v. 4, n. 1, 2024

Journal of
Engineering
Research

ARTIFICIAL INTELLIGENCE APPLIED IN THE DESIGN OF SEWAGE TREATMENT PLANT PROJECTS – COMPARATIVE STUDY WITH REAL DATA

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Journal of Engineering Research ISSN 2764-1317 DOI: https://doi.org/10.22533/at.ed.1317412415011

Abstract: To achieve the goals stipulated by the legal framework for sanitation, Federal Law Number 14,026, it is necessary to effectively increase the 3,368 (2019) Sewage Treatment Stations (ETEs) existing in the country. The development of conventional ETE projects involves interdisciplinary areas and considerable time for preparation. However, there are Artificial Intelligence (AI) tools on the market that can produce complete ETE projects in shorter intervals, covering areas of civil quantities, technical details of the process, chemical/energy consumption and sludge generation, in addition to floor plans in *Revit* and AutoCAD. In this context, the objective of this study was to carry out a comparative study, analyzing the application of an ETE project developed in the Transcend Design Generator software to a real project – ETE CEMEX, from SABESP.
Keywords*:* Wastewater Treatment Plants (WWTP); Artificial Intelligence (AI); Building Information Modeling (BIM).

INTRODUCTION

Levels of service related to basic sanitation are increasing globally, with around 54% of the world's population having access to treated sewage in 2020 (World Health Organization - WHO, 2020). Especially in Brazil, with the 'new legal framework for basic sanitation' - Federal Law nº 14,026 (BRAZIL, 2020), the metrics established by the legal requirement establish and guarantee that 90% (ninety percent) of the Brazilian population, that is: 204,874.723 (IBGE, 2022), are met with sewage collection and treatment until December 31, 2033, in accordance with Art. 11-B of Federal Law Number: 14,026 (BRAZIL, 2020).

According to the National Sanitation Information System (SNIS), in 2020, the country's average in the 'total sewage service index' was 55% (SNIS, 2020). Therefore, it is worth considering that almost half of the population is still not covered by basic sanitation actions. According to the National Water and Sanitation Agency (ANA), in 2019, the country had 3,368 Sewage Treatment Stations (ETEs), totaling only 36% of the Brazilian municipalities covered (ANA Bulletin, 2019).

The design of a Sewage Treatment Plant is a complex, multidisciplinary process that consumes an excessive amount of time – as it involves the participation and integration of several areas, such as: architects (plan design, zoning, land use and occupation); civil engineers (construction, design, earthworks); environmental engineers (sizing, type of treatment process); electrical engineers (electrical panels, installations) and other professionals (ECHOA ENGENHARIA, 2015).

Although conventional modeling (SABESP, 2018), carried out by contracted designers, is the most used, the use of Artificial Intelligence (AI), Digital Twins and *building Information Modeling* (BIM), are increasingly widespread in various industrial processes (MAGNO et al., 2022). In sanitation, one can observe the diffusion of these methodologies and tools, in companies such as: Bentley (Open Flows Sewer CAD – tools for planning, design, maintenance and operation of ETEs), Siemens (Siemens Water – optimizes energy efficiency and attacks water losses) and Transcend Water, with its Transcend Design Generator (TGD) platform, which can model sewage treatment plants in up to 8 hours.

With its AI located in Simba Software, a modern tool for modeling and dynamic simulation of hydraulic and sanitary engineering processes, developed by the ifak institute, and using references such as Metcalf & Eddy (2016); ABNT NBR 12209 (BRAZIL, 1992), ATV 131 (GERMANY, 2000), BAQUERO-RODRÍGUEZ et. al. (2018) and among others (see 6. Annex 1 – TDG

Bibliographic Reference), the TGD platform delivers projects in up to 8 hours, based on the parameters and characteristics of effluent input and output (VON SPERLING, 2005) defined by the user. The modeling generates deliverables with technical parameters, construction layouts (AutoCAD and Revit) and quantitative bases for calculating Capital Expenditure (Capex) and Operational Expenditure (Opex).

The use of AI in the design of ETEs – both in new and retrofit projects, offers a primary projection of rapid production and visualization (8 hours) and with results that can be studied for the efficiency of sewage treatment between one or more routes technological (Activated Sludge vs. Mobile Bed Biological Reactor, for example), in addition to information such as operational and construction costs. And, the data provided by the Transcend platform can be compared with the efficiency of organic matter removal in an ETE designed through conventional means (SABESP, 2018), and assist in technical proposals received by ETE designers.

By way of analysis, the "Executive Project – ETE CEMEX" (SABESP, 2018) was chosen for visualization and study between the conventional design vs. one produced by artificial intelligence. The chosen ETE (SABESP, 2018) consists of a station with a nominal capacity of approximately 15 L/s, secondary treatment and removal of at least 80% of the Biochemical Oxygen Demand (BOD), according to Decree-Law Number: 8,468 (SÃO PAULO, 1976). Although there is no information on how many days it took to be prepared, the authors believe that the Executive Project – ETE CEMEX (SABESP, 2018) took more than 8 hours to have its 91 pages constructed. It is possible to compare time when analyzing a Course Completion Paper (TCC) for an ETE proposal, which was developed over the course of a year (POLIDO et. al., 2013).

The results obtained will make it possible to compare the assertiveness of the platform and verify its technical principles adopted for the treatment of sewage, both in its liquid and solid phases. In the liquid phase, the effluent can (conventionally) go through three levels of treatment, which are, according to Metcalf and Eddy (2016): (I) Primary, removal of part of the Total Suspended Solids (TSS) and organic matter, which are organic compounds of carbon, hydrogen and oxygen (Sanitation Manual, 2004); (II) Secondary, which additionally removes biodegradable organic matter (animal and plant residues), in addition to TSS; (III) Tertiary, which includes the previous principles and, additionally, the removal of nutrients, such as phosphorus and nitrogen. And, the solid phase comprises sludge, which is any material produced in the treatment steps that has not been treated in pathogen or vector reduction processes (Metcalf & Eddy, 2016). And, in addition to checking the process steps, we can compare the list of materials and instrumentation provided by TDG with those adopted in the conventional project (SABESP, 2018). In this process, it is possible to 'audit' both projects, making it possible to identify any difficulties and inconsistencies that may be adopted by the AI or designer (SABESP, 2018).

Therefore, the objective of this work was to verify the applicability of the Transcend Design Generator software, based on an implemented project of an ETE, seeking (i) to compare the results obtained by simulation and those performed in the real environment and (ii) to establish the advantages (and possible disadvantages) along with the challenges and opportunities offered within the area of ETE projects using AI.

METHODOLOGY

To evaluate the uses of modeling ETEs

through the proposed software, an executive project of a sewage treatment plant was analyzed, the chosen one was the ETE CEMEX, in Porto Feliz, process SAAE: 473/2018 (SABESP, 2018).

The Executive Project included a system based on the biological treatment of sewage through the Activated Sludge process, which works based on biological principles of assimilation of carbonaceous matter by bacteria in the aeration tank (effluent that may be interfered with by a primary decanter or not, depending on case), then the floccules made up of bacteria that act on the degradation of organic matter are decanted into a secondary decanter where a part leaves as treated effluent and, the settled sludge, returns to the aeration tank as it is enriched by microorganisms (VON SPERLING, 2016)

In the sewage treatment process, especially those dealing with the treatment of organic matter, it is essential to achieve BOD removal levels above 80%, according to Decree-Law Number: 8,468 (SÃO PAULO, 1976), this being the demand for the amount of oxygen for degradation of matter through microorganisms, while Organic Chemical Demand (COD) follows the same purpose using chemical decomposition (VON SPERLING, 2014).

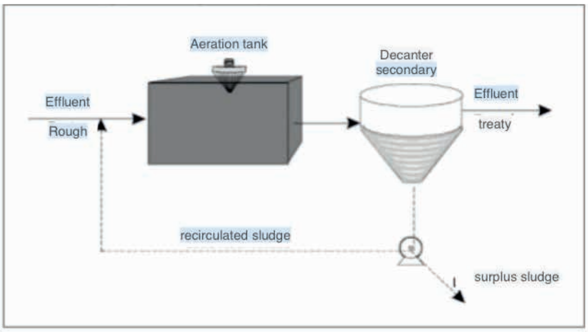


Figure 1. Activated Sludge Processes.

Source: VON SPERLING, 2014.

For the purpose of calculating the effluent flow, the occupation corresponding to 4055 inhabitants was initially considered. The characterization of raw sewage was inserted below, as shown in Table 1.

Parameter	Effluent inlet
Flow (L/s)	9.01
Maximum Flow (L/s)	15.02
Coefficient day of highest consumption (K1)	1.2
Coefficient hour of greatest consumption (K2)	1.5
Return coefficient	0.8
Infiltration Coefficient (L/s/km)	0.20
Organic load (KgBOD/inhabitant/day)	0.054
BOD (mg/L)	253.18
COD (mg/L)	500
SS (mg/L)	200
Total Nitrogen (mg/L)	90
Phosphorus (mg/L)	9
pH	7.5
Temperature (°C)	20
Treatment efficiency (São Paulo, 1976)	80%

Table 1 – Parameters adopted in the Executive Project

Source: ETE CEMEX – SABESP, 2018.

TRANSCEND DESIGN GENERATOR(TDG)

The TDG platform is a private tool, developed by the company Transcend Water, which, through global references in sanitation (see 6. Annex 1 – TDG Bibliographic Reference), has a robust database and is capable of simulating engineering outputs and calculating the principles of sizing ETEs through Simba Simulation – and its decision-making algorithms, based on the mandatory effluent input and output information that is defined by the user. If the modeling parameters are not possible to be applied due to technical or sizing principles, the platform recalculates them automatically, based on its AI.

DATA ENTRY

The flow of processes and their outputs, on platforms such as TDG, are quantified based on the mandatory initial information provided by the user, in addition to other optional ones, for better design accuracy.

The user has several options for measurement units within the platform, whether for temperature, flow, physical-chemical parameters of the sewage and particularities of the treatment system. Additionally, there are ranges for all inputs that must be respected to proceed with the design (e.g., input BOD must be in the range of 50-800 mg/L); If the user does not have these values, the platform offers average values based on the location and type of treatment chosen (Metcalf & Eddy, 2014), such as an average BOD of 258 mg/L – which would be considered average, depending on physical-chemical characteristics of the sewers of Metcalf & Eddy (1991).

Modeling is divided into 5 steps:

1. Information – Basic information about the project.

a) Mandatory information: Name of project owner; Project name; Location (country);

b) Optional information: Brownfields plants – where it already has existing assets (reactors, clarifiers, etc.); Greenfields plants – project started in an area without buildings; Effluent standard – treatment at secondary or tertiary level.

2. Plant – Technical preferences of the project.

a) Mandatory information: Need for a primary clarifier or upflow anaerobic reactor (UASB); Type of treatment (Activated Sludge, Membrane Bio Reactor - MBR, Moving Bed Biofilm Reactor - MBBR, Moving Bed Biofilm Reactor + Integrated Fixed Film - MBBR-IFAS, Sequencing Batch Reactor - SBR);

b) Optional information: Litter box (aerated, non-aerated or chosen by AI); Flow equalization (Use or not use equalization or leave it chosen by the AI); Preferred chemical for phosphorus removal ($FeCl_3$, $Fe_2(SO_4)_3$ etc.); Sludge Recirculation; Anaerobic Digester; Need for disinfection; Inclusion of administrative buildings.

3. Location marking – Step where it is possible to select the geographic coordinates of the plant construction site via *Google Earth* (it is possible to upload kml files) and, in cases of Brownfields, it is possible to select the location of existing assets – in addition to zones where construction is not permitted. It's not mandatory.

4.Flow – Insertion of operational information on effluent input and output.

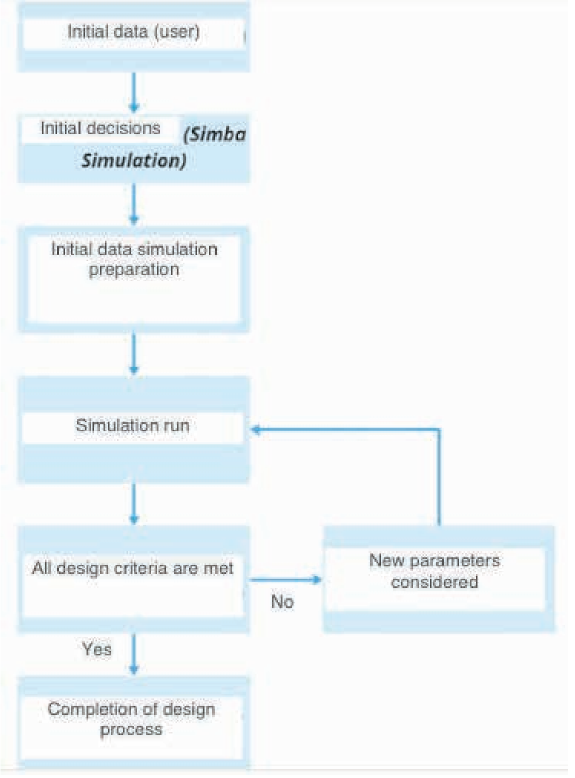
a) Mandatory information: Minimum and maximum effluent temperature; Design flow, COD (inlet only, optional outlet), BOD (inlet and outlet), Total Suspended Solids (inlet and outlet), Nitrogen (inlet only, optional outlet), Phosphorus (inlet only, optional outlet);

b) Optional information: Non-permanent flow, minimum and maximum flow (daily and hourly); *Bypass* from primary sewage to disinfection; Bypass of primary sewage to biological treatment; Biological sewage bypass until disinfection; volatile suspended solids; alkalinity; pH; oils and greases.

5.Preferences – Definition of preferences according to the treatment route defined in the *step 2*. This step is not mandatory; however, it is possible to provide details about the needs of the process, including information such as: number of reactors, sludge retention time and hydraulics, type of diffuser, mixed suspended solids (MLSS), depth of the reactors; media size; media occupancy rate, among others.

INTERNAL DATA PROCESSING

After the user inserts data into the system, the TDG platform begins validating the information in the operational window with the chosen processing technology. This process is responsible for any internal data changes that the software may make – as there is the possibility of the relationship established by the user is not compatible with the system sizing calculations, as illustrated in Flowchart 1. Work Flow.



Flowchart 1. Workflow.

Source: Transcend Water. Adapted by the authors.

The initial decisions for sizing the treatment process occur through Simba Simulation and, for example, in the case of Activated Sludge, MBR and MBR-IFAS treatments, the mathematical algorithm and programming logic for the process steps follow the ATV-manual. A131 (GERMANY, 2000) and the sizing rules of Metcalf & Eddy (2014). The programming logic can be observed in a simplistic way below, in Flowchart 2. Data validation by Simba Simulation.

At the end of the modeling process (8 hours), the platform delivers a complete scheme of the ETE, including preliminary treatment of the liquid and solid phase of the effluent. The documents that make up the platform's final deliverables can be divided into 3 groups:

1. Technical: Design basis; Technical flowchart of the process; Technical description; List of TAGs; Flowchart of the arrangement and rental of Equipment and Instruments; ETE Revit and AutoCAD files (Side sections, floor plan, top view).

2. CAPEX: List of Equipment; List of Civil Instrumentation and Quantities;

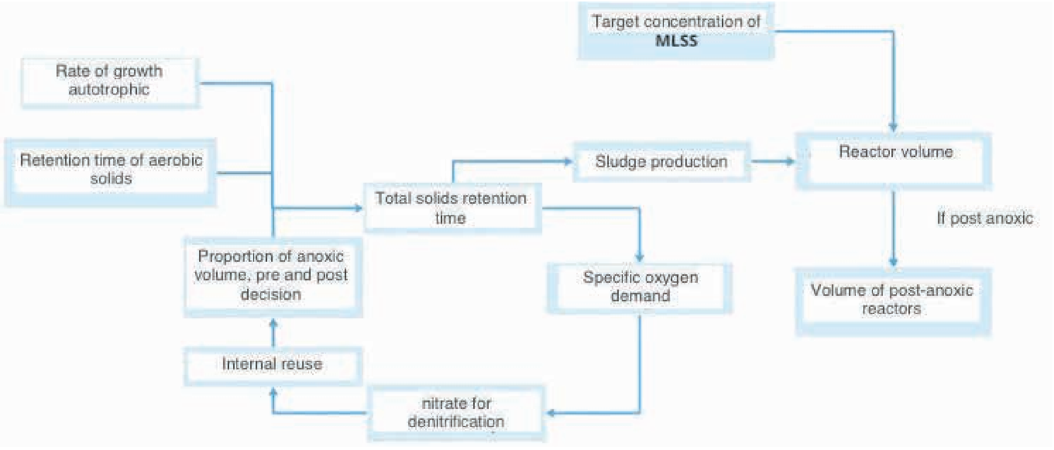
3. OPEX: Load List (kW installed and kWh in operation) and OPEX Output (grating, sludge generation, chemicals, power density, etc.)

RESULTS AND DISCUSSIONS

After modeling the ETE CEMEX within the TDG, it is possible to analyze the technical and quantitative differences between the dimensions (Conventional vs. Artificial Intelligence), the effluent input and output parameters were kept the same. The results presented below focused on (i) biological reactors; (ii) effluent aeration and (iii) sludge drainage.

BIOLOGICAL REACTOR

In both projects, 2 biological reactors were considered, without a primary clarifier. However, the software does not provide the



Flowchart 2. Data validation by Simba Simulation

Source: Transcend Water. Adapted by the authors.

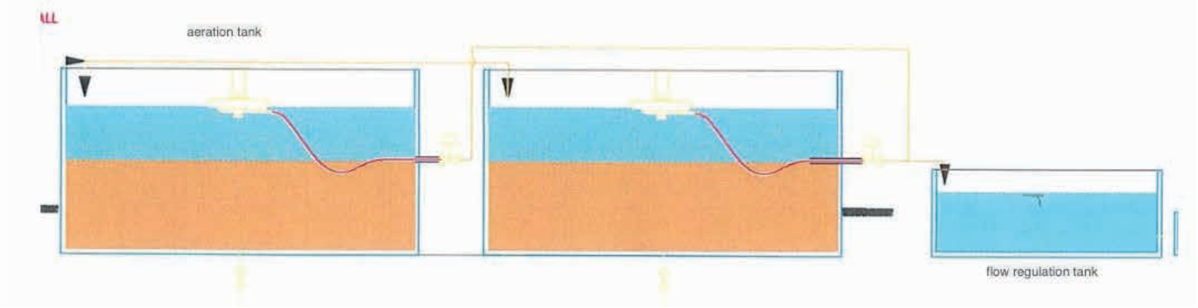


Figure 2. Conventional Project Flowchart – ETE CEMEX

Source: SABESP, 2018.

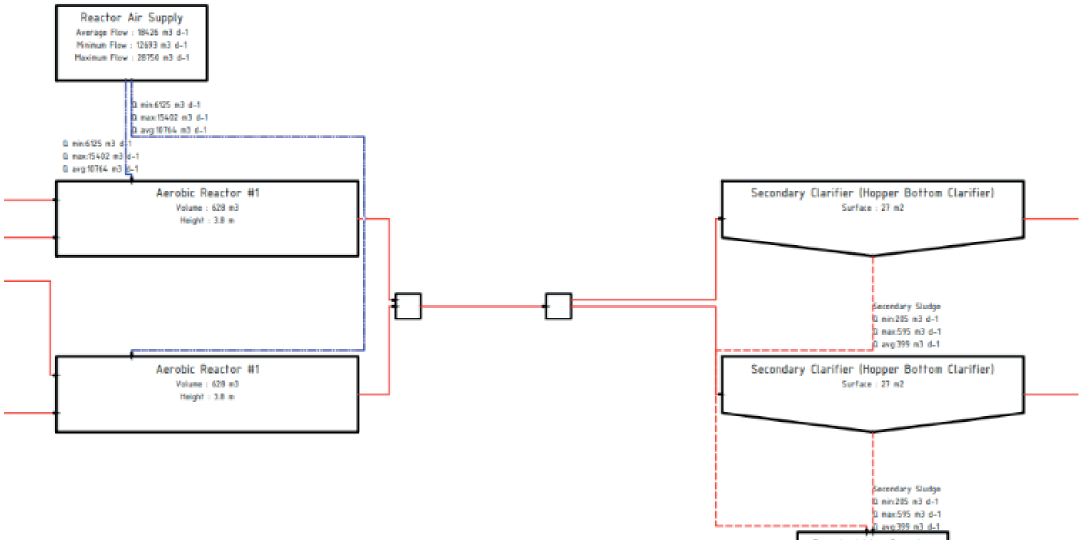


Figure 3. Flowchart of the Transcend Project – ETE CEMEX.

Source: Transcend Water, 2022.

option of removing the secondary decanter – with this design divergence between the AI and the conventional one, as can be seen below, in figures 2. Flowchart of the Conventional Project – ETE CEMEX and 3. Flowchart of the Transcend Project – ETE CEMEX.

The reactors adopted by IA have a smaller width (6.1 m) and a longer length (25 m), while the SABESP Project reactors were sized with the same width and length, 11 mx 11 m. It is important to note that the land selected for modeling was the same as the one delimited in the SABESP project, a land in Porto Feliz, however, the TDG reported that the delimited land would not be enough for the construction of the ETE.

The sludge age calculated in the Project was 29 days, with a concentration of Total Suspended Solids (TSS) in the decanted sludge (MLSS) equal to 5000 mg/L. By Transcend, the sludge's age was calculated at 29 days, with an MLSS concentration equal to 3228 mg/L. One of the reasons for the lower number may be the presence of a secondary decanter that does not exist in the original process.

EFFLUENT AERATION

Constant aeration is necessary for the aerobic zones to maintain mixing (mass balance) and provide sufficient oxygen for biological processes within the reactors.

In the project modeled by TDG, a single aerator was calculated in operation for the two tanks (including one on standby), with the following characteristics: aeration efficiency equal to 95% efficiency; nominal capacity of 50.3 CV; energy consumption equal to 33.64 kWh and transferred oxygen demand equal to 768 Nm^3/h. The analyzed project from SABESP (2018) has two aerators in operation, each with a nominal capacity of 25 CV; energy consumption of 36.77 kWh and has oxygen transfer at 548.84 Nm^3/h.

When analyzing the aeration requirements, the results are consistent, since the total nominal capacity (CV) of the blowers is close, with only a difference in their quantity. Energy consumption is also low, respecting the conceptual logic of the blowers' CV. However, due to the difference in biological reactor formats (see*3.1 Biological Reactors*), in the TDG project there is a greater demand for the transfer of oxygen in the medium, resulting in a greater mass transfer for degradation of the matter – in addition, the AI modeling has a lower MLSS than the designer, reaffirming the need for greater loads of oxygen in the medium.

According to the Project, the maximum load demand at the ETE is 54.56 kWh and the equipment included in this calculation includes: aerators, sewage pumping station pumps (EEE), air compressors, submersible mixer, metering pump of chemicals and lighting at ETE. The related equipment was mapped in AI modeling and has a maximum load demand of 39.03 kWh. However, one of the reasons for the inferiority in load demand is the AI's inability to calculate elevation levels and differences in the terrain, not conceiving EEE in the project because it considers a flat area.

SLUDGE DRAIN

In TDG modeling, the sludge is dewatered at a percentage of 20% Dry Solids (SS), and undergoes mechanical densification, with production at 0.59 m^3/day. The excess sludge from the dry cake is added with polymer and returns to the beginning of the process, after harrowing, with a flow rate of 22 m^3/day.

In the conventional design, the sludge is densified and subjected to a decanter centrifuge, which also has a percentage of 20% SS, a value commonly found in sanitation articles, such as VANZETTO (2012), and has a sludge cake of 0.50 m^3/day. The excess cake is filtered due to prior densification and returns

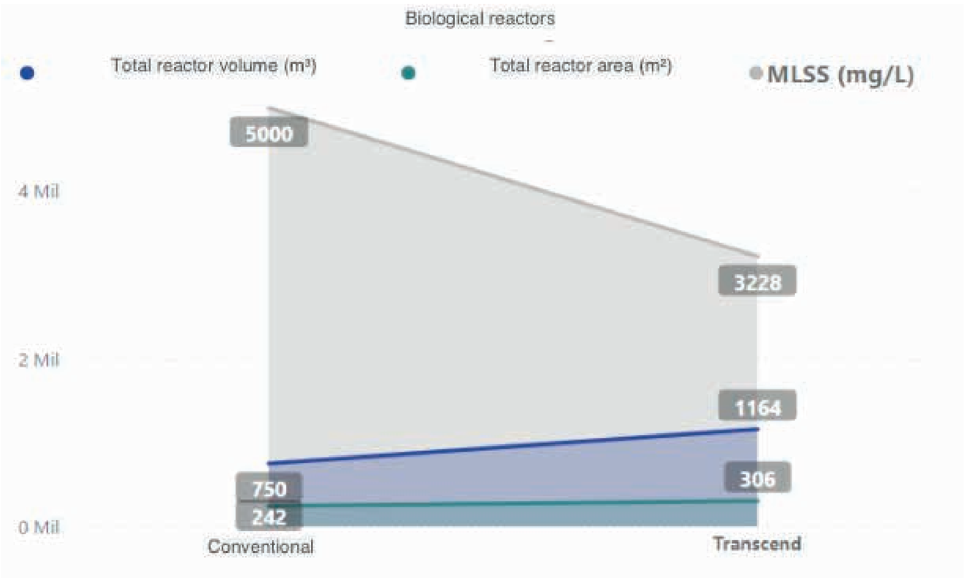


Figure 4. Biological Reactors.

Source: Authors.

Figure 5. Effluent Aeration

Source: Authors.

to the effluent inlet lift well, the flow rate is 19.68 m^3/day. As we can see below, in Figure 5. Sludge Drainage, the compared values are satisfactorily similar.

ADVANTAGES AND LIMITATIONS OF USING TDG

Although modeling by TDG occurs in a disruptive way, both due to its ease of data insertion and the agility in generating (14) complex deliverables applicable to different project aspects, it is necessary to understand that the technology does not exclude the need to hire designers for executive projects, as it is necessary to consider factors that the platform does not cover, such as:

1. Topographic elevation and terrain: The technology is not capable of distinguishing the differences in levels of a terrain, its projects do not have sewage lifting stations and booster pumps – as the platform considers the terrain to be flat.

2. Know-how: Although its algorithm includes bibliographic references (see 6. Annex 1 – TDG Bibliographic Reference) applicable to the area, what is covered in theory is not always in line with reality and, it is worth remembering that each location has its own particularities for ETE projects – whether due to local legal requirements, characteristics of the effluent and its disposal, geographic quotas and seasonality.

3. Bugs and divergences: seeing that this is a platform that still undergoes constant updates, design errors can always be observed in the famous "bugs" (which are corrected when identified). Furthermore, there are discrepancies in project values that may not be understood if there is no knowledge of the platform, for example: if the project's MLSS is not defined, the sizing of the reactors may differ in 2 identical projects. Another case is if there is no maximum hourly flow (L/s), the peak flow will be calculated based on the concentration of BOD mg/L and, consequently, equivalent population – generating different projects.

4. Comparisons: The need for a designer does not result in the inefficiency of the platform, it is actually a way of carrying out a 'match' between projects, identifying the differences and understanding the reasons that are leading to this. Furthermore, it is possible to analyze whether the reality of existing projects matches the literature. It is also possible to carry out retrofit simulations at the plant and have variations in CAPEX and OPEX, through changes in small parameters.

POSSIBILITIES AND APPLICATIONS

The use of Artificial Intelligence in the dynamic production of sanitation projects opens up possibilities to identify technical, CAPEX and OPEX nuances through one click. To illustrate the possibilities, in addition to the comparative project run at TDG (2. Methodology), 4 others were carried out, with slight procedural variations, as shown in Table 2.

In a case where we need to compare the values related to the cost of work (CAPEX) and its operation (OPEX), with the data extracted from the documents generated on the platform, it is possible to visualize the following curves:

The largest concrete (and steel) tanking and earthmoving services occur in the UASB + Activated Sludge modeling, as it requires anaerobic tanks for gas generation and aerobic tanks for the activated sludge process. Then the base project appears – which is equivalent to MBBR and the others.

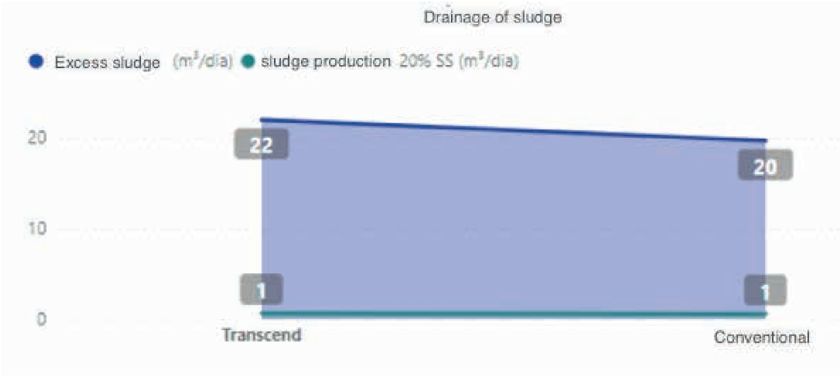


Figure 6. Sludge Drainage.

Source: Authors.

Base Project	Activated Sludge	No removal	BOD of 253.18 mg/L
Route 2	UASB + Activated Sludge	With removal (Table 1. Parameters adopted in the executive project, adopted in 90%)	BOD of 253.18 mg/L
Route 3	MBBR	No removal	BOD of 253.18 mg/L
Route 4	Activated Sludge	No removal	Low BOD 110 mg/L (Metcalf & Eddy, 1991)
Route 5	Activated Sludge	No removal	BOD Forte 400 mg/L (Metcalf & Eddy, 1991)

Table 2. Other possibilities.

Source: Authors.

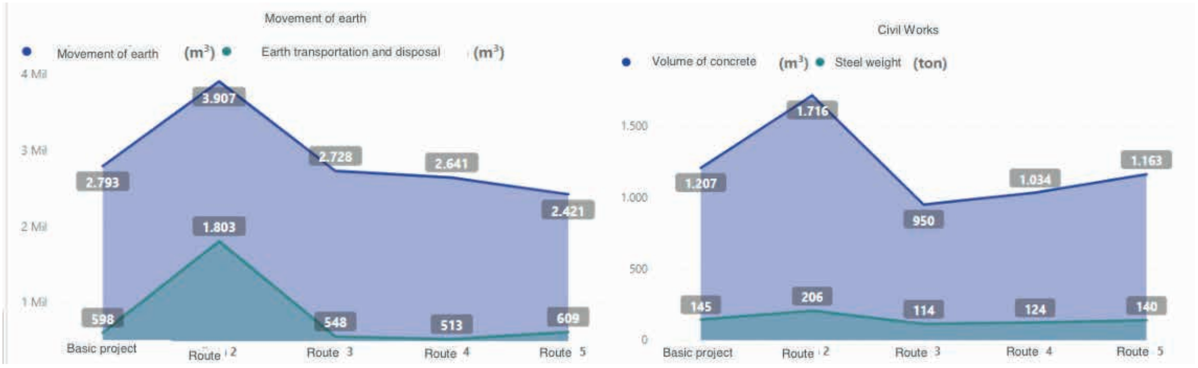


Figure 7. and 8. CAPEX curves.

Source: Authors.

OPEX CURVES.

When analyzing the OPEX curves, it is notable that the route that has the highest rates of installed power (operation and standby) and highest average energy consumption KW/h (Figure 9) is the process that requires nutrient removal in your treatment – Route 2. UASB + LA. The other numbers remain consistent, with Route 3. MBBR, having the lowest energy consumption demand – proving to be a treatment that has a more economical operation. The other Activated Sludge projects showed similar consumption. And, checking Figure. 10, it is notable that the project that presents the lowest power density (temporal energy transfer rate, PORTESCAP) is Route 4, which has the weakest BOD among the projects.

Sludge generation and polymer dosage for dewatering (Figure 11) are proportional. The MBBR had the lowest energy consumption, however, it is the one that requires the most dosages of chemicals to dehydrate the large amount of sludge. Again, Route 4. Weak BOD, proved to have the lowest volume of chemical generation and dosage. It is noted that the only process that requires methanol dosing is Route 2. UASB + LA, as phosphorus and nitrogen are removed within its modeling.

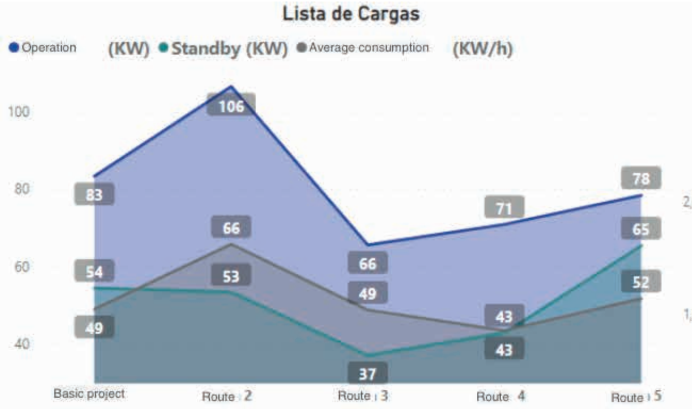
CONCLUSIONS

The Transcend Design Generator software presented satisfactory results when compared with the ETE CEMEX executive project. If we analyze the more technical parameters of the treatment, such as the age of the sludge in the biological reactors and the generation of environmental liabilities after the liquid phase, the precision between the two was accurate. Furthermore, even though the tank volumetric, oxygen transfer and energy demand results were not as accurate, the difference range and order of magnitude remained close to that of the designer – showing that the AI calculation is robust and safe.

The commercial and technical advantage of using the tool is, without a doubt, in its production time - since in less than 8 hours we had deliverables similar to those of the designer, with additional Revit and BIM modeling, adopting the market trend for industrial projects.

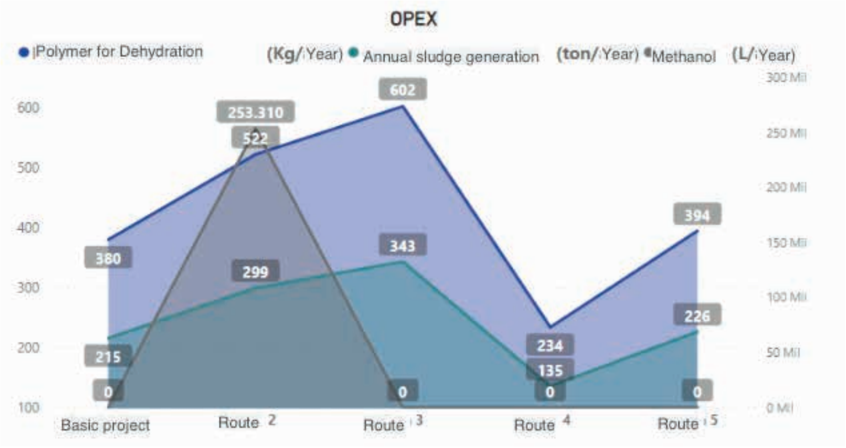
And, due to the agility and practicality of carrying out projects in TDG, comparison between different technological routes or operational windows is possible. This data allows us to obtain range curves for crucial parameters when making decisions, as we can see where a treatment route is most economical and where it has the highest costs, favoring the technical feasibility of the project.

Although it is not a substitute for hiring 'executive projects' by companies, the tool is a great ally in comparing them and is completely integrable into the process of modeling and sizing sewage treatment plants. Artificial intelligence and generation of deliverables is disruptive, with numerous applications for the technology (comparison, CAPEX and OPEX ranges, assistance in BIDs for sanitation blocks, etc.), depending only on the limitation of the user's creativity in data processing.



Figures 9 and 10. Energy consumption.

Source: Authors.



Source: Authors.

REFERENCES

World Health Organization. SANITATION. Disponível em: https://www.who.int/news-room/fact-sheets/detail/sanitation. Acesso em: 10 agosto 2022.

Associação Brasileira de Normas Técnicas. ABNT NBR nº 12209 - Projeto de estações de tratamento de esgoto sanitário, 1992.

Brasil. Fundação Nacional de Saúde. Manual de Saneamento. 3. ed. rev. - Brasília: Fundação Nacional de Saúde, 2004.

Brasil. Lei nº 14.026, de 15 de julho de 2020. Atualiza o marco legal do saneamento básico. Publicado no Diário Oficial da União, aos 16 de julho de 2020.

CARNEIRO, A. Medida de Distribuição da densidade de potência relativa do núcleo do reator

Comitê de Integração da Bacia Hidrográfica do Rio Paraíba do Sul. Boletim da ANA mostra aumento de ETEs no Brasil. Disponível em: https://www.ceivap.org.br/ceivap_news/ed118/CEIVAPNEWS-mat2.html#:~:text=A%20Ag%C3%AAncia%20Nacional%20de%20%C3%81guas,no%20pa%C3%ADs%2C%20em%202.007%20munic%C3%ADpios. Acesso em: 10 agosto 2022.

ECHOA Engenharia. ESTUDO DE CONCEPÇÃO, PROJETO BÁSICO E EXECUTIVO E ESTUDO AMBIENTAL DO SISTEMA DE ESGOTAMENTO SANITÁRIO DO MUNICÍPIO DE AREIAS/SP. Disponível em: http://sigaceivap.org.br/publicacoesArquivos/ceivap/arq_pubMidia_Processo_099-2014_P01.pdf. Acesso em: 4 setembro 2022.

Instituto Brasileiro de Geografia e Estatística. Projeção da população do Brasil. Disponível em: https://www.ibge.gov.br/apps/populacao/projecao/index.html?utm_source=portal&utm_medium=popclock&utm_campaign=novo_popclock. Acesso em: 10 agosto 2022.

MAGNO, Bruno Luiz Poça et al. A inovação na produção e gestão de projetos de arquitetura e design. [s.l: s.n].

METCALF, L.; EDDY, H. P. Tratamento de efluentes e recuperação de recursos. 5. ed. Porto Alegre: AMGH, 2016

METCALF, L.; EDDY, H. P. Wastewater Engineering: Treatment, Disposal, and Reuse. 3rd Edition, McGraw-Hill,1991.

Ministério do Desenvolvimento Regional, Secretaria Nacional de Saneamento. Diagnóstico Temático - Serviços de Água e Esgoto, Gestão Técnica de Esgoto. Disponível em: http://www.snis.gov.br/downloads/diagnosticos/ae/2020/DIAGNOSTICO_TEMATICO_GESTAO_TECNICA_DE_ESGOTO_AE_SNIS_2022.pdf. Acesso em: 4 setembro 2022.

PORTESCAP. Densidade de potência. Disponível em: https://www.portescap.com/pt-br/solu%C3%A7%C3%B5es-de-motores-controlados/densidade-da-pot%C3%AAncia#:~:text=Densidade%20de%20pot%C3%AAncia%20(ou%20densidade,%C3%A9%20a%20densidade%20de%20pot%C3%AAncia. Acesso em: 4 setembro 2022.

São Paulo. Decreto nº 8.468, de 8 de setembro de 1976. Aprova o Regulamento da Lei n.° 997, de 31 de maio de 1976, que dispõe sobre a prevenção e o controle da poluição do meio ambiente. Publicado na Casa Civil, aos 6 de setembro de 1976

VANZETTO, Aliny. ANÁLISE DAS ALTERNATIVAS TECNOLÓGICAS DE DESAGUAMENTO DE LODOS PRODUZIDOS EM ESTAÇÕES DE TRATAMENTO DE ESGOTO. PUBLICAÇÃO: PTARH.DM - 139/12; BRASÍLIA/DF: NOVEMBRO – 2012.

VON SPERLING, Marcos. Introdução à qualidade das águas e ao tratamento de esgotos. Universidade Federal de Minas Gerais, 4ª Ed., Belo Horizonte, 2014.

VON SPERLING, Marcos. Introdução à qualidade das águas e ao tratamento de esgotos: princípios do tratamento biológico de águas residuárias, Vol. 1. DESA-UFMG, Belo Horizonte, 2005.

VON SPERLING, Marcos. Princípios de tratamento de águas residuárias: Lodos Ativados. Departamento de Engenharia Sanitária e Ambiental – UFMG, 4ª ed. rev. e ampliada. – Belo Horizonte, MG, 2016.

ANEXO 1 – REFERENCIAL BIBLIOGRÁFICO TDG

10 State Standards - Recommended Standards for Wastewater Facilities (2014). Health Research, Inc., Health Education Services Division

ATV131 Dimensioning of Single Stage Activated Sludge Plants. (2000) GFA Publishing Company of ATV-DVWK Water, Wastewater and Waste, Hennef, Germany.ISBN: 3-935669-82-8

Baquero-Rodríguez G.A., Lara-Borrero J.A., Nolasco D. & Rosso D. (2018) A Critical Review of the Factors Affecting Modeling Oxygen Transfer by Fine-Pore Diffusers in Activated Sludge. Water Environ Res.; 90(5):431-441

Clarifier Design (2005) Water Environment Federation, Manual of Practice No. FD-8., McGrawHill

Faisal I. Hai, Kazuo Yamamoto, Chung-Hak Lee (2019) Membrane Biological Reactors: Theory, Modeling, Design, Management and Applications to Wastewater Reuse - Second Edition. IWA Publishing, London, UK

Henze, M., van Loosdrecht; M. C. M., Ekama; G.A., Brdjanovic, D. (2008) Biological Wastewater Treatment: Principles, Modelling and Design, IWA Publishing, London, UK.

Judd. S. & Judd. C. (2011). The MBR Book: Principles and Applications of Membrane Bioreactors in Water and Wastewater Treatment. Amsterdam: Elsevier

McQarrie J.P and Boltz J.P. (2011) Moving bed biofilm reactor technology. Water Environment Research (83) 6.

Metcalf & Eddy (2014) Wastewater Engineering: Treatment and Resource Recovery. 5th Edition, McGraw-Hill, New York.

Mueller,J. A., Boyle, W. C., and Pöpel, H. J. (2002). Aeration: Principles and Practice, CRC Press, Boca Raton.

Odegaard H., (2006) Innovations in wastewater treatment: The moving bed biofilm process. Water Science & Technology 53(9):17-33 DOI: 10.2166/wst.2006.284

Rieger; L., Gillot; S., Langergraber; G., Ohtsuki; T., Shaw; A., Takács; I., Winkler, S. (2012) Guidelines for Using Activated Sludge Models Scientific and Technical Report

Schraa, O., Rieger, L. and Alex, J. (2017). Development of a model for activated sludge aeration systems: Linking air supply, distribution, and demand. Water Sci. Technol., 75(3), 507-517

U.S. Environmental Protection Agency (USEPA), Office of Research and Development. (1989) Design Manual: Fine Pore Aeration Systems. EPA/625/1-89/023. U.S. E.P.A., Cinncinati, OH.

U.S. Environmental Protection Agency (USEPA), Office of Research and Development. (1993). Manual: Nitrogen Control. EPA/625/R-93/010. U.S. E.P.A., Cincinnati, OH.

Water Environment Research Foundation (WERF) (1995). Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance. Water Environment Research Foundation Final Project Report – Project 91-WWD-1. Alexandria. VA.