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Water network optimisation in the process industry—case study of a liquid detergent plant

M. Forstmeier*, B. Goers, G. Wozny

Department of Process Dynamics and Operation, Institute of Process and Plant Technology, Technical University Berlin, Sekr. KWT 9, Straße des 17 Juni 135, 10623 Berlin, Germany

Abstract

The main target of this research project is the optimisation of the water management in a liquid detergent production plant according to the concept for retrofit optimisation of water networks (CROWN) strategy in order to reduce freshwater consumption and the costs for wastewater disposal. A membrane process and a disinfection step are integrated into the water network in order to recycle process water and to recover concentrated product solutions.

Keywords: CROWN; Detergents; Membrane filtration; Water network optimisation

1. Introduction

For the retrofit optimisation of industrial water networks, the concept for retrofit optimisation of water networks (CROWN) strategy has been developed [1] (Fig. 1).

Up to now, the task of industrial water network optimisation has been performed in two different ways: on the one hand, there is the systematic method of mathematical optimisation by solving sets of equations based on theoretical concepts or process models, like the Water Pinch analysis, originally developed by Wang and Smith [2]. A comprehensive review on current developments in this field is given in [3]. As all mathematical models have to be simplified to some extent in order to be solvable, the applicability to real case studies is limited. Aspects of water chemistry are hardly ever taken into account.

On the other hand, the conceptual engineering approach consists of a set of experiments on laboratory and pilot plants leading to a final plant configuration based on heuristics and engineering experience in order to find quick solutions for individual problems. These concepts tend to result in solutions showing further potential for cost reduction as very often only the most evident water streams are considered.

CROWN has been developed in order to merge the advantages of the global strategy of the mathematical water network optimisation with the detailed focus on the real water streams and the proof by experiments. The concept includes five major steps to address all relevant aspects.

2. Analysis of water system and problem description

Initially, the general conditions on the production site have been analysed including legal, economical, technical and logistic aspects. Some common sense measures like the optimisation of the production schedules had already been applied in former phases of the project [4]. Furthermore, the water network of the entire plant has been balanced as far as water flow rate and chemical oxygen demand (COD) load are concerned. The initial water network has been subjected to a Water Pinch analysis in order to find possible links and potential for flow rate reduction. In contrast to rather theoretical studies showing huge potential for savings by direct reuse of water streams, in this case quality management (QM) systems and good manufacturing practice (GMP) prohibited the direct reuse of water streams. As a consequence, no savings could be achieved in this step.

* Corresponding author. Tel.: +49-30-3147-9816; fax: +49-30-3142-6915.
E-mail address: markus.forstmeier@tu-berlin.de (M. Forstmeier).

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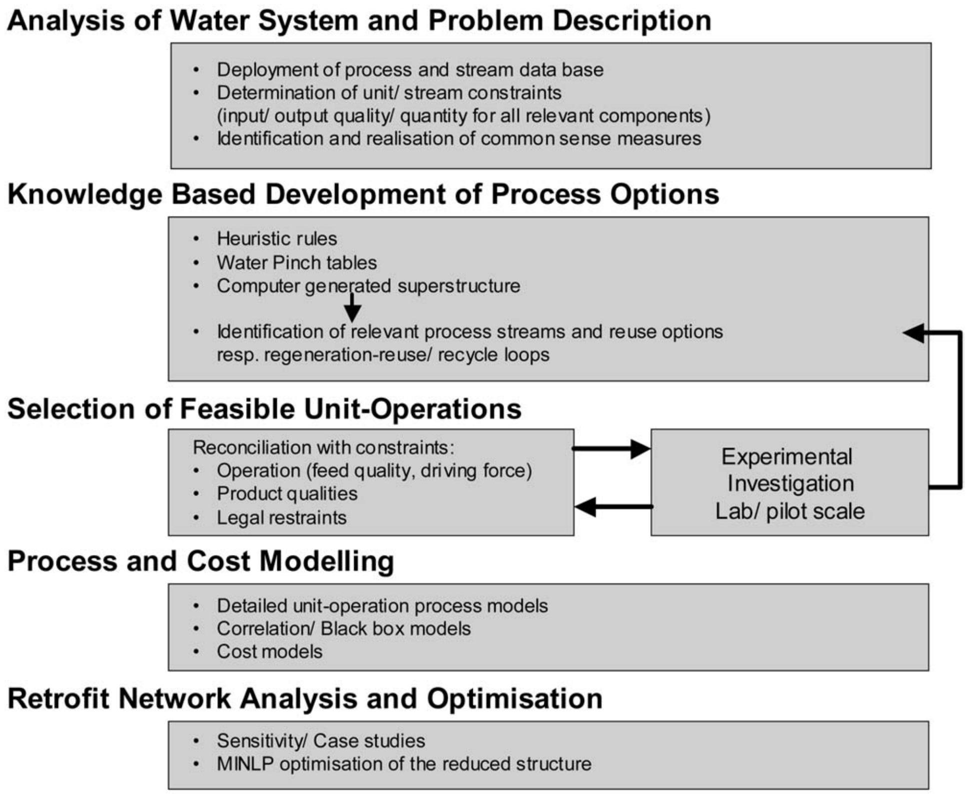

Fig. 1. CROWN—concept for retrofit optimisation of water networks.

3. Development of process options

Freshwater consumption is about 100,000 m^3/year; most of the water needed for liquid products can therefore neither be saved nor be replaced by recycled water.

In the production of liquid detergents, deionised water is part of the product formulations. For this purpose, large quantities are necessary which are produced in a reverse osmosis plant causing large amounts of retentate. As the feed of the RO plant is softened by an ion exchanger, the retentate can be reused as rinsing water and cooling tower blow down water after a disinfection step to address microbiological concerns.

Analysis has also shown that 70% of the total wastewater disposal costs are caused by the relatively small amount of cleaning-in-place (CIP) rinsing water stream that comes from the hot water cleaning processes accomplished after every product change. The COD load of this fraction of up to 300 g/l is the main expense factor for wastewater disposal costs.

4. Selection of feasible unit-operations

Based on the promising results achieved in former research projects on CIP water management and surfactant separation by means of membrane processes in [5] and [6], ultra- and nanofiltrations are now being used in order to recover resources and process water as well as to reduce the high COD load of the rinsing waters.

Membrane screening has been carried out in order to find suitable membranes. The product formulations are multi-component mixtures containing various substances like alcohol, dyes, perfumes, glycerine and silicone-based anti-foam agents that could influence both membrane performance and service life.

In the following, a pilot plant built by Enviro-Chemie that has been installed on the Henkel site is described. Depending on the CIP water characteristics, a reduction of the COD load and the surfactant load of up to 90% has been achieved (Fig. 2). The performance of the membrane plant depends on the feed quality; one simple removal ratio or outlet concentration as it is often used in mathematical water network optimisation could not describe the results properly.

As the permeate quality is still insufficient for direct reuse, this stream has to be disposed of, but the total costs are about 70% lower. The retentate is to be reused in washing powder production located in the same site. Fig. 3a shows the possible reduction of the emitted COD mass load in the CIP wastewater based on the water balance from 1999; the stream diameters are proportional to the corresponding COD load in ton/year.

Experiments with a disinfection pilot plant by Newtec have shown that after an electrochemical disinfection