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IMPACT OF CLIMATE CHANGE ON THE PERFORMANCE OF WASTEWATER TREATMENT PLANTS

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ABSTRACT

According to the United Nations Population Fund, the human population has grown from 1.6 billion to 6.1 billion people during the last century. As a conclusion, extensive consumption of fossil energy resources has associated with a significant increase in the mass of greenhouse gases. Besides the warming of earth`s surface, the water temperature is increasing day by day. It is clear that global warming is not only a CO_2 issue but also a water issue. As further consequences of climate changes, extreme weather conditions, flooding, drying, runoff pollution, and erosion are predicted to become increasingly frequent. The potential future effects of global climate change will cause largely environmental and economic damage. Climate change has a huge potential to impact on urban infrastructure, including water supply, sewer and wastewater treatment systems, so potential adaptations must become a normal part of urban planning, including management and operational adaptations. The aim of this study is to assess relative impact of climate change with respect to the performance of wastewater plants. Based on the results of investigations, climate change effects on performance of urban infrastructure systems may vary considerably in different regions, but the highest impact is predicted for winter climate condition which is dominated by snowmelt. In addition, biological nitrogen removal and secondary clarification processes are considerably affected by the climate factors in wastewater treatment plants.

Keywords: Climate change, wastewater treatment, urban infrastructure

INTRODUCTION

The human population has continued to grow at a significant rate and it has grown from 1.6 billion to 6.1 billion people during the last century is expected to increase from 8 billion in 2022 to 9.7 billion by 2050 (Laurance and Engert 2022). This rapid increase in the population of humans and urban development since the mid-1970`s causes significant increase in energy consumption (Avtar, Tripathi et al. 2019). Meanwhile extensive consumption of fossil energy resources has been associated with a significant increase in the mass of greenhouse gases (GHG), which are known to inhibit long-wavelength radiation from escaping into space, into the atmosphere (Smithson 2002, Galloway, Townsend et al. 2008). Carbon dioxide and other greenhouse gases (water vapor, methane, nitrous oxide, ozone etc.) are known to inhibit long wavelength radiation from escaping into space (Jain 1993, Farmer, Cook et al. 2013). Besides the warming of earth`s surface, the water temperature is increasing day by day. It is clear that global warming is not only a CO_2 issue but also a water issue. As further consequences of climate changes, extreme weather conditions, flooding, drying, runoff pollution, and erosion are predicted to become increasingly frequent. The potential future effects of global climate change will cause largely environmental and economic damage (Wilderer, P. A. 2009). Climate change has a huge potential to impact on urban infrastructure, including water supply, sewer and wastewater treatment systems, so potential adaptations must become a normal part of urban planning, including management and operational adaptations. For example, not only unpredictable positions of wastewater treatment, such as the characteristics of the influent (water quality and the volumes) or the response of microorganisms but also long term adaptations of climate change should be account for the robustness of systems when the wastewater treatment plants are designed (Rosenzweig, C., et al. 2007). The primary goal of this paper is to assess relative impact of climate change with respect to the performance of wastewater treatment plant operations and also identify the sources of uncertainty for wastewater treatment plant.

WASTEWATER TREATMENT PLANTS

There has been a significant increase in wastewater generation because of urban development and population growth, especially in developed countries (Rooijen 2011). Conventional wastewater treatment processes consist of physical, chemical, and biological processes that reduce the concentrations of organic matter, nutrients (especially nitrogen and phosphorous), suspended solids, and pathogens, in order to eliminate their detrimental effects on the environment and public health (Metcalf, Eddy et al. 2014). A conventional municipal wastewater treatment plant includes pretreatment, primary treatment, secondary treatment and tertiary treatment as main stages of treatment process (Metcalf, Eddy et al. 2014). The pretreatment aims to remove solid with relatively large diameters. Primary treatment is responsible for removal of solids that settle relatively easily thereby aiming to reduce the concentration of particulates. Secondary treatment is mainly responsible for removal of biodegradable organic substances by biological processes. Activated sludge system is the dominant biological process in municipal wastewater treatment plants (Wanner 2021). In an activated sludge system, a biological floc composed of bacteria consumes organic matter from the wastewater while using oxygen for respiration (Figure 1) (Nathanson, Ambulkar 2023). Lastly, tertiary treatment and disinfection are the final stage to remove of residual solids and nutrients and stabilization of pathogenic microorganisms. Additionally, many municipal wastewater treatment plants have sludge treatment and disposal stage since conventional aerobic treatment processes produce large amounts of sludge (Appels, Baeyens et al. 2008, Zhen, Lu et al. 2017).

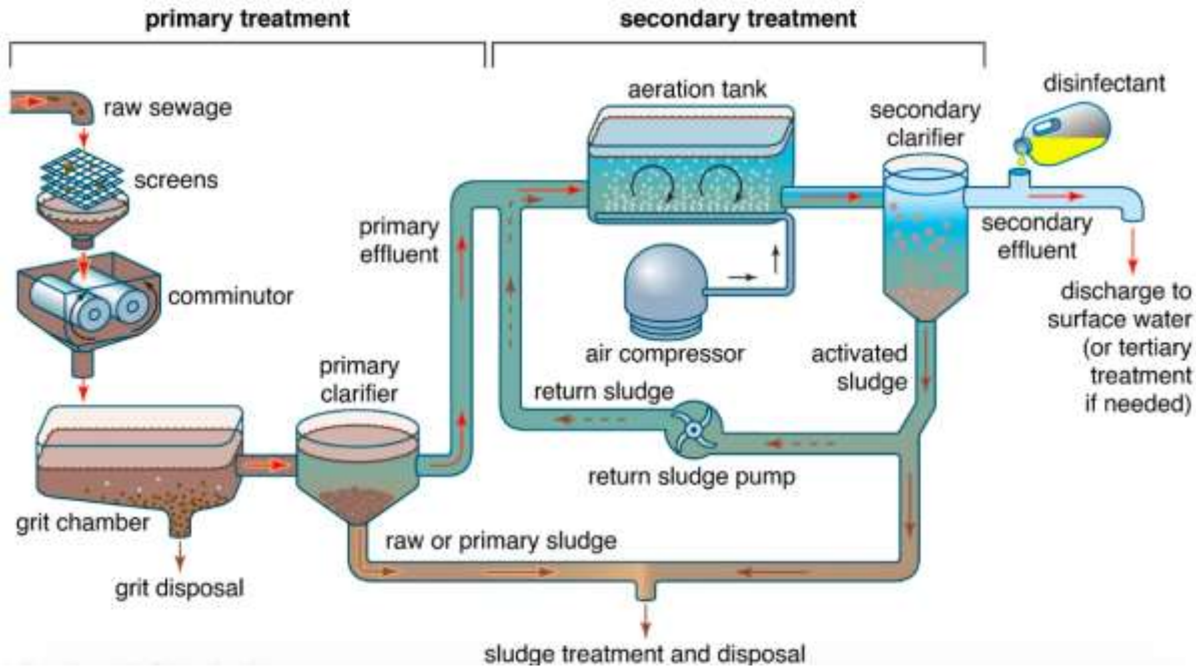

Figure 1. Municipal wastewater treatment plant diagram (Nathanson, Ambulkar 2023).

WASTEWATER TREATMENT PLANTS PROBLEMS BY CLIMATE CHANGE

Wastewater systems are potentially affected by increased rainfall intensity. In addition, the temperature increase will raise the likelihood of sewer corrosion and odour problems. One of the most sensitive process is biological wastewater treatment by climate change especially temperature changes. Climate change effects on performance of urban drainage systems may vary considerably in different regions, but the highest impact is predicted for winter climate conditions related to snowmelt poor water quality, flooding, overflows into receiving water without treatment, and high hydraulic loads in sanitary sewers (Semadeni-Davies 2004). The major impact of temperature is on the kinetics of the various biochemical reactions, so anaerobic wastewater treatment systems are very sensitive to change in inflow temperatures because of the methanogens (Grady Jr, Daigger et al. 2011). Besides, biological activity of microorganisms is slowed by cold water. As a conclusion, biological nitrogen removal and secondary clarification processes are considerably affected by the cold climate factors in wastewater treatment plants. The significant effects on the nitrogen removal process ocur due to the changes in wastewater temperature and the sludge age because these systems are carried out by autotrophic nitrifying bacteria and heterotrophic denitrifies. Nitrifying bacteria are very sensitive to temperature than heterotrophs. Because the growth rate of bacteria are small even 15 °C, low temperatures require bioreactors to have very long solid retention time (SRTs) for nitrifying bacteria to grow up, so temperature is the most important parameter in the design of activated sludge system. Therefore, the choice of SRT for nitrifying bioreactor must be made for the lowest temperature expected when the system are designed (Plósz, Liltved et al. 2009). Furthermore, because of snow melting periods during winter or spring, sudden decrease of wastewater temperature from 20°C to 10°C leads to reduce nitrification efficiency than predicted by the generally used temperature correction factor of 1.072 (Hwang and Oleszkiewicz 2007). In addition, nitrification needs clarification process and the amount of required chlorine increases for the effluent wastewater due to the effect of temperatures on nitrification efficiency. Experiments show that microbial activity is necessary to obtain best reflocculation of activated sludge flocs. As a result of lower biological activity in the sludge, flocculation processes can deteriorate because the action of flocculation depends on fluid temperature as well as the characteristics of particulates and the mixing conditions (Montgomery 1985, Wilén, Keiding et al. 2004).

Cold regions communities have significant problems related to snowmelt. Snow starts to accumulate in the winter (generally November) and snowmelt starts usually in the spring (April and May). Hydraulic loads can be significantly greater than the wastewater component because of limiting sewer infiltration. Sewer infiltration can be seen anywhere the length of a pipe, especially at joints. Furthermore, it is clear that climate change brings with it other potential adaptations in infrastructure including combined sewer overflows, which can trigger poor water quality, and pumping station overflows of untreated wastewater. Managing potential risks by adapting long term systems to the effects of climate change must become a regular part of planning design and operation for wastewater treatment and other urban infrastructure (Semadeni-Davies 2004, Semadeni-Davies, Hernebring et al. 2008). Obviously, these adaptations are very costly and energy intensive, so cost assessment should be performed.

UNCERTAINTY SOURCES OF WASTEWATER TREATMENT PLANT

Process designers can use uncertainty analysis in process models to conceive risk assessment, so they should figure out some questions about sources of uncertainty, available process models, the effect of risk assessment on model designs, and etc in wastewater treatmnet systems. Most researches identify the sources of uncertainty based on three or four main areas: model inputs, (i.e. influent flow, wastewater characteristics, weather, or measurement techniques); model structure, (i.e. activated sludge model, hydraulic model or clarifier model); model parameters (i.e. settling coefficients); the forth source of uncertainty from model technical aspects (i.e. solver settings and bugs) (Copp 2002, Reichert 2006). Table 1 shows the sources of uncertainty based on the location of uncertainty (Belia, Amerlinck et al. 2009)

Table 1. The sources of uncertainty in wastewater treatment plant

Area	Examples
Input	Inlet data (flow rate, ammonia, COD, etc.)
	Physical data (reactor volume and design, etc.)
Model	Model structure (process models such as biological and settlings)
Model parameters	Biokinetics (Max. growth rate)
Model technical aspects	Software limitations

After the uncertainty sources are determined and data are collected, a specific model can be used to evaluations of predictive quality of the model. The most often quantities analysis is the scatter plot of observations vs. plots of residuals. The statistical coefficients are used and these coefficients were calculated for most common indicators of wastewater plant such as ammonia, nitrates, MLSS, etc. (Belia, Amerlinck et al. 2009). It is clear that the great amount of uncertainty of wastewater treatment plants come from climate changing which affects especially characteristics of bacterial community.

Design engineers can use safety factors for getting risk minimization and robust design, so we could optimize each process of designs and a protocol can be developed in plant which is included design, upgrade, and optimization projects.

CONCLUSION

It is clear that huge amount of consumption of fossil energy resources triggers some significant problems which are related to water resources, water quality, sewer, and wastewater treatment systems. Based on the results of investigations, climate change effects on performance of urban infrastructure systems may vary considerably in different regions, but the highest impact is predicted for winter climate condition which is dominated by snowmelt. Biological nitrogen removal and secondary clarification processes are considerably affected by the climate factors in wastewater treatment plants. The crucial effect on the nitrogen removal process has the wastewater temperature and the sludge age in activated sludge systems. Improving of water quality comes into prominence under the environmental regulations. However, advance treatment systems bring with cost of consumption and environmental emissions. Process designers should use uncertainty analysis in wastewater treatment models to minimize costs and emissions as well as to conceive risk assessment, so in this context they can figure out sources of uncertainty, available process models, and the effect of risk assessment on model designs. Consequently, managing risk by the effects of climate change must become a normal part of planning design and operation for wastewater treatment. Therefore, this research area should have considerable priority in the designs of municipal wastewater plants.

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REFERENCES

Appels, L., J. Baeyens, J. Degrève and R. Dewil (2008). "Principles and potential of the anaerobic digestion of waste-activated sludge." Progress in energy and combustion science **34**(6): 755-781.

Avtar, R., S. Tripathi, A. K. Aggarwal and P. Kumar (2019). "Population–urbanization–energy nexus: a review." Resources **8**(3): 136.

Belia, E., Y. Amerlinck, L. Benedetti, B. Johnson, G. Sin, P. A. Vanrolleghem, K. Gernaey, S. Gillot, M. Neumann and L. Rieger (2009). "Wastewater treatment modelling: dealing with uncertainties." Water Science and Technology **60**(8): 1929-1941.

Copp, J. B. (2002). The cost simulation benchmark: Description and simulator manual: A product of cost action 624 and cost action 682, EUR-OP.

Farmer, G. T., J. Cook, G. T. Farmer and J. Cook (2013). "Carbon dioxide, other greenhouse gases, and the carbon cycle." Climate Change Science: A Modern Synthesis: Volume 1-The Physical Climate: 199-215.

Galloway, J., A. Townsend, J. Erisman, M. Bekunda, Z. Cai, J. Freney, L. Martinelli, S. Seitzinger and M. Sutton (2008). "Transformación del ciclo del nitrógeno: tendencias recientes, preguntas y posibles soluciones." Ciencias **320**(5878): 889-892.

Grady Jr, C. L., G. T. Daigger, N. G. Love and C. D. Filipe (2011). Biological wastewater treatment, CRC press.

Hwang, J. H. and J. A. Oleszkiewicz (2007). "Effect of cold-temperature shock on nitrification." Water Environment Research **79**(9): 964-968.

Jain, P. (1993). "Greenhouse effect and climate change: scientific basis and overview." Renewable energy **3**(4-5): 403-420.

Laurance, W. F. and J. Engert (2022). "Sprawling cities are rapidly encroaching on Earth's biodiversity." Proceedings of the National Academy of Sciences **119**(16): e2202244119.

Metcalf, Eddy, M. Abu-Orf, G. Bowden, F. L. Burton, W. Pfrang, H. D. Stensel, G. Tchobanoglous, R. Tsuchihashi and AECOM (2014). Wastewater engineering: treatment and resource recovery, McGraw Hill Education.

Montgomery, J. M. (1985). Water treatment: principles and design. Water treatment: Principles and design, John Wiley & Sons.

Nathanson, J. A. and Ambulkar,.Archis (2023, March 22). *wastewater treatment*. *Encyclopedia Britannica*. https://www.britannica.com/technology/wastewater-treatment

Plósz, B. G., H. Liltved and H. Ratnaweera (2009). "Climate change impacts on activated sludge wastewater treatment: a case study from Norway." Water Science and Technology **60**(2): 533-541.

Reichert, P. (2006). "A standard interface between simulation programs and systems analysis software." Water Science and Technology **53**(1): 267-275.

Rooijen, D. J. V. (2011). Implications of Urban development for water demand, wastewater generation and reuse in water-stressed cities: case studies from South Asia and sub-Saharan Africa, Loughborough University.

Semadeni-Davies, A. (2004). "Urban water management vs. climate change: impacts on cold region waste water inflows." Climatic Change **64**(1-2): 103-126.

Semadeni-Davies, A., C. Hernebring, G. Svensson and L.-G. Gustafsson (2008). "The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Combined sewer system." Journal of Hydrology **350**(1-2): 100-113.

Smithson, P. A. (2002). IPCC, 2001: climate change 2001: the scientific basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, edited by JT Houghton, Y. Ding, DJ Griggs, M. Noguer, PJ van der Linden, X. Dai, K. Maskell and CA Johnson (eds). Cambridge University Press, Cambridge, UK, and New York, USA, 2001. No. of pages: 881. Price£ 34.95, US 49.95,ISBN0-521-01495-6(paperback).£90.00,US 130.00, ISBN 0-521-80767-0 (hardback), Wiley Online Library.

Wanner, J. (2021). "The development in biological wastewater treatment over the last 50 years." Water Science and Technology **84**(2): 274-283.

Wilén, B.-M., K. Keiding and P. H. Nielsen (2004). "Flocculation of activated sludge flocs by stimulation of the aerobic biological activity." Water research **38**(18): 3909-3919.

Zhen, G., X. Lu, H. Kato, Y. Zhao and Y.-Y. Li (2017). "Overview of pretreatment strategies for enhancing sewage sludge disintegration and subsequent anaerobic digestion: Current advances, full-scale application and future perspectives." Renewable and Sustainable Energy Reviews **69**: 559-577.