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Amsterdam, June 30th 2015

Subject : LCA Quickscan Filter back wash water reuse

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Dear Mr. Dubbelink,

Please find enclosed the LCA Quickscan for the ceramic filter back wash water reuse system.

If you have any questions or comments, please contact me. If you want to extend certain investigations, or if you want to proceed in and full LCA, please let me know.

Kind regards

Search Consultancy B.V.



Gert-Jan Vroeg

LCA Background Report

Search Consultancy B.V.

Filter back wash water reuse

According to ISO 14040 and ISO 14044

Research data

Research type	LCA Quick Scan
Date	May-June 2015
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1 General aspects

1.1 LCA commissioner and practitioner

This LCA-research is conducted by Gert-Jan Vroege and commissioned by Search Consultancy B.V.

1.2 Date of report

June 30th 2015

1.3 Standards

This LCA-report complies with the standards set by ISO14040 and ISO14044. The LCA research is a quickscan, there has been no third party review. The EcolInvent database and the Dutch Nationale Milieudatabase are the bases for environmental data sources.

1.4 Goal of the study

1) Reasons for carrying out the study

The goal of this study is to evaluate the environmental impacts of the ceramic filter back wash water reuse system that is tested at the Vitens location WTP Wierden.

2) The intended applications

3) The target audiences

This report is written for: the grant provider of the project IWEC, the members of the consortium and the public.

1.5 Scope of the study

1) Function

The function of the study is to compare the environmental impact between three scenarios in treating backwater by the production of drinking water. The three scenarios are:

1. Base scenario, back wash water is not filtered and discarded as supernatant and sludge. Indicated as "1. Base";
2. Filter scenario, back wash water is filtered by a ceramic filter to reuse it as drinking water. Indicated as "2. Filter";
3. Future scenario, optimization of scenario 2 with the use of less energy. Indicated as "3. Optimized energy".

2) Functional unit

The functional unit is m³ drinking water.

3) System boundary

For this study the system boundary is set for the back wash water process. Included in de production stage:

- Energy for de backwater system in the three scenario's;
- Production and transport of (raw) material used in the back wash water process;
- Production and transport of extra infrastructure installed for scenario 2 and 3. The extra infrastructure is taken into account in this retro fit situation;
- Waste scenario's for phase the discard of materials of the back wash water process;
- Emissions to river and ground.

The back wash water process causes several gains outside the system boundary. These gains are taken into account as avoided production (i.e. energy, transport, material).

The use phase has not been taken into account in this analysis.

The end-of-life has not been taken into account in this analysis.

This is a cradle-to-gate LCA.

See figure 1 for system boundary, with outlined boundary for Filter Scenario: back wash water is filtered by a ceramic filter to reuse it as drinking water.

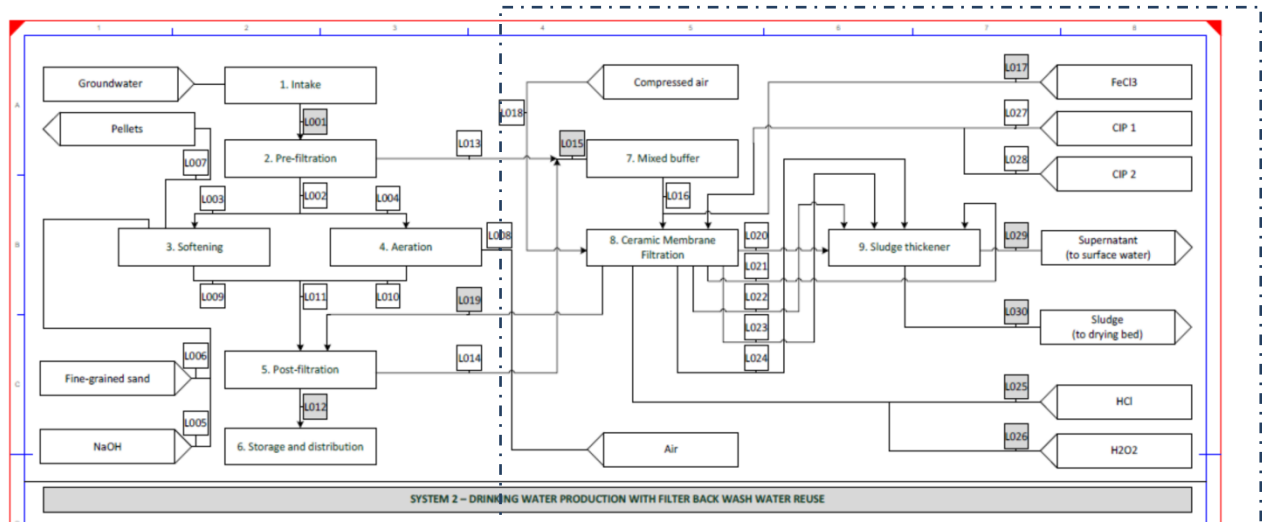


Figure 1. Scheme of System Boundary (boundary for outlined)

4) cut-off criteria for initial inclusion of inputs and output

The cut-off criteria in this analysis are based on economic tipping point of materials. Furthermore, all mass and energy related to the study have been taken into account for this study. All emissions to air, soil and water have been taken into account as far as characterized by CML-2013.

2 Life cycle inventory analysis

2.1 Data collection procedures

The data used for the products, co-products and waste for this study is provided by RWB Water Services and Vitens. The production data of the year 2014. Internationally accepted databases have been used. The references for the energy inputs, raw material inputs, ancillary inputs and other physical inputs are listed in table 4.

Emissions to air, discharges to water and soil and other environmental aspects related to the production of Test Search were derived from environmental permits.

For the waste phase a scenario has been made based on current waste treatment processes for these types of materials.

1. Base scenario

Nr.	Material base scenario	Total amount per year	Unit	Source of data	Remarks
L001	Ground water	7.021.589	m3	Baseline report	From 3 fields
L013	Back wash water (direct)	221.700	m3	Base line report	
L014	Back wash water (after post filtration)		m3		
L017	FeCl3, liquid 42% solution	4.345	kg		Dosage 19,6 mg/l
L018	Supernatant	220.940	m3		
L020	Supernatant		m3		
L021	Sludge	760.000	kg	Base line report	Dry matter 11,7 %.
	Drinking Water produced	6.799.889	m3		

Table 1. Material base scenario

nr.	Process Energy back wash water treatment base scenario	Total amount per year	Unit	Source of data	Remarks
	Energy	0	kWh	baseline report (total energy consumption of drinking water production plant)	Green with Guarantee of Origin.

Table 2. Proces base scenario

Nr.	Transport base scenario	Type of transport	Distance one-way in km	Average loading factor return transport
T4	Transport of FeCl3	Truck > 16 ton	150	0%
T5	Transport of Sludge	Truck > 28 ton	50	0%

Table 3. Transport base scenario

2. and 3. Filter and “optimized energy” scenario with filtration

Nr.	Material filter and “optimized energy” scenario	Description	Total amount per year	Unit	Source of data
L001	Ground water		6.802.038	m3	calculation from de base line result
L013	Back wash water (direct)		214.768	m3	Calculated from de base line result
L014	Back wash water (after post filtration)				
L017	FeCl3, liquid 42% solution	2 mg/l per litre permeate	430	kg	Data analysis
L025	HCl, liquid 10% solution	5 kg HCl per 1000 m3 ground water	1.074	kg	Data analysis
L026	H2O2, liquid 35% solution	1,14 kg H2O2 per 1000 m3 ground water	245	kg	Data analysis
L027	CIP 1 citric acid		20	kg	Process and membrane
L028	CIP 2 hypochlorite 150 g/l active chloride		40	liter	Process and membrane
L021	Sludge from sludge thickener, dry matter 12%		727.000	kg	Base line results
L018/L020	Supernatant		1.421	m3	Calculated
	Drinking water produced		6.799.890	m3	
Infrastructure					In optimized infra scenario
	Installation Steel	Life cycle 50 years	8.910	kg	4.370 kg.
	Installation Ceramic membrane	Life cycle 25 years	600	kg	290 kg
	Installation Concrete foundation	Life cycle 50 years	70.000	kg	34300 kg
	Installation Plastic	Life cycle 50 years	1.740	kg	850 kg

Table 4. Material filter and “optimized energy” scenarios

Process back wash water treatment	Total amount per year	Unit	Remarks	Source of data
Energy filter scenario	53.907	kWh	Green with Guarantee of Origin (total energy consumption of drinking water production plant)	Baseline result and data analysis included mixer in buffer
Energy optimized scenario	30.282	kWh	Green with Guarantee of Origin (total energy consumption of drinking water production plant)	Baseline result and data analysis without mixer in buffer

Table 5. Energy filter and “optimized energy” scenarios

Nr.	Transport	Type of transport.	Distance one-way in km	Average loading factor return transport
T4	Transport of FeCl3	Truck > 16 ton	150	0%
T5	Transport of Sludge	Truck > 28 ton	50	0%
T6	Transport of HCl	Truck > 16 ton	150	0%
T7	Transport of H2O2	Truck > 16 ton	150	0%
T8	Transport of CIP 1	Truck > 16 ton	150	0%
T8	Transport of CIP 2	Truck > 16 ton	150	0%

Table 6. Transport filter and “optimized energy” scenarios

In scenario 2 and 3, the outside system boundary gains are:

- 13,554 ton less Sodium Hydroxide 50% solution is used (material and transport);
- 0,00595 kWh less energy per m3 drinking water (f.e.) is used because of less energy consumption of ground water and less energy in filtration systems.

Conclusions from the data collection:

- 3,2% of the ground water is lost in the back water process in the Base scenario . In the Filter and “Optimized energy” scenarios only 0,03% is lost;
- 90,1% less FeCl3 is used in the Filter and “Optimized energy” scenarios;
- 33% more energy is used in the Filter scenario. In the “Optimized energy” scenario the energy used is 25% less than the base scenario;
- HCl, liquid 10% solution, H2O2, liquid 35% solution, citric acid, hypochlorite 150 g/l active chloride are introduced in the filter and “Optimized energy” scenario;
- 99,3 % less supernatant is discharged in the filter and “Optimized energy” scenarios;
- The infrastructure is over dimensioned in this project. Half of the size will be the right dimension for the production of this site.

2.2 Qualitative and quantitative description of unit processes and sources of published literature

This chapter shows which reference materials have been used in this study and from which source they have been derived. Taken into account that it is a LCA scan.

Material, emissions and waste	Reference material	Source	Motivation, if not exact fitting
Ground water	Water, well, in ground/m3	Basic	
FeCl3, liquid 42% solution	Iron (III) chloride, 40% in H2O, at plant/CH S	Ecoinvent 2.2	Difference in solution % doesn't have influence, since the impact

RWB Water Services B.V.

Mr. E. Dubbelink

30-6-2015

Material, emissions and waste	Reference material	Source	Motivation, if not exact fitting
			is in kg pure material
HCl, liquid 10% solution	Hydrochloric acid, 30% in H ₂ O, at plant/RER S	Ecoinvent 2.2	Difference in solution % doesn't have influence, since the impact is in kg pure material
H ₂ O ₂ , liquid 35% solution	Hydrogen peroxide, 50% in H ₂ O, at plant/RER S	Ecoinvent 2.2	Difference in solution % doesn't have influence, since the impact is in kg pure material
CIP 1 citric acid	Adipic acid, at plant/RER S	Ecoinvent 2.2	Citric acid is not available in common databases, Adipic is the most fitting
CIP 2 hypochlorite 150 g/l active chloride	Sodium chlorate, powder, at plant/RER S	Ecoinvent 2.2	
Energy	Electricity, at wind power plant 2MW, offshore/OCE S	Ecoinvent 2.2	100% Dutch wind, with Guarantee of Origin
Sodium Hydroxide	Sodium hydroxide, 50% in H ₂ O, production mix, at plant/RER S	Ecoinvent 2.2	
Transport bulk	SBK vrachtwagen > 28 ton vol heen leeg terug (Truck > 28t empty return)	Nat. Milieu Database	
Transport chemicals	SBK vrachtwagen > 16 ton enkele reis vol (Truck > 26t empty return)	Nat. Milieu Database	
Installation Ceramic membrane	Sanitary ceramics, at regional storage/CH S	Ecoinvent 2.2	Sanitary ceramics is the only ceramic available
Installation Steel	SBK Steel, Medium Construction Products c2	Nat. Milieu Database	
Installation Concrete foundation	SBK 1032 Betonmortel C20/25 (CEM III)	Ecoinvent 2.2	Sanitary ceramics is the only ceramic available
Installation Plastic	Polycarbonate, at plant/RER S	Ecoinvent 2.2	
Waste scenario Supernatant to surface water	Waste water emission to water (river)	Basic emission	
Waste scenario Sludge	Sludge eff. Cleaning final waste stream	Basic emission	Sludge is used as building material (construction for road) no waste process is needed, therefore only transport is taken into account
Waste scenario Hypochlorite to surface water	Sodium hypochlorite emission to water, river	Basic emission	
Waste scenario FeCl ₃ to sludge and surface water	Iron waste to ground, HCL to water, river	Basic emission	FeCl ₃ reacts with 3H ₂ O to Fe(OH) ₃ an 3 HCL. Fe(OH) ₃ causes Flocculation and is not soluble.
Waste scenario HCL to surface water	Hydrogen chloride emission to water, river	Basic emission	
Waste scenario Citric Acid to surface water	Citric acid emission to water, river	Basic emission	
Waste scenario H ₂ O ₂ to surface water	H ₂ O ₂ is dissolving in H ₂) and)2, therefor no waste scenario is added		

Table 7. Used reference materials

2.3 Validation of data

Since only one production site has been taken into account for this analysis, no aggregation has been made. This ensures an accurate technological and geographical representation.

2.4 Sensitivity analysis for refining the system boundary

The system boundary in this report is consistent with the goal and scope and with the unit processes stated earlier. Therefore, no further revision of the system boundary has been made.

2.5 Allocation principles and procedures

No allocation is needed, all materials and energy is allocated to the back wash water process.

3. Life cycle impact assessment

3.1 The LCIA procedures, calculations and results of the study

The values of the impact categories are calculated by assigning the environmental impacts from the inventory to the impact categories, multiplying the environmental impacts with the characterization factors and summing the values for each impact category. The scores for the different impact categories together form the LCIA profile. The LCIA profile is shown in table 8.

Effect category	Unit	scenarios		
		1. Base	2. Filter	3. "Optimized energy"
abiotic depletion, non fuel (AD)	kg Sb eq	1,127E-08	-6,132E-10	-1,635E-09
abiotic depletion, fuel (AD)	kg Sb eq	1,182E-05	2,200E-06	1,870E-06
global warming (GWP)	kg CO2 eq	1,620E-03	3,463E-04	2,968E-04
ozone layer depletion (ODP)	kg CFC-11 eq	8,540E-10	3,078E-10	3,048E-10
photochemical oxidation (POCP)	kg C2H4	1,121E-06	7,067E-07	6,797E-07
acidification (AP)	kg SO2 eq	8,470E-06	1,567E-06	1,355E-06
eutrophication (EP)	kg PO4 ⁻⁻⁻ eq	1,784E-06	7,007E-07	6,614E-07
human toxicity (HT)	kg 1,4-DB eq	8,423E-04	2,185E-04	2,990E-05
Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	2,018E-05	7,086E-06	6,333E-06
Ecotoxicity, marine water (MAETP)	kg 1,4-DB eq	8,663E-02	1,202E-02	9,593E-03
Ecotoxicity, terrestrial (TETP)	kg 1,4-DB eq	1,518E-05	-1,518E-05	-1,576E-05
Energy, primary (MJ)	MJ	2,965E-02	5,470E-03	-8,427E-03
Energy, primary, renewable (MJ)	MJ	9,714E-04	3,158E-03	-1,004E-02
Energy, primary, non-renewable (MJ)	MJ	2,868E-02	2,312E-03	1,613E-03
Waste, hazardous (kg)	kg	0,000E+00	5,104E-06	5,104E-06
Waste, non hazardous (kg)	kg	1,124E-01	1,069E-01	1,069E-01
Water, fresh water use	m3	1,038E+00	9,951E-01	9,948E-01

Table 8 - The environmental profile

The green marked number are indicating lower figures than the Base scenario.

3.2 The relationship and limitations of the LCIA results relative to the defined goal and scope of the LCA

The LCIA shows clearly the differences of the environmental impacts for the three scenarios. The LCIA results are contributing to the further LCA analyses .

Possible relevant limitations are:

- The absence of a good reference material for the ceramic;
- The "Optimized energy" scenario is a prediction;
- The energy is 100% wind generated in the Vitens case;
- Waste, hazardous is due to the installed infrastructure;
- The boundary is set tight to only the back wash water system. The out of side boundary effects are casing gains that lead to negative impacts (positive environmental impact). This looks strange, for further study it is recommended to set the boundary for the entire plant.

3.3 Characterization models, characterization factors and methods used.

The impact categories and category indicators considered are shown in table 9. The categories and characterization factors are derived from CML-2013. For more information on methodology and value choices, see CML-IA Characterization Factors from CML, Leiden. The impact categories and category indicators used have been selected because they show an accurate depiction of the overall environmental impact of the goal and scope of the system studied here.

3.4 Weighting

Weighting is the process of converting indicator results of different impact categories by using numerical factors based on value-choices. It may include aggregation of the weighted indicator results. To achieve the goal set under goal and scope, for this study, the Societal Cost Indicator (SCI) is used as a means of weighting impact categories into one endpoint. Table 9 shows which conversion factors are used for calculating the Societal Cost Indicator (SCI).

The SCI is an indication and the value choices and justification for the use of SCI can be found in the report "Toxicity has its price" by TNO, 2004.

Effect category	SCI Factor (euro)
Climate change (kg CO ₂)	0.05
Energy (MJ)	0
Abiotic depletion (kg Sb)	0.16
Abiot. Depl. Fuel (kg Sb)	0.16
Ozone (kg CFK11)	30
Human toxicity (kg 1,4 DB)	0.09
Freshwater tox. (kg 1,4 DB)	0.03
Freshwater sed. tox. (kg 1,4 DB)	0.02
Saltwater tox. (kg 1,4 DB)	0.0001
Saltwater tox. sed. (kg 1,4 DB)	0.0003
Soil toxicity (kg 1,4 DB)	0.06
Smog (kg C ₂ H ₄)	2
Acidification (kg SO ₂)	4
Eutrophication (kg PO ₄ 3-)	9

Table 9 - SCI values

Table 9 shows which conversion factors are used for calculating the Societal Cost Indicator (SCI). This enables specification of each environmental impact into the SCI. The SCI is strictly indicative.

4. Life cycle interpretation

4.1 Results

The LCIA results are listed in table 8 under life cycle impact assessment. In table 10 sensitivity analysis over the LCIA results is visualized. As described here above, the CML-2013 and Societal Cost Indicator (SCI) is used.

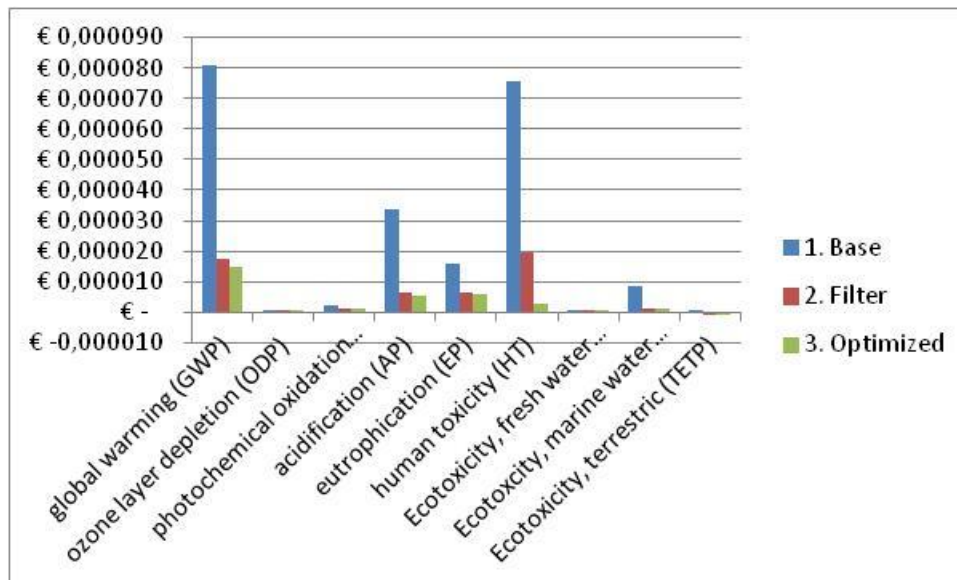


Figure 2 - End point analysis

Analysing the outcome of the CMI-2003 Societal Cost Indicator end point analysis:

- There is a significant better performance for the filter and optimized scenario;
- For the base scenario, GWP, Acidification and Human toxicity has a much higher impact than the two other scenario's.

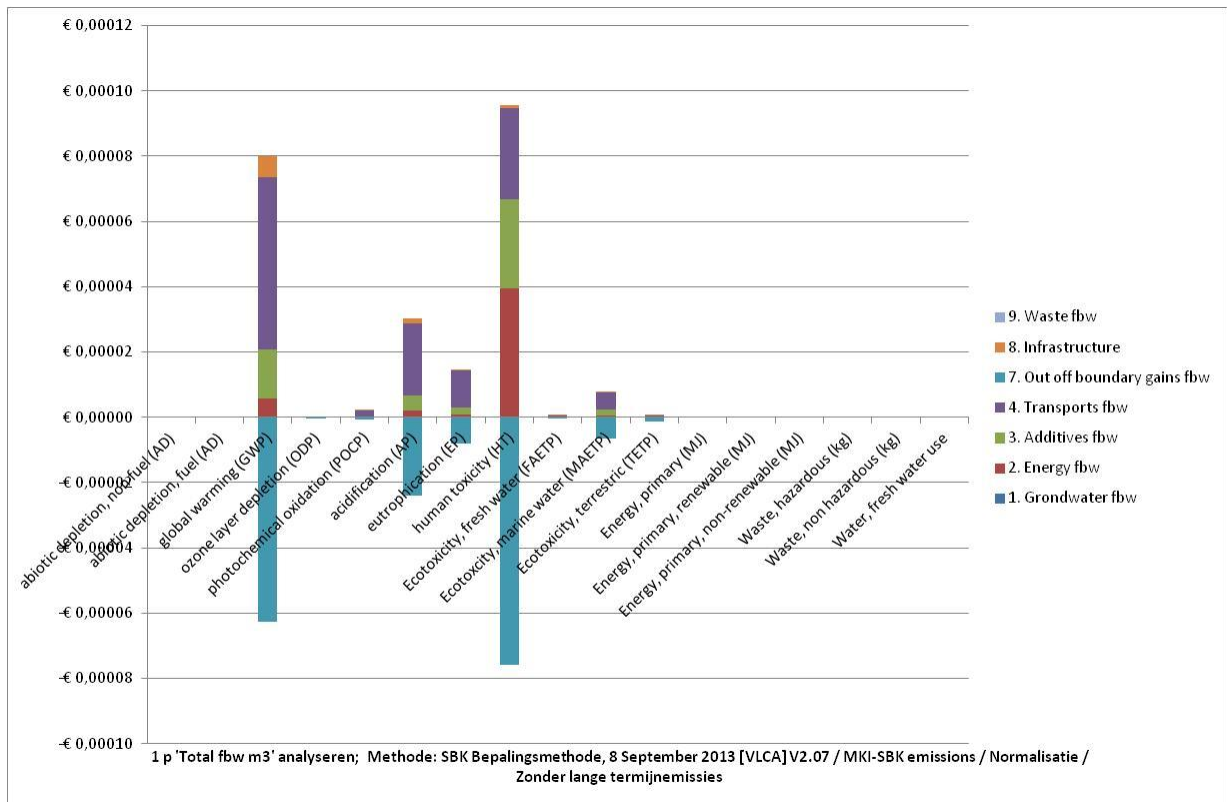


Figure 3 - End point analysis for Filter scenario

Figure 3 shows the total impact for the Filter scenario. This is showing the impact of the different processes. It is showing the out of boundary gains below the horizontal axis. Analysing the outcomes:

- Human Toxicity has the highest weighted impact, equally caused by transport, additives and energy. It has also the biggest gain, due to less use of Sodium Hydroxide for softening and less use of energy for the ground water pumps and softening and aeration process;
- Global Warming has the second highest impact and gain, the impact is mainly due to the transports. The gain is due to less use of Sodium Hydroxide;
- An optimized greenfield situation could further reduce the environmental impact. The usage of energy and the needed construction infrastructure will be reduced in the greenfield situation.

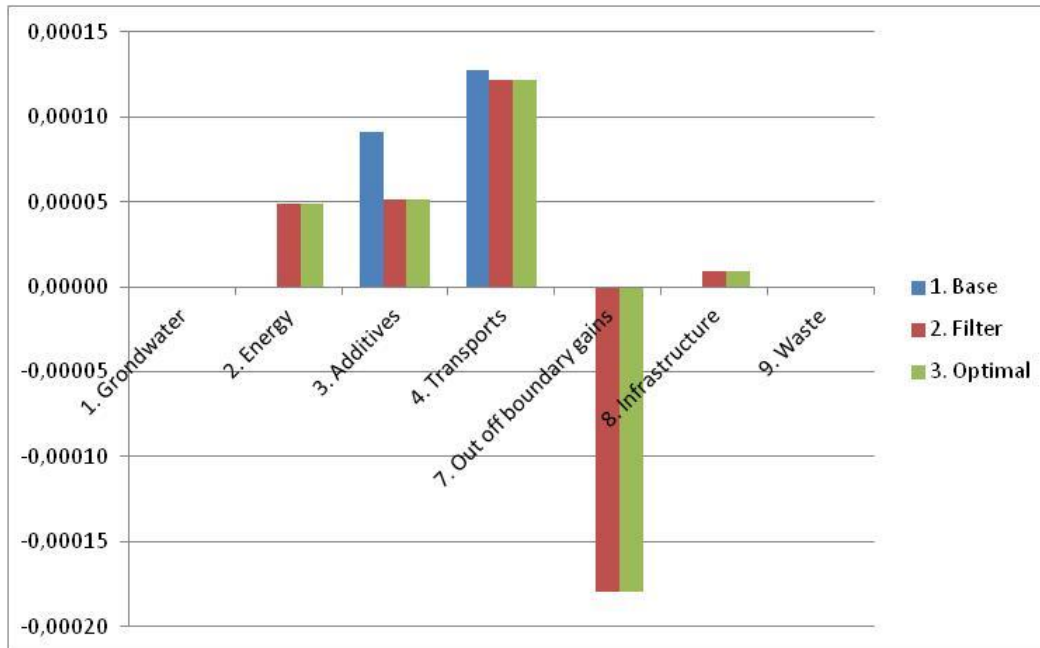


Figure 4 - End point analysis for three scenario's

Figure 4 shows the total impact for the three scenarios for the different processes.

- Depletion of ground water has no impact in the CML end point result;
- Energy for the back wash water treatment is zero in the base situation;
- Transport has the highest impact for the three scenario's , differences are relative small;
- An optimized greenfield situation could further reduce the environmental impact. The impact of the needed construction infrastructure is relative small compared to transport and additives. Optimization should be focused on those two.

4.2 Data quality assessment

As data is derived from direct and verified sources, the quality is considered of high enough level to meet the goal. Because of the quick scan character of this study no pedigree matrix for data quality analyses is made.

5. Specific indicators for IWEK project

The indicators for the IWEK project can be derived from the study. These results are shown in table 10.

Drinking water produced		6799890	m3								
Indicator	Midpoint methode	Eenheid	per m3 drinking water			per year (2014)			change		
			Base	Filter	Optimized	Base	Filter	Optimized	Filter	Optimized	
CO2	CML2013	ton CO2	1,543E-06	2,040E-07	1,581E-07	10,5	1,4	1,1	-9,10	-9,42	
Methane	CML2013	ton CO2eq	6,322E-08	1,214E-08	9,048E-09	0,430	0,083	0,062	-0,35	-0,37	
Methane	CML2013	ton Methane	3,161E-09	6,072E-10	4,524E-10	0,0	0,0	0,0	-0,017	-0,018	
PM	ReCipe	kg PM10eq	3,55E-06	1,39E-06	1,27E-06	24,2	9,5	8,6	-14,68	-15,54	
Mutagenic / Carcinogenic	Ecoindicator 99 Carcinogenic	DALY	9,31E-11	-4,56E-11	-5,39E-11	0,001	0,000	0,000	-0,0009	-0,0010	
Toxic	CML-2013	ton 1,4-DB eq	8,67E-05	1,20E-05	9,58E-06	589	82	65	-507,67	-524,14	
Hazardous waste	CML-2013	ton	0	5,10E-09	5,10E-09	0,000	0,035	0,035	0,035	0,035	
Reduced resource	abiotic depletion, non fuel (AD) CML2013	kg Sbeq	1,13E-08	-6,13E-10	-1,64E-09	0,077	-0,004	-0,011	-0,08	-0,09	

Table 10 – IWEK indicators

References

CML-IA Characterization Factors from CML, Leiden

NEN-EN-ISO 14040, Environmental management - Life cycle assessment - Principles and framework (ISO14040:2006, IDT)

NEN-EN-ISO 14044, Environmental management - Life cycle assessment - Requirements and guidelines (ISO 14044:2006, IDT)

Toxiciteit heeft z'n prijs, TNO, 2004.

SEARCH IS NOW PART OF SGS, THE WORLD'S LEADING INSPECTION, VERIFICATION, TESTING AND CERTIFICATION COMPANY.

