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Life Cycle Assessment to Municipal Wastewater Treatment Plant

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This analysis is a partial study of inventory over a Wastewater Treatment Plant (WTP), and establishing the main impacts in the Life Cycle of municipal wastewater treatment systems with the application of Life Cycle Assessment (LCA) according with ISO 14040 and ISO 14044. The results showed, in the inventory assessment, an important decreasing in the Biochemical Oxygen Demand and Total suspends solids (75 and 77 percent, respectively). On the other hand, it was observed a reduction in Ecotoxicity category in the impacts assessment stage. Finally, consumption of additive and energy as well as the generation waste do not imply in a considerable increase of other impacts.

1. Introduction

Although there are historical references from ancient times, the problem of pollution of water has reached peak levels in recent times. It seriously jeopardizes the future of humanity not only due to the large industrial growth, also because of the demographic trends. The problem is accentuated by the merger, both industrial and human in narrowly defined areas, it is determined that the world population majority nowadays is urban (Pierre, 2009; Renou, 2008). There are many aspects and methodologies for assessing the problem of pollution of water, so that all environmental burdens are taken into account when framing the real solutions that meet the needs of potable water supply (Sainz, 2007). LCA is defined as a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a system throughout its life cycle: from the production of raw materials to the disposal of the waste generated. (ISO, 2006)

2. Definition of Objective and Scope

2.1 Context

This study has been based on data reported by the plant. In cases where it was impossible to count with data from the plant, data were taken from the literature and

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Ecoinvent® database (Frischknech et al, 2007). The aim of this preliminary study was to identify environmental impacts and to propose alternatives for its reduction (ISO 14040, ISO 14044).

2.2 Objective and scope
The main objective of this work is to apply Life Cycle Assessment (LCA) to WTP using SIMAPRO® ver. 7.0, to determine the environmental impacts, realizes a comparison of several scenarios and proposes improvements.
The Figure 1 shows the system and its boundaries. The system to be analyzed in this paper is a treatment plant for municipal wastewater and the influent of the plant from the entrance to it, even before discharge to the receiving body.

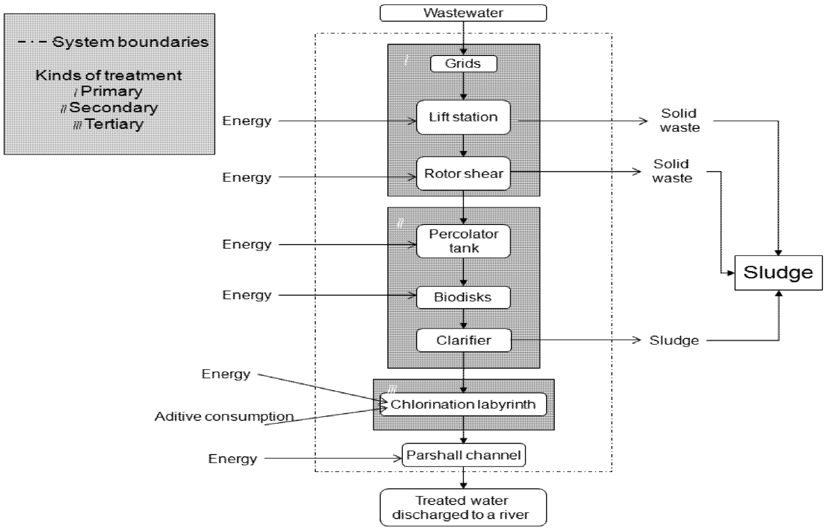

Figure 1: System description and its boundaries.

3. Inventory Analysis

3.1 Hypothesis and limitations
In the wastewater treatment plant scenery, the data for sludge production and chlorine consumption by the plant have been obtained from a plant with similar characteristics because there is no data reported by the WTP. Three values from literature were used for the production of sludge and also for chlorine consumption, in order to compare between the possible consumption and its impact on the analysis (Sainz, 2007). In the case of electricity consumption data was obtained through an approximation, considering all electricity consuming equipments.

3.2 Data sources
Most of data used in this analysis are data reported by the plant, except total nitrogen, sludge production, electrical and chlorine consumption. For other compounds, were assumed constant during treatment, this is because the water treatment process does not represent any change on these components except for nitrites.

4. Results

4.1 LCA Inventory results

In Tables 1 and 2 are showing the inventory results of two scenarios analyzed and the results of linkage of this data with the functional unit. Bibliographic data used for the development of this assessment are for the electrical consumption 3.6489 KWh/m^3, for chlorine consumption 0.02 Kg/m^3 and sludge production 8.28E-09 Kg/m^3. Total nitrogen has a value between 30-60 ppm (Sainz, 2007).

Table 1: Reference scenery. Stream before treatment

	[L/s]			[mg/L]				
Day	Q	DQO	DBO5	N tot.	NO_3^-	NO_2^-	P	As
01/12/2009	25.7	289	217	35	0.113	0.019	5.94	0.002
07/12/2009	20	259	194	49	0.113	0.019	6.31	0.002
Average[m3/h]	22.85	274	206	42	0.113	0.019	6.125	0.002
Month[Kg/m3]	82.26	0.274	0.206	0.042	1E-04	2E-05	6.E-03	2E-06

Day	Cd	Cu	Cr	Hg	Ni	Pb	Zn
01/12/2009	0.1	0.1	0.2	0.003	0.2	0.2	0.12
07/12/2009	0.1	0.1	0.2	0.003	0.2	0.2	0.12
Average[mg/L]	0.1	0.1	0.2	0.003	0.2	0.2	0.12
Month[Kg/m3]	1.E-04	1E-04	2.E-04	3E-06	2E-04	2.E-04	0.0001

Table 2: Analyzed scenery. Stream after treatment

	[L/s]			[mg/L]				
Day	Q	DQO	DBO5	N tot	NO3-	NO2-	P	As
01/12/2009	25.7	180	48	41.8	0.372	0.019	9.44	0.002
07/12/2009	20	1158	52	38.9	0.481	0.019	9.45	0.002
Average*[m3/h]*	22.85	1169	50	40.35	0.427	0.019	9.445	0.002
Month*[Kg/m3]*	82.26	0.169	0.05	0.404	4.E-04	1.9 E-05	9.4 E-03	2.E-06

Day	Cd	Cu	Cr	Hg	Ni	Pb	Zn
01/12/2009	0.1	0.1	0.2	0.003	0.2	0.2	0.12
07/12/2009	0.1	0.1	0.2	0.003	0.2	0.2	0.12
Average[mg/L]	0.1	0.1	0.2	0.003	0.2	0.2	0.12
Month*[Kg/m3]*	1.E-04	1.E-04	2.E-04	3.E-06	2.E-04	2.E-04	1.E-04

4.2 Impact Assessment

The impact assessment method used in this study is the TRACI method (Garcia, 2010). In the next list is present the impact assessment of the three analyzed scenarios:

1. Reference scenario: the effluent from the plant without any treatment. It serves as a reference to determine the impact categories and its effects.

2. Bibliographic scenario: scenario taken from the database Ecoinvent®.
3. Analyzed scenery: scenario with data reported by the plant. The average bibliographic values are used as results of life cycle inventory.

In the Figure 2 and 3 are showed the contribution to the impact categories of different scenarios. In Tables 3, 4 and 5 are showing the impact assessment results of three analyzed scenarios.

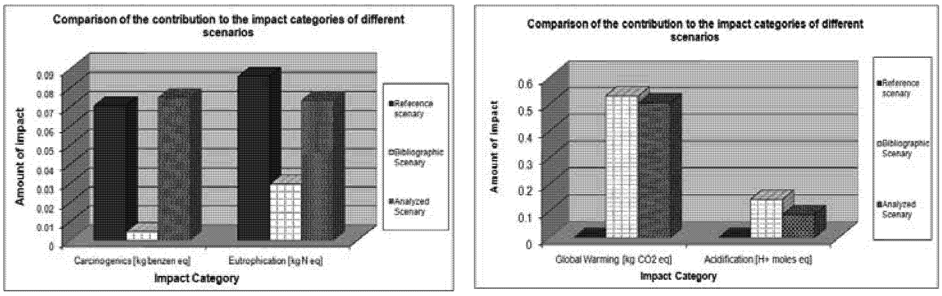

Figure2: Comparison of the contribution to the impact categories by different scenarios

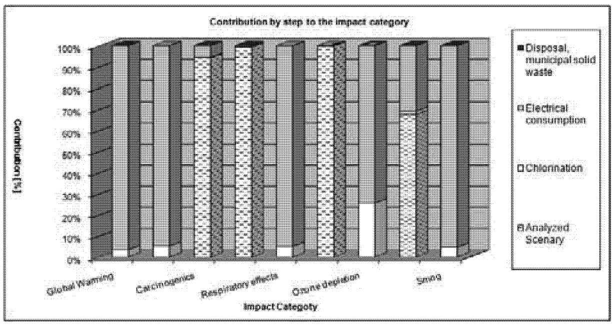

Figure 3: Comparison of the contribution by steps in the analyze scenery to the impact categories from scenario analyzed

Table 3: Comparing processes

Impact category	Unit	Reference scenery	Bibliographic Scenery	Analyzed Scenery
Global Warming	kg CO2 eq	0	5.30E-01	5.03E-01
Acidification	H+ moles eq	0	1.43E-01	8.64E-02
Carcinogenics	kg benzeneq	7.05E-02	4.72E-03	7.48E-02
Non carcinogenics	kg toluen eq	2.47E+03	8.97E+01	2.48E+03
Respiratory effects	kg PM2.5eq	0	5.82E-04	6.07E-04
Eutrophication	kg N eq	8.58E-02	2.96E-02	7.34E-02
Ozone depletion	kg CFC-11eq	0	2.88E-08	8.23E-08
Ecotoxicity	kg 2.4-D eq	2.18E+00	1.33E+01	3.23E+00
Smog	kg NOx eq	0	1.30E-03	7.83E-04

Table 4: Reference scenery. Effluent without treatment

Impact category	Unit	Total	Reference scenery
Global Warming	kg CO2 eq	0	0
Acidification	H+ moles eq	0	0
Carcinogenics	kg benzen eq	7.05E-02	7.05E-02
Non carcinogenics	kg toluen eq	2.47E+03	2.47E+03
Respiratory effects	kg PM2.5 eq	0	0
Eutrophication	kg N eq	8.58E-02	8.58E-02
Ozone depletion	kg CFC-11 eq	0	0
Ecotoxicity	kg 2.4-D eq	2.18E+00	2.18E+00
Smog	kg NOx eq	0	0

Table 5: Analyzed scenery

Impact category	Unit [eq]	Total	Analyzed Scenary	Chlorination	Electrical consumption	Disposal. municipal solid waste
Global Warming	kg CO_2	5.E-01	0.E+00	2.E-02	5.E-01	5.E-09
Acidification	H+ moles	9.E-02	0.E+00	5.E-03	8.E-02	7.E-11
Carcinogenics	kg benzen	7.E-02	7.E-02	1.E-04	4.E-03	1.E-09
Non carcinogenics	kg toluen	2.E+03	2.E+03	4.E-01	2.E+01	5.E-05
Respiratory effects	kg PM2.5	6.E-04	0.E+00	3.E-05	6.E-04	2.E-13
Eutrophication	kg N	7.E-02	7.E-02	9.E-06	9.E-05	6.E-11
Ozone depletion	kg CFC-11	8.E-08	0.E+00	2.E-08	6.E-08	3.E-17
Ecotoxicity	kg 2.4-D	3.E+00	2.E+00	5.E-02	1.E+00	3.E-07
Smog	kg NOx	8.E-04	0.E+00	4.E-05	7.E-04	2.E-12

5. Discussion

5.1 Remarks

As we can see in Figure 2, the contribution to eutrophication decreased after treatment. The reduction represents approximately 15%. The parameters COD and BOD_5 are reduced, indicating that water treatment helps to reduce the contribution of this category. On the other hand, there is an increase in the contribution to global warming by the plant compared to untreated effluent caused by energy consumption as a result of water treatment (see Figure 3).

Other impact categories with increments between reference and analyzed scenario are acidification, smog, ozone depletion, and carcinogenesis.

5.2 Improvement aspects

The wastewater treatment plant does not report the electrical consumption data. The results highlighted the influence that electrical consumption has on the contribution to different impact categories. It is required to have real electrical consumption in order to establish the relationship between plant consumption and the effects on the contribution to impact categories. Actually the WTP does not have a sludge management program. It is important that the WTP consider the sludge management in order to decrease the impacts and its environmental causes.

6. Conclusion

The main objective of WTP is the reduction of impacts in the environment from the urban wastewater. However, should be emphasized that such treatment in turn produces burdens on the environment, as a result the importance of knowing to what extent it is affecting the environment by wastewater treatment.

The results of applied LCA to WTP show positive aspects like decrease in the potential of eutrophication and its possible effects on the natural body. As we mentioned before, the real electrical consumption and additive data are needed. Nevertheless the data used in this paper were from a plant with similar characteristics as the analyzed plant. The consequence will not be a large difference between those results.

On the other hand, results showed that it is necessary to establish general management procedures at the plant. The preliminary results of LCA could be used to propose of rehabilitation of the plant.

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