LIMITATIONS IN EVALUATING WASTEWATER TREATMENT PLANTS CARBON FOOTPRINT

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Abstract

A wastewater treatment plant's carbon footprint is represented by the amounts associated with collection, treatment and final disposal of treated wastewater and sludge. The importance of evaluating the carbon footprint in wastewater treatment facilities consists in the fact that it's reduction is directly related to energy efficiency measures and plant operation improvements. Considering the fact that, at a national scale, there is a lack in methodologies and solutions for evaluating wastewater treatment plants' carbon footprint, the main international methodologies and tools were studied and the paper presents the main parameters that have to be taken into account during evaluations, as well as the weak and strong points in the studied methodologies.

Keywords*:* *carbon, footprint, wastewater*

1. Introduction

Climate change has become a highly debated topic, both internationally and nationally, due to the threat posed to the environment. UN Framework Convention on Climate Change adopted at the Summit held in Rio de Janeiro in 1992 is a key tool for managing this challenge.
During the past years, the concern on human activities effects on ecosystems has increased considerably [1]. In the sustainability context, one of the most used tool for evaluating the impact of greenhouse gasses emission is represented by the carbon footprint estimation.
For the evaluation of the carbon footprint of wastewater treatment, as a measure of the amount of greenhouse gases produced, all emissions associated with collection, treatment and disposal have to be taken into account [2]. Depending on the type of processes, wastewater treatment plant location and facilities, the highest contribution on the carbon footprint can be represented by: power consumption, direct emissions resulting from the treatment process, waste or transport associated emission.
In several countries, corporations are required to register and report their emissions if they control individual facilities that emit high quantities of greenhouse gasses (GHGs) or if their own systems that involve large power production or consumption. The regulations on reporting apply in most cases mostly to wastewater treatment facilities and lead to the need of evaluating their carbon footprints as indicators of greenhouse gasses emissions.

2. Sources of greenhouse gasses emission in wastewater treatment plants

In greenhouse gasses emissions evaluation, the carbon footprint is expressed in kilograms or tones of CO_2 equivalent (CO_2-e). Converting all gases in CO2-e can summarize the impact of various emissions into a consistent way.

The main GHGs that are considered in calculating the carbon footprint, according to the Intergovernmental Panel on Climate Change (IPCC) [3] are:

- Carbon dioxide;
- Methane;
- Nitrous oxide;
- CFC-12;
- HCFC-22;
- Tetrafluoromethane;
- Hexafluoroethane;
- Sulfur hexafluoride.

The share of these gases in the greenhouse effect depends on three parameters: concentration and lifetime in the atmosphere, the ability of each gas to absorb heat, and the amount of anthropogenic emissions for each gas. The Global Warming Potential of each considered GHG represents the instantaneous emission of 1 kg of gas compared to the emission of 1 kg of CO_2.

Carbon dioxide emissions contribute to climate change if they come from burning fossil fuels to generate the power needs of the wastewater treatment plant. At the same time, carbon dioxide may originate from the conversion of organic matter through biochemical processes in the aeration tanks. Most of the nitrous oxide results from nitrogen removal processes from wastewater by nitrification and denitrification, being a gas with a greenhouse potential of 300 times greater than carbon dioxide.

For wastewater treatment facilities, the quantity and distribution of resulting GHGs depends on influent loading, effluent quality parameters requirements, types of treatment processes, plant’s location, etc.[4].

GHGs emissions occur during all the biological degradation processes used in wastewater treatment as naturally created by-products. For wastewater treatment plants designed only with aerobic degradation processes for organic matter removal, used for low strength wastewater, lead mainly to CO_2 emissions that are easily estimated by considering the oxygen consumption. The approach is not applicable for biological nutrient removal configurations that are foreseen with an aerobic stage due to the oxygen needs of nitrification. Other GHGs emissions in aerobic processes can consist in low concentrations of CH_4 and the indirect emissions generated during the energy production for the stage’s needs [5]. Biological nitrogen removal processes have high contribution to the wastewater treatment plants carbon footprint by being significant sources of N_2O emissions [6]. When it comes to anaerobic biological processes – especially anaerobic digestion, the main GHGs emissions consist in varied quantities of CH_4 and CO_2. If the resulting biogas is used for energy production, and there are no accidental leaks in the atmosphere, the processes’ GHG emission can be negative due to CO_2 savings [4].

3. Carbon footprint assessment methods and limitations

When estimating GHG emissions from wastewater treatment plants, the main considered categories are direct and indirect on-site emissions and indirect off-site emissions. The on-site emissions are generated by the biological degradation processes (aerobic and nitrogen removal), dissolved gases stripping during dewatering processes and on-site energy production or consumption [7]. Indirect off-site emissions are related to power production, fuels and reagents transportation, by-products (waste, sand, sludge) disposal and degradation of the remaining constituents in the wastewater treatment plant’s effluents [8].

In order to asses GHGs emissions in wastewater treatment plants, empirical, simplified or complex mechanistic models can be used. The methods can be based on both experimental and modeling tools [8,9]. Extensive experimental research resulted in developing set-ups for emissions measurements and data gathering [10]. Using mechanistic dynamic models for evaluating GHGs emissions presents the advantage that the plant's design, operating conditions and influent loading variability are considered [9,11]. The accuracy of GHGs emissions values, resulting from wastewater treatment processes, obtained through modeling are based on process knowledge, quality and quantity of measured data, model calibration and structure.

Of the main methodologies used for evaluating wastewater treatment plants carbon footprint, the one elaborated by IPCC [5] represents the basis for multiple subsequent methods, being recognized internationally. The IPCC methodology is designed for macro scale evaluations, being based on a "Top Down" approach. The methodology developed by WSAA (Water Services Association of Australia) is country specific and represents a standard for wastewater treatment facilities in Australia. Local Governments Operations (LGO) Protocol is based on the IPCC approach. The model developed by Bridle [12] is specific for estimating the emissions resulting from wastewater and sludge treatment processes.

All studied models have both advantages and disadvantages, starting from the required amount of monitored data, to the user's ability to calibrate complex models. Recommendations based on the results of the studies can be made for each specific study, but there is a global lack in taking into consideration GHGs emissions criteria during the design phase of wastewater treatment facilities.

When trying to evaluate a wastewater treatment plant's GHGs emissions over extensive time frames, it's necessary to have access to the required data. Not having it over extensive periods of time makes the assessment impossible, or reduces the certainty level of the results. Also, since only a few of the existing models and possibilities are described above, it's almost impossible to make comparisons with the data available for various WWTPs and previous studies, thus a unified protocol for GHGs emissions is necessary.

The aim of evaluating GHGs emissions is, partly, to identify the main contributors and the potential mitigation measures. The identified recommended measures vary widely, most of them being based on processes control optimization.

When estimating GHGs emissions based on modeling tools, uncertainty plays an important role and the information obtained through the models can contain significant errors if uncertainty isn't carefully evaluated and recognized. Although they usually offer rough estimations, simplified approaches have reduced uncertainty levels and are still being successfully used.

4. Conclusions

In order to evaluate GHGs emissions in wastewater treatment plants, no matter what method is considered, extensive data on the plant's configuration, influent characteristics variations and operational strategy is necessary. All available methods have both weak and strong points and reliable results are to be obtained only by having knowledge on both mathematical and empirical models. Once the GHGs inventory was elaborated, plant-specific mitigation measures can be established and implemented.

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