School of Engineering

OENG1118: Sustainable Engineering Practice and Design

Test 1 sample questions and answers

March 2021

Contents

1 LCA

What is the first phase of the life cycle assessment (LCA) technique?

What is the second phase of the life cycle assessment (LCA) technique?

What is the third phase of the life cycle assessment (LCA) technique?

What is the fourth phase of the life cycle assessment (LCA) technique?

2 Goal statement

List one intended application that an LCA study can support?

List one audience at which an LCA study be aimed?

We use the goal to decide which of the following to include:

A. Life cycle stages
B. Processes
C. Flows
D. Environmental impacts
E. Language
F. All listed options

3 Functional unit

In an LCA study of a light bulb, the functional unit is: *X of artificial light for Y*. What are the most-correct values of *X* and *Y*?

A. X = 500 lumens, Y = 10,000 hours
B. X = maximum light intensity, Y = 10,000 hours
C. X = average light intensity, Y = the warranty period
D. X = 500 lumens, Y = the warranty period

4 Cut-off criteria

Which of the following statements is NOT a valid cut-off criteria?

- Mass
- Energy
- Environmental relevance
- Mass: Exclude flows that are < 1% of the cumulative mass of all the inputs and outputs
- Energy: Exclude flows that are < 1% of the cumulative energy of all the inputs and outputs
- Environmental relevance: Include flows that potentially have a significant environmental impact, even if they meet the above criteria
- The sum of the excluded flows shall not exceed 1% of mass, energy or environmental relevance

5 Data quality assessment

Which of the data quality assessment criteria may be defined by the percentage of locations reporting primary data from the potential number in existence for each data category in a unit process?

6 Characterisation factors

Write down one characterisation factor (numerical value and unit of measurement) and its impact category.

7 Characterisation

A process emits the following air emissions:

- 7 kg NH_3
- 11 kg SO_2
- 9 kg NO_2
- 4 kg SO

Using the ReCiPe Hierarchist characterisation factors, calculate the particulate matter formation indicator result and the human health indicator result.

8 Normalisation reference values

Write down one reference value (numerical value and unit of measurement).

9 Normalisation

A process has a terrestrial acidification impact of 50 kg SO_2-eq. Using the ReCiPe World, per-person per-year, Hierarchist reference values, calculate the normalised indicator result.

10 Weighting

A process has the following normalised environmental impacts:

- Ecosystems: 8.1×10^{-9} person.year
- Resources: 1.3×10^{-8} person.year
- Human health: 6.9×10^{-9} person.year

Using the ReCiPe average weighting factors, calculate the weighted score.
Note: Ignore the 'Total' factor of 1000. Do not multiply or divide by 1000.

11 Impact assessment

A process has the following inputs and outputs:

- X kg substance A
- Y kg substance B
- Z kg substance C

Calculate the weighted score using the ReCiPe Hierarchist factors and reference values.

12 Contribution

The table shows the characterised freshwater eutrophication results for a product's life cycle. What is the contribution to freshwater eutrophication of the highest-contributing substance in any single life-cycle stage?

Inventory (input/output)	Raw materials extraction	Manufacturing	Transport	Use	End-of-life	Total
Phosphorus (kg P-eq)	4.9	199	0	0	0.8	204.7
Phosphate (kg P-eq)	0.9	201	0	202	1.1	405.0
Phosphoric acid (kg P-eq)	0	73	20	178	0	271.0
Phosphorus pentoxide (kg P-eq)	0	144	28	51	1.4	224.4
Total (kg P-eq)	5.8	617	48	431	3.3	1105.1

13 Uncertainty: variance

Using the ecoinvent 2 method, what is the variance (σ_g^2) for a hard coal input of 2000 kg (combustion) given the following data quality assessment?

- Reliability: Verified data based on measurements
- Completeness: Representative data from only one site relevant for the market considered or some site but from shorter periods
- Temporal correlation: 17 years of difference to our reference year
- Geographical correlation: Data from area under study
- Further technological correlation: Data from processes and materials under study but from different technology

14 Uncertainty: confidence interval

Assuming a lognormal probability distribution, what is the 95.5% confidence interval for a hard coal input of 2000 kg with a variance (σ_g^2) of 1.5798?

15 Sensitivity

A product's lifecycle has an ionizing radiation impact of 0.000350 kBq Co-60 to air-eq, of which a krypton 85 (Kr-85) emission of 9 kBq is the highest contributor and most uncertain. Given that the plausible range of the krypton 85 emission is 7-13 kBq, and using the ReCiPe Hierarchist characterisation factors, calculate the plausible range of the life-cycle ionizing radiation impact.

16 Answers:

1. ……
2. ……
3. ……
4. ……
5. ……
6. ……
7. Calculations:

From the *ReCiPe 2016 v 1.1* database workbook, in the *Particulate matter formation* worksheet, we find the following characterisation factors:

- NH_3: 0.24 kg PM2.5-eq/kg
- SO_2: 0.29 kg PM2.5-eq/kg
- NO_2: 0.11 kg PM2.5-eq/kg
- SO: 0.39 kg PM2.5-eq/kg

Particulate matter formation
= flow$_1$ x characterisation factor$_1$ +
flow$_2$ x characterisation factor$_2$ +…
flow$_n$ x characterisation factor$_n$
= 7 kg NH_3 x 0.24 kg PM2.5-eq/kg NH_3 +
11 kg SO_2 x 0.29 kg PM2.5-eq/SO_2 +
9 kg NO_2 x 0.11 kg PM2.5-eq/NO_2 +
4 kg SO x 0.39 kg PM2.5-eq/SO
= 1.68 kg PM2.5-eq + 3.19 kg PM2.5-eq + 0.99 kg PM2.5-eq + 1.56 kg PM2.5-eq
= **7.42 kg PM2.5-eq**

From the *ReCiPe 2016 v 1.1 characterisation factors* workbook, in the *Midpoint to endpoint factor* worksheet, we find the following mid-to-end factor:

- Fine particulate matter formation - Human health: 0.000629 DALY/kg PM2.5-eq

Human health
= midpoint indicator result x mid-to-end factor
= 7.42 kg PM2.5-eq x 0.000629 DALY/kg PM2.5-eq
= **0.00467 DALY**

8. ……
9. Calculations:

From the *ReCiPe 2016 v 1.1 normalization scores* workbook, in the *Final normalization scores* worksheet, we find the following reference value:

- 40.98 kg SO_2-eq/p/yr

Normalised indicator result
= impact category indicator result / reference value
= 50 kg SO_2-eq / 40.98 kg SO_2-eq/p/yr
= **1.22 person.year**

A process has a resources impact of $450 because of its use of aluminium. Using the ReCiPe World, per-year per-year, Hierarchist reference values, calculate the normalised indicator result.

From the *ReCiPe 2016 v 1.1 normalization scores* workbook, in the *Final normalization scores* worksheet, in the *Mineral resource scarcity* row, we find the following reference value:

- $27,741.96/p/yr

Normalised indicator result
= impact category indicator result / reference value
= $450 / $27,741.96/p/yr
= **0.016 person.year**

10. Calculations:

From the *OENG1118 LCA impact assessment* slides, in the *Weighting* section, we find the following weighting factors:

- Ecosystems: 400
- Resources: 200
- Human health: 400

Weighted result
= normalised Ecosystems result x Ecosystems weighting factor + normalised Resources result x Resources weighting factor + normalised Human Health result x Human Health weighting factor
= 8.1×10^{-9} person.year x 400 Pt/person.year + 1.3×10^{-8} person.year x 200 Pt/person.year + 6.9×10^{-9} person.year x 400 Pt/person.year
= 3.24×10^{-6} Pt + 2.60×10^{-6} Pt + 2.76×10^{-6} Pt
= **8.6×10^{-6} Pt**

11. Instructions:
    - Insert your own flow quantities and substances
    - Calculate the weighted score by combining the steps in the previous answers.
12. Tables:

Inventory (input/output)	Raw materials extraction	Manufacturing	Transport	Use	End-of-life	Total
Phosphorus (kg P-eq)	4.9	199	0	0	0.8	204.7
Phosphate (kg P-eq)	0.9	201	0	202	1.1	405.0
Phosphoric acid (kg P-eq)	0	73	20	178	0	271.0
Phosphorus pentoxide (kg P-eq)	0	144	28	51	1.4	224.4
Total (kg P-eq)	5.8	617	48	431	3.3	1105.1

13. Calculations:

From the *LCA: Interpretation* slides (p. 16), we find the following U_1-U_5:

Criterion	Score	U factor
Reliability	1	$U_1 = 1$
Completeness	4	$U_2 = 1.1$
Temporal correlation	5	$U_3 = 1.5$
Geographical correlation	1	$U_4 = 1$
Further technological correlation	3	$U_5 = 1.2$

From the *LCA: Interpretation* slides (p. 17), we find the following U_b:

- Resources > Primary energy carriers, $U_b = 1.05$

$$\sigma_g^{\;2} = \exp^{\sqrt{[\ln(U_1)]^2+[\ln(U_2)]^2+[\ln(U_3)]^2+[\ln(U_4)]^2+[\ln(U_5)]^2+[\ln(U_b)]^2}}$$

= exp √ ($[\ln(1)]^2 + [\ln(1.1)]^2 + [\ln(1.5)]^2 + [\ln(1)]^2 + [\ln(1.2)]^2 + [\ln(1.05)]^2$)
= exp √ (0 + 0.0091 + 0 + 0.1644 + 0.0332 + 0.0024)
= exp √ (0.2091)
= $e^{0.4573}$
= **1.5798**

For a lognormal probability distribution, the 95.5% confidence interval:
Upper bound
= mean x σ_g^2
= 2000 kg x 1.5798
= 3160 kg

For a lognormal probability distribution, the 95.5% confidence interval:
Lower bound
= mean / σ_g^2
= 2000 kg / 1.5798
= 1266 kg

Therefore, the 95.5% confidence interval is **[1266 kg, 3160 kg]**.

14. Calculations:

For a lognormal probability distribution, the 95.5% confidence interval:
Upper bound
= mean x σ_g^2
= 2000 kg x 1.5798
= 3160 kg

For a lognormal probability distribution, the 95.5% confidence interval:
Lower bound
= mean / σ_g^2
= 2000 kg / 1.5798
= 1266 kg

Therefore, the 95.5% confidence interval is **[1266 kg, 3160 kg]**.

15. Calculations

From the *ReCiPe 2016 v 1.1* database workbook, in the *Ionizing radiation* worksheet, we find the following characterisation factor:

- Kr-85: 0.00000848 kBq Co-60 to air-eq/kBq

Kr-85 ionizing radiation
= flow x characterisation factor

Therefore,
Kr-85 ionizing radiation mean
= 9 kBq Kr-85 x 0.00000848 kBq Co-60 to air-eq/kBq Kr-85
= 0.00007632 kBq Co-60 to air-eq

Kr-85 ionizing radiation lower bound
= 7 kBq Kr-85 x 0.00000848 kBq Co-60 to air-eq/kBq Kr-85
= 0.00005936 kBq Co-60 to air-eq

Kr-85 ionizing radiation upper bound
= 13 kBq Kr-85 x 0.00000848 kBq Co-60 to air-eq/kBq Kr-85
= 0.00011024 kBq Co-60 to air-eq

Life-cycle ionizing radiation lower bound
= Life-cycle ionizing radiation mean - Kr-85 ionizing radiation mean + Kr-85 ionizing radiation lower bound
= 0.000350 kBq Co-60 to air-eq - 0.00007632 kBq Co-60 to air-eq + 0.00005936 kBq Co-60 to air-eq
= 0.000333 kBq Co-60 to air-eq

Life-cycle ionizing radiation upper bound
= Life-cycle ionizing radiation mean - Kr-85 ionizing radiation mean + Kr-85 ionizing radiation upper bound
= 0.000350 kBq Co-60 to air-eq - 0.00007632 kBq Co-60 to air-eq + 0.00011024 kBq Co-60 to air-eq
= 0.000401 kBq Co-60 to air-eq

Therefore, life-cycle ionizing radiation is **[0.000333 kBq Co-60 to air-eq, 0.000401 kBq Co-60 to air-eq]**