Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Comparative life cycle assessment of municipal wastewater treatment systems: lagoon and activated sludge

Marzieh Mohammadi, Ebrahim Fataei*

Department of Environmental Sciences and engineering, Ardabil Branch, Islamic Azad University, Ardabil, Iran

* *Corresponding author's E-mail: eafataei@gmail.com & ebfataei@iauardabil.ac.ir*

ABSTRACT
Providing health conditions, prevention of water pollution and wastewater reuse are needed to select the best wastewater treatment process before designing and implementing, according to regional climatic conditions. the aim of the present study was to evaluate the lagoon and activated sludge wastewater treatment systems using life cycle assessment and ISO14040 standards within four steps. Required data in the study systems were matter and energy inputs, including NH_3-N, TP, TN, CL, O_2 and electricity, as well as pollutant outputs involving BOD5, COD, SS, NH3-N, TP, TN, CL, CO_2, and CH_4. The data were obtained from treatment systems of Ardabil (aerated lagoon) and Tabriz (activated sludge), Iran. Some of the data were obtained by calculation and the eco-invent database was used to complete the information required. Data were analyzed by Simapro 8.0.1 software. The results of the study demonstrated that the lagoon system in comparison with the other systems had 100% negative impacts in every effect classes, while the activated sludge system on global warming (6.39%) and photochemical oxidation (7.14%) had the least impact. Therefore, the lagoon system was recognized as the environmentally-harmful system, while the activated sludge as the best wastewater treatment system.

Key words: Activated sludge, Aerated lagoon, Effect classes, Environmental impact, Life cycle assessment, Wastewater.

INTRODUCTION
Providing health conditions, prevention of water pollution and wastewater reuse are needed to select the best wastewater treatment process before designing and implementing. The best treatment process is selected according to the regional climatic conditions. So that, the wrong choice can increase costs and failure to achieve desired results (Dabaghian *et al.* 2009; Bahmanpour *et al.* 2017). Choosing optimized municipal wastewater treatment process is an important and multi-dimensional issue that needs a systematic and scientific process in the selection of the optimal treatment process with the least environmental impact because of the damage caused by the rupture of design and waste costs, in addition to compliance with environmental standards and requirements (Saiedi *et al.* 2009). There are several life cycle assessment (LCA) studies on wastewater treatment systems. Some of them have examined competing technology configurations, and consistently identified the strong influence of energy consumption on the overall environmental impact (Emmerson *et al.* 1995; Vidal *et al.* 2002; Racoviceanu *et al.* 2007 and Gallego *et al.* 2008). In particular, solids removal, transportation and recycling have attracted a lot of attention in some researches (Dixon *et al*. 2003; Gaterell *et al*. 2005). In these processes, authors have represented a major fraction of the environmental footprint of wastewater treatment systems, especially when considering the toxicological effects of heavy metals in bio solids (Hospido *et al*. 2004 and Pasqualino *et al*. 2009; Godin *et al.* 2011). Other studies have focused more upon small and decentralized wastewater systems (Machado *et al*. 2007; Godin *et al.* 2011). These studies have highlighted the important role of waste water treatment plants (WWTPs) in protecting waters from eutrophication, and hence increased levels of nutrient removal are generally considered highly beneficial (Gaterell *et al.* 2005; Lassoux *et al.* 2007; Foley *et al.* 2009). LCA evaluates a product from raw material extraction and acquisition of the

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336
DOI: 10.22124/cjes.2019.3806

Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research

material, energy and building materials to use and end of life review. For such a systematic overview and perspective, potential environmental handling of the life cycle or the unique process can be prevented if identified (Iran standard-ISO 14040). Life cycle is one of the methods of stability impact assessment based on the production process (Ness *et al*. 2007). So that, during the life cycle assessment, the impacts imposed by the production of a product or a process or an activity are assessed by identifying and quantifying of energy, materials and wastes entered into the environment (Dekamin *et al*. 2012). Also during this assessment, the effects resulting from the use of these materials and energies on the environment and the opportunities available to correct these effects are detected within four evaluation stages including: scope and aim, functional unit, system boundary and inventory (Pelletier & Tyedmers 2010). LCA is a relative approach in relation to a functional unit describing study matter. All subsequent analyses are harmonized with the functional unit as all inventory inputs and outputs of life cycle and thus inventory evaluation profile of life cycle assessment are associated with functional unit (Iran standard-ISO 14040). The scope represents methodological choices that are of great importance, including the methodology and limitations of research assumptions (ISO 2006). The aim of study in assessing life cycle is a stage that is designed on the basis of stated goals; in other words, a set of decisions specifying the study method (ISO 2006). The aim of this study was to compare the life cycle assessment of wastewater treatment systems (lagoons and activated sludge) for determining the system with minimum environmental impact. In this study, two wastewater treatment systems (lagoons, activated sludge) were compared and evaluated for their functions, the type of equipment and machinery as well as their biological effects.

MATERIALS AND METHODS

Functional unit

Functional unit is a reference by which to measure the functions of the study systems. Therefore, it is a reference to determine quantitative assessment of the functioning of production systems (ISO 2006). In this study, functional unit was a cubic meter of municipal wastewater to compare different processes of wastewater treatment.

System boundary

System boundaries should also be determined with high accuracy, since if not, working for researchers will become difficult because of extensive life cycle, input and output data (Dekamin *et al.* 2012). In the current study, the aeration and filtration system boundary for ease of doing the work included the original process input and output (Fig. 1).

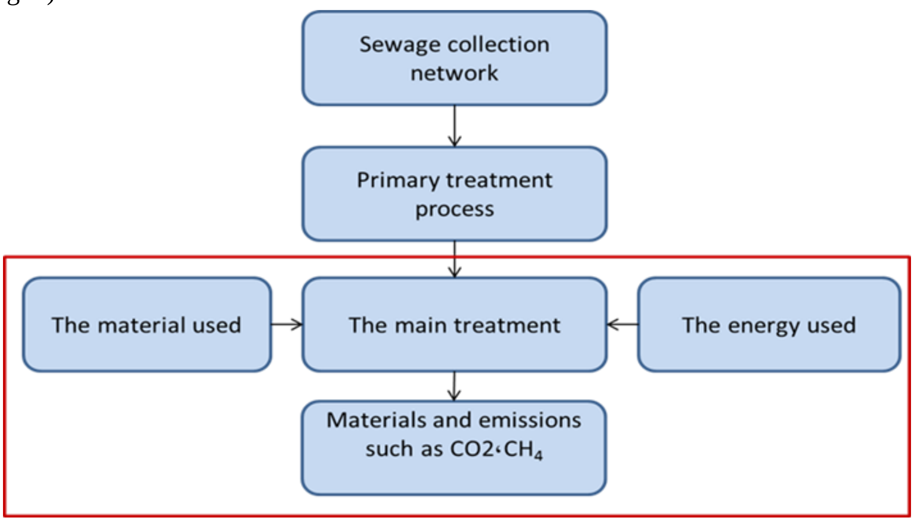

Fig. 1. Life cycle assessment system boundary for urban sewage treatment systems of Ardabil and Tabriz, Iran.

Inventory

In this study, life cycle assessment involved collection of data to quantify all inputs and outputs related to the treatment of one cubic meter of wastewater, such as the amount of suspended solids, oxygen demand for organic

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336
DOI: 10.22124/cjes.2019.3806

Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research

matter oxidation, chemical oxygen demand, oxygen consumption, energy consumption, emissions of greenhouse gases of methane and carbon dioxide per day to direct observation, and also calculation and internal resources on water treatment plants. The calculations have been mentioned below (Metcalf & Eddy 2003). Additional underlying data have been collected using European eco-invent database including issues related to infrastructure, raw materials, chemicals and energy. In this study, transportation due to network wastewater collection and infrastructures due to low environmental impact have been ignored. Finally, information on pollution emission and consumption are included in the index of global impact (including global warming, using primary energy, energy consumption, etc.). Inventory list for lagoons and activated sludge systems are presented in Table 1. Then the data were analyzed using Simapro software and CML 2001 method.

Table 1. Inventory list for aerated lagoon and activated sludge systems.

Material consumption and emissions	**Lagoon**	**Activated sludge**	**Unit**
Flow	23760	109	m^3/d
Input BOD_5	213	165	mg/l
Output BOD_5	58	20	mg/l
Input COD	400	325	mg/l
Output COD	108	40	mg/l
Input SS	226	140	mg/l
Output SS	26	25	mg/l
Input NH_3-N	19	25	mg/l
Output NH_3-N	8	5	mg/l
Input TN	85	40	mg/l
Output TN	19.3	6.5	mg/l
Input TP	20	8	mg/l
Output TP	11	1	mg/l
Electricity	9213.4	616966	kw/d
CL	12.25	108	kg/hr
O_2	5856.7	23668	kg/d
CO_2	15665.2	3707.2	kg/d
CH_4	29092.5	7527.2	kg/d

Calculation of the amount of methane, carbon dioxide and oxygen gases in activated sludge treatment system:

(The cell mass produced per liter of wastewater) X= 52.9 mg L^{-1}; (Input to the digester)

VSS = 43006.7 Lb d^{-1}, (Flow) Q = 109728 M^3/d; O_2 = 215.7 mg L^{-1}; Y = 0.5

$$(O_2)_T = O_2 \times Q \quad \textbf{(1)}$$

$(O_2)_T$ = 215.7g/m^3 × 10^{-3} kg g^{-1} × 109728 m^3/d=23668.33 kg d^{-1}

Density of digester gas is 0.86 and the density of the air is 0.076 Lb d^{-1} and 18 Ft^3 of gas is produced per pound of volatile solids.

$$\text{Total gas production}= 18ft^3\ Lb^{-1} \times Y \times VSS \times 0.86 \times 0.76\ Lb\ \ d^{-1} \quad \textbf{(2)}$$

Total gas production= 18 ft^3 Lb^{-1} × 0.5 × 43006.7 Lb d^{-1} × 0.86 * 0.76 Lb d^{-1} = 11234.5 kg g^{-1}

2/3 of produced gas is methane and the rest is carbon dioxide.

VCH_4 = 11234.5 kg × 0.86 = 7527.2 kg d^{-1}

VCO_2 = 11234.5 - 7527.2 = 3707.3 kg d^{-1}

Calculation of the amount of methane, carbon dioxide and oxygen gases in the lagoon treatment system:

$(CO_2)_{End}$ = 322.1 mg L^{-1}; (Carbon dioxide produced in the oxidation)($CO_2)_{OX}$ = 351.2 mg L^{-1}; Q = 23760 m^3/d

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336 Received: June 03. 2019 Accepted: Oct. 31. 2019
DOI: 10.22124/cjes.2019.3806 Article type: Research

(The amount of oxygen for synthesis) $(O_2)_X = 0.96$ mg L^{-1}; (The amount of oxygen necessary for the oxidation) $(O_2)_{OX} = 255.4$ mg L^{-1}

$(O_2)_{End} = 175.36$ mg L^{-1}

$$(O_2)_T=(O_2)_X+(O_2)_{OX}+(O_2)_{End} \quad \textbf{(3)}$$

$(O_2)_T = 0.96 + 255.4 + 175.36 = 431.72$ mg $L^{-1} \times 10^{-3} \times 23760$ m^3 $d^{-1} = 10257.66$ kg d^{-1}

$$(CO_2)T = (CO_2)_{OX} + CO_2End \quad \textbf{(4)}$$

$(CO_2)T = 351.2 + 322.1 = 673.3$ mg $L^{-1} \times 10^{-3} \times 23760$ m^3 $d^{-1} = 15997.6$ kg d^{-1}

Aerated lagoons

Aerated lagoons are exploited as single-pass or solid recirculation. The solid recirculation lagoons are essentially similar to activated sludge process (Metcalf & Eddy 2003). In this system, raw sewage after collecting rubbish into the aerated lagoon and the optimal time for aeration is considered to be outside the lagoon (Arcevala 2004). Common values of aeration time in aerated lagoon are between 3 and 10 days (Metcalf & Eddy 2003). Lagoon sedimentation is located after aerated lagoons as final clarifier and biological solids produced in the aerated lagoons are separated by sedimentation lagoons. Sedimentation lagoon is usually made of concrete and equipped with mechanical rakes to remove sludge continuously (Reynolds & Richards 1996).

Activated sludge

In activated sludge process, vast populations of aerobic microorganisms are used to serve a diverse population. Main units include a biological reactor with a source of oxygen (aeration basin), a solid-liquid separator system (final clarifier) and pumps for returning the sludge. The flow of raw sewage immediately before entering the biological reactor or immediately upon arrival is mixed with the flow of recycled activated sludge. Liquid mixture (mixture of active sludge and sewage) enters into the biological reactor. by liquid passing through the reactor, the active mass absorb soluble and insoluble organic materials and oxidize to produce carbon dioxide, water and other byproducts and to create new cells.

Simapro

There are several methods and software to assess the effects in the LCA depending on the product. Simapro is one of the most useful and comprehensive software. The Simapro includes various methods to calculate the results of the impact assessment. Specific environmental factors have been evaluated in each of methods. Simapro is used as a professional tool for analyzing the environmental aspects of products or services. The software runs this procedure in a systematic and permanent method. So that, we can provide the best solutions for the project. Simapro has several versions and includes an extensive collection of information and impact assessment procedures. Simapro version 8 was used in this study.

CML 2001 method

In CML 2001, a new application method has been introduced for the implementation of ISO standards. In this approach, the implementation of ISO standards has been presented as a project. For life cycle assessment stage, the special collection of effect classes as well as characterizing methods have been introduced along with executives to inventory list. This action leads to a simple assessment of the effects of CML 2001 for use in database and avoid possible errors while conversion effect. In this method, the results can be classified using the amount of their impact in different effects.

The effect classes calculated in this method are abiotic depletion, abiotic depletion (fossil fuels), global warming, ozone layer depletion, human toxicity, fresh water aquatic exotoxin, marine aquatic, terrestrial toxicity, photochemical oxidation, and acidification. The sets are suitable for life cycle assessment activities related to wastewater treatment.

RESULTS

Considering the whole life cycle of the wastewater treatment systems of lagoon and activated sludge and the relative contribution of each phase–construction and operation–their environmental impacts by Simapro

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336 Received: June 03. 2019 Accepted: Oct. 31. 2019
DOI: 10.22124/cjes.2019.3806 Article type: Research

software are presented in Figs. 2-4. Also Tables 1-3 present the inventory results per impact category, expressed in relation to functional units.

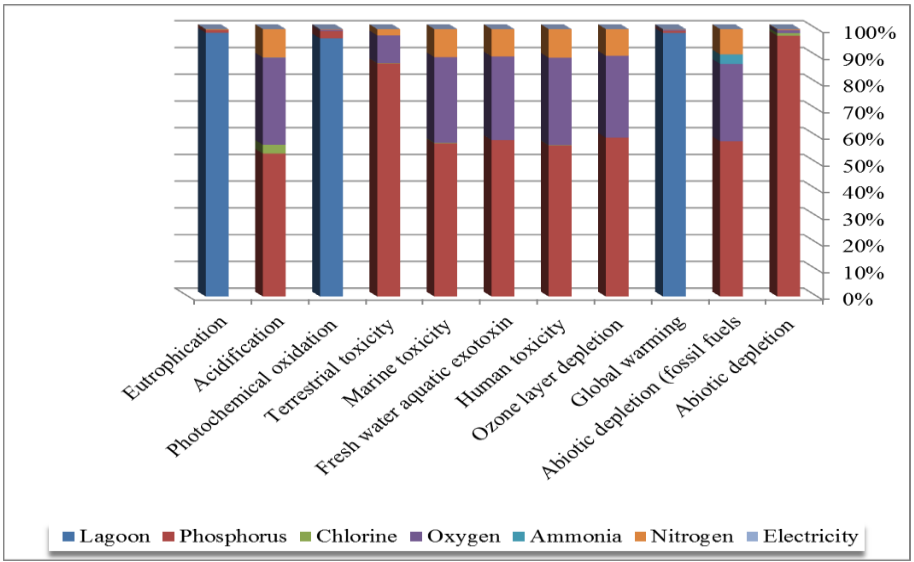

Fig. 2. The environmental impact per cubic meter of wastewater and the impact percentage of components in lagoon system.

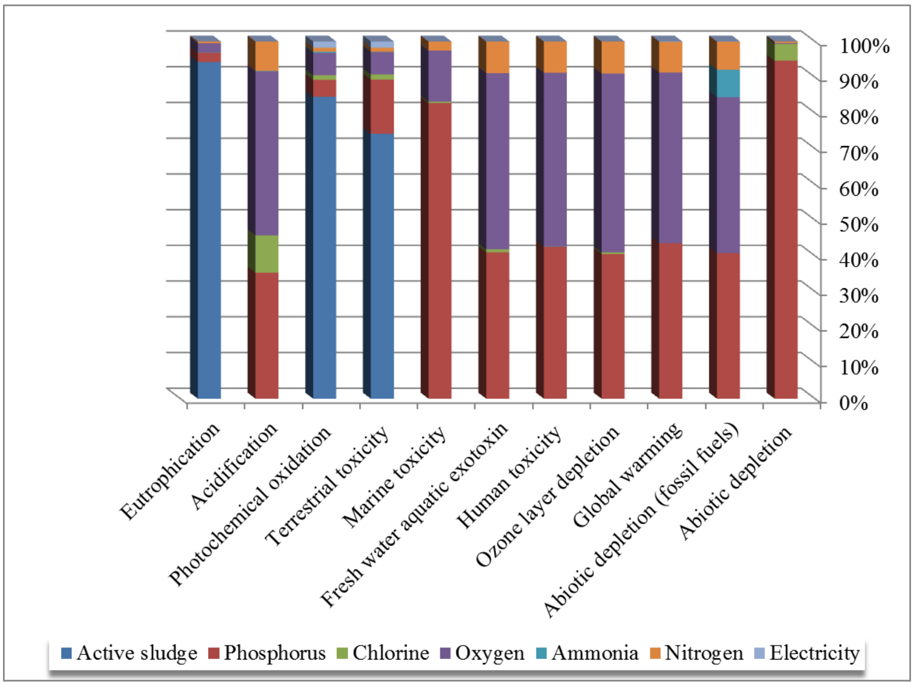

Fig. 3. Environmental impact per cubic meter of wastewater and impact percentage of components in activated sludge process.

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336
DOI: 10.22124/cjes.2019.3806

Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research

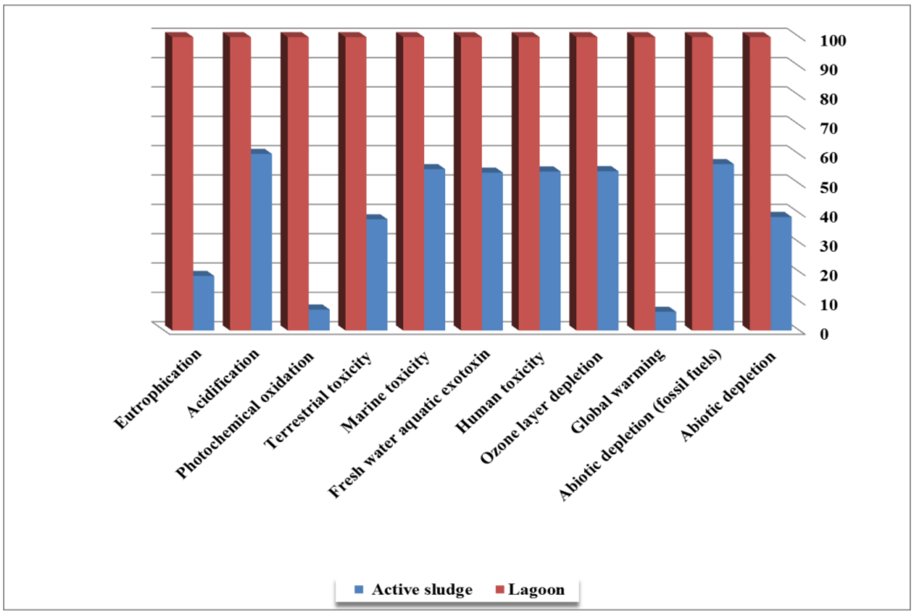

Fig. 4. Contribution activated sludge process and lagoon process on the different effect classes per cubic meter of wastewater.

Table 2. Environmental impact per cubic meter of sewage and participation of lagoon system components.

Effect floors	Unit	Total	Lagoon	Chlorine	Nitrogen	Phosphorus	Ammonia	Oxygen	Electricity
Abiotic depletion	kg sb eq	5.2E-07	*	5.3E-09	1.9E-09	5.1E-07	*	5.86E-09	6.35E-14
Abiotic depletion(fossil fuels)	MJ	7.35	*	*	0.694	4.25	0.258	2.12	0.000199
Global warming	kg co_2 eq	32.4	31.9	0.0142	0.0492	0.246	0.00615	0.15	0.00248
Ozone layer depletion	kg CFC-11 eq	2E-08	*	*	2.01E-09	1.2E-08	*	6.19E-09	9.4E-13
Human toxicity	kg 1,4-DB eq	0.121	*	0.00017	0.013	0.0686	3.65E-06	0.0397	5.01E-07
Fresh water aquatic exotoxin	kg 1,4-DB eq	0.122	*	1.6E-05	0.0125	0.0715	*	0.0382	2.99E-07
Marine toxicity	kg 1,4-DB eq	604	*	1.25	63.2	345	*	193	0.00125
Terrestrial toxicity	kg 1,4-DB eq	0.00093	*	8.4E-07	2.22E-05	0.000824	*	9.79E-05	5.43E-10
Photochemical oxidation	kg C_2H_4 eq	0.00777	0.0075	4.2E-06	1.32E-05	0.000211	4.4E-07	4.05E-05	6.67E-07
Acidification	kg co_2 eq	0.00316	*	0.00011	0.000336	0.00169	1.64E-06	0.00103	1.81E-08
Eutrophication	kg po_4--- eq	0.0454	0.0446	4.5E-06	0.000082	0.000501	3.95E-07	2.51E-05	4.74E-09

Notes: * Indicate the minimum value.

Aerated lagoon system

As shown in Fig. 2, electricity has not contributed in any of the effect classes. About chlorine, it can also be said that the component had little effect on abiotic depletion (1.02%) and acidification (3.33%) had no effect on any of the classes. This also is true for ammonia and, abiotic depletion (fossil fuels) (3.53%) which had too low impact on the effect class. Intake oxygen in wastewater treatment system had no impacts on the effects of global warming class, but its impacts in other classes were as follows: abiotic depletion (1.2%), abiotic depletion (fossil fuels) (29%), ozone layer depletion (30.5%), human toxicity (32.1%), fresh water aquatic exotoxin (31.3%), marine toxicity (32%), terrestrial toxicity (7.28%), photochemical oxidation (0.52%), acidification (35.5%) and eutrophication (0.55%). Nitrogen has impacts on abiotic depletion (fossil fuels) (79.9%), ozone layer depletion (9.98%), human toxicity (7.28%), fresh water aquatic exotoxin (3.31%), marine toxicity (10.2%), terrestrial

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336
DOI: 10.22124/cjes.2019.3806
Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research

toxicity (5.12%) and acidification (10.6%). However, phosphorus contributed in all effect classes and its greatest impacts were found in abiotic depletion (97.5%) and terrestrial toxicity (90%), and its minimum effect was on global warming (0.76%). It has been effective in other classes as follows: abiotic depletion (fossil fuels) (58%), ozone layer depletion (59%), human toxicity (56.5%), fresh water aquatic toxicity (58.5%), marine toxicity (57.02%), acidification (53.5%), photochemical oxidation (27%), eutrophication (10.1%). Table 2 presents the effect classes of lagoon system expressed in terms of unit.

Table 3. Environmental impact per cubic meter of sewage and participation percentage of activated sludge system components.

Effect floors	Unit	Total	Activated sludge	Chlorine	Nitrogen	Phosphorus	Ammonia	Oxygen	Electricity
Abiotic depletion	kg sb eq	2.2E-07	*	1E-08	9.01E-10	2.04E-07	*	5.02E-10	9.21E-13
Abiotic depletion (fossil fuels)	MJ	4.17	*	*	0.326	1.7	0.323	1.82	0.00289
Global warming	kg co_2 eq	1.1E-08	*	*	9.48E-10	4.81E-09	*	5.28E-09	1.36E-11
Ozone layer depletion	kg cfc-11 eq	0.0679	*	0.00031	0.0061	0.0275	4.56E-06	0.034	0.00000726
Human toxicity	kg 1,4-DB eq	0.0673	*	3.1E-05	0.00588	0.0286	*	0.0328	0.00000434
Fresh water aquatic exotoxin	kg 1,4-DB eq	337	*	2.91	29.8	138	*	166	0.0181
Marine toxicity	kg 1,4-DB eq	0.00041	*	1.6E-06	1.04E-05	0.000337	*	5.82E-05	7.87E-09
Terrestrial toxicity	kg 1,4-DB eq	0.00056	0.000412	8.1E-06	6.23E-06	0.0000843	5.5E-07	3.47E-05	0.00000967
Photochemical oxidation	kg C_2H_4 eq	2.07	1.75	0.0271	0.0232	0.0985	0.00768	0.129	0.0359
Acidification	kg co_2 eq	0.00192	*	0.0002	0.000158	0.000676	2.05E-06	0.00088	2.63E-08
Eutrophication	kg po_4---eq	0.008	0.00754	4.9E-06	3.86E-05	0.0002	4.94E-07	0.000215	6.87E-08

Notes: * Indicate the minimum value.

Activated sludge system

Fig. 3 exhibits a subset of participants in the process of wastewater treatment in activated sludge system. As shown in this Fig., phosphorus, oxygen and nitrogen have effects on all the classes. The phosphorus has a greater role than the other two factors. The greatest effect of phosphorus was in abiotic depletion (92.7%), abiotic depletion (fossil fuels) (40.8%), global warming (4.76%), ozone layer depletion (43.5%), human toxicity (40.4%), fresh water aquatic toxicity (42.5%), marine toxicity (41%), terrestrial toxicity (82.2%), photochemical oxidation (15.2%), acidification (35.2%) eutrophication (2.5%) contributed. The influence of oxygen on effect classes included abiotic depletion (2.28%), abiotic depletion (fossil fuels) (43.6%), global warming (6.24%), ozone layer depletion (47.8%), human toxicity (50.1%), fresh water aquatic toxicity (48.7%), marine toxicity (49.3%), terrestrial toxicity (14.3%), photochemical oxidation (6.25%), acidification (45.9%) and eutrophication (2.69%). The nitrogen impacts were as follows: abiotic depletion (0.41%), abiotic depletion (fossil fuels) (8.83%), global warming (1.12%), ozone layer depletion (8.83%), human toxicity (8.99%), fresh water aquatic toxicity (7.74%), marine toxicity (7.84%), terrestrial toxicity (2.56%), photochemical oxidation (1.12%), acidification (8.24%) and eutrophication (0.48%). Ammonia has contributed just in abiotic depletion (fossil fuel) (7.74%). The electricity exhibited small influences on global warming (1.74%) and photochemical oxidation (1.74%). The chlorine impacts were found to be on abiotic depletion (4.61%), global warming (1.31%), human toxicity (0.46%), marine toxicity (0.85%), terrestrial toxicity (1.45%) and acidification (10.5%). In Table 3, the amount of each effect classes of activated sludge unit are specifically illustrated.

Comparison of wastewater treatment systems

The aim of this study was to determine, identify and compare the environmental impact of lagoon wastewater treatment system (Ardabil) and activated sludge (Tabriz), both with similar weather conditions. As shown in Fig. 4, lagoon system compared to activated sludge wastewater treatment exhibited 100% impacts on all of the effect classes, while the influences of activated sludge wastewater treatment system were minimum

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336 Received: June 03. 2019 Accepted: Oct. 31. 2019
DOI: 10.22124/cjes.2019.3806 Article type: Research

on global warming (6.39%) and photochemical oxidation (7.17%). The effects of activated sludge treatment system in other classes had maximum influences on acidification (60.2%), marine toxicity (55%), ozone layer depletion (54.3%), terrestrial toxicity (37.9%), fresh water aquatic toxicity (53.8%), human toxicity (54.2%) and eutrophication (18.6%).

Discussion and conclusion

Input energy of wastewater treatment in both treatment systems depends heavily on the type of activities performed during the treatment. In the studied systems, most of the energy was employed for generators, pumps and aerators. In this study, two evaluated types of systems were different in terms of energy requirements. The different demands of energy had direct impact on the contributed of these systems upon various effect classes. The lack of contributed of lagoon system on different effect classes may be due to the direct relation of low energy consumption in the system. The activated sludge system also has been influential on global warming and photochemical oxidation due to the difference in energy consumption because of the extended aeration in this type of system. Nitrogen and phosphorus of wastewater are resulting from the use of detergents and agricultural fertilizers. The presence of high levels of both elements in the system influences on almost all classes. Especially, the influence of phosphorus on acidification is very high on both systems. Chlorine is also used for disinfection in wastewater treatment. Various applications of chlorine in treatment systems can affect different classes, but its main impact is found to be on abiotic depletion and acidification. Aerators are used to produce enough oxygen required for biological treatment of sewage and to hold biological solids suspended. However, the process is very extensive. Therefore, the impact of oxygen is visible in all classes in this system, but its impact on abiotic depletion and eutrophication is very low. Ammonia is formed by decomposition of nitrogen organic substances in wastewater that generally influences abiotic depletion (fossil fuels). Between two studied treatment systems, contributed of activated sludge system on global warming (6.39%) and photochemical oxidation (7.14%) were the lowest compared to the lagoon system. However, in other classes including abiotic depletion (fossil fuel) (38.7%), ozone layer depletion (54.3%), human toxicity (54.2%), aquatic toxicity (53.8%), marine toxicity (55%), acidification (60.2%), eutrophication (18.6%) displayed a better condition compared to lagoon system, because in all effect classes the lagoon treatment system showed 100% contributed compared to activated sludge treatment and exhibited major adverse impacts on the health of aquatic ecosystems and soil and human health. Hence, this system in terms of environmental conditions is evaluated to be harmful compared with the lagoon system. According to the assumptions, functional unit, geographic positions of systems and other issues contained in the municipal treatment systems and the difference with other study assumptions, there was no possibility of exact comparison of results. Nevertheless, generally it can be said that on this effect class, the results of this study are consistent with other aforementioned studies. The present study revealed that the LCA approach can be used as a decision tool in design studies. This result is in line with the findings of Machado *et al.* (2007).

Suggestions

The superiority of the activated sludge system is due to small amounts of phosphorus and nitrogen per thousand cubic meters compared to the lagoon system. With this interpretation, although the results of this study showed that the activated sludge system is superior compared to the other systems, but the environmental impact of the system should not be ignored. This type of system in future research compared to the social and economic assessment should also be taken at the local level. Hence, the convenient system of any location should be selected according to weather conditions to have the lowest environmental load.

REFERENCES

Arceivala SJ 2004, Wastewater treatment for pollution control. Tata MacGraw–Hill, 2th ed., 362p.

Bahmanpour, H, Habashi, R, Hosseini SM, 2017, Investigating the Efficiency of Lightweight Expanded Clay Aggregate (LECA) in Wastewater Treatment of Dairy Industry, *Anthropogenic Pollution Journal*, 1 (1): 9-17.

Dixon, A, Simon, M & Burkitt, T 2003, Assessing the environmental impact of two options for small-scale wastewater treatment: comparing a reedbed and an aerated biological filter using a life cycle approach. *Ecological Engineering*, 20: 297-30.

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336 Received: June 03. 2019 Accepted: Oct. 31. 2019
DOI: 10.22124/cjes.2019.3806 Article type: Research

Dabaghian, MR, Hashemi, H, Ebadi, T, 2009, Technical economic and environmental assessment of wastewater treatment systems in the electroplating industries using AHP. *Environmental Science Technology*, 11: 107-115.

Dekamin, M, Veisi, H, Liaghati, H, Khoshbakht, K, Beheshti, M, Heydarzadeh, M, 2012, Assessing the environmental impacts of fish production systems (integrated cold-water fish) in Iran, using Life Cycle Assessment. Department of Agro-ecology, Institute of Environmental Sciences, Martyr Behest University, 238p.

Emmerson, RHC, Morse, GK, Lester, JN & Edge, DR 1995, The Life-Cycle Analysis of Small-Scale Sewage Treatment Processes. *Journal of Chartered Institution of Water & Environmental Management*, 9: 317-325.

Foley, J, de Haas, D, Hartley, K, Lant, P 2009, Comprehensive life cycle inventories of alternative wastewater treatment systems, water research. *Journal of Waters*, 1: 11-21.

Gallego, A, Hospido, A, Moreira, MT & Feijoo, G 2008, Environmental performance of wastewater treatment plants for small populations. *Resources Conservation and Recycling*, 52: 931-940.

Gaterell, MR, Griffin, P & Lester, JN 2005, Evaluation of environmental burdens associated with sewage treatment processes using life cycle assessment techniques. *Environmental Technology*, 26: 231-249.

Godin, D, Bouchard, C, Vanrolleghem, PA, 2011, LCA of wastewater treatment systems: introducing a net environmental benefit approach. Département de génie civil ET de génie des eaux, Université Laval, 1065 Avenue de la médecine, watermatex, Conference Proceeding, 18-25.

Houillon, G & Jolliet, O 2005, Life cycle assessment of processes for the treatment of wastewater urban sludge: energy and global warming analysis. *Journal of Cleaner Production*, 13: 287-299.

Hospido, A, Teresa Moreira, M, Fernandez-Couto, M & Feijoo, G 2004, Environmental performance of a municipal wastewater treatment plant. *International Journal of Life Cycle Assessment*, 9: 261-271.

Iran Standard and Industrial Research Institute of Standard ISO 14040, 2012, Environmental management – Life cycle assessment - Principles and framework, 1st Ed., 79p.

ISO, ISO 2006, 14044: Environmental management—life cycle assessment—requirements and guidelines. International Organization for Standardization, 112p.

Lassaux, S, Renzoni, R & Germain, A 2007, Life Cycle Assessment of Water from the Pumping Station to the Wastewater Treatment Plant. *International Journal of Life Cycle Assessment*, 12: 118-126.

Machado, AP, Urbano, L, Brito, AG, Janknecht, P, Salas, JJ & Nogueira, R 2007, Life cycle assessment of wastewater treatment options for small and decentralized communities. *Water Science and Technology*, 56: 15-22.

Tchobanoglous, G, Louis Burton F, David Stense H, Metcalf & Eddy, Inc., Burton F, 2003, Wastewater engineering: treatment and reuse .4th ed., McGrow Hill, 1819p.

Ness, B, Urbel-Piirsalu, E, Anderberg, S, Olsson, L 2007, Categorizing tools for sustainability assessment. *Ecological Economics*, 60: 498-508.

Pasqualino, JC, Meneses, M, Abella, M & Castells, F 2009, LCA as a decision support tool for the environmental improvement of the operation of a municipal wastewater treatment plant. *Environmental Science & Technology*, 43: 3300-3307.

Pelletier, N, Tyedmers, P 2010, Life cycle assessment of frozen tilapia fillets from Indonesian lake-based and pond-based intensive aquaculture systems. *Journal of Industrial Ecology*, 14: 467-481.

Racoviceanu, AI, Karney, BW, ASCE, M, Kennedy, CA, Colombo, AF, 2007, Life-cycle energy use and greenhouse gas emissions inventory for water treatment systems. DOI: 10.1061/ASCE1076-0342, 2007, 13:4 261.

Reynolds,TD, Richards, PA, 1996, Unit operations and process in environmental engineering., 2nd ed. Congress Proceeding, 798.

Saiedi, M, Abessi, A, Sarpak, M, 2009, Hazardous waste landfill sitting using GIS and prioritize sites using AHP, *Environmental Science Technology*, 11: 231-241.

Vidal, N, Poch, M, Marti, E & Rodriguez-Roda, I 2002, Evaluation of the environmental implications to include structural changes in a wastewater treatment plant. *Journal of Chemical Technology and Biotechnology*, 77: 1206-1211.

Caspian J. Environ. Sci. Vol. 17 No. 4 pp. 327~336
DOI: 10.22124/cjes.2019.3806

Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research

مقایسه ارزیابی چرخه حیات سیستم های تصفیه فاضلاب شهری لاگون و لجن فعال

مرضیه محمدی، ابراهیم فتائی*

گروه علوم و مهندسی محیط زیست، واحد اردبیل، دانشگاه آزاد اسلامی، اردبیل، ایران

(تاریخ دریافت: ۹۸/۰۳/۱۳ تاریخ پذیرش: ۹۸/۰۸/۰۹)

چکیده

تأمین شرایط بهداشتی، جلوگیری از آلودگی منابع آب و نیاز به استفاده مجدد از فاضلاب‌های شهری اقتضا می‌کند که قبل از طراحی و اجرای هر تصفیه‌خانه فاضلاب، بهترین فرآیند تصفیه با توجه به شرایط اقلیمی هر منطقه انتخاب شود. در این مطالعه، با استفاده از روش LCA و با در نظر گرفتن استانداردهای ISO14040 طی چهار مرحله به ارزیابی روش‌های تصفیه فاضلاب لاگون و لجن فعال پرداخته شد. داده های مورد نیاز شامل ورودی های ماده و انرژی همچون NH3-N، TP، TN، CL، O2، Electricity و خروجی آلاینده‌های BOD5، COD، SS، NH3- N، TP، TN، CL، CO2، CH4 در روش‌های تصفیه فاضلاب مورد مطالعه بود، که از تصفیه خانه های شهرهای اردبیل(لاگون هوادهی) و تبریز (لجن فعال) تهیه شد. برخی داده ها از طریق محاسبه به دست آمد و برای تکمیل اطلاعات از پایگاه داده‌ای اکواینونت استفاده شد. از نرم افزار SimaPro 8.0.1 و روش CML Baseline 2001 برای تجزیه و تحلیل داده ها استفاده شد. نتایج حاصل از بررسی روش‌های تصفیه فاضلاب نشان داد که روش لاگون اثر منفی خود را به صورت ۱۰۰٪ در تمامی طبقه اثرها بر جای گذاشته است، در حالی که اثر گذاری روش لجن فعال در طبقه اثرهای گرمایش جهانی (۶٫۳۹٪) و اکسیداسیون فتوشیمیایی(۷٫۱۴٪) دارای کمترین مقدار بوده است. از این رو از نظر زیست محیطی روش لاگون به عنوان روش نامطلوب و لجن فعال نیز به عنوان بهترین روش تصفیه فاضلاب ارزیابی شد.

*مؤلف مسئول

Bibliographic information of this paper for citing:

Mohammadi, M, Fataei, E 2019, Comparative life cycle assessment of municipal wastewater treatment systems: lagoon and activated sludge. Caspian Journal of Environmental Sciences, 17: 327-336

Received: June 03. 2019 Accepted: Oct. 31. 2019
Article type: Research