COURSE “Introduction to Green and Sustainable Chemistry”

Written exam (Mid-Term) - 05 December 2014

**1) A ten year old report concerning the positive and negative impact of the chain value (LCA) based on fossil or biological raw materials is reported below. Analyzing the environmental, social and economic effects, do You believe that the vision is correct, somewhere lacking or completely outdated in 2014?

⊕ Positive impact
⊖ Negative impact or risk

	Raw material sourcing	Chemical production	Product use and end-of-life options
Environmental effects	⊕ No hazards in raw material sourcing ⊕ Decrease in the consumption of non-renewable resources ⊕ Reduction in biomass-related waste ⊖ Risk of eutrophication due to use of fertilizers and plant protection products (not applicable to by-product streams) ⊖ Potential contribution of imported biomass to biodiversity losses	⊕ Reduction in non-renewable energy consumption ⊕ Reduction in GHG emissions ⊕ Modernisation of process technology and energy concepts ⊖ Increase in water consumption ⊖ Increase in particulate emissions from feedstock preparation	⊕ Less toxic waste ⊕ Less GHG emissions from waste incineration ⊕ Biodegradability offers opportunities for composting ⊕ Recycling possibilities of biobased products
Social effects	⊕ Contribution to rural development ⊖ Risk of involvement in the GMO controversy ⊖ Potential contribution of imported biomass to food insecurity	⊕ Contribution to rural development ⊕ Increasing sustainability and greening of chemical industry image ⊕ Reduction in VOC emissions improves workforce health and safety ⊖ Risk of involvement in the GMO controversy	⊕ Decrease in human toxicity ⊕ Contribution to sustainable development ⊖ Risk of involvement in the GMO controversy
Economic effects	⊕ Utilisation of wastes and by-product streams ⊕ Contribution to rural development ⊖ Competitiveness of raw materials compared to fossil fuels; possible need for subsidies ⊖ Need to develop the logistics of raw material sourcing	⊕ Contribution to innovations and European competitiveness ⊕ Creation of jobs and maintaining production in Europe ⊕ In some products, savings in production costs ⊖ Investment costs ⊖ Risks of up-scaling	⊕ Possible green premiums ⊕ Market entry in environmentally sensitive markets ⊕ Reacting on increasing consumer awareness ⊕ New innovations and products with superior functionality ⊕ Savings in waste charges

**2) In LCA the societal weighting factors for each category of environmental impact must be assigned. In the eco-efficiency analysis method of BASF the values reported in Figure 1 were applied.

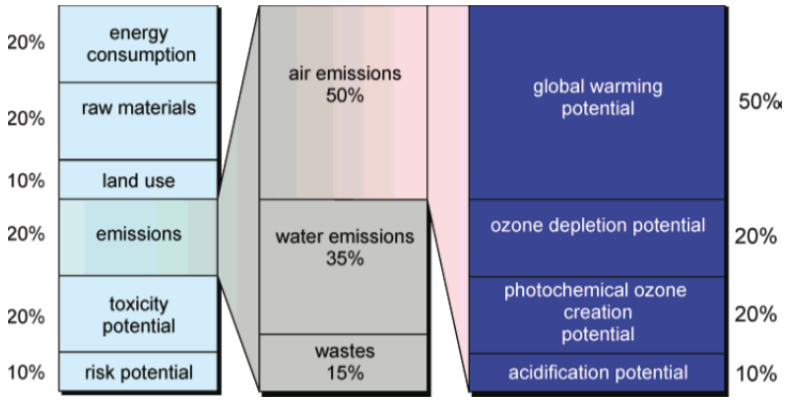


Fig. 1 - Weighting factors (proposed by BASF - Europe) for categories of environmental impact.

Do You think that these proposed weighting factors are appropriate? Suggest which quantitative data must be provided for a consistent evaluation of these parameters.

3) Assume that You are carrying out a life-cycle-assessment on the use of alternative 5 curing systems for coating of a polymer surface. (Curing is a polymerization process in which a tiny viscous film of a liquid at the surface of target material harden by applying an initiation agent (the symbols mends 2C-PU is polyurethane coating, AC is physical vapor deposition of carbon, NC is carbon deposition by plasma, UV is use of UV light of acrylic esters).
By using the data of Figure 2 and Figure 3, related to the complete LCA analysis of the 5 systems, deduce and explain which curing system is more environmental and economic sustainable.
i. What would be the functional unit used for the LCA?
ii. In what stage of the LCA is expect to find the greatest environmental impact for each alternative?

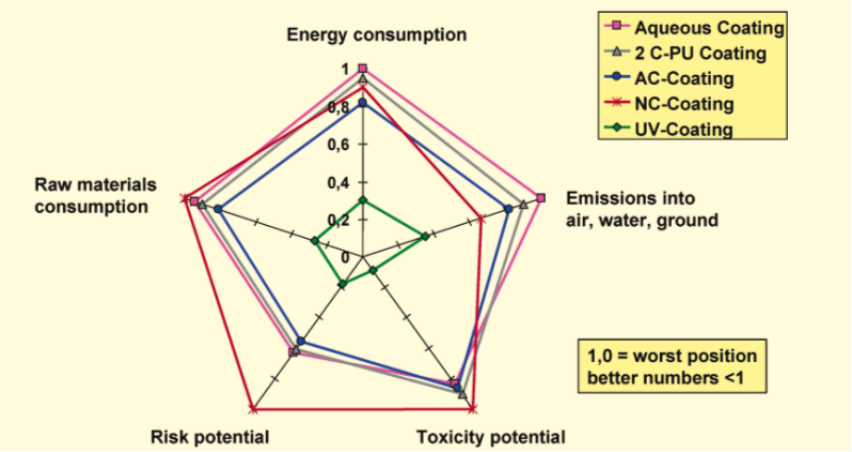


Fig. 2 - Environmental fingerprint for alternative curing systems

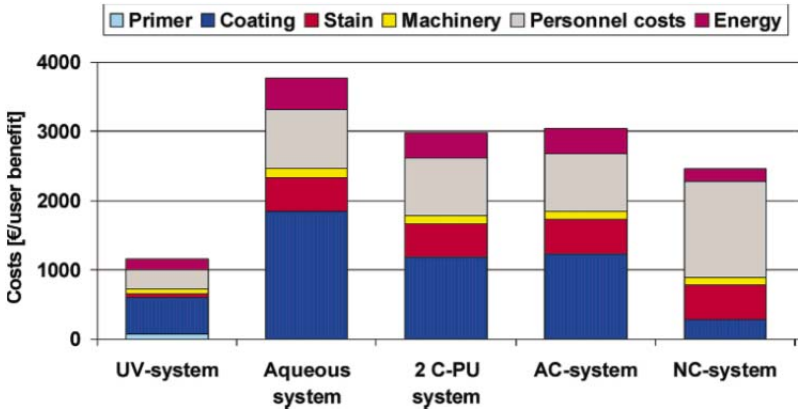
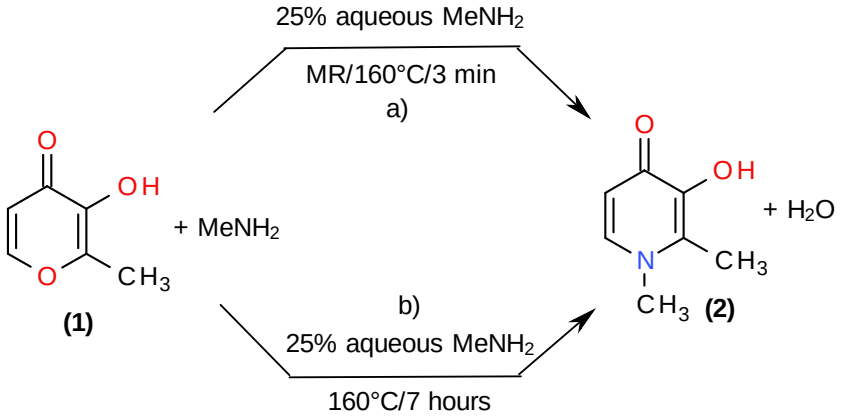


Fig. 3 - Life cycle cost calculation of alternative curing systems

4) Summarize the definitions of atom economy, E-factor and RME. Calculate these metrics for the following synthesis of 3-hydroxy-1,2-dimethyl-4-pyridone (deferiprone) (**2**) from maltol (**1**) through two alternative procedures: a) by microwave irradiation (80% conversion, 80% selectivity) in a Teflon vessel and b) by normal heating (86% conversion, 70% selectivity) in steel reactor. In both case a threefold excess of aqueous methylamine was used in a close vessel and nothing was recycled. Taking into account all experimental condition used and green metric parameters, which procedure is preferable? (Explain)



5) Discuss which of the following statements about biomass are true? Please select all that apply.
   a) Water supply is not a concern for large scale biomass production.
   b) Food production can be in competition with biomass production.
   c) Electricity from biomass does not require energy storage.

d) Biomass is not a carbon-neutral fuel.

**6) Which type of enzymes and microorganism are used in the production of bioethanol from starch seeds and from lignocellulosic feedstock? Explain briefly the molecular bases which make the first process somewhat more easy than the second one?

**7) “Bioavailability, bioactivity, space-temporal range, distribution and interaction mode with biological targets are the four physiological resorts to define the toxicology of chemicals and therefore to design benign chemicals and manage the toxicological risk”. Provide examples illustrating the concepts hold in this sentence.

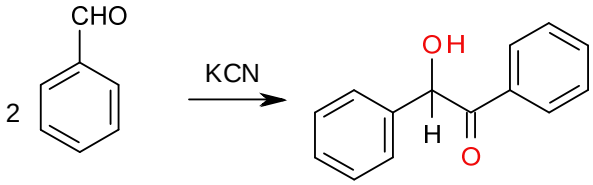
8) It’s correct to say that the twelve principle of Green Chemistry fall in four category: a) reduce energy use, b) reduce waste, c) reduce hazard, d) reduce resource use and utilize renewable materials?
The same categorization can be applied also to the twelve principles of Green Engineering? Explain.

9) Which of the following is true about toxicology: a) most substance are toxic at some level b) exposure pathway is irrelevant to effect of poison c) toxicity can easily be measured by devises and machines d) acute exposure occurs over long periods of time and the effect could take years to be realized.
By using examples and EU law framework explain the correct answer/answers.

10) Eco-industrial parks (EIP) are commonly based on the concept of industrial symbiosis (IS). It has been proposed that the collaboration opportunities in EIP can belong to three major groups, mutualization synergy, substitution synergy, and genesis synergy (creation of new activities and relocation of the existing ones). Can You give examples to clarify these terms?

*11) Green Chemistry is often said to be a 'cradle to grave' approach. Explain what this term means with specific reference to the industrial production of nylon-6,6 polymer.

*12) Benzoin can be obtained by heating benzaldehyde with potassium cyanide in a solvent-free condition (60% conversion, 95% selectivity).



The process can be considered as an example of green chemistry and green engineering? Suggest which approach You will suggest to improve further the greenness of the reaction.

*13) The following have been identified as advantages (a-d) and as disadvantages (e-f) of bioethanol as fuel:

a) good short term solution/ can use existing vehicles
b) conserves fossil fuel/ renewable
c) less reliance on imports
d) improves farm income
e) does not reduce other exhaust pollutants/example
f) land use/monoculture
g) will still need to be imported if an high proportion of current fuel demand must be reach
h) energy produced in combustion is lower than when gasoline is used.

13.1 Do You think that the analysis is complete or some advantages and disadvantages were missed?

13.2 The bioethanol production plant can also have its advantages and disadvantages, briefly explain?

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*For chemical engineering
**For environmental engineering