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Significant Economical and Ecological Benefits by Continuous Process Improvement in an Industrial Vitamin Synthesis Process

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Abstract. A large number of today's technical vitamin bulk synthesis processes are performed in single product facilities. Some of them rely on chemistry and technology which has been in place for decades. In the meantime, generations of process chemists and specialists have successfully spent huge efforts in optimizing these processes and pushing chemical yields to the limit. Despite of the late stage in the product life cycles of vitamins, there is still room for improvement.

In view of the highly increased competitiveness and price pressure, cost cutting, both operational and administrative, is a major goal and a key success factor in addition to the ecological performance. This article illustrates the benefits of a simplifying and relatively minor process change, which not only leads to economical but also to ecological benefits by complete elimination of solvent cycles in the process. As a subsequent measure, the associated solvent recovery plant was shut down.

Keywords: Bulk vitamin synthesis · Continuous process improvement · *Costs of Goods Produced* (COGP) · Economical and ecological benefits · Green chemistry · Process simplification

1. Introduction

The cost structure of one of the most important vitamin synthesis processes is characterized by a dominant contribution of the raw material prices to the *Costs of Goods Produced (COGP)* compared to the other operating or variable cost elements. In addition the ecological awareness in our society is setting new standards also for the chemical and pharmaceutical industries. As a result not only technical but also ecological process improvements are key success factors in our business environment. This is reflected as a top priority in the site and department performance goals in addition to profitability, productivity and social, safety and human resource aspects.

Together with colleagues from the Center of Excellence for Chemical Research and Development for the Vitamins Division which is also located on the Sisseln site, we are continuously looking for new technical and chemical processes and also for improvements of the existing, well-established production facilities and techniques.

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2. Production Process and Technical Improvement

One of the main chemical reaction steps in an important vitamin synthesis is followed by a continuous extraction process to separate the by-products and traces of starting materials. Up to now this separation was performed in a counter current extraction unit with a mixture of a polar solvent plus water on the one hand and a non-polar solvent on the other hand (Fig. 1). The main product entered the extraction after it had been previously separated from the reaction solvent and leaves the extraction dissolved in the non-polar solvent, as the by-products are separated into the polar solvent/water mixture.

The main product stream then was fed to a distillation unit, where the non-polar solvent was distilled off and recycled back to the extraction unit for reuse. After pH correction, the by-product stream was separated into a water/waste fraction and a solvent/water mixture in a dedicated rectification column, which guaranteed that no solvent left the process in the water/waste fraction and additionally functioned to adjust the correct solvent/water ratio to be recycled to the extraction unit again.

Optimization of this extraction unit including two solvent purification and recycle equipment trains leads to a major simplification of this process (Fig. 2).

The polar extraction phase is simply replaced by pH- and temperature-adjusted de-ionized water, and, as non-polar phase, the reaction solvent of the previous step in a certain concentration ratio is used. The extraction/reaction solvent is now distilled off afterwards. The water/by-product stream leaves the process after passing the wastewater stripper to be further treated in the central site wastewater treatment facility.

This results in a complete elimination of the polar and the non-polar chemical solvent streams including the shutdown of the corresponding purification / recycling equipment (distillation and rectification units, holding tanks, *etc.*).

After several months of optimization of parameters such as flow rates, agita-

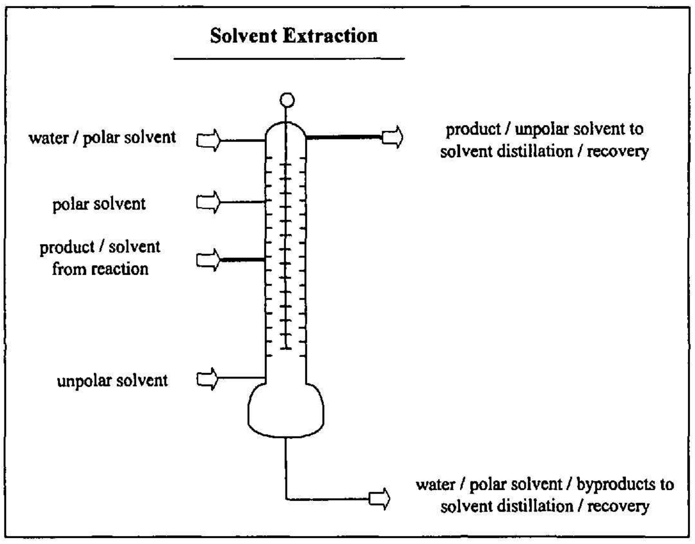

Fig. 1

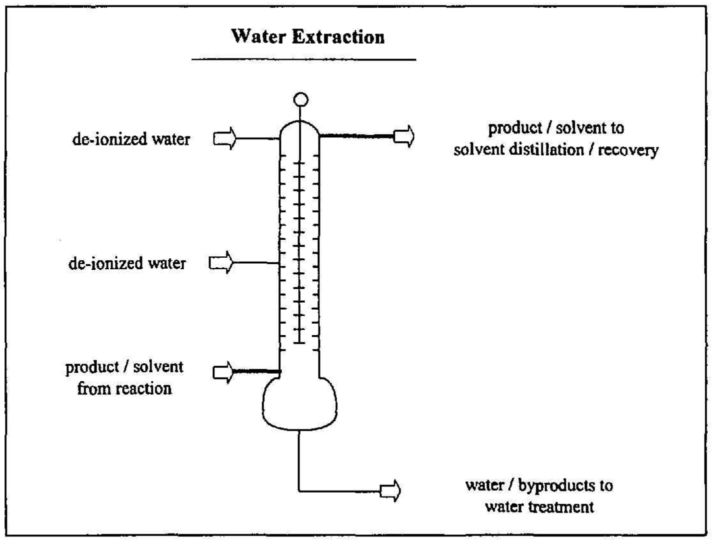

Fig. 2

tion speed, temperatures, differential pressure *etc.*, within two production trials, the change was implemented with great success.

3. Process Change and Quality Assurance

The implemented details related to this process change had been described in a validation plan, including test and specification descriptions, and previously passed all procedures in regulatory compliance with our process change and GMP guidelines. Verification of the expected results, analytical testing of the separation performance and long-term stability tests of the finished products, from several production steps downstream, completed the final report.

4. Economical and Ecological Benefits

The economical benefits of this process change (Table), which are mainly based on raw material cost and energy savings, highly overcompensate the additional expense for de-ionized water and its pH and temperature adjustment.

Only a rough estimate is included for the reduction in costs from reduced regular and preventive maintenance for the equipment, which could have been shutdown. No savings are outlined for the partial manpower, which could have been set free from controlling the solvent recycle distillation steps to perform other tasks in the production process.

Quality cost savings originate from reduced number of in-process control samples from the solvent recovery steps.

The investment for the necessary minor piping, equipment and automation adjustments was only *ca.* CHF 50 000.–, which leads to a pay back of the optimization project based on the above savings of less than two months.

Table 1. Annual cost savings

raw materials / solvents	– 90 000.–
de-ionized water	+ 38 000.–
energy	– 195 000.–
pH treatment / temp. adjustment	+ 40 000.–
maintenance	– 80 000.–
quality control	– 50 000.–
treatment of waste streams	– 150 000.–
Cost savings / year / CHF	**– 487 000.–**

The ecological benefits are fairly difficult to calculate. Certainly the major contributor is the discontinued use of a total of *ca.* 350 t/year of solvents, which is already included in the above raw material cost savings.

Additionally considered are saved treatment costs for losses of solvents ending up in vent streams, which were collected and further processed in a central site vent treatment facility. The saved expenses for treatment of the solvent losses into the aqueous effluents to the central wastewater treatment facility are also significant. Thus, with saving raw materials, less incineration of solvents in an 'end of pipe' installation, and less organic carbon in the wastewater, three key elements of sustainability are fulfilled.

5. Discussion and Conclusion

Eco-efficiency as a key performance indicator of industrial synthesis processes is becoming more and more important in our environment. Often it is even the trigger for process development. The possibility of combining economical with ecological benefits is the ideal justification for implementation of ongoing improvement projects, since capital investment in well-established, long-running production facilities does have a significant impact on depreciation costs and value of the installed assets.

The technically simplifying improvement project as described here is very attractive because one-time costs for implementation are marginal compared to the high benefits year by year, as long as the process is in operation.

Last but not least ecological aspects and performance figures of the production processes are becoming key arguments for discussions with customers and other stake holders of our industry segment.

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