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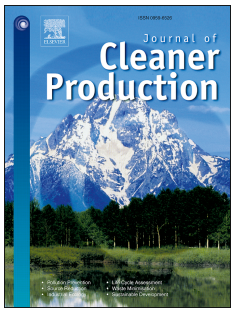

Mathematical modeling and environmental analysis of heat pumps integrated in a spent pickling liquors treatment process

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Abstract

Spent pickling liquors are hazardous materials due to their high concentration of metals and presence of several acids.

Different processes are developed for treatment of spent pickling liquors aiming to energy efficiency and there are few works in literature about the use of heat pumps (energy efficient and environmentally friendly process) to this purpose. In this article a new process for regeneration of spent pickling liquors producing fertilizers ($FeSO_4$, $ZnSO_4$, $FeSO_4 \cdot 7H_2O$, $ZnSO_4 \cdot 7H_2O$) and integrated with heat pumps is developed. A vapor compression heat pump whit indirect expansion is used in evaporation and crystallization section. A sensitivity analysis is carried out to evaluate the effect of heat pump parameters on coefficient of performance. Through response surface a mathematical model is developed for coefficient of performance, CO_2 emissions and primary energy consumption. In addition a factorial design allows to evaluate the significance of same factors on them. In this way process parameters and not heat pump parameters are used for factorial design: the integration of heat pumps is more enhanced.

Results shows that overall the two heat pumps, compared to an industrial boiler, allow a reduction of 38% of CO_2 emissions and Total Equivalent Warming Impact, 39% and 57% reduction on tons of equivalent petroleum and costs respectively, according to the European Union climate package.

Economical incentives in terms of white certificates are obtained so the process is more economically feasible. A Life Cycle Analysis is carried out to evaluate the environmental advantage of heat pumps over the industrial boilers. Results show that environmental sustainability of all heat pump systems could improve with the greater penetration of renewables in the electricity mix.

The future construction of the plant will allow to verify the obtained results in order to realize a more accurate mathematical model optimizing all process.

Keywords: spent pickling liquors treatment, heat pumps, boilers, energy efficiency, Life cycle analysis, mathematical modeling.