Fact Sheet 3 of 4 - Project 1075

Optimising Instrumentation for Better Process Performance

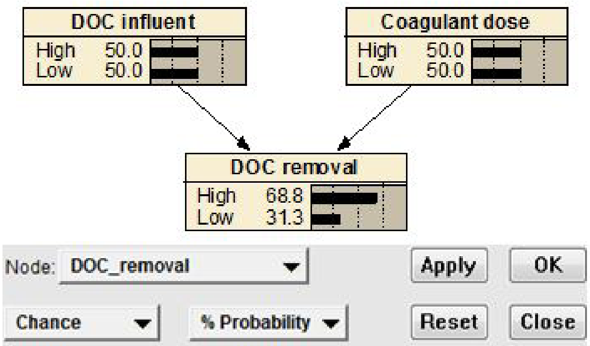
Module 3: Improving Decision Making in Water Plant Operability Through Bayesian Belief Networks

Background

The increase in stringency of water quality requirements in Australia has driven the need for improved data collection and process monitoring practices at water treatment plants (WTPs). Despite the clear benefit of online monitoring for risk reduction and improved compliance, obtaining the full effective value of large volumes of data created by online instruments is still an ongoing challenge. The overall aim of this study was to develop a framework for applying a qualitative risk assessment tool called a Bayesian Belief Network (BBN) to expand use of historical data for improving decision making in water treatment plant operability.

Bayesian Belief Networks (BBNs)

BBN is a graphical model that represents a set of variables and their probabilistic dependencies. In BBN, variables are represented by nodes, and the relationships between variables are represented by directed arcs. Quantitatively, these relationships are expressed in conditional probability tables (CPTs). A simple example based on the impact of dissolved organic carbon (DOC) influent concentration and coagulant dose on the DOC removal efficiency is provided below:



DOC influent	Coagulant dose	High	Low
High	High	80	20
High	Low	30	70
Low	High	90	10
Low	Low	75	25

Conditional probability table for impacts of DOC influent and coagulant dose on DOC removal efficiency

Case study Mt Pleasant WTP

Mt Pleasant WTP sources its water from River Murray through River Murray-Mannum off take and the Mannum Adelaide pipeline. Mt Pleasant WTP has two independent flow processes with nominal capacity of 2.5 ML/day. The operation stream is a conventional water treatment process consisting of MIEX pre-treatment, PAC contact tank, flocculation tank, sedimentation tank and multimedia filters. The case study in the final report focused on the filtration steps of the operation stream.

Mt Pleasant WTP process schematic

The aim of the project

Based on available on-line turbidity data and related operational inputs from a filtration process at the Mount Pleasant WTP, this case study aimed to develop BBNs, which could allow the determination of probability of possible causes and corresponding corrective actions for given high filter outlet turbidity readings. Such quantitative statistical information from the models may assist operators to decide appropriate course of action when facing 'out of normal' operational events and thus improve effectiveness of decision making.

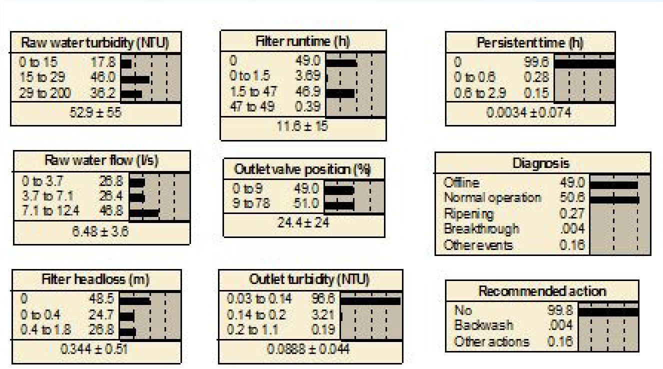
Developing BBNs for Mt Pleasant WTP

The following steps were taken:

- Define model objective and scope
  - Turbidity sensor after individual filters of the operation stream
- Collect and format data
  - Standard Operating Procedure
  - Water Quality Operating Plan providing operational targets of critical monitoring locations, responses to system specific water quality issues, details of key water quality and system information;

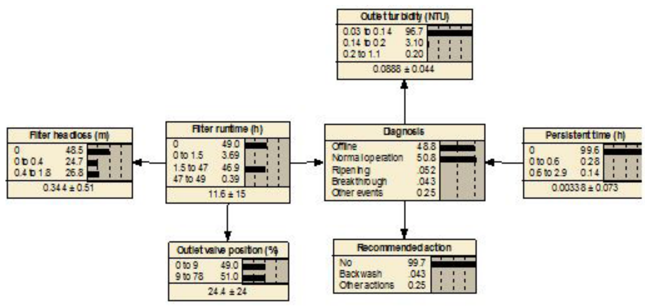
- Mt Pleasant WTP Schematic Flow Diagram including filtration step;
- Mt Pleasant WTP Water Supply Schematic;
- Mt Pleasant WTP Process P and ID

Below are shown the states and intervals used for the selected variables:



- Define model structure
  - Selecting variables for the model
  - Defining number of states for variables
  - Defining connections between variables
- Parameterise the model
- Evaluate and validate the model

The resulting BBN was produced, and used to consider a number of possible scenarios, ranging from ripening, breakthrough:



Conclusions

Opportunities

BBNs appear to be a reasonable approach for modelling of water treatment processes. The information provided by the BBNs in this case study is potentially useful for the plant operators in identifying and confirming possible causes and corresponding actions in given scenarios. As a result, better decision tools can be built from historical data.

BBNs can be a good training tool for new operators as BBNs can stimulate better understanding about the links between different parameters in the processes.

BBNs can also serve as a complementary strategy to existing management strategies of the plant to improve the reliability of its processes.

Challenges and lessons learned

The challenge of this exercise is to find appropriate dataset and information for the model development and validation. Plants having both wide range of "out of normal" events, and high quality of operation management are ideal for the model development and validation. However, these plants are rarely found in reality. Quality of operation management including: quality monitoring; quality data recording and logging; quality protocols and strategies for corrective actions.

In practice, two extreme scenarios are experienced: On one hand, plants with high quality of operation management, usually have little "out of normal operation" events. So although it is feasible to collect all monitoring data, operational and maintenance records, the variation of the data is not sufficient enough to capture all interesting incidents, and therefore they are not very useful in developing and validating comprehensive BBNs. On the other hand, plants those have a wide range of "out of normal operation" incidents, usually are not managed and monitored well, so although there are interesting incidents, related data as well as operational and maintenance activities are not recorded, and therefore not available for model development and validation. Thus, the optimum plants for developing and validation the BBNs in reality are the plants having good balance between sufficient "out of normal operation" incidents and sufficient monitoring data, and operational and maintenance records.

Next steps

This study demonstrates a proof of concept of how BBN could help to expand the use of historical data for improving decision making at WTPs through a case study of a filtration process in Mt Pleasant WTP. In the future, extensive case studies should be conducted for other processes and/ or at other WTPs to further clarify the use of BBN in such applications.

The next step is to develop universal BBNs for typical processes at WTPs, which could be used by any WTP with little modifications. In addition, BBNs can also be applied to address other questions from the industry such as prediction of treated water quality, identify important factors affecting treatment process performance, identifying when maintenance activities (e.g. changing filter media etc.) should be conducted etc. Such information could potentially help to optimise and improve the processes.

Another interesting future work concept would be to develop online automatic diagnosis system from BBNs. This would include develop software that could learn data from monitoring sensors to update BBNs continuously, and provide diagnosis in real-time.

Module 3 Project Team

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