Berichte aus der Umwelttechnik

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Approach for an integrated assessment and optimisation of waste water treatment and sediment remediation processes

Shaker Verlag
Aachen 2006

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Zugl.: Hamburg-Harburg, Techn. Univ., Diss., 2006

Printed in Germany.

ISBN-10: 3-8322-5702-0
ISBN-13: 978-3-8322-5702-6
ISSN 0945-1013

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
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Titel: „Approach for an integrated assessment and optimisation of waste water treatment and sediment remediation processes“

Zusammenfassung

The evolution of environmental thinking in the direction of sustainability has set a new paradigm for process assessment and optimisation. The emergence of sustainability engineering supposes that processes should be designed in a way that not only costs are minimised but also environmental impacts. In this context, environmental issues are not merely constraints imposed by regulations anymore but they are to be integrated in process design and optimisation strategies. Following this line of thinking, this work dealt with the design and implementation of an approach to assess and optimise treatment processes in terms of economic and environmental criteria.

An environmental assessment approach according to the notion of sustainability must attempt to evaluate all potential impacts on the all environmental compartments, not only on a site-specific scale but along the complete process *life-cycle*. The assessment strategy designed combines an approach based on the life-cycle assessment with tools to evaluate site-specific impacts in order to account for all environmental interventions associated to treatment processes.

The approach developed was applied exemplarily on two treatment processes. The first one was a laboratory scale process to treat dockyard waters contaminated with copper, zinc and tributyltin (TBT). The elimination of the heavy metals was done by means of flocculation with ferric salts, while TBT was decomposed by means of electrolysis. The anode materials tested in the electrochemical reactor where boron-doped diamond (BDD) and titanium coated with iridium dioxide (Ti/IrO_2). The results of the assessment showed that it was possible to eliminate the pollutants of concern down to the target concentrations set. The life-cycle assessment of this process revealed that the most environmentally “costly” operation unit was the electrochemical treatment and was therefore subjected to optimisation.

The electrochemical reactor was optimised in terms of treatment costs and life-cycle impacts (depletion of abiotic resources, emissions of CO_2 and SO_2 through the process life-cycle). The resulting multi-objective optimisation problem was solved using the ε-constraint method to obtain the *non-inferior* solutions for the criteria considered. The resulting analysis suggested that it was advantageous to operate the electrochemical reactor with Ti/IrO_2 at a current density of 9.5 mA/cm^2. This resulted in treatment costs of 1.18 €/m^3, consuming 72.8 MJ of fossil energy equivalents per m^3 and caused emission of 6.0 kg CO_2 equivalents and 34 g SO_2 equivalents per m^3.

The second process was a pilot scaled electrochemical process to remediate TBT contaminated sediments. The sediment throughput of the plant was 0.2 t/h. The process was able to decrease TBT down to the target 100 µg/kg applying current densities in the range of 4.4 to 6.6 mA/cm^2 with costs between 20 to 23 €/t. Nevertheless, the ecotoxicological test investigation indicated high toxicity of the sediment. By-products and residual oxidants were the cause of these effects.

These examples showed the compatibility of life-cycle assessment with site-specific tools in order to improve the quality of environmental assessments, as well as its compatibility with multi-criteria tools for optimisation in terms of environmental and economic criteria in a sustainability-oriented approach.