LIFE CYCLE ASSESSMENT OF DMSO SOLVENT, COMPARING AN OPEN MANUFACTURING SYSTEM WITH A CLOSED ONE

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Abstract
This paper has been elaborated during the project called "DMSO contaminated industrial waste water recycling by distillation" which action connects to the Hungarian water quality improvement program. The dimethyl sulfoxide (DMSO) is frequently used as a solvent for chemical reactions and is also extensively used as an extractant in biochemistry and cell biology. It is known as environmental friendly solvent, and the DMSO can be efficiently recovered from aqueous solutions – even though contaminated with volatile and/or non-volatile impurities – by distillation due to its high boiling point (189 °C). This paper compares two technologies an open and closed system from viewpoint of sustainability, by LCA, in which the DMSO used as solvent, and it was recovered.

Introduction

The factory of the Project Promoter S-Metalltech 98 Ltd. produces arsenic, phosphorus,iodine and fluorine removal adsorber for drinking and technological waters. During the production process 1m^3 high 20 w/w% dimethyl sulfoxide(DMSO) content hazardous waste water is produced daily, which needs to be collected and transferred to the incineration plant to be burned, sothe transferred DMSO need to be replaced with fresh solvent in the production process.This method is really expensive and also has significant negative effect on the environment, due to these reasons the Project Promoter seeks to modernize the production technology regarding both the treatment of the waste water and the solvent replacement (this project is called "DMSO contaminated industrial waste water recycling by distillation").The waste water beside DMSO contains:soluble polymer – ethylene-vinyl alcohol copolymer (EVOH) and minerals such as cerium-hydroxide.

The aims of the project are:

- to reduce the volume of the hazardous waste water,
- to reuse the recovered solvent and water in the production process so to turn the open manufacturing system into a closed one.

The solvent recycling meets with the new initiative of European Environmental Policy as „the Circular Economy" as achieve a new way towards the green and sustainable economy. An EU action plan for „the Circular Economy", the overall objective of resource efficiency can be achieved only through the implementation of circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized[5].

Experimental

Dimethyl sulfoxide (DMSO) is a sulfur-containing organic compound; molecule formula: $(CH_3)_2SO$. It exhibits as colorless, odorless, hygroscopic and flammable transparent liquid at room temperature. It has both high polarity as well as high-boiling point. It also has aprotic and water-miscible characteristics. DMSO is known as environmental friendly solvent that effectively dissolves numerous organic and inorganic chemicals. Its excellent safety characteristics have led to its use for a wide range of purposes, notably as a cleaning agent for electronic components, and as a reaction solvent for pharmaceuticals and agricultural chemicals.Vignes (2000) mentioned as "New" Clean, Unique, Superior Solvent, because it's low toxicity, the outstanding properties of DMSO when compared to competing solvents, and existing and potential applications. It has many benefits comparing with other solvent stated Marti et al. (2013), especially with well chosen recovery process [6]. The solvent recovery in a circular economy results economical benefit [2]and the life cycle assessment of recovery process shows objective result of environmental benefit [3],[1],[4], while the LCSA highlights both of environmental, economic and social effect too [7].

Applied methods during the project:

- qualitative and quantitative analysis of waste water components,
- separate the different types (water, solvent /DMSO/ and other components) with distillation and analyze the efficiency of the separations in laboratory level and also during the manufacturing process,
- prepare sustainability analysis based on technical performance, life-cycle analysis (analyze the environmental, economic and social impacts of these two processes with LCA, LCCA, S-LCA), CAPEX and OPEX in laboratory level and also during the manufacturing process.

This paper focuses to Life Cycle Assessment from aspect of sustainability, where the recovery of DMSO takes 98 % (scenario 1), and where beside this recovery it is used renewable resources too (scenario 2). The functional unit was 1 m^3AsMetadsorber product. The system boundaries were determined from gate to waste treatment. The analysis based on the ISO 14040 standard, ecoinvent database and CML 2001 method.

The flowchartsof two technologies show the differences. The open system results 1 m^3 per day waste water as hazardous waste, what after collection they transport to incineration.

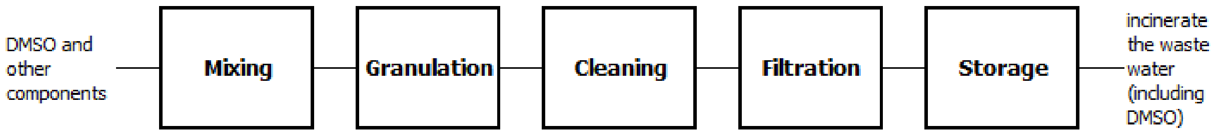

Figure 1. The current manufacturing process (open technology)

The closed technology as a model of circular economy contents a two steps distillation process with 98 % recovered of DMSO and recycled water.

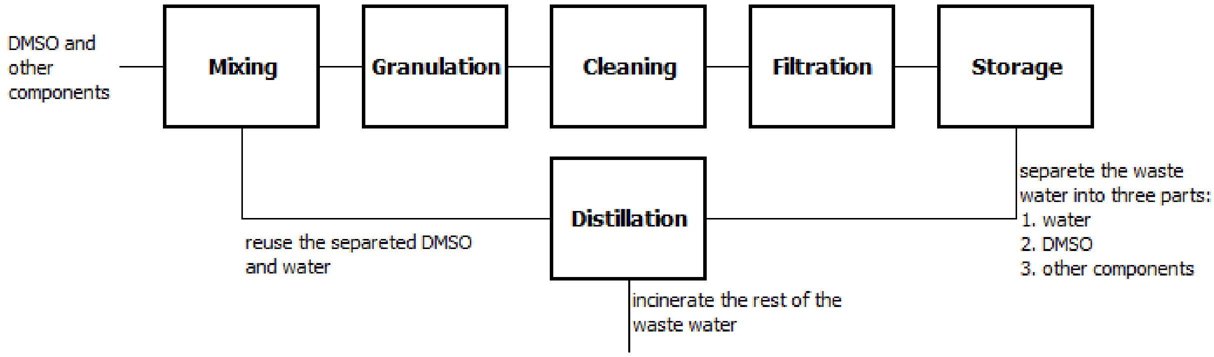

Figure 2. The planned manufacturing process (closed technology)

Results and discussion

The result of analyses shows although the recovery process requires additional electricity and technological equipments, but possible to recover the 98 % of DMSO in quite analytical purity. Comparing the environmental profile of 1 kg DMSO from database and recovery process there are significant differences in every impact category, and it results less environmental impact of closed technology too. There are the greatest differences in the adiabatic potential, global warming potential and ecotoxicity.

Table 1. Comparing Environmental impact of the DMSO(from database) and recovered DMSO, and recovered DMSO with solar PV (RES) (characteristic factors)

	Abiotic Deplation (ADP)	Acidifica-tionPotential (AP)	Eutrophica-tion Potential(EP)	Global WarmingPotential (GWP)	Human Toxicity (HT)	OzonelayerDeplation(ODP)	Photochemi-calOxydation (POP)
	kg Sbeq.	kg SO2 eq.	kg PO4 eq	kg CO2 eq	kg 1,4-DB eq	kg CFC_11 eq.	kg C_2H_4
DMSO	0,021	0,054	0,002	1,272	1,083	1,76E-07	1E-03
DMSO_R'	0,004221	0,002758	0,001693	0,569501	0,345368	3,4806E-08	0,000107
DMSO_R'+SPV	0,002906	0,001834	0,001089	0,395032	0,05917	2,3855E-08	7,18E-05

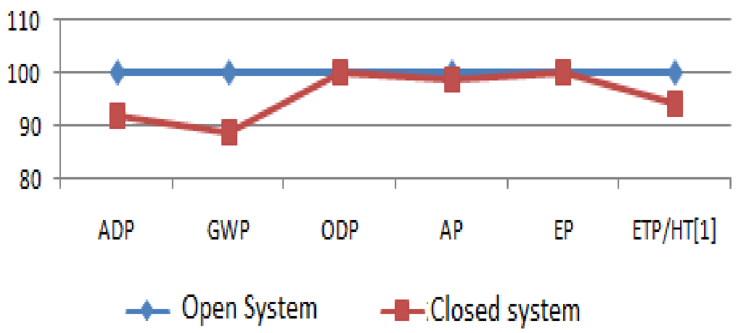

Figure 3. Environmental impact of the two technologies (open technology impact =100 %)

The criteria of sustainability is the following:

LCSA $_{open}$(=LCA+LCC+SLCA) > LCSA $_{closed}$(= LCA + LCC + SLCA),
and each of the three pillars has less impact in the closed system than in the opened one.

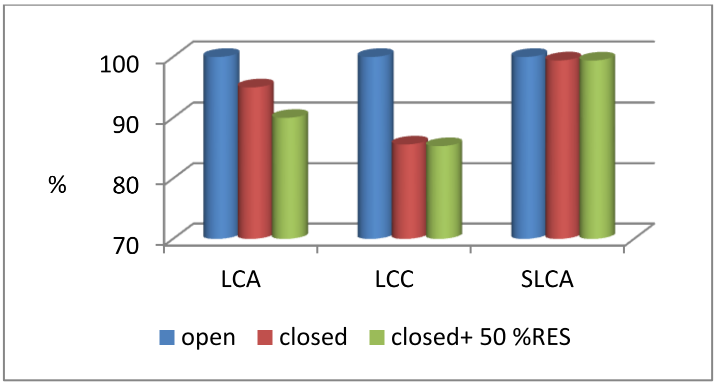

Figure 4. The sustainability assessment of the technologies

Conclusions

In our ongoing project we executed the preliminary measurements and due to these results we found the two-step vacuum distillation as the best solution. Now we are testing the efficiency of the separations in laboratory level and we started the life-cycle analysis and CAPEX, OPEX calculations.

We expected the following results at the end of the project according to preliminary estimates:

- the amount of hazardous waste water could be reduced from 265,2 ton/year to 5,5 ton/year, so with 98%;
- the amount of water used in the manufacturing process could be reduced approximately with 27%.
- the reused amount of the DMSO solvent depends on the efficiency of the distillation process, so its purity.

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