Environmental Burdens of a Large Water Treatment Plant: The Operational Phase

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Abstract. Being a metropolis, Istanbul requires a well-functioning urban service system. Water supply is among the most important infrastructures in this city that has around 15-16 million habitants. There are many water treatment plants all around Istanbul to facilitate healthy water supply to people. On the other hand, these plants are sources of negative environmental impacts. In this perspective, it is necessary to investigate the ways to reduce these negative environmental impacts. The objective of this study is to evaluate the environmental impacts of Kagithane Water Treatment Plant (KWTP) by adopting life cycle assessment (LCA) methodology. KWTP is one of the biggest water treatment plants in Turkey. The treatment plant is located on the western side of Istanbul. It withdraws water from Terkos Lake and Alibey Dam. Energy input is addressed as the most important contributor to all environmental impact categories. In conclusion, it is recommended to develop strategies for the reduction of energy consumption together with adopting from renewable sources for energy input.

Keywords: Water treatment, Environmental impacts, Life cycle assessment, Operation.

1. Introduction

Important levels of environmental burdens arise from the infrastructure services in metropolitan areas with large inhabitants. Water supply systems that are composed of water treatment plants and the distribution networks are among the significant infrastructural services in a metropolis.

Life cycle assessment (LCA) is a useful tool to pinpoint the environmental impacts of products, processes and services as it provides quantitative information. Therefore, strategies for lowering the environmental impacts can be developed based on the results of LCA studies.

There are LCA studies in literature conducted on water treatment plants (Alaa et al., 2019; Capitanescu et al. 2015; Mery et al. 2013). Operation stage of water treatment plants is stated to generate the highest environmental impacts in comparison with the construction and decommissioning stages (Friedrich et al. 2007; Friedrich and Buckley 2002). A sound environmental management that targets lowering the negative environmental impacts generated especially by the operation of water treatment plants is of concern.

In this perspective the aim of this study is to appraise the environmental impacts generated during the operation phase of a large water treatment plant. Strategies to decrease the unwanted environmental impacts are also put forward.

2. Materials and Methods

Life cycle assessment methodology having the following four stages of: i) goal and scope definition; ii) life cycle inventory; iii) life cycle impact assessment and; iv) interpretation of findings; is applied. The mentioned four phases are iteratively performed with feedbacks. The scope of the study is the operation phase as it is indicated in literature that this is the main contributing phase to all investigated environmental impact categories (Friedrich and Buckley 2002). Therefore, construction and decommissioning stages of the facility is not covered in this study. The main processes of the plant are the screen, input/output pumps, aeration, ozonation, slow/rapid mixing, clarification, filtration, disinfection and sludge processing. The schematic flowchart of the treatment plant is illustated in Figure 1. The views from the treatment is given in Figure 2. Data collected from the actual plant for about a year is to establish the inventory. The functional unit of the study is 1 m^3. The material usage, electricity consumption and transportation of chemicals are normalized for this functional unit. Modelling is performed on GaBi software version 7.3 and Professional Database is used for background processes.

CML 2001 is used for converting input and output flows to impact categories. The following environmental impact categories are investigated: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), ozone layer depletion potential (ODP), abiotic depletion potential elements& fossil (ADP elements&fossil), freshwater aquatic ecotoxicity potential (FAEP), human toxicity potential (HTP), marine aquatic ecotoxicity potential (MAEP), photochemical ozone creation potential (POCP) and terrestric ecotoxicity potential (TETP).

The aggregat ... ectively.

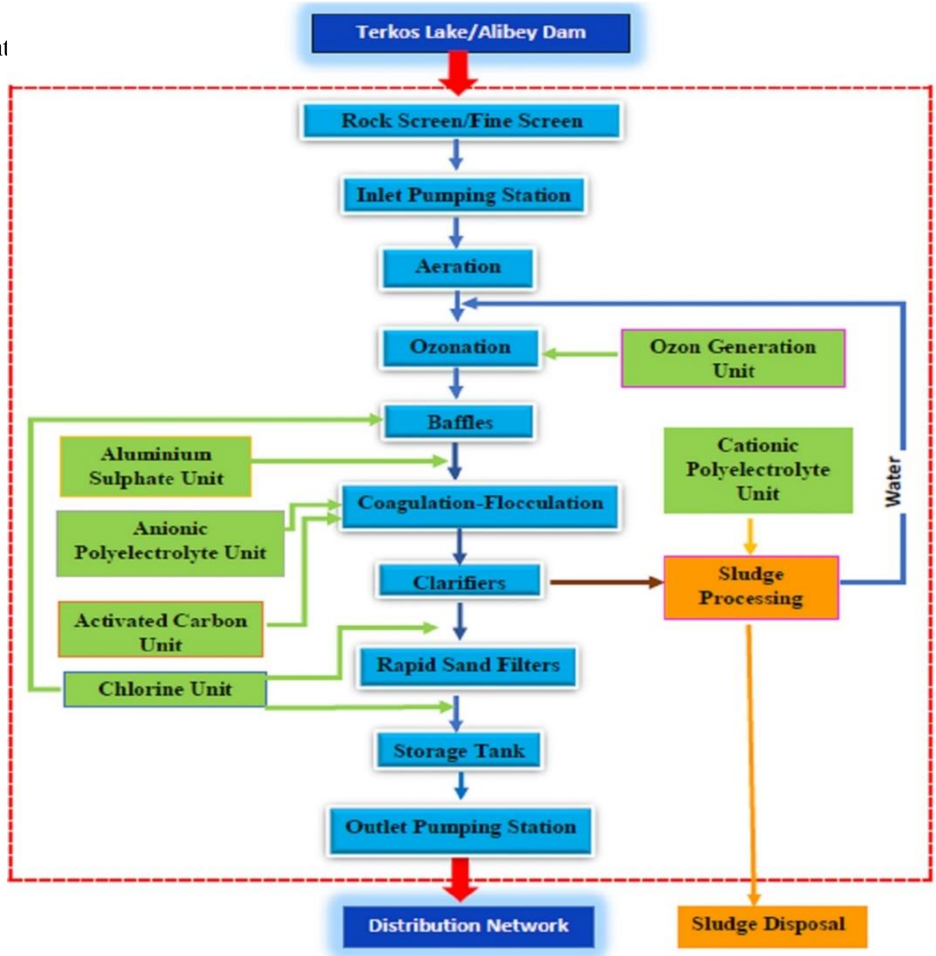

Figure 1. The schematic flowchart of the investigated treatment plant

Figure 2. Aeration unit and rapid sand filters

Table 1. Aggregated Inventory

Data	Amount	Unit
Inputs		
Lake Water	1.045	m^3
Electricity	7.6×10^{-1}	kWh/m^3
Chlorine Cl_2	3.5×10^{-3}	kg/m^3
Aluminium Sulfate	6.6×10^{-2}	kg/m^3
Anionic Polyelectrolyte	$1.9x10^{-4}$	kg/m^3
Cationic Polyelectrolyte	3.0×10^{-4}	kg/m^3
Activated Carbon	$1x10^{-3}$	kg/m^3
Compressed air	$1.9x10^{-1}$	Nm^3/m^3
Ozone	2.03×10^{-3}	kg/m^3
Diesel	2.43×10^{-4}	kg/m^3
Outputs		
Treated water	1	m^3
Sludge	$6.7x10^{-2}$	kg/m^3

Table 2. Data on transportation

Chemical	Approximate transportation distance (km)	Type of transportation	Country
Chlorine	100	Truck	Turkey
Aluminum Sulfate	250	Truck	Turkey
Anionic and Cationic Polyelectrolyte	8090+45 2746+45 7072+45 1464	Ship+Truck Ship+Truck Ship+Truck Truck	USA Spain China İtaly
Activated Carbon	9677+45 2759	Ship+Truck Truck	USA Holland

3. Results and Discussion

About 0.76 kWh electricity is required to generate one cubic meter of treated water in the treatment plant. A high portion of this requirement is due to inlet (22 %) and outlet (63 %) water pumping stations. Ozonation process requires 5.4 % of the electricity usage.

The environmental impacts obtained in this study are given in Table 3. These findings are in accordance with the literature values listed for conventional treatment (Rodriguez et al. 2016; Zine et al. 2013; Bonton et al. 2012; Friedrich and Buckley 2002).

The highest shares to GWP, HTP, MAEP and EP come from output and input pumping stations. The main contributors to AP, ADP fossil, FAEP, TETP can be enlisted as input and output pumps and coagulation-flocculation. Mainly output and input pumps and chlorination stages contribute to ODP. ADP element mostly arises from chlorination and input and output pumps. Coagulation-flocculation is the main contributor to FAEP.

Table 3. The environmental impacts

Environmental Impacts	
ADP element(kg Sb -Equiv.)	1.51E-07
ADP fossil (MJ-Equiv.)	5.00
AP (kg SO_2-Equiv.)	8.16E-04
EP (kg PO_4-Equiv.)	6.78E-05
FAEP (kg DCB -Equiv.)	4.32E-04
GWP (kg CO_2 Equiv.)	3.92E-01
HTP (kg DCB Equiv.)	1.1E-02
MAEP (kg DCB Equiv.)	4.07E-01
ODP (kg R11 Equiv.)	24.43

POCP (kg Ethane-Equiv.)	4.37E-05
TETP (kg DCB -Equiv.)	1.71E-04

Electricity consumption has a significant contribution to all the investigated impact categories, apart from ODP**.** Aluminium sulfate input cause 55 % of ODP. After that chlorine usage with a 31 % and electricity input with 11 % shares in total ODP come. ODP mostly arises due to halogenated organic, namely dichlorotetrafluoroethane emissions, to air. The contribution of electricity consumption to GWP is about 89 %. GWP is generated mainly because of inorganic emissions (CO_2) to air. Electricity and aluminium suphate inputs have 62 and 31 % shares in AP category, respectively. Mainly sulphur dioxide and to a less extent nitrogen oxide emissions to air cause AP. Electricity requirement, aluminum sulphate input and sludge processing contribute 78, 11 and 6 % of EP, namely. Emissions of nitrogen oxides to air generates EP. Electricity and chlorine inputs cause 65 and 31 % of ADP elements, respectively. ADP elements is generated mainly due to sodium chloride and to lesser degrees copper and molybdenum usage. Electricity requirement has a 96 % share in ADP fossil. Non-renewable energy sources of natural gas, lignite, hard coal and crude oil create ADP fossil. Both aluminium suphate and electricity inputs have the same shares of around 48 % to FAEP. FAEP is mainly caused by heavy metal discharges such as nickel, cadmium and copper to fresh water. Electricity and aluminium suphate requirements cause 84 and 12 % of HTP, respectively. Main reasons of HTP can be listed as heavy metals emissions (especially arsenic (+V) and selenium) to air and polycyclic aromatic hydrocarbon emissions to air. About 93 % of MAEP is due to electricity input and the reason can be quoted as the hydrogen floride emissions to atmosphere. Electricity and aluminium suphate inputs generate 63 and 32 % of POCP, respectively. POCP is generated mainly due to sulphur dioxide emissions to air. Electricity requirement and aluminium suphate input have 84 and 11 % shares in TETP, namely. TETP is generated mainly as a result of mercury emissions to atmosphere.

4. Conclusions

The following conclusions are derived from this study aiming to investigate the environmental burdens arising from the operation phase of a large water treatment plant. The main causes of impacts for different categories can be summarized as: ODP: Halogenated organic, namely dichlorotetrafluoroethane emissions, to air; GWP: Inorganic emissions (CO_2) to air; AP: Sulphur dioxide and nitrogen oxide emissions to air; EP: Nitrogen oxides emissions to air; ADP elements: non-renewable sodium chloride, copper and molybdenum usage; ADP fossil: Non-renewable natural gas, lignite, hard coal and crude oil usage; FAEP: Nickel, cadmium and copper discharges to fresh water; HTP: Arsenic (+V), selenium and polycyclic aromatic hydrocarbon emissions to air; MAEP: Hydrogen floride emissions to atmosphere; POCP: Sulphur dioxide emissions to air; TETP: mercury emissions to atmosphere. Therefore for ODP, GWP, AP, EP, HTP, MAEP, POCP and TETP, emissions to air is significant, whereas for FAEP discharges to freshwater is of importance.

For ODP, chemical inputs such as aluminium sulfate and chlorine, generate most of the environmental impact. Apart from ODP, energy requirement causes significant shares in all of the investigated environmental impact categories. In this respect, strategies involving the reduction of electricity consumption or supplying electricity from renewable sources instead of grid are recommended to decrease these negative environmental impacts. Furthermore, since pumping stations are addressed as the most energy requiring location within the treatment plant, increasing the efficiency of the pumps can also reduce the environmental impacts by lowering the energy inputs.

When the environmental impacts of the used chemicals are considered, among their manufacturing, transportation, preparation and usage; manufacturing of the chemicals causes the highest impact. Electricity requirement is the most important contributor to all environmental impact categories.

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