Egypt. J. Chem. **Vol. 65**, No. 9 pp. 513 – 519 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Using Life Cycle Assessment (LCA) in Appraisal Sustainability Indicators of Najaf Wastewater Treatment Plant

Mohammad Ali Al-Anbari[1] Sahar. A.Altaee[1] Sabreen L.Kareem[2*]

[1]College of Engineering, University of Babylon, Babylon, Iraq, [2] College of Engineering, Al-Qasim Green University, Babylon, Iraq.

Abstract

Sustainability in wastewater treatment can encourage the processes of planning, maintenance, design, operation, and management of wastewater infrastructure in a manner that minimizes the consumption of depletable resources and reduce the impacts and damages caused by them on the environment. Life cycle assessment (LCA) is an appropriate methodological framework for evaluating the sustainability of wastewater treatment systems. The present study used the Simapro7 program that is based on the basics of LCA, it was used for impact and damage analyzing Najaf Waste Water Treatment Plant WWTP. LCA results proved Najaf WWTP has a significant environmental impact and damage equal to 120 point / 1m3 wastewater, The potential reasons behind environmental impacts were (non-renewable energy, respiratory inorganics, and global warming). The most affected phase was the construction phase rather than operation.

Keywords: Environmental Impact, Sustainability, Wastewater Treatment, Life Cycle Assessment (LCA), Mid point.

1. Introduction

Municipal wastewater service directors have met numerous problematic and complex challenges [1,2]. Some of the strong and important points that the services deal with are:

1- Formation of decisions regarding capital enhancement and employment projects in difficult economic periods

2- Dealing with many methods aimed at getting rid of the vital solid waste at a time when concerns are increasing about the health impact, the excessive disposal cost, and the limited land available for application.

3- Increasing strict adherence to the granting of permits.

4- Increasing concerns about the lack of water resources and the failure of the compensation process for them due to the cost of reuse.

5- Increasing the costs of energy projects.

because wastewater services are directly affected by the previous points, so there has become an increase in awareness and acceptance by services whose decisions have a great and lasting impact even outside their borders. This change is due to the sustainability movement in wastewater treatment that appeared recently [3,4].

Life Cycle Assessment (LCA) is an important sustainability tool and has been applied to assess and analyze environmental impacts on the entire life cycle of wastewater treatment processes. This application is because (LCA) is a useful and also promising technology that can provide a complete and comprehensive view of the environmental impacts of any process, product, or activity. The other point is that LCA provides an appropriate framework for environmental assessment and also an opportunity to improve environmental performance through the identification of materials and energy used or input of any activity and the emissions and pollutants resulting[5,6].

LCA is included in the ISO 14040:1997 series, as follows: objective definition, analysis of inventory and scope within ISO 14041: 1997, Environmental Impact Assessment within ISO 14042: 1997, and Interpretation within the standard - ISO 14043: 1997. SimaPro 7 was applied to the inventory and database of resource influent and environmental emissions effluent in the current LCA [7,8]. In applying for SimaPro program, usually, the impact of the project under study (here, wastewater treatment plants) are separated into four different categories (human health, ecosystem quality, natural resources, and climate change). SimaPro provides a broad environmental impacts database related to products and industrial processes [9]

.2. Material and methods

2.1.Description of the study area:

*Corresponding author e-mail: prof.dr.maalanbari@uobabylon.edu.iq
Received date 26 December 2021; revised date 24 January 2022; accepted date 31 January 2022
DOI: 10.21608/EJCHEM.2022.113093.5139

Al Najaf WWTP in this study was designed to serve 140750 citizens with unit and sequences [10] shown in Fig.1

2.2.Steps to apply the LCA method

life cycle assessment method followed to evaluate environmental indicators, where all raw materials, energy input and consumed, as well as the resulting emissions and pollutants, are analyzed in water and air. In the case of sewage treatment plants, emissions, and pollutants are calculated per cubic meter. LCA was applied by following the next steps [11]. Table.1

System boundaries represent the processes that are taken into account or not. treatment units related to sewage treatment processes, sludge treatment, and other processes such as construction and material transportation were considered as system boundaries in the current study, as shown in Fig.2.

2.2 Soil Sampling and Analysis

2.2.2 Inventory Analysis

Fig.1. Flow chart of Najaf WWTP [10]

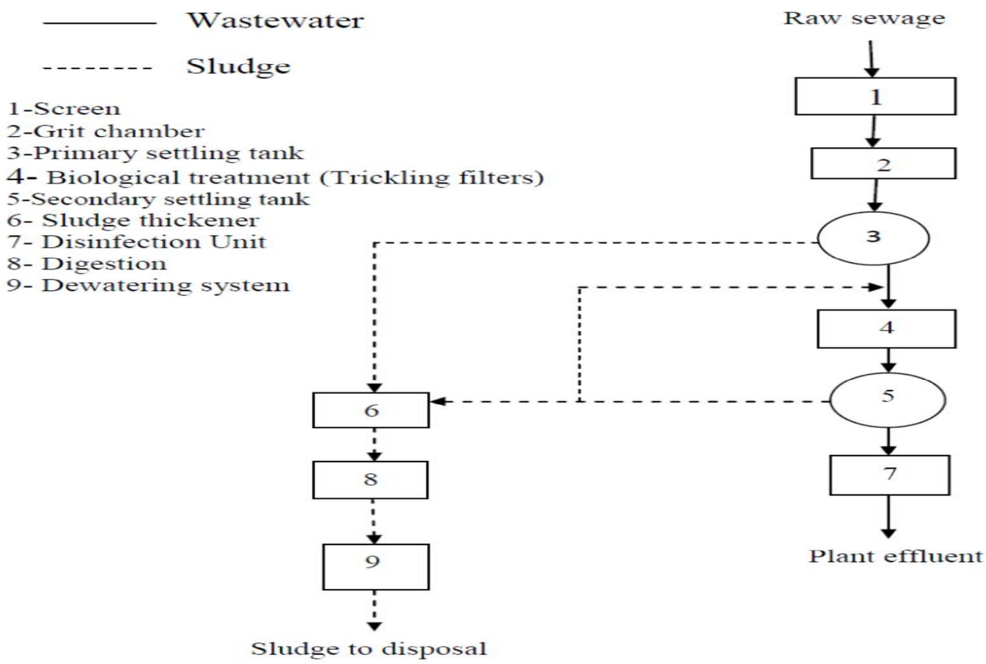

Fig.1. Flow chart of Najaf WWTP [10]

2.2.1.Goals setting and scope definition in LCA study

Analysis and evaluation of environmental impacts in AL Najaf wastewater treatment plants represent the goal of life cycle assessment. As for the scope of the study, it is to determine the main unit of account for the evaluation defined by 1 cubic meter of wastewater for the studied station, as well as the assessment criteria represented by the consumed resources and the resulting environmental effects [12] as shown in

level	Environment	Resources
Global	Global warming	Fuel e.g. oil, coal, and natural gas
regional	Acidification Nutrient enrichment	
local	Human toxicity	Biomass e.g. sludge

Table 1 Assessment criteria in the study

The “IMPACT2002 +” process was implemented to assess environmental treatment plant impacts. the outline of the IMPACT 2002+ outline, concerning all mid-point Life Cycle Indicator LCI outcomes for 14 categories as shown in Fig.3[13]. Output can be classified into three main groups; emission to air – CO_2, CH_4 and N_2O which come from wastewater treatment process especially CH_4 which is biogas produced from anaerobic digestion and N_2O mainly produced from uncompleted nitrification process; discharge to water – BOD, COD, SO_4, Cl, NO_3 and PO_4 those were wastewater characteristic; and co-product – sludge produced from the final process of wastewater treatment.

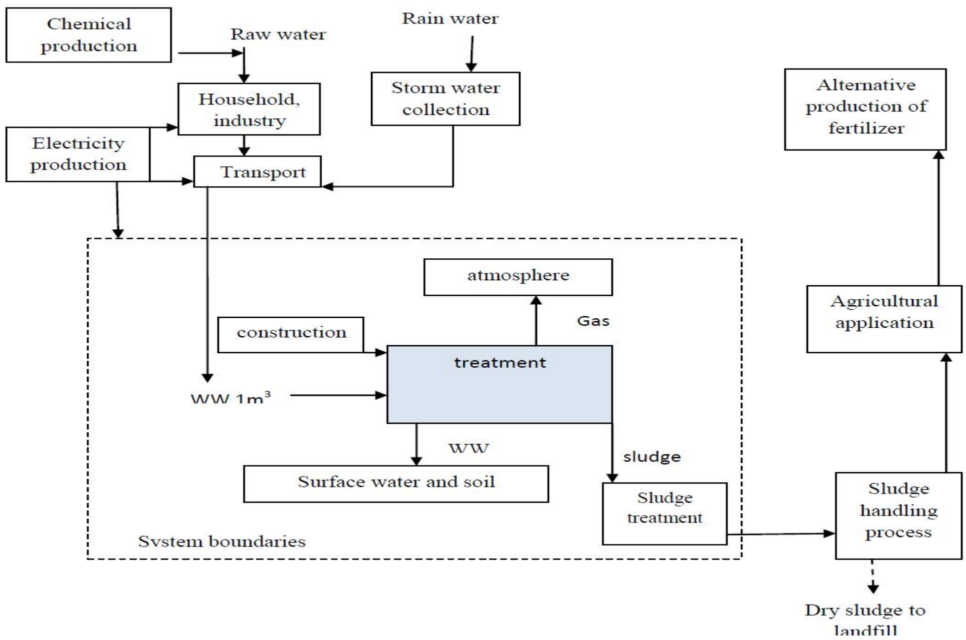

Fig.2: System boundaries for wastewater treatment system (Modified from) [14].

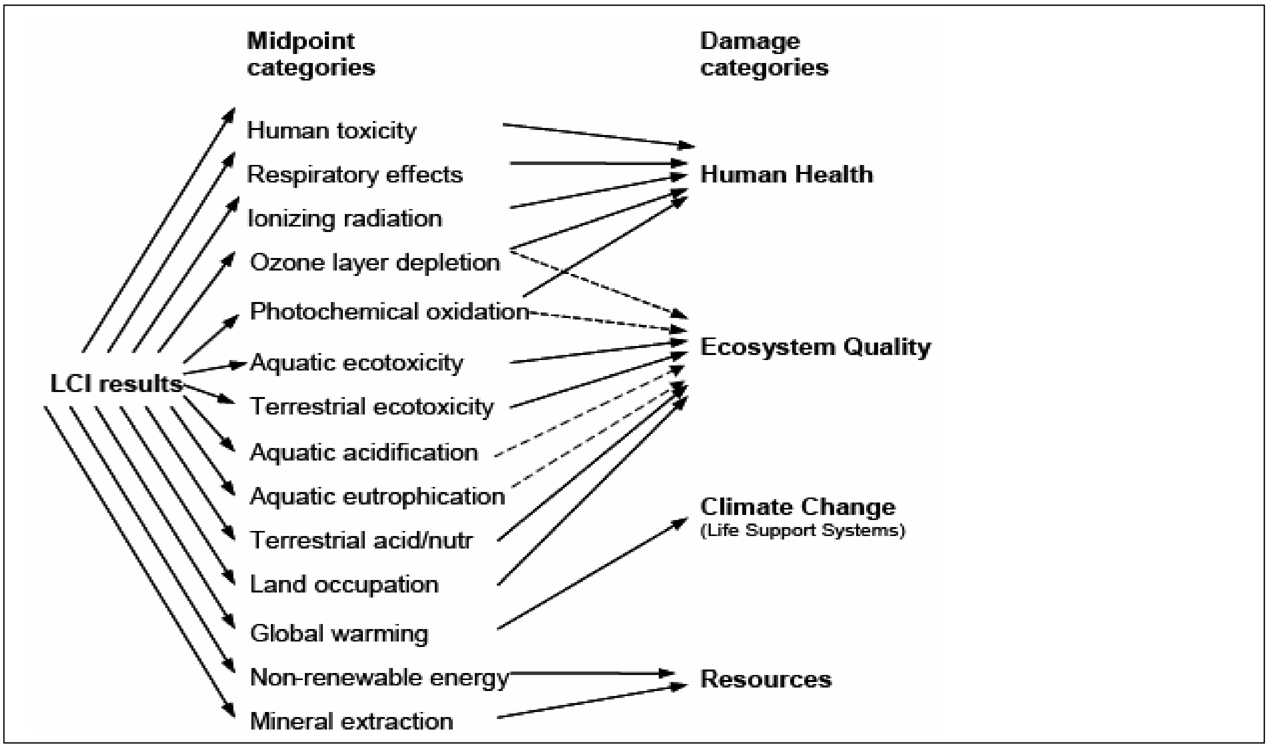

Fig. 3 outline of the IMPACT 2002+ framework [15].

Inventory analysis includes methods that characterize resource and material consumed, water pollutants, and air emissions resulted. Evaluation includes the whole life cycle of Sludge disposal, activities and products; construction; and all transportation involved. LCA database can be obtained from data collection, usually, the prepared form must be used in the collection of process, called process normalization [16]as shown in Fig. 4. After that, all collected data must be entered to simapro7 to be analyzed.

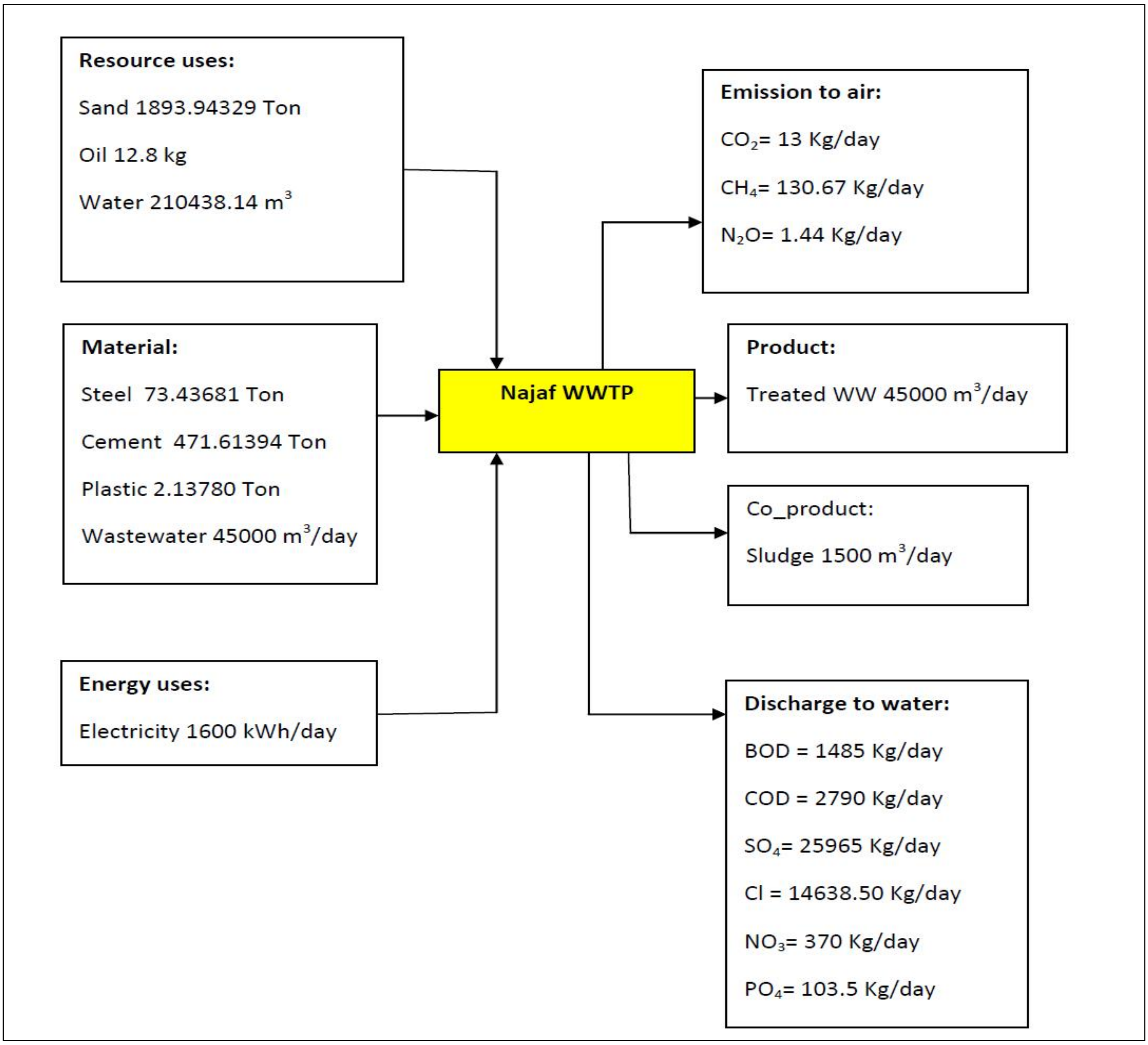

Fig.4 Inventory analysis of Najaf wastewater treatment plant[16].

3.Impact assessments

Based on the inventory results, potential environmental impacts significance can be assessed as an important step of the life cycle assessment which involves correlating inventory data with specific environmental impacts. An impact assessment was calculated based on the environmental design of industrial products, and the inventory was interpreted by assessing the size of the contribution [14].In SimaPro, the impact methods are divided into four steps: characterization, damage assessment, normalization, and weighing.

3.3.1.Characterization

Environmental impact category (j) of any matters or substances are multiplied by a characterization factor that states the matter's contribution percentage. For example, the characterization factor for carbon dioxide CO2 in the climate change forcing class could be 1, whereas the characterization factor for methane CH4 could be 21, in other words, the release of 1 kg of CH4 origins the similar quantity of climate change as 21 kg of CO2. The overall score is expressed as effect category indices as shown in Eq.1 [9].

$$EP(j)Qi*EF(j)i \quad \text{--------(1)}$$

EP / Potentials Environmental impacts

Q / Quantity of matters

EF / Matters equivalency factor
(j) / Environmental impact category
(i) / Emission . of the matters .

3.3.2.Normalization

The relative environmental potential impact magnitude can be determined by Eq.2[9] . the result is expressed in the appropriate form for the final weighting and decision-making.

NEP(j)=EP(j)1/(T.ER(j)) --------(2)

NEP / Normalized. Potentials Environmental . ... impact.
EP/ Potentials Environmental . . impact.
ER / Normalization . reference . for impact category . for specific area.
T / Functional unit Time.

The impact equivalency factor will be obtained with matters quantities. Normalization is a relative grading of the potential impact of products and consumptions of sources with a reference.

3.3.3.Weighting

The most important resources use and environmental impact determining by the weighting step as shown in Eqs (3,4&5) [9]

WEP =WF(j)*EP(j) ---------(3)

WEP(j)=*EP(j)/ER(j) *1/T -----------(4)

WEP(j)=(EP(j))/ER(j)2000*1/T -----------(5)

Where :
WEP/ Weighted Potential Environmental impact
WF/ Weighted Factor
ER / Target Potential Environmental Impact in the year 2000

A single number can be obtained by adding weighted values together in a single score step

3.3.4. Interpretation

All data used and results obtained are illustrated in the complete table and different result graphical representations.

4.Results and Discussion

LCA results had to be weighted or interpreted. The procedure of IMPACT2002+ and LCA weighting was particularly established for product design. This system had shown to be a valuable tool for engineers to combine LCA results into a clear simple way, so it was named as (IMPACT 2002, IMPact Assessment of Chemical Toxics) [17].

Najaf WWTP impact categories discussed as the universal eco-score damage, It noticed that respiratory inorganics (30.5 pt), global warming (49.2 pt), and non-renewable energy (24.5 pt) have the most potential environmental impacts of total impact 120 pt as shown in Table 2 and Fig.5.

Human Health 39.2pt, Ecosystem Quality 6.25pt, Climate Change 49.2 pt, and Resources 24.9 pt were analyzed by IMPACT 2002+ as categories of damage with points of contributions written adjacent to each other **(Fig.6 &7)**

Process	Unit	Global warming	Respiratory Inorganic	Non-Renewable Energy	Terrestrial ecotoxicity	Carcinogens	Non-carcinogens	acidification / nitrification
Total of all processes	Pt	49.2	30.5	24.53905	5.398158	4.115955	4.34401	0.429029
Cement	Pt	35.8	19.9	0.001436	4.57085	3.715818	1.461933	0.244504
Steel	Pt	12.7	10.2	-8.5E-05	0.822217	0.378217	2.880998	0.174398
Plastic	Pt	0.623	0.355	13.27261	0.004191	0.02099	-0.00036	0.00939
Electricity	Pt	0.083	0.0584	-0.03388	0.004733	0.00113	0.001955	0.000803
Emissions of plant	Pt	0.0227	0.000517	0.754902	-	-	-	-
Wastewater	Pt	0.000694	-8.51E-5	0.113352	7.13E-05	7.21E-05	0.000129	7.84E-06
Treated wastewater	Pt	-0.00011	-0.00491	10.42686	-1.4E-05	-1.3E-05	-1.4E-05	-1.1E-06
sludge	Pt	-0.00815	30.5	0.003857	-0.00389	-0.00026	-0.00063	-7.4E-05

Table 2. Processes contributing to mid point categories

From fig.7, It is noticed that the order of operations from the largest negative environmental impact to the least was cement, then steel, then plastic, while sludge and treated wastewater had positive environmental effects.

5. Conclusions

The IMPACT2002+ procedures were applied to assess environmental indicators for Najaf WWTP in Iraq country. From applying IMPACT 2002+ on that WWTP it concluded that global eco-score on Najaf WWTP have 120 Pt, The most environmental impact potential were global warming, non-renewable energy, and respiratory inorganics as a result of steel and cement (phase of construction), plant operation, and electricity utilize chemical storing and pipes and plastic used and of Najaf WWTP emission.

Environmental damage affected human health, climate change, and resources were 39.2, 49.2, and 24.9 points respectively.

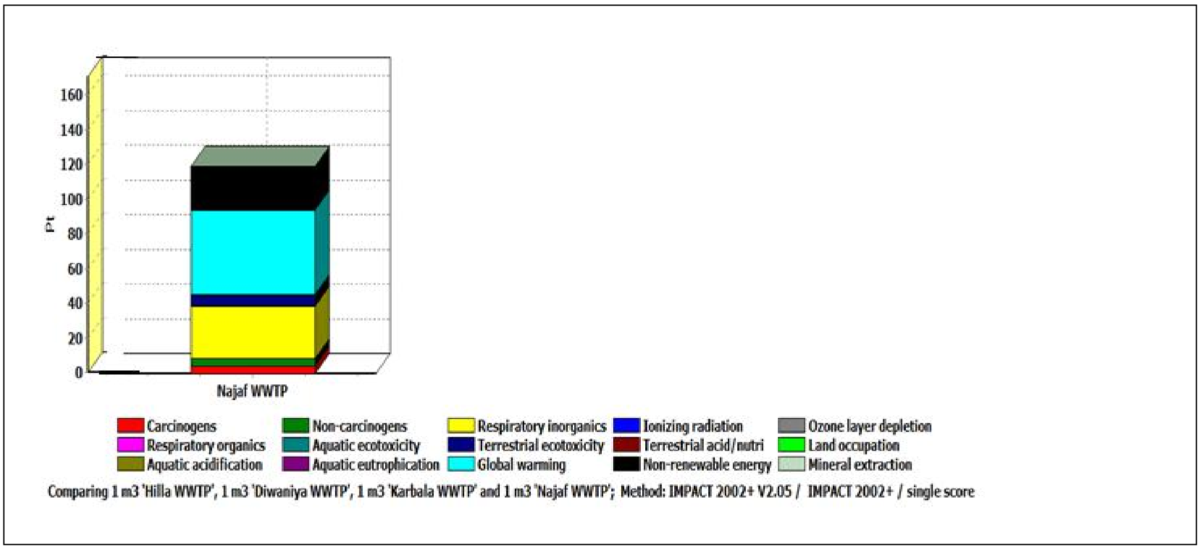

Fig .**5.** Impact categories describing the universal (global) eco-score damage

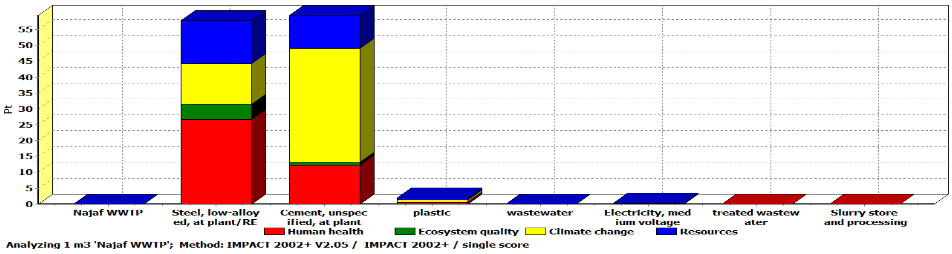

Fig.6. Universal eco-score of damage categories.

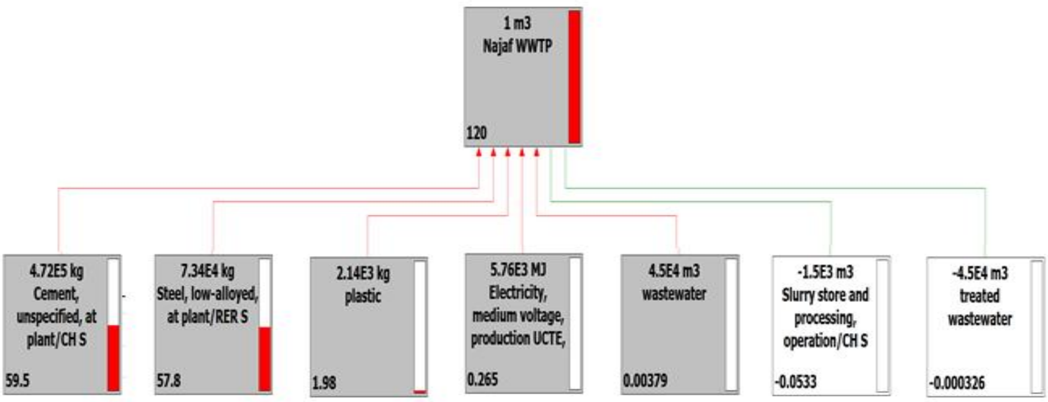

Fig.7. Processes contributions of Najaf WWTPs.

5- Conflicts of interest

There are no conflicts to declare.

6. Funding sources

No funding sources in a standard way to facilitate compliance to funder's requirements.

7. Acknowledgments

The authors were so acknowledged by the Najaf Wastewater Treatment Plant staff for aiding them in the experimental test.

8. References

[1] Al-Nasrawi, F. A., Kareem, S. L., Saleh, L .A., Using the leopold matrix procedure to assess the environmental impact of pollution from drinking water. *IOP Conf Ser Mater Sci Eng*.671-012078(2020).

[2] Mohammed,A.A.,Kareem,S.L., Enhancement of Ciprofloxacin Antibiotic Removal from Aqueous Solution Using ZnO Nanoparticles Coated on Pistachio Shell. *Desalin Water Treat* 213,229-239(2021).

[3] Whitehead, P. G., Barbour, E., Futter, M. N., Sarkar, S., Rodda, H., Caesar, J., Butterfield, D., Jin, L., Sinha, R., Nichollsf, R., Salehinh, M., Impacts of climate change and socio-economic scenarios on flow and water quality of the Ganges, Brahmaputra, and Meghna (GBM) river systems: low flow and flood statistics. *Environmental Science: Processes & Impacts*, 17(6), 1057–1069(2015). doi:10.1039/c4em00619d.

[4] Raghuvanshi, S., Bhakar, V., Sowmya, C., & Sangwan, K. S., Waste Water Treatment Plant Life Cycle Assessment: Treatment Process to Reuse of Water. *Procedia CIRP,* 61, 761 766(2017). doi:10.1016/j.procir.2016.11.170.

[5] Zhang, Z., Wilson, F., Life-Cycle Assessment of a Sewage-Treatment Plant in South-East Asia" Research Student and Assistant Professor, respectively, School of Civil and Structural Engineering, Nanyang University, Singapore. (2000).

[6] Morsy, K. M., Mostafa, M. K., Abdalla, K. Z., & Galal, M. M.,Life Cycle Assessment of Upgrading Primary Wastewater Treatment Plants to Secondary Treatment Including a Circular Economy Approach. *Air, Soil and Water Research, 13,* (2020). doi:10.1177/1178622120935857.

[7] PRé Consultants, Introduction to LCA with SimaPro 7. 2010.

[8] Rahmberg,M., Andersson,S.L., Lindblom,E.U., Johansson,K., LCA analysis of different WWTP processes. © IVL Swedish Environmental Research Institute IVL Swedish Environmental Research Institute Ltd. 2020.

[9] Leah Flowers, Katya Bilyk, P.E., Joyeeta Banerjee, P.E.,Tony Greiner, P.E., Sandeep Mehrotra,P.E., and Paul Pitt,P.E., 21st Century Sustainability Metrics: An Introduction to Life Cycle Analysis. 2003.

[10] Naji,R.H., Al-ObaidiB.H.K., Salman,M.S., Evaluating the efficiency of some wastewater treatment plants in Najaf Governorate 2021 *IOP Conf. Ser.: Mater. Sci. Eng*. 1145 012053

[11] Lemos, D., Dias, A. C., Gabarrell, X., Arroja, L., Environmental assessment of an urban water system. Journal of Cleaner Production, 54, 157–165(2013.). doi:10.1016/j.jclepro.

[12] Mohammed, A.A., Kareem, S.L., Peters, R.J., Mahdi, K. Removal of Amoxicillin from Aqueous Solution in Batch and Circulated Fluidized Bed System using zinc oxide nanoparticles: Hydrodynamic and Mass Transfer Studies. *Journal of Environmental Nanotechnology, Monitoring, and Management*, in press.

[13] Rolf, F., Niels, J., Implementation of Life Cycle Assessment Methods. Swiss Centre for Life Cycle Inventories. 2007

[14] Thitirut, C., Appraisals of Environmental Sustainability Indicators on The Conventional Sewerage and Domestic Wastewater Treatment Systems in Thailand. Case Study in Bangkok City, Thesis, Asian Institute of Technology School of Environment, Resources and Development Thailand. 2005.

[15] Szulc, P., Kasprzak, J., Dymaczewski, Z., Kurczewski, P., Life Cycle Assessment of Municipal Wastewater Treatment Processes Regarding Energy Production from the Sludge Line. *Energies,* 14, 356(2021).doi.:10.3390/en 14020356.

[16] El-Sayed Mohamed Mahgoub, M., van der Steen, N. P., Abu-Zeid, K., & Vairavamoorthy, K., Towards sustainability in urban water: a life cycle analysis of the urban water system of Alexandria City, Egypt. *Journal of Cleaner Production, 18(10-11), 1100–1106* (2010). . doi:10.1016/j.jclepro.

[17] Al-Anbari, M. A., Rahman, I., .Evaluating and Comparing the Potential Environmental Impacts from the Production of Diesel and Liquefied Petroleum Gas, Al-Daura Refinery, Baghdad. *Journal of Engineering and Sustainable Development.* 22(2)(2018).