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EFFECT OF ICE PIGGING ON BIOFILM
in non-chlorinated drinking water distribution systems in Denmark

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BACKGROUND
Ice Pigging is an innovative technique for cleaning drinking water pipelines. The method (which is a patented service provided by Suez Advanced Solutions (UK) Ltd.) uses slush ice prepared with drinking water and food-grade salt (to cause a freezing point depression). The ice is emplaced in drinking water pipeline and the pipeline pressure pushes the ice through to a discharge point, cleaning as it goes.

Advantages: 1) Fast – Disturbance of the consumer only lasts about 1½ hours, 2) Efficient – Large sheer forces between ice and pipe wall remove virtually all debris, 3) Flexible – Since the slush ice is easily formed by its environment, pipeline challenges such as valves, elbows, and changes in pipe diameter are no problem.

Disadvantages: 1) Considerable planning and valve pre-testing is required, 2) Knowledge about the DWDS connections is required, 3) Hygiene considerations are important in non-chlorinated systems, 4) Cast iron pipes are challenging.

In non-chlorinated drinking water distribution systems, a healthy, mature biofilm on pipeline walls may be seen as an advantage for ensuring biologically stable drinking water. A major question of this research project was to determine the effect of ice pigging on this biofilm.

EXPERIMENTAL SETUP
Practical Ice Pigging was executed on 7 distribution networks belonging to Aarhus Water and TREFOR Water in Denmark. The pipe diameters ranged from 80 -200 mm and included PVC, PE and cast iron. In addition, a pilot-scale test rig was set up at Lysholt Waterworks, Velle, Denmark. Here, 3 pipes in operation were excavated and a new 100 m coil of 50 mm PE was used, see below. ATP samples were swabbed from pipe walls before and after pigging.

RESULTS
Old PE pipes (a) appear like new after ice pigging (b). Swabbing of an old pipe section was carried out to measure ATP in the biofilm (c). Old corroded cast iron pipes (d) do not become smooth following ice pigging.

In the 7 full-scale pipelines that were tested, an extreme variation in the amount of accumulated debris (3–300 kg/km) was found. This debris was characterized (e) as mainly containing small iron oxide particles (< 10 µm) with lesser amounts of calcium carbonate, manganese oxides and organic matter. The source of the iron oxide particles was likely release to the pipeline in the minutes immediately following filter backwash (PVC and PE) and pipeline corrosion (cast iron).

The biofilm was not removed completely, but ATP fell during pigging (f).

Dispersion of bacteria from young biofilms is seen after about two weeks in new PE pipelines, but NOT in the same PE pipeline after it underwent Ice Pigging (g).

CONCLUSIONS/PERSPECTIVES
Main conclusions of this research include:

• The amount of debris in drinking water pipelines varies greatly from pipe section to pipe section, but is mainly composed of small iron oxide particles.
• Most, but not all, biofilm is removed by Ice Pigging. Therefore, pipelines in non-chlorinated systems may immediately be put into operation following Ice Pigging without concern of an explosion of bacterial caused by biofilm dispersion.
• Empirical microbiological/chemical analyses and modelling of Ice Pigging debris opens a window to greater understanding of our Drinking Water Distribution Systems.