characteristics and chemistry of the water being transported through the pipe and can help guide and tailor system maintenance programs.

The analysis assesses the weight value of material removed from the pipe during the cleaning process and provides qualitative information designed to evaluate the presence of mineral and biological materials found in the distribution system. A series of samples collected during each project is submitted to a laboratory upon completion so the sediment can be filtered, dried, and weighed to quantify the overall volume of material removed from the pipe system. A portion of the sediment removed from the submitted samples is then selected to undergo additional testing to identify the primary minerals present and evaluate the microbiological community.

Testing is aimed at identifying common waterborne deposits and treatment chemicals, including iron, calcium, manganese, phosphate, sulfate, silica, and aluminum. Biological testing is also performed to assess the total bacterial population and characterize the types of water bacteria active in the distribution system. A microscopic analysis of the material is also used to verify results and identify the presence of any larger bacteria, silt, clay, plant materials, or other particulate matter in the sample.

All laboratory testing procedures are performed according to the guidelines set forth in Standard Methods for the Examination of Water and Wastewater, as established by AWWA, American Public Health Association, and Water Environment Federation. To date, the database encompasses 16 projects, 26 miles of pipeline, 927 individual weight samples, and 47 individual composition analyses.
Based on the assessment of the quantitative weight analysis data compiled in the current database, the highest amount of sediment removed from a single ice run was 206.8 pounds per mile. The least amount removed per run was 0.09 pounds per mile, and the average amount of material removed with the ice pigging technology is 21.07 pounds per mile.

Understanding the amount and composition of sediment in a distribution piping system can help water and wastewater utilities identify the root cause of problems such as system pressures and flows. Such information can also be used to identify problem areas within the piping system and guide preventive maintenance procedures or operational changes that may correct or eliminate those issues and related customer complaints.

**COMPOSITION ANALYSIS**

Further evaluation is accomplished by the composition analysis process. This phase uses the material removed from the samples and, as described previously, identifies the prominent components of the sediment removed during the cleaning process. Additionally, an adenosine triphosphate (ATP) test is used to evaluate the number of bacteria in the sediment, which can help identify the cause of many bacterial-related problems.

The top three minerals found in the sediment materials are iron, manganese, and calcium. Iron has been the predominant mineral 56 percent of the time. Manganese was predominant 32 percent of the time, and calcium was predominant 12 percent of the time.

The presence of iron and manganese sediment within a distribution pipe system is generally associated with colored water, metallic taste, and staining complaints, and it can challenge a water utility’s efforts to maintain disinfection residuals. Also, the buildup of these deposits can foul pipelines, reducing flows and affecting system pressures. These metals are generally targeted for removal at a water treatment plant. However, their presence in distribution pipes can come from buildup over time.

**Mineral Occurrence**

*The top three minerals found in sediment materials are iron, manganese, and calcium.*

- **Iron**: 56%
- **Manganese**: 32%
- **Calcium**: 12%

From left: Project samples are filtered, dried, and weighed to quantify the volume of material removed from the pipe system.
System Operations

or, as in the case of iron, potential corrosion activities.

Calcium is the most common component of water hardness. Treated and balanced water from a treatment plant shouldn’t precipitate calcium deposits, but their presence in distribution systems isn’t uncommon because of changes in temperature, pressure, and solids content, which can affect scale formation.

The presence of bacteria in the sediment doesn’t represent an unsafe pipe system, as none of the organisms identified are regulated by drinking water standards. However, of the 47 composition analyses performed, 32 contained bacteria that are common iron and manganese oxidizers. Iron- and manganese-oxidizing bacteria change these metals to form more insoluble compounds and encourage the deposition of these metal oxides.

Correspondingly, of the 30 samples where iron or manganese was identified as the primary mineral in the sediment, 26 had a positive occurrence of iron-related bacteria. This represents an 87 percent correlation of iron and manganese bacteria to the presence of iron or manganese as the primary metal in the sediment.

From the ATP test results showing the number of bacteria present in the sediment material, 13 of the 47 samples tested had bacterial counts above the level where biofilms have generally initiated and are starting to form masses of material that can plug the pipe system and associated flow and pressure issues. In addition to these problems, biofilm buildup in distribution pipes can affect disinfection residuals and disinfection byproduct formation.

These relationships can point to potential causes of sediment buildup in a distribution system and guide maintenance procedures, including effective pipe-cleaning technologies, treatment processes, and system operations. The case study below illustrates a practical application of the information gained following ice pigging and the subsequent analysis of sediment collected as part of the process.

CASE STUDY

ICE PIGGING RESULTS PROVIDE WATER QUALITY INSIGHTS

A southeastern Massachusetts community of approximately 15,000 residences continually faced water quality issues from the buildup of iron and manganese deposits in its cast-iron distribution lines. These minerals can cause colored water and staining complaints from residents as well as inhibit flows and create pressure problems in the system.

Although treatment plants in the city use iron and manganese removal technologies, it isn’t uncommon for these minerals to build up in distribution pipes. This is particularly common in areas where the groundwater is rich in these minerals and the pipe material is cast iron.

Ice pigging technology was applied in two separate runs of 8-in. cast-iron pipe. The first run was into 4,600 ft of pipe, and the total amount of sediment removed was 180 pounds. This equates to 206 pounds per mile. The second run was into 4,700 ft of pipe, and the total amount of sediment removed was 42 pounds, which equates to 47 pounds per mile.

The composition of the material removed from the first run was 59 percent calcium, 17 percent iron, and 20 percent manganese, with other minor constituents. The material removed from the second run was 47 percent calcium, 39 percent iron, and 14 percent manganese, with other minor constituents. The high percentage of calcium is common to groundwater, and the formation of calcium deposits such as calcium carbonate is generally seen in a matrix with iron and manganese entrained with organic biofilm.

The strong presence of iron compounds in the removed sediment points to the mobilization of debris in the pipe system and potential corrosion. Knowledge about the composition of the sediment removed can be used to evaluate treatment processes and system operations.