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Research Article

The Life-Cycle Assessment of Urban Sewage Sludge Disposal Systems of Ekbatan Tehran Wastewater Treatment Plant

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Abstract
The present study has assessed the life-cycle as an efficient method for environmental analysis, four disposal systems, and the management of urban sewage sludge in Ekbatan Tehran wastewater treatment plant. In order to assess the effects of the life-cycle Eco Indicator 99 method was used by OPENLCA software, and system boundary has been considered since the arrival of swage to wastewater treatment until its exit and the disposal of sludge. According to the results, using sludge in agricultural lands has positively influenced the group effect of fossil fuels due to economizing the production of phosphor and nitrogen fertilizers. On the other hand, using sludge in agriculture has negatively influenced the carcinogenetic group effects, Inorganics Respiratory, ecotoxicity, acidification, and fertilization, which is mainly due to the heavy metals in sludge. However, industrial fertilizers have some heavy metals. Therefore, comparing the effects of life cycle from two processes of using sludge and industrial fertilizer may be considered in decision making to select the optimal process.

Keywords: Life Cycle Assessment, Sewage Sludge Disposal, Ekbatan Tehran Wastewater Treatment, Openlca, Eco Indicator 99

Introduction

The treatment and disposal of the surplus are considered a problem in wastewater treatments around the world, considering environmental, economic, social, and legal factors (Wang et al., 2017). Therefore, the approach of wastewater treatments has always moved to the development of technologies for reducing the production of sewage sludge or their optimal management aiming at reducing the environmental effects. The sewage sludge has resulted from wastewater treatment produced during elementary, secondary and sometimes tertiary treatment, the production of biological sludge and its qualitative characteristics besides the qualitative and quantitative features of swage, depends on the process of treatment and its guiding conditions (Ahmad et al., 2016). One

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of the main disadvantages of biological wastewater treatment is the almost high production of surplus biological sludge so that around 40% to 60% of investment cost and more than 50% of the cost of guiding and maintaining wastewater treatments are related to the treatment of sludge resulted from the processes of wastewater treatment (Ahmad et al., 2016).

Common wastewater treatment plants in Iran mostly use physical and biological methods for sewage treatment. The process of activated sludge is widely used doe biological treatment around Iran. Still, as a result of using this method, a considerable amount of disposal surplus sludge is produced that has to be disposed (Amin et al., 2018). The sludge of these treatment plants contains a significant amount of Volatile Solids (VS) and water (>95%). The costs of disposing of them are considerable due to the high amount of solids. In fact, the costs of treatment and disposal of surplus sludge resultant from wastewater treatment consist the 25% to 65% of the total costs of exploitation, so the problem of water pollution turns into the problem of solid wastes disposal (Mohammadi et al., 2018). This problem is increasing in developing and industrial countries. Finally, surplus sludge disposal is the most important serious challenges in biological wastewater treatment because of two reasons (Droste and Gehr, 2018). Therefore, disposing of sewage sludge may be important in the environmental effects of wastewater treatment plants, and at last, it may read to the reduction of wastewater treatment environmental effects.

Most of the present established wastewater treatment installations in Iran need revision and improvement to be considered in a sustainable development route. Also, it is necessary to recognize the harmful environmental effects of these installations and establishing them considering the reduction of these effects in order to establish new installations to cover more people covered by sewage management systems. For example, according to some studies, more than 5% of electric energy consumption in the world is spent on wastewater treatment plants (Barceló and Petrovic, 2011). Also, 1% of released greenhouse gases in America is resulted from wastewater treatment equipment (Nguyen et al., 2019; Saber and Venayagamoorthy, 2010). Considering the lack of conducted studies in the field of assessing wastewater treatment plants, it is essential to conduct such studies in Iran.

One of the approaches to select suitable sewage sludge disposal systems is using life-cycle assessment models, which leads to a precise and proper comparison model through scientific and quantitative approach and the selection of a suitable system based on environmental, economic and social criteria. LCA method, with its comprehensive approach, provides the decision-makers with the possibility to be aware of the environmental effects of a section and to investigate improvement choices and the reduction of effects. These models have developed in many advanced countries, which depend on the frequency of use reliance on decision making that, unfortunately, these models have not been regarded in Iran yet (Finkbeiner et al., 2006). So many studies have been conducted so far utilizing LCA technique on water and wastewater systems. Some of these studies have considered the water cycle from the arrival to water treatment plant and consumption to exit from wastewater treatment plant (Halleux et al., 2008; Hospido et al., 2012; Rahman et al., 2015); however, due to the expansion of data needed for LCA studies, the smaller study field is selected. For example, some of them have only considered the effects of water treatment (Stokes and Horvath, 2006, 2011) . The studies on the assessment of life-cycle of wastewater treatment plants have investigated different fields. Some of LCA studies have considered effects related to three phases of construction, exploitation, and disposal (Buonocore et al., 2018; Flores et al., 2019; Garfí et al., 2017). some of them have regarding the environmental effects of the construction phase negligible in comparison to the exploitation phase (Lyons et al., 2009). Therefore, some of these studies didn't include this phase in their studies and have only considered the function phase of the wastewater treatment plant (Hospido et al., 2010). Some of the researches have included construction and function phases in their measurements, and they have only removed the sludge disposal phase (Finkbeiner et al., 2006; Nguyen et al., 2020).

Few studies have been conducted in the field of modeling sewage sludge life-cycles. Sargazi and colleagues (2017) have assessed the life-cycle of sewage treatment plant sludge management options from energy and global warming point of view (Sargazi. H, 2017). This study has used six scenarios in the sludge treatment of sewage treatment plants, including using in agriculture, burning in fluidized bed furnace, wet oxidation, pyrolysis, burning in cement, and landfill furnaces. The study focuses on energy and pollutions related to global warming during all stages of sludge treatment. The production of side products in different methods of sludge management prevents problems and damages, which is very important regarding energy consumption and pollution production. Energy balance shows that burning sludge and using it in agriculture has the lowest consumption rank among non-renewable energies. Considering global warming, burning in cement furnace has the best balance, and landfills and used in agriculture have the worst balance.

Gholamreza Assadollah Fardi and others (2016) assessed the environmental life-cycle of Khomein wastewater treatment plant (Abadi et al., 2016). This study aimed at analyzing the assessment of life-cycle including greenhouse gases release, the ozone layer, eutrophication, photochemical oxidation, the effect of human toxicity and the effect of toxicity on marine creatures resultant from Khomein wastewater treatment plants located in Markazi Province during exploitation utilizing ISO14040 standard and the application of SimaPro-v7.1.8-2008 and through CML 2 Baseline 2000 method. This study has synchronously used data from BUWAL 250, DK Input-Output Database, and Ecoinvent system processes. Hamed Parsajou and colleagues (2016) assessed the life-cycle of Khalkhal wastewater treatment plant system (Sharifi et al., 2016). This study has assessed sledge treatment system (activated sludge) of Khalkhal wastewater treatment plant.

Also, Tabesh and Masouleh Feizi (2012) reviewed the assessment of life-cycle and its application in urban wastewater treatment plants. This study first explained the assessment method of life-cycle and wastewater treatment plants and its stages, then the common methods of assessing LCIA life-cycle was described; finally, the studies of assessing the life-cycle of wastewater treatment plants were investigated which have been conducted so far.

Using LCA for environmental assessment has a long history. However, this environmental assessment method has been less considered and used in developing countries like Iran. Wastewater treatment plants have a major role in generating environmental effects. So many studies have been conducted to assess these structures in different countries, especially in developed ones. Considering the different characteristics of sewage and the used processes in different countries, the necessity to conduct similar studies in Iran is necessarily felt.

Thus, according to what has been mentioned, the assessment of life-cycle to select sewage sludge disposal process in Iran wastewater treatment plants is very important and Ekbatan Tehran wastewater treatment plant with 45000 m^3 discharge per day chosen for this purpose, so 4 different scenarios of sludge disposal have been investigated for this treatment plant in the following.

Material and Methods

Ekbatan Tehran Wastewater Treatment Plant

Ekbatan Site Wastewater Treatment Plant has been designed for the population of 100000 population and 24000 m^3 average discharge per day and the maximum discharge of 45000m^3 per day with 262HA covered area and 7HA the area of wastewater treatment plant ground and around 97% removal efficiency. Its type of process is A_2O, and Nahr-e-Firuzabad is its wastewater disposal place (TPWW, 2019). Right now, the average of produced sewage is around 675 thousand m^3 per day and night, and these six units can produce more than 240 million m^3 wastewater. This wastewater supplies water needed for the agriculture of low plains of Tehran, which do not have water, or they are watered by surface water or raw wastewater. Then the operational units of this treatment plant have been explained in the following:

- Entrance Pumping Station

This pumping station includes three rotary screw pumps at the entrance of the western transfer line with 1950l/s capacity and 5.25m pumping height. In order to prevent undesirable odors produced by entered raw sewage to the treatment plant, they have been constructed in a roofed manner. Odors collected in this unit will be removed after being transferred to the odor treatment unit.

- Screen

This unit consists of four coarse mechanical screens with 50mm distance between bars and four fine screens with 10mm distance between bars and the comprehensive transfer and compression of collected materials in screens. This unit is roofed and wastes produced in this unit after compression transferred to garbage trucks, and then they are carried to landfills.

- Grit Chamber and Grease Trap

The type of grit chamber and grease trap is aeration. The gravel and sand particles and greases remove in this process. The removal mechanism of these materials is based on rotational flow, which is not dependent on entrance flow and grease, oil and foam transferred to the surface of water merely through rotation, and they are collected by grease trapper paddle. Three bowlers supply the needed air. This unit is consisted of four pools in 11.5m×50m dimensions and 3.9m depth.

- Primary Clarifier

First, the suspended solids settled through the gravity method, and then they are discharged as primary sludge. The primary clarifier consists of four rectangular basins with a mechanical foam trap and a scraper with linear movement. The primary clarifier removes around 50% suspended solids, 30% BOD_5, 9% nitrogen, and 11% phosphate. There are four rectangular clarifiers with 27m×60m dimensions and 3m depth in this center.

- Aeration Basins

This unit is one of the important units of wastewater treatment plants with the activated sludge method. This unit uses a step-by-step aeration diffuser, which merely removes carbons and BOD. Also, around two days is considered as the age of sludge in the aeration unit. There are four aeration basins in this unit, each of them including one selector responsible for transforming produced nitrate from the nitrification process in trickling filters into N_2 and lowering the total nitrogen in the nitrification process. Also, the selector is responsible for controlling filamentous bacteria and preventing the sludge bulking phenomenon in the secondary clarifier.

- Trickling Filter

There are four trickling filters and six submersible pumps that receive 50% of output wastewater from the secondary clarifier. The transformation of ammonia nitrogen into nitrate is done through the nitrification process.

- Secondary Clarifier

These basins are designed rectangular-shaped and scraper with linear movement. The biological mass of sludge is settled by gravity method, and a percent of sludge is transferred to the aeration basin by four spiral pumps to activate and to reproduce the bacteria. 50% of output wastewater from the secondary clarifier, as well as output wastewater from the sludge dewatering unit, is guided to trickling filter, and the ammonia nitrogen operation is done.

- Chlorination

The wastewater is chlorinated for 15 min retention time, and all pathogenic reasons are removed, and then the wastewater will be used for watering farms.

- Sludge Treatment

For sludge treatment utilizing gravity and mechanical concentration process, the sludge from primary and secondary clarifiers is concentrated, and then it will be stabilized through anaerobic digestion method. After stabilization, the produced sludge is sent to the impounding stage, and after the production of sludge cake and drying, it will be used as fertilizer in agriculture. In sludge impounding, the concentration of sludge increases from 7000mg/l to 60000mg/l, then it is mixed with primary sludge, and then it is transferred to the digester. Digesters digest and stabilize sludge utilizing anaerobic digestion method and also remove pathogenic bacteria; then, the produced methane is used to produce electricity and to supply the energy of the system.

The Assessment of Life-Cycle

The assessment study of life-cycle has been developed based on ISO 1404 Standard. According to this standard, the process of assessing life-cycle has consisted of the following stages (Lerner et al., 2018):

- Determining purpose and range, which includes the stages of field survey and collecting primary information, determining the boundary of the system and functional units.
- Analyzing the list of life-cycle (determining inputs and outputs or the release of pollutants)
- Assessing the effects of life-cycle
- Interpreting results

The stages of the study will be explained shortly as follows (Ciroth et al., 2014; Rodríguez and Greve, 2016; Winter et al., 2015):

- First Stage-Filed Survey and Collecting Primary Information

In this stage, the needed information about the study is collected. Besides collecting primary information, the general framework of a life-style assessment study including results and outcomes of the study, functional unit description, production unit and its boundaries, sources allotment, and choosing effective section will be specified in this stage. Selecting system boundary is among the important and necessary operations in this stage due to a high effect on the results of life-cycle assessment. Based on ISO 1404 Standard, the functional unit determines the function of a production unit or system as a reference unit.

- Second Stage-Scenario Development:

Different options of managing and disposing of sludge are selected and investigated in this stage to assess the environmental effects of each option by means of the life-cycle assessment method.

- Third Stage-Completing Life-Cycle Assessment (LCA) List:

All used sources and the release of pollutants are considered in total or a part of the product or process life-cycle considering functional unit and system boundary in this stage. In other words, the life-cycle list includes collecting and organizing input and output data to achieve the predetermined purposes of the study.

- Fourth Stage-Assessing Life-Cycle Effects (Modeling by Software):

This stage assesses the potential effects of consuming environmental sources and producing pollutants on humans and nature. In fact, LCA aims at interpreting most of the life-cycle data list. In order to assess the effects of the study subsystem's life-cycle effects, the data from the life-cycle list enters OPENLCA or Eco Indicator99. These types of software are among the most useful and the most popular LCA soft-wares (Ciroth et al., 2014; Rodríguez and Greve, 2016; Winter et al., 2015).

This software is one of the most useful and the most popular software LCA soft-wares. Based on ISO14042 instruction, the assessment of life-cycle effects contain four stages (Grudziński et al., 2016):

1. Selecting group effect and classification
2. Characterization
3. Normalization
4. Weighting. It is important to mention that the third and fourth stages are optional.

The third stage will be done in order to equalize units and to compare different group effects with each other. In other words, units' equalization is conducted because generally, each of the group effects in an LCA study has different measurement unit so that comparing the importance of group effects in a subsystem and also between different subsystems is impossible.

Therefore, the normalization method is usually used so that every group effect is divided into a reference value which is the average of annual environmental effect in a country or a climate per person. Normalizing group effects equalizes the measurement units of these sections, and as a result, comparison between them and their application as the same unit values will be more comfortable.

Eco-indicator 99 evaluates damages to human health, ecosystem quality, and mineral and fossil, which are discussed in detail as follows.

Human health damages assume the possible basic problems for humankind, including; transmitted illnesses by the environment, disabilities due to pollution or premature deaths, climate change, ozone layer depletion, ionizing radiation, respiratory effects, and carcinogenesis (Dreyer et al., 2003).

- Fifth Stage-Interpreting Results:

This stage evaluates the results of the inventory, and the assessment of effect to recognize stages or steps with the most and the least destructive effects on the environment in production and consumption, and finally, conclusion and representing approaches will be investigated.

Results and Discussion

The following scenarios have been considered in this design for sludge management of Ekbatan Tehran Wastewater Treatment Plant:

1. First scenario: the production of chemicals and carrying them to treatment plants that, according to the taken information from the management of treatment plants, polymer and chlorine are the main used chemicals whose effects of producing and carrying them to treatment plants are investigated.
2. Second scenario: producing energy for doing processes of wastewater and sludge treatment, which a part of it is supplied through burning biogas from burning sludge, and another part is supplied through natural gas power plants.
3. Third scenario: digesting sludge and producing gases from wastewater treatment process like CH_4, CO_2, N_2O, NH_3 and H_2S.
4. Fourth scenario: carrying sludge and using it for agricultural lands.

Figure 1 shows system boundaries, inputs, and outputs.

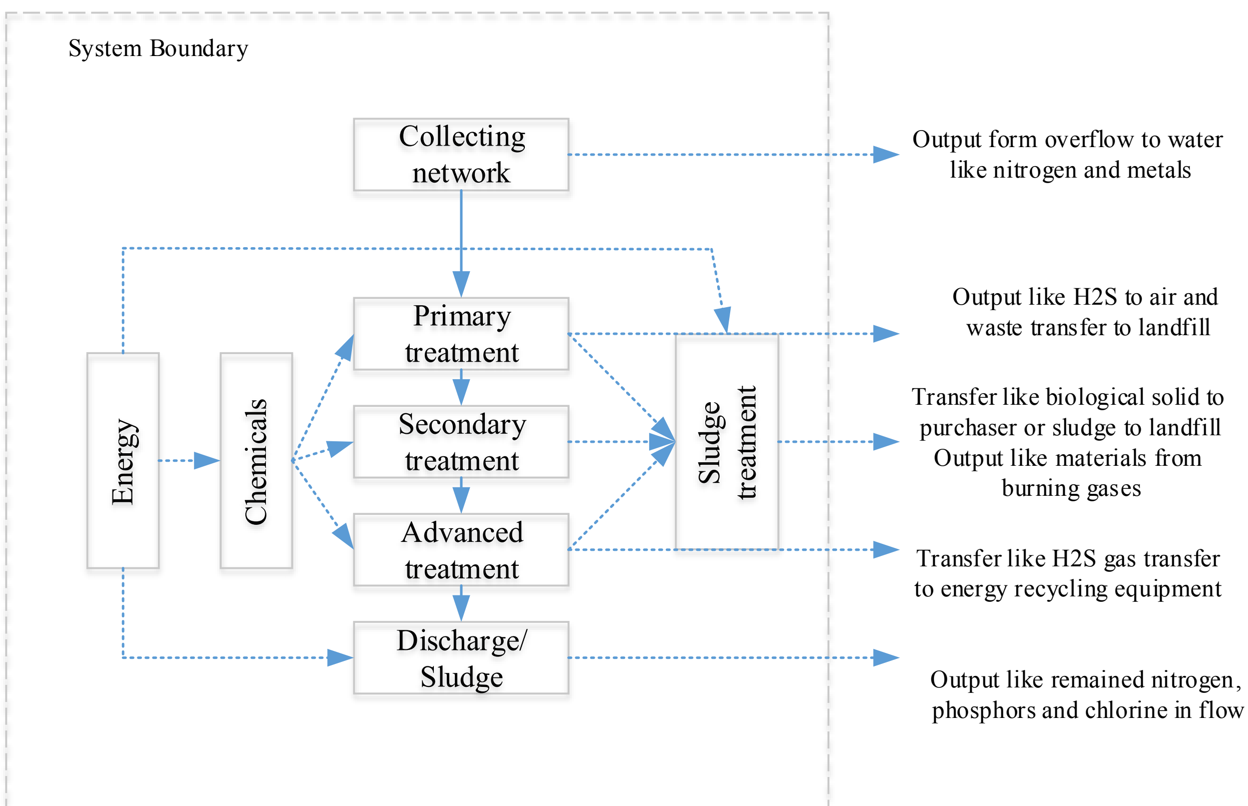

Figure 1. System boundaries, inputs and outputs

The considered functional unit among produced pollutants and consumed energy is 2018 for produced sludge based on kilograms per day and study temporal framework. In this stage, data related to different stages are collected.

The needed data for life-cycle primary listing obtained from Tehran Wastewater Organization reports and conducted designs and studies and also in-person interviews with the staff of Tehran Treatment Plant (Table 1-3) (TPWW, 2019).

Table 1. Input and output wastewater characteristics

Parameter	Value	Unit
Q	450000	m^3/d
TKN_{in}	50	mg/l
TKN_{out}	35	mg/l
TSS_{in}	340	mg/l
TSS_{out}	25	mg/l
BOD_{in}	300	mg/l
BOD_{out}	25	mg/l
COD_{in}	540	mg/l
BOD_{out}	70	mg/l

Table 2. Sludge characteristics

Parameter	Value	Unit
Q	450	ton/day
TS	56.9	%
TKN	1.43	%TS
Total Phosphorus	0.7	%TS

Polymer and chlorine are mainly used in treatment plants. The polymer is used for stabilizing sludge, and chlorine is used to remove pathogenic microorganisms.

Table 3. Chemicals used in treatment plants

Material	Weight	Unit
Polymer	4500	kg/day
Chlorine	850	kg/day

Electric and thermal energies are used in wastewater treatment plants to do different processes like pumping, activated sludge, and nitrification. The total energy used for wastewater treatment is 6.25MW in this plant which 80% of this energy is supplied by burning biogas from digesting sludge and the rest of it by gas power plants.

According to the taken information from the treatment plant, the distance of carrying chlorine and polymer is consistent with table 4. Also carrying is supposed to be done by 40t trucks. Sludge transportation to the depo site has also been considered in calculations. The effects of sludge diffusion, such as fuel consumption and output to air and soil, have been modeled in OPENCAL software. Table 4 shows the carrying of different materials.

Table 4. Materials replacement to Ekbatan Treatment Plant

Material	Mass (ton)	Distance (km)	Distance × Mass
Chlorine	4.5	100	4500
Polymer	0.8	100	80
Sludge to depo	450	4	1800
Sludge to agricultural field	450	18	8100
Total			14500 t.km

Outputs from sludge anaerobic digestion and burning biogas include CO_2, carbon monoxide, dihydrogen oxide, and nitrogen oxides. Table 5 shows these outputs. Also, diffusing sludge in fields releases methane, ammonium, and nitrogen oxides, and table 6 shows these values. Table 7 shows the values of released gases from activated sludge and trickling filter processes.

Table 5. Outputs of sludge digestion and biogas burning

Process	Name	Value	Unit	Source
Sludge digestion	Biogenic CO_2	145237	kg/day	Rodriguez-Garcia et al. (2012)
	Particulates	9	kg/day	
	CO	95	kg/day	
	NO_2	95.6	kg/day	
Biogas burning	CO_2	9405	kg/day	
	CH_4	614	kg/day	
	NO_x	1025	kg/day	
	SO_2	36	kg/day	
	CO	518	kg/day	

Table 6. Output gases from using sludge in agriculture

Name	Value	Unit	Source
CH_4	358	kg/day	Hospido et al. (2005)
NO_x	93	kg/day	Svanström et al. (2005)
NH_3	214	kg/day	Svanström et al. (2005)

Table 7. Gases from the total of two activated sludge and trickling filter processes

Name	Value	Unit	Source
N_2O	160	kg/day	EPA (2010)
Biogenic CO_2	3800	kg/day	

After assessing the effects of different group's effects on life-cycle, the generating reasons for effects are identified.

According to the information and other minor information which it is not possible to represent it in this article due to high volume, 4 suggested scenarios of sewage sludge disposal have been modeled in OPENCLA and by means of Eco-Indicator 99 database that the results will be represented and compared with each other based on effects titers in the following:

Carcinogenesis

Many chemicals lead to cancer in humans and animals in long contact. A carcinogenic substance can act differently. For example, it can change DNA or increase cell division rate. Asbestos, radon, arsenic, and benzene are among toxic substances. According to table 2, only the sludge scenario has caused negative effects, which is due to the discharge of heavy metals into soil. Cadmium disposed to soil due to the use of sludge is fields have the most negative effect in this group. Although the value of cadmium in sludge is much less than other heavy metals (0.0003% of the whole heavy metals), the most negative effect in the carcinogenesis group effect is because of this metal (Daly 0.0268% or 99.2% of total negative effects in the group). The total carcinogenesis equals 0.0246 in the Daly scale. The energy scenario also has caused positive effects, which is negligible.

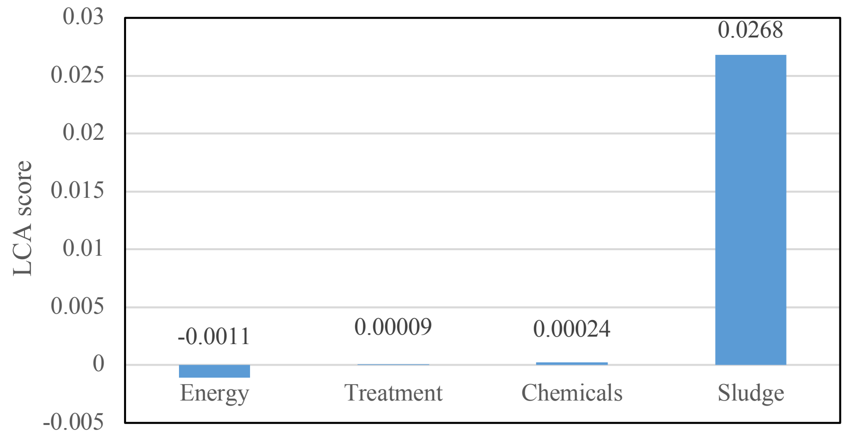

Figure 2. Results from carcinogenesis life-cycle assessment

Respiratory Organics

A group of toxic organics called Toxic Organic Micro Pollutants or TOMPs have generated due to fuels incomplete combustion and contain a wide range of very toxic chemicals such as PAHs, PCBs, dioxin, and furan.

According to the results in Figure 3, the use of chemicals has the most negative effect on this group effect. The production of chlorine and polymer leads to negative effects due to releasing NMVOCs and hydrocarbons. Sludge disposal scenario has also caused negative effects in this group effect, which is similar to chemicals scenarios due to NMVOC releasing as a result of sludge carrying to agricultural fields.

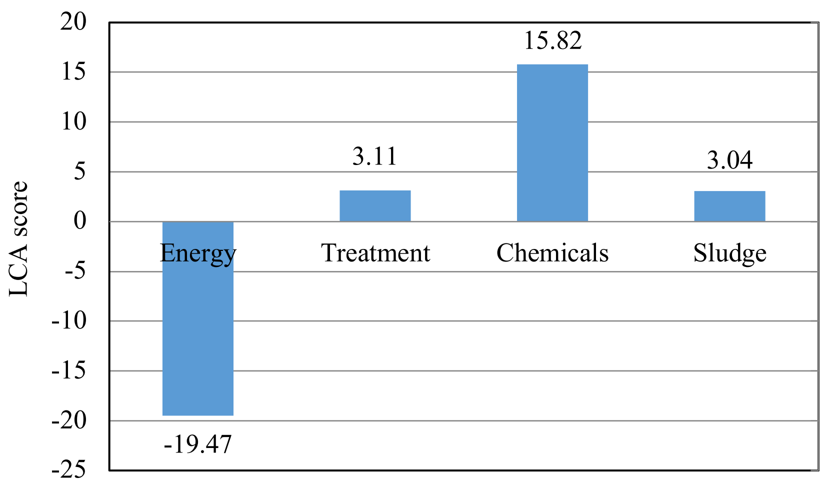

Figure 3. Results from respiratory organics life-cycle assessment

Respiratory Inorganics

Particulates are a set of small mineral particles in the air with negative effects for humans, such as respiratory diseases and death for humans. Many studies have confirmed the increase in the death rate as a result of environmental particulates increase. The particulates can release as particles or to be the product of chemical processes in the air. SO_2 and NO_x have the most percent of transformation into particulates. Women, elderlies, and patients who have asthma are more exposed to the negative effects of particles. According to the results in Table 4, all scenarios in the inorganic substances group effect effective in the respiratory system except energy have caused the negative effect, but only gases from wastewater treatment have significant effects in this group.

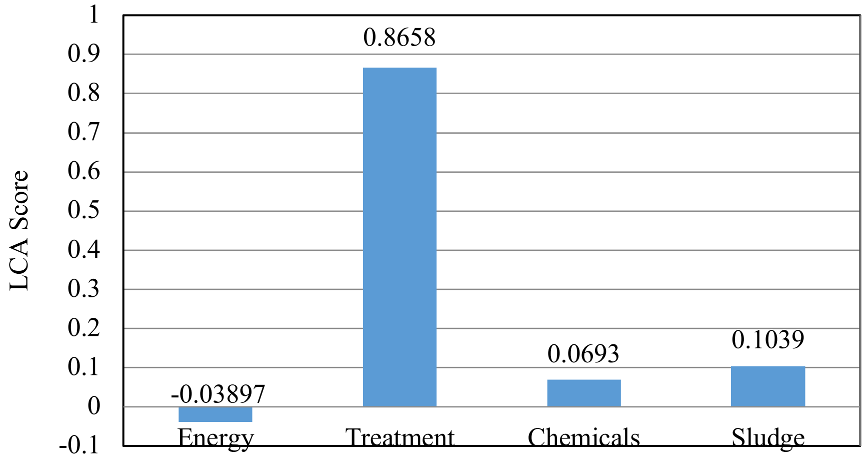

Figure 4. Results from respiratory inorganics life-cycle assessment

Climate Changes

Global warming is the increase in average temperature near Earth and troposphere, which changes global climatic patterns. This phenomenon happens due to natural and human activities, but the increase in greenhouse gases from human activities is usually considered global warming. Right now, climate change is used instead of global warming to other effects, except temperature increase be also considered.

Gases from treatment plants and chemicals have caused negative effects in climate changes group, but the negative effects of chemicals are negligible rather than gases from treatment. Figure 5 shows the negative effects related to different gases. According to the table, CO_2 and N_2O have had more negative effects on other gases.

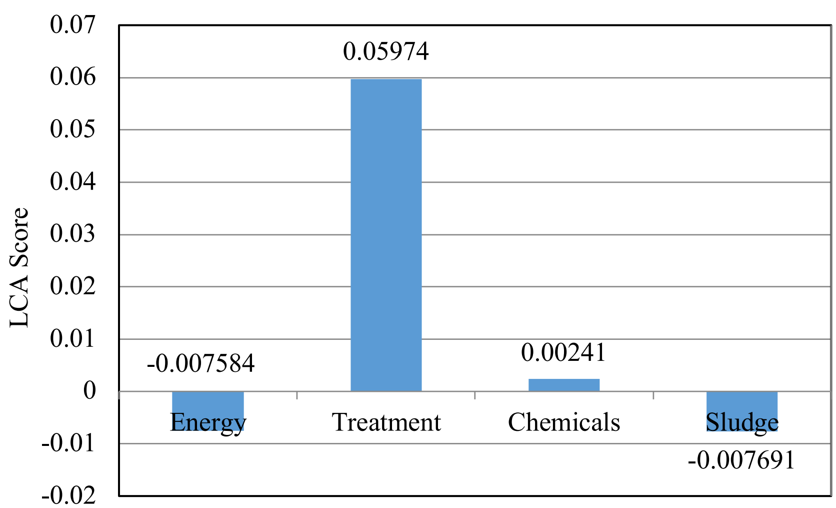

Figure 5. Results from climate change life-cycle assessment

N_2O is produced as a result of nitrification and denitrification. Although this process has improved the quality of treated sewage, the increase of greenhouse gases also increases the global warming potential. Sludge scenario has had a positive effect in this group effect due to economizing fertilizer, but its positive effects are not significant rather than the negative effects of gases scenario. On the other hand, two sludge and energy scenarios have had no such significant positive effects, which is due to preventing N_2O, methane, and CO_2 release.

Ecotoxicity

Ecotoxicity estimates the damage to air, water, and soil as a result of toxicants release. The sludge scenario is the only scenario that has affected this group. Chromium in sludge, which has the most percent of heavy metals in sludge, caused 91.6% of sludge scenario negative effects. However, it has appropriated 53% of the whole sludge heavy metals weight to itself. The total negative effects in this group resulted from sludge equals to 88199 in PAF×year×m^2. PAF specifies the species which are exposed to dangerous concentration. The increase in concentration increases the number of species that are influenced. Figure 6 shows effects related to the main substances generating this group effect.

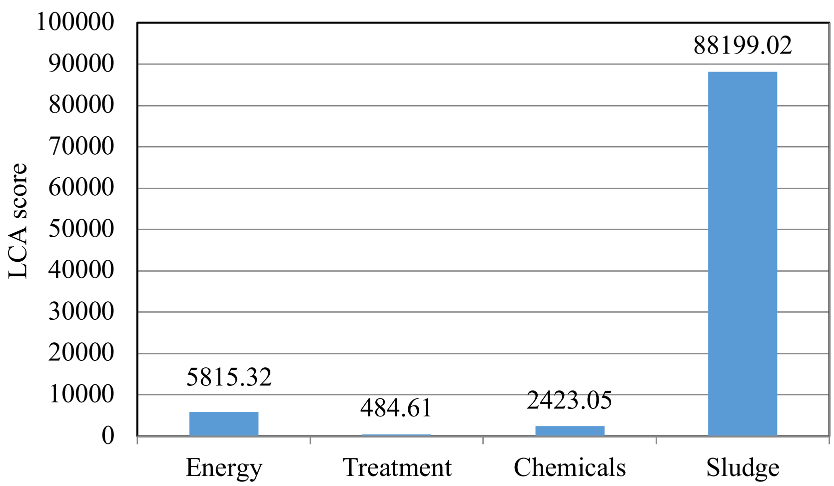

Figure 6. Results from ecotoxicity life-cycle assessment

Acidification/Fertilization

Acidification is the increase of hydrogen ion in the environment. This matter is either related to the release of acids like nitric acid and sulfuric acid to the environment or the release of chemicals because chemical reactions or natural cycles like soil change due to plant growth may lead to this process. Acidifiers are usually gases that can be replaced kilometers before sedimentation as acid rain, fog, snow, or dust particles (Bare, 2011).

Substances that lead to acidification may damage different building materials, lakes, rivers, plants, and animals. The sensitivity of the environment to these substances depends on various parameters like region buffering capacity, local plant and animal species, and the environment acidity. Fertilization is the ecosystem response to human activities that fertilizes waters with nitrogen and phosphorus. This process may lead to a change in plant and animal population and water removal. Nitrogen oxides and sulfur dioxide have caused gases from the treatment plant scenario to appropriate the maximum negative effects to themselves. Ammonium also has had a significant role in generating negative effects in sludge and energy scenario. Figure 7 shows the effect of each significant output.

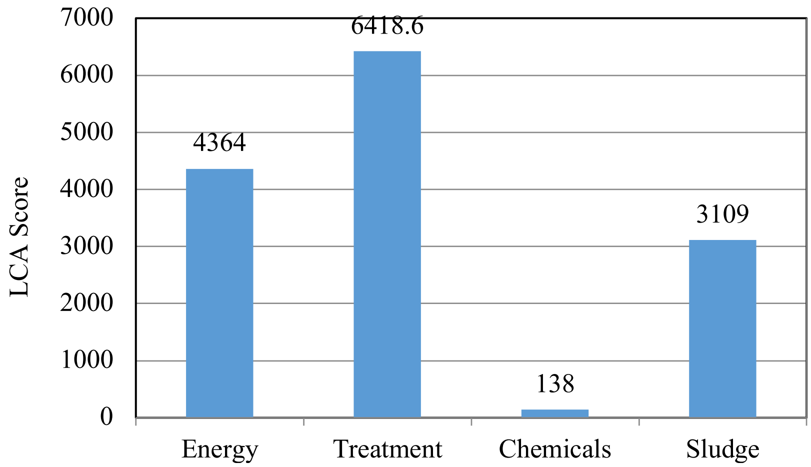

Figure 7. Results from acidification life-cycle assessment

Fossil Fuels

There are three types of fossil fuels, including coal, oil, and natural gas. According to the statistics, the resources of fossil fuels, which are easily removable such as liquid oil, is decreasing. This does not necessarily mean that fossil fuels are running out, but resources with lower quality like oil shale have to be used. This lower quality may be defined as extra energy because extracting oil shale needs more energy than liquid oil (Elduque et al., 2015).

According to the results in Figure 8, using biogas from sludge digestion for supplying treatment plants has caused an energy scenario to appropriate 100% positive environmental energy in this group to itself. This is because of not using natural gas for supplying treatment plant energy and, as a result economizing fossil fuel consumption. Also, using sludge as fertilizer has economized energy in the sludge scenario.

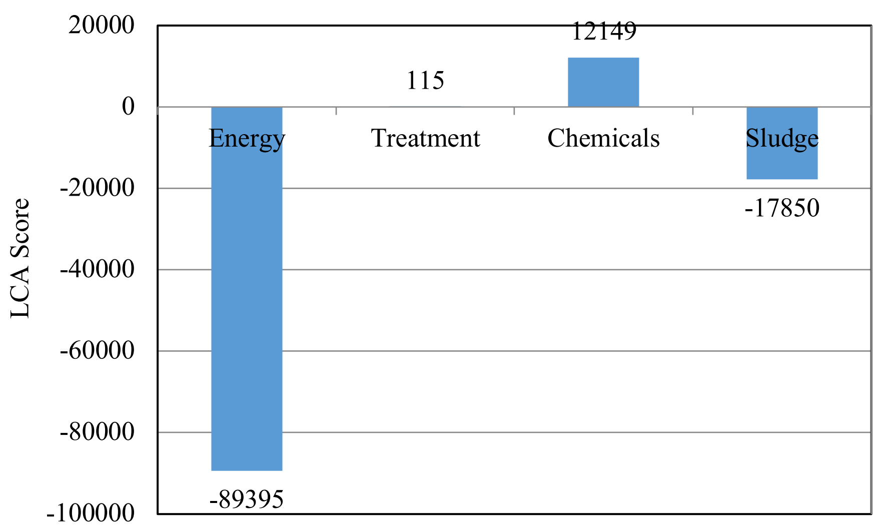

Figure 8. Fossil fuels negative effects (MJ)

Normalization

Normalization is a process that specifies the effect of a group effect rather than the whole environmental problem. There are two primary purposes in the normalization stage:

1. Group effects with smaller effect rather than other group effects cannot be considered, and as a result, they reduce assessment items.
2. Results from normalization show the magnitude of environmental problems resulted from a product rather than all environmental effects.

After the description stage, the normalization will be conducted, and figure 9 shows the results. In Eco Indicator99 normalization values are based on European values per each person.

According to the diagram, group effects with significant effects are carcinogenesis, respiratory inorganics, climate changes, ecotoxicity, acidification/fertilization, and fossil fuels.

The significant point in this diagram is the significant positive effects of the energy scenario in the fossil fuel group effect, which turns the fossil fuels group effect into the most important group effect. This is because of supplying 80% of treatment plant energy from burning methane in sludge digestion. Also, the most negative effect belongs to the respiratory inorganics group effect whose gases from sewage treatment scenario has the most negative effect.

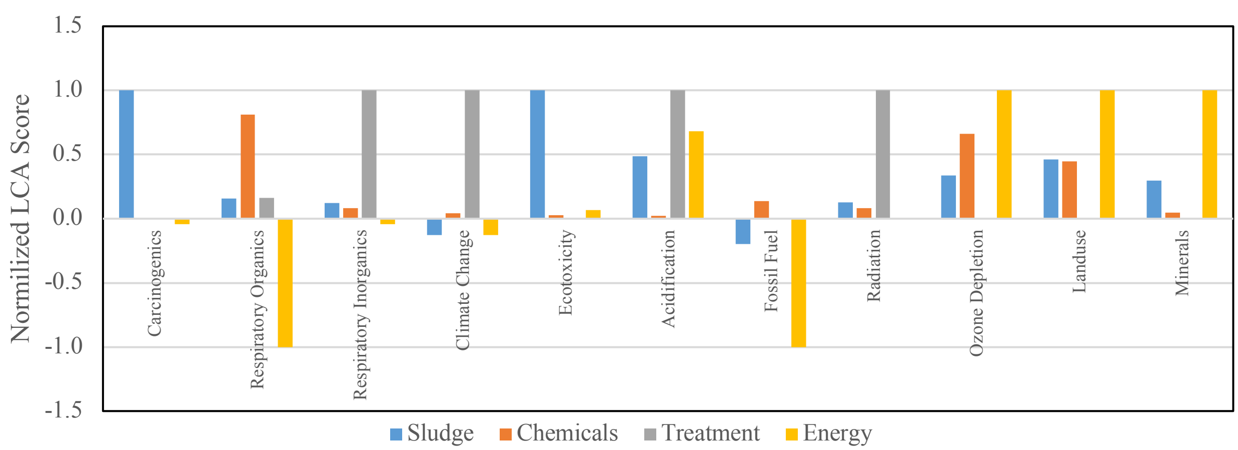

Figure 9. Normalization results from different scenarios

Using sludge from sewage treatment as agriculture fertilizer causes significant positive effects in the fossil fuels group effect. This is because economizing needed energy to produce chemical fertilizers. But it has negative effects on two ecotoxicity and carcinogenesis group effects. As mentioned before, heavy metals in sludge have caused such negative effects in these group effects. The reduction of heavy metals in sludge may reduce the negative effects of using sludge. But it is important to mention that industrial fertilizers have significant values of heavy metals. Therefore, the reduction of these metals has to be considered in fertilizers. Sludge burning is one of the approaches to reduce negative effects from disposal and or using sludge. However, this process also releases toxic gases into the environment and need to use energy. Comparing the life-cycle of using sludge in agriculture, burning, and disposal scenarios may help decision-makers select a suitable process.

Using chemicals has only significant negative effects on the fossil fuel group effect. Investigating chemicals needed optimal value by a different process of sludge stabilization, and water disinfection may reduce consuming them. As a result, this effect may influence this group effect less.

Negative effects of the treatment process in the inorganics group influential on the respiratory system and climate change are observable. NO_x from burning biogas has caused negative effects in the inorganics group effect influential on the respiratory system. Despite the negative effect of burning gas because of producing NO_x, it is possible to ignore the negative effects because of significant economizing fossil fuel consumption and not producing negative effects from it. In section 4-10 two scenarios of using biogas and not using it have been compared with each other.

Investigating the Use of Biogas as Fuel in Treatment Plant

As mentioned before, the treatment plant supplies 80% of its needed energy from burning biogas. To investigate the positive effect of this process on treatment plant environmental performance, the energy scenario is supposed to supply its needed energy through natural gas.

According to the results of this analysis, using 100% natural gas to supply needed energy in treatment plants in climate changes and inorganics influential in respiratory system group effects have caused negative effects. Although, in the previous state, not only the energy scenario caused a negative effect, but also it has positive effects. The most change from not using biogas to supply energy is observed in the fossil fuels group effect.

Investigating the Effects of Sewage Discharge into the Rivers

Treated sewage after existing from Ekbatan Tehran Treatment Plant is used for watering Varamin plains agricultural fields. However, some treatment plants discharge treated sewage into rivers. Here the effect of discharged treated sewage of the plants into rivers is investigated to use its results in deciding the establishment of new treatment plants.

Eco Indicator99 method does not consider the effect of releasing nutrients and acids on water and soil. Therefore, CML2000, as a moderate method, is used to compare the environmental effects of two scenarios of using treated sewage in agriculture and discharging it into the river.

According to the results, discharging treated sewage into the river has many negative effects on the fertilization group effect. This group effect with a high difference has the most negative environmental effect rather than other group effects. Table 8 shows the substances with the most effective in generating this effect.

Table 8. the main substances in generating fertilization in Ekbatan Tehran wastewater treatment plant

Name	Effect	Unit	Outflow Site
Total nitrogen	55420	$kgPO_4$	Water
Total phosphorus	54230	$kgPO_4$	Water
Total phosphate	12980	$kgPO_4$	Water
COD	598	$kgPO_4$	Water

Fertilization is one of the basic criteria for determining sustainable sewage treatment (Nkoa, 2014). Despite using advanced treatment processes (trickling filter) in treatment plants, fertilization potential in bodies of water is still the most important negative environmental effect imposed on treatment plants.

Three following solutions are suggested to reduce this negative effect:

1. Not discharging treated sewage into bodies of water.
2. Enhancing advanced treatment degree to remove nitrogen and phosphorus
3. Reducing sewage nutrients

In the case of increasing treatment degree, the consumption of materials and energy will be increased. As a result, this may lead to an increase in negative effects in other group effects.

Conclusion

Life-cycle assessment studies have been conducted about Ekbatan Tehran Wastewater Treatment Plant by means of OPENCAL and life-cycle effects assessment method Eco Indicator 99, and these effects determined in seven groups. Totals outputs and inputs of processes are defined in four scenarios of energy, chemicals, treatment process gases, and sludge transfer and using it for agriculture.

According to the results of this analysis, using sludge in agricultural fields has positive effects on the fossil fuel group effect due to economizing the production of phosphorus and nitrogen fertilizers. On the other hand, using sludge in agriculture may have negative effects on carcinogenesis, respiratory inorganics, ecotoxicity, and acidification/fertilization group effects which mainly because of heavy metals in sludge. However, industrial fertilizers have some heavy metals. Therefore, comparing life-cycle effects from these two processes of using sludge and industrial fertilizer may be effective in deciding to choose the optimal process. Also, comparing the effects from different processes of sludge disposal have to be studied in the future.

This treatment plant has used a trickling filter to reduce nitrogen in sewage. This reduction also decreased nitrogen in sludge. So this reduces the economized fertilizer. Also, denitrogen oxide is one of the products of this process, which has a significant negative effect on the climate change group effect. As mentioned earlier, treated sewage is used for watering, and it does not enter bodies of water. Thus, nitrogen reduction processes have to be investigated to determine their positive and negative effects and to see whether they have been useful or not.

One of the most important aspects of the results is the significant positive effects of using biogas to supply treatment plant energy. Using fossil fuels may cause many problems for future generations due to their limited resources. Therefore, using clear processes to supply energy besides conserving fossil resources may reduce the negative effects of climate changes and respiratory problems. Using biogas from the sludge disposal process besides preventing methane release into the air and its negative effects such as global warming may economize the use of fossil fuels.

Despite using processes to reduce nitrogen in sewage, in the case of releasing sewage into the rivers, many negative effects will appear in the fertilization group effect. Normalization specifies that the negative effects in this group are more than three times of total negative effects of group effects. Therefore, in the case of discharging sewage into the river, its nitrogen has to be reduced as possible. On the other hand, more reduction of nitrogen increases energy consumption, chemical use, and NO2 production. So it is recommended to prevent treated sewage disposal into rivers. In the case of discharging it into rivers, its optimal value of nitrogen removal has to be determined by life-cycle assessment studies.

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