Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 17, número 5, 2021

Sanitary sewage: characterization, treatment and ecotoxicity

Isadora Vitali Lobo
M.Sc. Student, Civil Engineering Post-Graduation Program, UNESP, Brazil.
isadora.vitali@unesp.br

Juliana Heloisa Pinê Américo-Pinheiro
Ph.D. Lecturer, Civil Engineering Post-Graduation Program, UNESP, Brazil.
juliana.heloisa@unesp.br

ABSTRACT

The treatment and disposal of domestic sewage is one of Brazil's main challenges. Sewage composition varies with the habits of the population and the frequency with which new contaminants are released into the environment. This study is a bibliographical review of the main aspects related to the characterization and composition of sanitary sewage, types of sewage treatment systems and pertinent legislation; and toxicity of domestic effluents. The review was based on publications available on Science Direct, Google Scholar and Scielo, as well as on printed publications, relevant legislation, and normative instructions. The research period adopted for the selection of publications was from 2005 to 2021. We found out that, in addition to the levels of organic matter from domestic sewage, residues from products used in daily life, such as pharmaceuticals and cleaning products, can be found in effluents in concentrations harmful to the environment. Often, the types of treatment used in municipal sewage treatment plants do not efficiently remove these contaminants. Thus, even if sewage is treated to meet the limits required for the physical-chemical and biological parameters established by law, domestic effluent can present a high potential for toxicity to various aquatic species such as microcrustaceans, mollusks and fish. Thus, ecotoxicological analyses represent a remarkable mechanism for indicating the efficiency of removal of emerging contaminants present in treated sanitary effluent, in addition to indicating the deleterious effects caused by these residues to the environment and ecosystems associated with the receiving water body.

KEYWORDS: Ecotoxicology, effluents, aquatic environments.

1 INTRODUCTION

The vulnerability of the environment under the effect of anthropic activities has provoked in-depth discussions. Among the subjects in question, proper treatment and disposal of domestic sewage represent a universal concern because of its polluting potential (COLAÇO; ZAMORA; GOMES, 2014). In Brazil, large volumes of domestic sewage are generated every day, reaching and estimated value of 21,267,971 m³, 51.6% of which are treated in plants built for such purpose, whereas the remaining percentage is discarded with no treatment at all or unsatisfactorily treated in inappropriate systems (IBGE, 2020).

Domestic sewage is defined by normative instruction NBR 9648 as the effluent resulting from the use of water for human hygiene and physiological needs, which contributes to the formation of sanitary sewage. In turn, sanitary sewage is defined as the effluent consisting of domestic and industrial sewage, infiltration water, and rainwater runoff that is inevitably absorbed by the sanitary sewage network (ABNT, 1986).

Sewage composition varies according to the population's daily habits and the frequency with which new contaminants are produced and launched in the environment. Domestic sewage, besides high organic matter and pathogen contents, contains contaminants used in daily activities, such as products for household cleaning and personal hygiene and pharmaceuticals (DEL-GUERCIO; CHRISTOFOLETTI; FONTANETTI, 2017).

Besides the traditional constituents, the presence of other contaminants in sanitary sewage is mainly associated with discharges in the sewage network from industrial activities dealing with organic and inorganic compounds, such as dyes and pigments, tanneries, pharmaceuticals, galvanoplastics, foundries, laundries, and petroleum derivatives (VON SPERLING, 2014).

In a survey presented in the latest published version of the Sanitation Atlas, the main contaminants of water collected for public supply are sanitary sewage and pesticides and solid residues that are inadequately disposed. In this context, sanitary sewage responds for 72% of the incidence of pollution in water bodies, 60% in shallow wells, and 54% in deep wells (IBGE, 2011).

Pollution caused by launching untreated of partially treated sewage in water bodies can lead to hazards that result from changes in water quality, causing great concern in relation to sewage treatment and disposal, as well as the consequences regarding the environment in which sewage is launched (JORDÃO; PESSÔA, 2014). Residues and subproducts of different types present in untreated or treated sanitary sewage are launched in aquatic environments as a form of final disposal. They can induce chronic and mutagenic effects on organisms present in the receiving water bodies and contaminate sediments existing in such environs (HAMADA et al., 2011).

Therefore, it is fundamental to characterize domestic sewage, in order to determine the proper treatment system, to understand the pertaining legislation, and to analyze the contaminant ecotoxicity relative to aquatic organisms, focusing on the mitigation of the impacts associated with the launching of effluents in water bodies.

2 OBJECTIVE

The objective of this study is to present a bibliographic review of the main aspects related to the characterization and composition of the sanitary sewage, of the types of sewage treatment systems and pertaining legislation, and the toxicity of domestic effluents.

3 METHODOLOGY

The bibliographic review was based on scientific publications available on the Science Direct, Academic Google, and Scielo research platforms, was well as on printed publications, legislation, and normative instructions. The keywords used in the research of electronic periodicals were: ecotoxicology, aquatic ecotoxicology, domestic sewage, and wastewater. The period adopted for the search of bibliographical material ranged from 2005 to 2021.

4 DEVELOPMENT

4.1 SANITARY SEWAGE CHARACTERIZATION

The sanitary sewage characteristics are divided in three distinct categories, consisting of: physical characteristics, encompassing solid matter, temperature, odor, color, and turbidity; chemical characteristics, divided in organic and inorganic matter; and biological characteristics, associated with bacteria, fungi, protozoa, and viruses (JORDÃO; PESSÔA, 2014; VON SPERLING, 2014; METCALF; EDDY, 2016).

Some factors are important when characterizing sanitary effluents, such as the direct influence of temperature in physical, chemical, and biological reactions used in sewage treatment (KLÜSENER, 2006), and solid matter classification by size, that is: suspended solids (10^3 to 100 µm), colloidal solids (100 to 10^{-3} µm), and dissolved solids (10^{-3} to 10^{-6} µm) (CETESB, 2018).

Anaerobic decomposition of sulfur compounds is the main cause of odor in domestic sewage (BRANDT; SOUZA; CHERNICHARO, 2017). Color and turbidity highlight the decomposition state of the sewage; thus, fresh sewage is typically grayish, while black indicates partial decomposition (JORDÃO; PESSÔA, 2014). Organic matter can be found either in solution as dissolved organic solids, which are quickly biodegradable, or in suspension as solids suspended in liquid, which are slowly biodegradable (SILVA; BERNARDES; RAMOS, 2015).

According to Jerônimo et al. (2012), the concentration of organic matter can be indirectly determined by the analysis of oxygen consumption and chemical oxidation. The main variables involved in these processes are the concentration of dissolved oxygen (DO), the biochemical oxygen demand (BOD), and the chemical oxygen demand (COD).

Nutrients present in the domestic sewage, such as nitrogen and phosphorous, may be abundant even after treatment. This is a challenging problem, as pollution promoted by launching of nutrients in excess in water bodies results in eutrophication, which in turn stimulates the excessive growth of algae, exerting deleterious actions and leading to the degradation of springs (LI et al., 2020; PENG et al., 2020; ZHANG et al., 2021).

The biological characteristics of the sanitary sewage are determined by a complex variety of pathogens excreted by humans via feces, urine and the peeling of the skin (MARTÍNEZ-PUCHOL et al., 2020). The contamination caused by these pathogens contributes to the loss of water quality (BETANCOURT et al., 2014; GARCÍA-ALJARO et al., 2018) and can be harmful to public health, once the receiving water bodies become reservoirs of antibiotic-resistant, pathogenic microorganisms (AMÉRICO-PINHEIRO et al., 2021; STORTO et al., 2021).

The main microorganisms present in sanitary effluents are fungi, protozoa, viruses, algae, and bacteria. Bacteria play a primordial role in organic matter stabilization, both in nature and treatment plants. Similarly, some bacteria, as those pertaining to the thermotolerant coliform group, are used as indicators of fecal contamination of water bodies (BRASIL, 2019). In this group, Escherichia coli stands out as widely used in monitoring the quality of superficial waters (AMÉRICO-PINHEIRO et al., 2021; STORTO et al., 2021).

The enteric viruses found in human residual waters are quickly transported through aquatic environments and are hardly removed from them (FARKAS et al., 2020). In the present world scenario, the new coronavirus (SARS-CoV-2) pandemic is a turning point in public awareness regarding sanitation (BOGLER et al., 2020), directly related to the detection of SARS-CoV-2 in sanitary sewage (RIMOLDI et al., 2020; TRAN et al., 2021; THAKUR et al., 2021; AHMED et al., 2021).

Studies highlight that other contaminants can be present in sanitary sewage, among them: illicit drugs and pharmaceuticals (BAKER; KASPRZYK-HORDERN, 2011), tensioactive agents present in cleaning products (GRANATTO et al., 2019), antibiotics (CUNHA et al., 2021), anti-inflammatory drugs (AMÉRICO et al., 2012; RAGASSI et al., 2019), microplastic fibers resulting from textile products used in personal hygiene (BRIAIN et al., 2020), heavy metals (MOLOI; OGBEIDE; OTOMO, 2020; CHAI et al., 2021), pharmaceuticals for personal care (RASHID; LIU, 2021), and nanocellulose from toilet paper (ESPÍNDOLA et al., 2021). The presence of these contaminants can be associated with the fact that many urban sewage treatment plants simultaneously treat domestic and industrial residual waters (GAO et al., 2020).

Some of the compounds present in sanitary sewages in low concentrations (μg L^{-1} to ng L^{-1}) can lead to toxic effects on living beings exposed to them (LEITE; AFONSO; AQUINO, 2010). In this context, effluent launching and dilution should be properly investigated by managing agencies, via monitoring and control of the impacts on receiving water courses (MARÇAL; SILVA, 2017).

4.2 BRAZILIAN LEGISLATION REGARDING THE LAUNCHING OF SANITARY EFFLUENTS

The management of water resources is related to political decision-making processes in environmental, social, economic, and cultural spheres (SILVA et al., 2018). The impact of the launching of effluents from sewage treatment plants on these resources generates great concern, when it comes to ensuring water quality, selection of discharge loci, and treatment necessary for an environmentally adequate final destination. These aspects are constrained by legislation, criteria, policies, and reviews, with the expectation that the impacts of effluent launching in water bodies are acceptable and unharmful to the environment (OLIVEIRA; VON SPERLING, 2005).

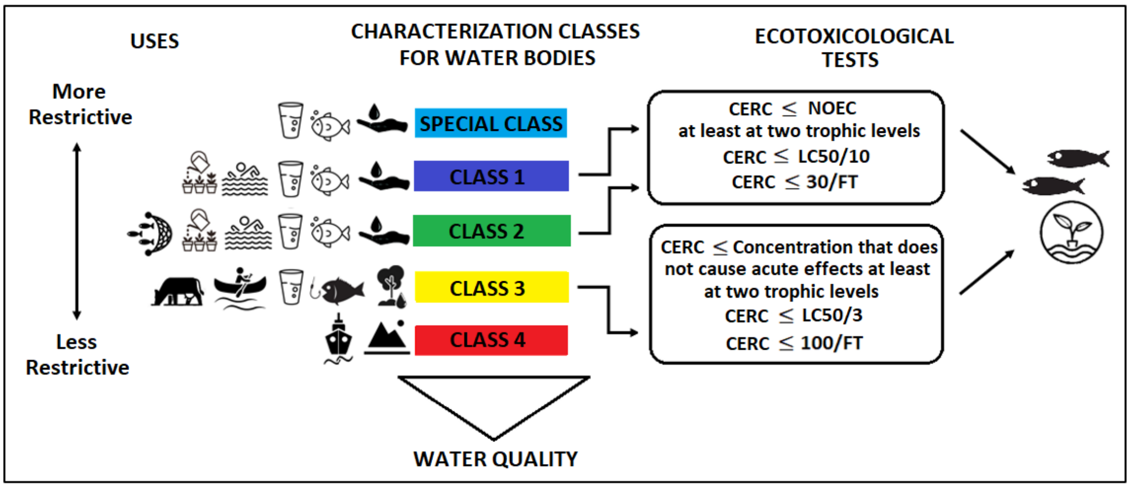
Regulatory toxicology is responsible for the establishment of quality standards and criteria specific for each characterization class and water use, having a key role in the protection of water resources based on national, statal and municipal normative instructions, in regulating the disposal of effluents in water bodies, and in guaranteeing the protection of the multiple uses of water (UMBUZEIRO; KUMMEOW; REI, 2010).

The Brazilian federal resolutions that establish water quality and pollutant launching parameters are, respectively, CONAMA Resolution 357 – dated 17th March 2005, which establishes the classification of water bodies and the environmental guidelines for their characterization (BRASIL, 2005), and CONAMA Resolution 430 – dated 13th May 2011, which establishes effluent launching conditions and parameters, complementing and changing the previous resolution (BRASIL, 2011).

CONAMA Resolution 430/2011 represents a considerable advance in respect to ecotoxicology (ALMEIDA; ROSA; PAIXÃO, 2013): it determines that the launching of effluents cannot be potentially toxic or cause toxic effects to aquatic organisms living in the receiving water body, on the basis of results of ecotoxicity tests performed with reference to the Effluent Concentration in the in the Receiving Body (CECR) and its effects on aquatic organisms, at least at two different trophic levels (BRASIL, 2011).

Ecotoxicity test results express the concentration of the sample that causes 50% mortality of the tested organisms (LC50 – Lethal Concentration); the concentration of the sample that causes an acute effect in 50% of the tested organisms (CE50); concentration that causes no observed effect (NOEC – No-Observed-Effect Concentration), and concentration of observed effect (CEO). The results are expressed in percentages and are inversely related to toxicity, that is, the smaller the numerical value, the higher the toxicity (COSTA et al., 2008). Figure 1 presents the characterization classes for water courses, according to their use and characterization of the ecotoxicity tests according to effluent launching.

Figure 1: Characterization classes, their respective uses and ecotoxicity criteria



Source: Adapted from Brasil (2005) and Brasil (2011)

Despite the advances of the Brazilian legislation, only half of the treated sewage volume has reached quality levels for its launching in water bodies, which shows that the municipalities that implemented sewage treatment policies are not fully prepared to reach the indexes established by the legislation (PASSARINI et al., 2014).

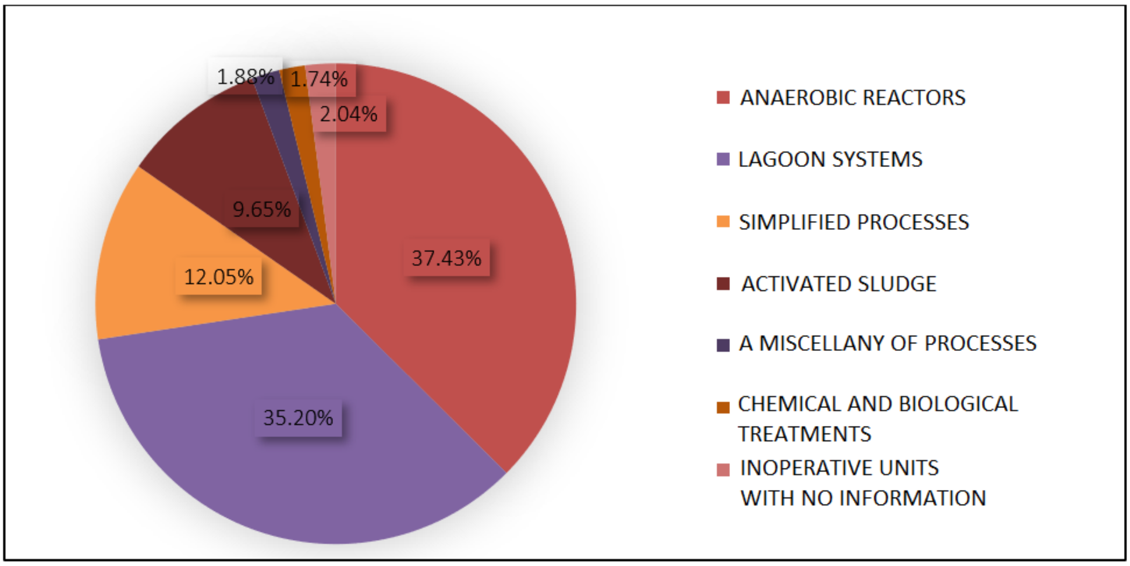
4.3 SANITARY SEWAGE TREATMENT SYSTEMS

According to NBR 12.209, Sewage Treatment Plant (STP) is a facility that gathers treatment units, equipment, auxiliary sectors, accessories, and utility systems with the objective of diminishing the polluting charges of the sanitary sewage and of conditioning the residual matter resulting from the sewage treatment (ABNT, 1992).

STP treatment systems can be classified according to definition (aerobic, anaerobic), operation (physical, chemical, and biological), and level of treatment (pre-treatment, primary, secondary, tertiary) (CORNELLI et al., 2014). STPs – via chemical, physical, and biological processes – assume the responsibility that the effluent launched in water bodies meets its respective characterization class, in order to not put in risk the intrinsic self-purification capability of the receiving water bodies (SILVA et al., 2016).

In a survey carried out by the National Water Agency (Agência Nacional das Águas – ANA) in 2020, 3,668 sewage treatment plants (STPs) were identified in Brazil, being 3,419 “active”. The main treatment types are: anaerobic reactors (1,373 units), lagoon systems (1.291 units), simplified processes (442 units), activated sludge (354 units), a miscellany of processes (69 units), and chemical and biological treatments (64 units). The other units were inoperative or no information on them was available (BRASIL, 2020). The values in percentage of the sewage treatment systems used in Brazil are presented in Figure 2.

Figure 2: Values in percentage of the main treatment types adopted in the Brazilian STPs



Source: Adapted from Brasil (2020)

The sanitation company of the State of São Paulo (Companhia de Saneamento Básico do Estado de São Paulo – CETESB), encompassing 487 STPs, responds for the treatment of the sewage coming from 364 municipalities, including domestic, commercial, and industrial effluents. The main technologies used by CETESB are upflow anaerobic reactors, facultative lagoons, anaerobic lagoons, aerated lagoons, infiltration trenches, flotation units, and maturation lagoons (SÃO PAULO, 2014). In a reliability analysis performed with STPs in operation and that adopt six different treatment processes, Oliveira and Von Sperling (2008) observed that the performance of only a few treatment systems operating under certain conditions was reliable, meeting recommended values for BOD, COD, total suspended solids, total nitrogen, total phosphorus, and thermotolerant coliforms.

Gonçalves, Marques, and Saraiva (2015), when assessing two large-scale STPs in Belo Horizonte – State of Minas Gerais, observed the inefficiency of the STPs in reducing values of BOD, COD, and total suspended solids. Chaves et al. (2017), when assessing five sewage treatment plants in Aracaju – State of Sergipe, observed that the removal of pollutants by the types of treatment adopted by the STPs produced values below the expected for BOD, total nitrogen, total phosphorus, and thermotolerant coliforms. Only two STPs complied with the conditions required by CONAMA Resolution 430/2011 (BRASIL, 2011).

Sanitary sewage treatment can result in adequate characterization for its launching in receiving water bodies, as established by the legislation. However, certain pollutants, which are not considered in the normative instructions but are present in sanitary sewage, can put the environment in which it is launched in risk (RODRIGUES; JÚNIOR; SALEH, 2015). When it comes to emerging contaminants in trace concentrations, Brazilian STPs are not properly equipped to remove them from domestic and industrial residual waters (MARTÍN-POZO et al., 2019). The presence of pharmaceuticals, such as anti-inflammatory drugs, in untreated and treated sewage in Brazilian STPs adopting different treatment systems highlights the persistence of these compounds after treatment (AMÉRICO et al., 2012; RAGASSI et al., 2019).

Traces of organic contaminants, such as pharmaceuticals and personal hygiene products, represent global menaces to the aquatic systems; thus, choosing an efficient sewage treatment technology requires a careful consideration of environmental, economic and social implications, besides the adaptations to traditional physico-chemical and biological parameters reported in the legislation (MELVIN; LEUSCH, 2016). Therefore, to guarantee safety and quality of water and its multiple uses, monitoring should be performed in an integrated manner, using bioindicators allied to traditional water quality parameters (SILVA et al., 2021).

4.4 SANITARY SEWAGE ECOTOXICITY

Ecotoxicology is a science equipped with analytical instruments capable of responding to the toxicity of chemical compounds predictively, signaling potential ecotoxicological effects and mechanisms acting in organisms, assessing the concentration-effect and the concentration-response by means of acute and chronic exposure tests (MAGALHÃES; FERRÃO FILHO, 2008). Chart 1 lists the results of ecotoxicity tests using aquatic organisms exposed to sanitary effluents.

Chart 1: Ecotoxicological effects in aquatic organisms exposed to sanitary effluents

Reference	Tests	Results
Movahedian, Bina, and Asghari (2005)	Acute toxicity of untreated and treated domestic effluent to *Daphnia magna*	LC50 of untreated sewage: 30% LC50 after preliminary treatment: 32% LC50 after primary treatment: 53% LC50 after secondary treatment: 85%
Diniz et al. (2005)	Exposure of fish species *Carassius carassiu* to treated domestic effluents for 28 days	In males: estrogenic activity with induction of vitellogenin and histological changes in the testicles. In females: oocyte degeneration, atretic oocytes and oogenesis inhibition.
Bartolini et al. (2009)	Exposure of two fiddler crab species *(Uca annulipes* and *Uca inversa)* to domestic sewage	Effluent – 20%, 40%, and 60% dilution in sea water – caused changes in the behavior of the organisms.
Wan et al. (2015)	Exposure of mollusk *Meretrix* to different concentrations of domestic effluents for 15 days	Biochemical changes in gills and oxidative stress.
Chen et al. (2016)	Exposure of fish species *Oryzias melastigma* to domestic sewage containing pharmaceuticals for 21 days	Changes in fertility, sexual behavior and gene expression.
Barszcz et al. (2019)	Performance of constructed wetlands in reducing domestic effluent toxicity; acute toxicity tests with the microcrustacean *Daphnia similis*	CE50 of untreated sewage: 1.33%. CE50 of treated effluent: from 59 to 78%. Constructed wetlands are efficient in reducing domestic effluent toxicity.
Ribeiro et al. (2020)	Embriotoxicity test by means of the exposure of fish species *Danio rerio* (zebrafish) to chemically-assisted, primary-treated STP effluent	Embryo lethality. Embryos with physiological, sensory, skeletal and muscle changes.
Silva et al. (2021)	Exposure of *D. rerio* (zebrafish) to urban effluents treated via Upflow Anaerobic Sludge Blanket (UASB) reactor, with efficiency parameters acceptable by the legislation	The treated effluent reached acceptable efficiency regarding the legislation parameters, but the toxic effects were acute and chronic for different *D. rerio* stages (embryo, larval and adult); exposition to untreated and treated effluent, classified as highly toxic (25% < LC50 <50%). Increased estrogenic activity for the treated sewage when compared to the untreated sewage.

Source: Prepared by the authors

The remaining toxicity of treated effluents can indicate deleterious effects to aquatic organisms present in receiving water bodies. Ecotoxicity tests are capable of characterizing effluents more comprehensively, encompassing all chemical constituents, mainly by accusing the bioavailability of the substances present in the effluents, thus detecting the possible toxic effects of the constituent substances, as well as their interactions (BERTOLETTI, 2013).

Several studies record the toxicity of untreated and treated sanitary sewage to aquatic organisms of different trophic levels, such as crustaceans, mollusks, and fish species. The main effects observed in these studies are change in behavior, oxidative stress, fertility and endocrine disruption (BARTOLINI et al., 2009; WAN et al., 2015; CHEN et al., 2016).

5 FINAL CONSIDERATIONS

The composition of the sanitary sewage can vary and cannot be based only on the parameters inserted in the Brazilian legislation for water and effluents. The complexity of sanitary sewage characterization is related not only to population's activities, but also to the support capacity of the municipal treatment plants in receiving industrial effluents. Therefore, even if sewage is treated in order to comply with the expected physico-chemical and biological parameters established by law, the domestic effluent can present a high toxicity potential for a variety of aquatic species.

Residues of emerging contaminants, such as pharmaceuticals, personal hygiene products, metals, and microplastics, are not totally removed by conventional sewage treatment systems, once they are detected in treated sanitary effluents. Consequently, ecotoxicological analysis represents a remarkable mechanism to predict not only the efficiency in removing emerging contaminants present in treated sanitary effluents, but also the deleterious effects caused by these residues to the environment and ecosystems associated with the receiving water bodies.

The insertion of parameters for emerging contaminants in the legislation that defines limits for effluent launching and implantation of treatment systems aiming at the removal of these compounds is fundamental to reduce the impacts on water resources. Another valid measure is to promote public policies alerting against the indiscriminate consumption of pharmaceuticals and chemical products by the population, as well as the mandatory reverse logistics for some types of products that are potentially harmful to the environment, and to guarantee their proper disposal and protection of the quality and multiple uses of water.

6 REFERENCES

ABNT. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 12209: Projeto de estações de tratamento de esgoto sanitário**. Rio de Janeiro, 1992.

ABNT. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 9648: Estudo de concepção de sistemas de esgoto sanitário**. Rio de Janeiro, 1986.

AHMED, W. et al. SAR-CoV-2 RNA monitoring in wastewater as a potential early warnig system for COVID-19 transmission in the community: A temporal case study. **Science of the Total Environment**, v. 761, 144216, p. 1-9, 2021. Disponível em: <http://twixar.me/SN8m>. Acesso em: 17 maio 2021.

ALMEIDA, E. dos. S.; ROSA, E. V. C.; PAIXÃO, J. F. da. Avaliação da legislação para lançamento de efluentes em relação à ecotoxicidade. *In:* CONGRESSO BRASILEIRO DE GESTÃO AMBIENTAL, 4., Salvador. **Anais eletrônicos** [...] Salvador: IBEAS, 2013. Disponível em: <http://twixar.me/kQ8m>. Acesso em 21 maio 2021.

AMÉRICO, J. H. P. et al. Fármacos em uma Estação de Tratamento de Esgoto na Região Centro-Oeste do Brasil e os Riscos aos Recursos Hídricos. **Revista Brasileira de Recursos Hídricos**, v. 17, n. 3, p. 61-67, 2012. Disponível em: <http://twixar.me/xC8m>. Acesso em: 21 de maio de 2021.

AMÉRICO-PINHEIRO, J. H. P. et al. Monitoring microbial contamination of antibiotic resistant *Escherichia coli* isolated from the surface water of urban park in southeastern Brazil. **Environmental Nanotechnology, Monitoring & Management**, v. 15, 100438, p. 1- 9, 2021. DOI 10.1016/j.enmm.2021.100438

BAKER, D. R.; KASPRZYK-HORDERN, B. Multi-residue determination of the sorption of illicit drugs and pharmaceuticals to wastwater suspended particulate matter using pressurised liquid extraction, solid phase extraction and liquid chromatography coupled with tandem mass spectrometry. **Journal of chromatography A**., v. 1218, p. 7901-7913, 2011. Disponível em: <http://twixar.me/JV8m>. Acesso em: 28 maio 2021.
BARSZCZ, L. B. et al. Avaliação ecotoxicológica de efluentes tratados por alagados construídos. **Engenharia Sanitária e Ambiental**, v. 24, n. 6, p. 1147-1156, 2019. Disponível em: <http://twixar.me/D28m>. Acesso em: 21 maI. 2021.

BARTOLINI, F. et al. Behavioural responses of the mangrove fiddler crabs (*Uca annulipes* and *U. inversa*) to urban sewage loadings: Results of a mesocosm approach. **Marine Pollution Bulletin**, v. 58, p. 1860-1867, 2009. Disponível em: <http://twixar.me/528m>. Acesso em: 22 mai. 2021.

BERTOLETTI, E. **Controle ecotoxicológico de efluentes líquidos no estado de São Paulo**. CETESB: São Paulo, 42 p. 2013. Disponível em: <http://twixar.me/ZC8m>. Acesso em 20 mai. 2021.

BETANCOURT, R. Q. et al. Cryptosporidium and Giardia in tropical recreational marine Waters contaminated with domestic sewage: Estimation of bathing-associated disease risks. **Marine Pollution Bulletin**, v. 85, n. 1, p. 268-273, 2014. Disponível em: <http://twixar.me/ZN8m>. Acesso em: 16 mai. 2021.

BOGLER, A. et al. Rethinking wastewater risks and monitoring in light of the COVID-19 pandemic. **Nature Sustainability**, v. 3, p. 981-990, 2020. Disponível em: <http://twixar.me/gN8m>. Acesso em: 16 mai. 2021.

BRANDT, E. M. F.; SOUZA, C. L.; CHERNICHARO, C. A. L. Alternativas para o controle de odores e corrosão em sistemas de coleta e tratamento de esgoto. **Engenharia Sanitária e Ambiental**, v. 22, n. 4, p. 611-623, 2017. Disponível em: <http://twixar.me/QV8m>. Acesso em: 09 mai. 2021.

BRASIL. Conselho Nacional do Meio Ambiente. Resolução CONAMA nº. 357 de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. **Diário Oficial da União**. República Federativa do Brasil, Poder Executivo, Brasília, DF, 18 mar. 2005.

BRASIL. Conselho Nacional do Meio Ambiente. Resolução CONAMA Nº 430 de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução nº 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente-CONAMA. **Diário Oficial da União.** República Federativa do Brasil, Poder Executivo, Brasília, DF, 16 mai. 2011.

BRASIL. Agência Nacional das Águas. **Atlas esgotos: atualização da base de dados de estações de tratamento de esgotos no Brasil**. Brasília: ANA, 2020. 44 p. Disponível em: <http://twixar.me/DQ8m>. Acesso em: 20 maio 2021.

BRASIL. Ministério da Saúde. Fundação Nacional de Saúde. **Manual de Sanemaneto**. 5 ed. Brasília: FUNASA, 2019. 545 p. Disponível em: <http://twixar.me/cN8m>. Acesso em: 17 mai. 2021.

BRIAIN O. O. et al. The role of wet wipes and sanitary towels as a source of white microplastic fibres in the marine environment. **Water Research**, v. 182, 116021, p. 1-12, 2020. Disponível em: <http://twixar.me/XV8m>. Acesso em: 01 mai. 2021.

CHAI, W. S. et al. A review on conventional and novel materials towards heavy metal adsorption in wastwater treatment application. **Journal of Cleaner Production**, v. 296, 126589, p. 1-16, 2021. Disponível em: <http://twixar.me/bV8m>. Acesso em: 28 mai. 2021.

CHAVES, V. S.; et al. Desempenho das estações de tratamento de esgoto de Aracaju. **Revista DAE**, v. 66, n. 209, p. 51-58, 2018. Disponível em: <http://twixar.me/xx8m>. Acesso em: 20 mai. 2021.

CHEN, T. H. et al. Endocrine disrupting effects of domestic wastewater on reproduction, sexual behavior, and gene expression in the brackish medaka Oryzias melastigma. **Chemosphere**, v. 150, p. 566-575, 2016. Disponível em: <http://twixar.me/w28m>. Acesso em: 22 mai. 2021.

COLAÇO, R.; ZAMORA, P. G. P.; GOMES, E. C. Poluição por resíduos contendo compostos farmaceuticamente ativos: aspectos ambientais, geração a partir dos esgotos domésticos e a situação do Brasil. **Revista de Ciências Farmacêuticas Básica e Aplicada**, v. 35, n. 4, p. 539-548, 2014. Disponível em: <http://twixar.me/488m>. Acesso em: 04 abr. 2021.

CORNELLI, R. et al. Métodos de tratamento de esgotos domésticos revisão sistemática. **Revista de estudos ambientais**, v. 16, n. 2, p. 20-36, 2014. Disponível em: <http://twixar.me/3C8m>. Acesso em: 19 mai. 2021.

COSTA, C. R. et al. A toxicidade em ambientes aquáticos: discussão e métodos de avaliação. **Química Nova**, v. 31, n. 7, p. 1820-1830, 2008. Disponível em: <http://twixar.me/d28m>. Acesso em: 21 mai. 2021.

CUNHA, C. C. R. F. da. et al. Low-temperature partitioning ex-traction followed by liquid chromatography tandem mass spectrometry detremination of multiclass antibiotics in solid and soluble wastewater fractions. **Journal of Chromatography A**., v. 1650, 462256, p. 1-11, 2021. Disponível em: <http://twixar.me/zV8m>. Acesso em: 28 mai. 2021.

DEL-GUERCIO, A. M. F.; CHRISTOFOLETTI C. A.; FONTANETTI, C. S. Avaliação da eficiência do tratamento de esgoto doméstico pelo teste do micronúcleo em *Oreochomis riloticus* (Cichlidae). **Engenharia Sanitária e Ambiental**, v. 22, n. 6, p. 1121-1128, 2017. Disponível em: <http://twixar.me/gR8m>. Acesso em: 07 abr. 2021.

DINIZ, M. S. et al. Estrogenic effects in crucian carp (*Carassius carassius*) exposed to treated sewage effluent. **Ecotoxicology and Environmental Safety**, v. 62, p. 427-435, 2005. Disponível em: <http://twixar.me/z28m>. Acesso em: 22 mai. 2021.

ESPÍNDOLA, S. P. et al. Nanocellulose recovery from domestic wastwater. **Journal of Cleaner Production**, v. 280, 124507, p. 1-10, 2021. Disponível em: <http://twixar.me/hV8m>. Acesso em: 01 mai. 2021.

FARKAS, K. et al. Viral indicators for tracking domestic wastewater contamination in the aquatic environment. **Water Research**, v. 181, 115926, p. 1-20, 2020. Disponível em: <http://twixar.me/4N8m>. Acesso em: 16 mai. 2021.

GAO, L. et al. Simultaneous nitrate and dissolved organic matter removal from wastewater treatment plant effluent in a solid-phase denitrification biofilm reactor. **Bioresource Technology**, v. 314, 123714, p. 1-8, 2020. Disponível em: <http://twixar.me/xN8m>. Acesso em 17 mai. 2021.

GARCÍA-ALJARO, C. et al. Pathogens, faecal indicators and human-specific microbial source-tracking markers in sewage. **Journal of Applied Microbiology**, v. 126, p. 701-717, 2018. Disponível em: <http://twixar.me/hN8m>. Acesso em: 16 mai. 2021.

GONÇALVES, C. A. M.; MARQUES, J. R.; SOARES, A. F. S. Avaliação da eficiência de duas modalidades de tratamento de esgoto em escala real e de grande porte. **Periódico Cientifico do Núcleo de Biociências**, v. 5, n. 10, p. 6-15, 2015. Disponível em: <http://twixar.me/wx8m>. Acesso em: 20 mai. 2021.

GRANATTO, C. F. et al. Scale-up evaluation of anaerobic degradation of linear alkylbenzene sulfonate from sanitary sewage in expandede granular sludge bed reactor. **International Biodeterioration & Biodegradation**, v. 138, p. 23-32, 2019. Disponível em: <http://twixar.me/pV8m>. Acesso em: 01 mai. 2021.

HAMADA, N. et al. Avaliação Ecotoxicológica da Estação de Tratamento de Esgotos Suzano (São Paulo) Utilizando *Daphnia similis* e *Vibrio fischeri*. **Journal of the Brazilian Society of Ecotoxicology**, v. 6, n. 1, p. 31-35, 2011. Disponível em: <http://twixar.me/dY8m>. Acesso em: 07 abr. 2021.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Atlas do saneamento 2011**. Diretoria de Geociências, Rio de Janeiro, IBGE, 2011. Disponível em: <http://twixar.me/w88m>. Acesso em: 04 abr. 2021.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Pesquisa nacional de saneamento básico 2017: abastecimento de água e esgotamento sanitário**. Coordenação de População e Indicadores Sociais, Rio de Janeiro, IBGE, 2020. Disponível em: <http://twixar.me/g88m>. Acesso em: 04 abr. 2021.

JERÔNIMO, C. E. M. et al. Estudo comparativo entre técnicas de determinação da matéria orgânica em efluentes industriais de composição carbonácea. **HOLOS**, v. 2, p. 34-44, 2012. Disponível em: <http://twixar.me/J4Pm>. Acesso em: 20 mai. 2021.

JORDÃO, E. P.; PESSÔA, C. A. **Tratamento de esgotos domésticos**. 7. ed. Rio de Janeiro: ABES, 2014. 1087 p.

KLÜSENER, J. J. **Influência da temperatura sobre o processo de decomposição dos esgotos domésticos em lagoas facultativas**. 2006. 133 f. Dissertação (Mestrado em Engenharia Civil) – Universidade Federal de Santa Maria, Santa Maria, 2006. Disponível em: <http://twixar.me/YV8m>. Acesso em: 09 mai. 2021.

LEITE, G. S.; AFONSO, R. J. C. F.; AQUINO, S. F. de. Caracterização de contaminantes presentes em sistemas de tratamento de esgotos, por cromatografia líquida acoplada à espectrometria de massas tandem em alta resolução. **Química Nova**, v. 33, n. 3, p. 734-738, 2010. Disponível em: <http://twixar.me/QN8m>. Acesso em: 17 mai. 2021.

LI, X. et al. Nitrogen and phosphorus removal performance and bacterial communities in a multi-stage surface flow constructed wetland treating rural domestic sewage. **Science of Total Environmental**, v. 709, 136235, p. 1-9, 2020. Disponível em: <http://twixar.me/J78m>. Acesso em: 16 mai. 2021.

MAGALHÃES, D. de. P.; FERRÃO FILHO, A. da. S. A ecotoxicologia como ferramenta no biomonitoramento de ecossistemas aquáticos. **Oecologia Brasiliensis**, v. 12, n. 3, p. 355-381, 2008. Disponível em: <http://twixar.me/qC8m>. Acesso em: 21 mai. 2021.

MARÇAL, D. A.; SILVA, C. E. Avaliação do impacto do efluente da estação de tratamento de esgoto ETE-Pirajá sobre o Rio Parnaíba, Teresina (PI). **Engenharia Sanitária e Ambiental**, v. 22, n. 4, p. 761-772, 2017. Disponível em: <http://twixar.me/MN8m>. Acesso em: 17 mai. 2021.

MARTÍNEZ-PUCHOL, S. et al. Characterisation of the sewage virome: comparison of NGS tools and occurence of significant pathogens. **Science of Total Environmental**, v. 713, 136604, p. 1-9, 2020. Disponível em: <http://twixar.me/Y78m>. Acesso em: 16 mai. 2021.

MARTÍN-POZO, L. et al. Analytical methods for the determination of emerging contaminants in sewage sludge samples. A review. **Talanta**, v. 192, p. 508-533, 2019. Disponível em: <http://twixar.me/WQ8m>. Acesso em: 20 mai. 2021.

MELVIN, S. D.; LEUSCH, F. D. L. Removal of trace organic contaminants from domestic wastewater: a meta-analysis comparison of sewage treatment technologies. **Environment International**, v. 92-93, p. 183-188, 2016. Disponível em: <http://twixar.me/ZQ8m>. Acesso em: 20 mai. 2021.

METCALF, L.; EDDY, H. P. **Tratamento de efluentes e recuperação de recursos**. 5. ed. Porto Alegre: AMGH, 2016. 1980 p.

MOLOI, M.; OGBEIDE, O.; OTOMO, P. V. Probabilist health risk assessment of heavy metals at wastwater discharge points within the Vaal River Basin, South Africa. **International Journal of Hygiene and Environmental Health**, v. 224, 113421, p. 1-10, 2020. Disponível em: <http://twixar.me/9V8m>. Acesso em: 01 mai. 2021.

MOVAHEDIAN, H.; BINA, B.; ASGHARI, G. H. Toxicity Evaluation of Wastewater Treatment Plant Effluents Using Daphnia magna. **Iranian Journal of Environmental Health Science & Engineering**, v. 2, n. 2, p. 1-4, 2005. Disponível em: <http://twixar.me/QH8m>. Acesso em: 20 mai. 2021.

OLIVEIRA, S. C.; VON SPERLING, M. Reability analysis of wastewater treatment plants. **Water Research**, v. 42, p. 1182-1194, 2008. Disponível em: <http://twixar.me/LQ8m>. Acesso em: 20 mai. 2021.

OLIVEIRA, S. M. A. C.; VON SPERLING, M. Avaliação de 166 ETEs em operação no país, compreendendo diversas tecnologias. Parte I – Análise de desempenho. **Engenharia Sanitária e Ambiental**, v. 10, n. 4, p. 347-357, 2005. Disponível em: <http://twixar.me/kM8m>. Acesso em: 18 mai. 2021.

PASSARINI, K. C. et al. Assessment of the viability and sustainability of na integrated waste management system for the city of Campinas (Brazil), by means of ecological cost accounting. **Journal of Cleaner Production**, v. 65, p. 479-488, 2014. Disponível em: <http://twixar.me/CM8m>. Acesso em: 18 mai. 2021.

PENG, S. et al. Iron-carbon galvanic cells strengthened anaerobic/anoxic/oxic process (Fe/C-A2O) for high-nitrogen/phosphorus and low-carbon sewage tratmente. **Science of Total Environmental**, v. 722, 137657, p. 1-13, 2020. Disponível em: <http://twixar.me/y78m>. Acesso em: 16 mai. 2021.

RAGASSI, B. et al. Monitoramento e remoção de anti-inflamatórios em estação de tratamento de esgoto com lagoas de estabilização. **Revista Brasileira de Ciências Ambientais**, n. 53, p. 1-12, 2019. Disponível em: <http://twixar.me/sC8m>. Acesso em: 20 mai. 2021.

RASHID, S. S.; LIU, Y. Q. Comparison of life cycle toxicity assesstment methods for municipal wastwater treatment with the inclusion of direct emissions of metals, PPCPs and EDCs. **Science of the Total Environment**, v. 756, 143849, p. 1-13, 2021. Disponível em: <http://twixar.me/lV8m>. Acesso em: 01 mai. 2021.

RIBEIRO, R. X. et al. Ecotoxicological assessment of effluents from Brazilian wastewater treatment plants using zebrafish embryotoxicity test: A multibiomarker approach. **Science of the Total Environment**, v. 735, 139036, p. 1-10, 2020. Disponível em: <http://twixar.me/W28m>. Acesso em: 21 mai. 2021.

RIMOLDI, S. G. et al. Presence and infectivity of SARS-CoV-2 virus in wastewaters and rivers. **Science of the Total Environment**, v. 744, 140911, p. 1-8, 2020. Disponível em: <http://twixar.me/bN8m>. Acesso em: 16 mai. 2021.

RODRIGUES, A. de. M.; JÚNIOR, E. D. da. S.; SALEH, B. B. Estudo qualitativo da água do Ribeirão Campo Alegre mediante influência da Estação de Tratamento de Esgoto da cidade de Santa Helena de Goiás. **Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental**, v. 19, n. 3, p. 752-760, 2015. Disponível em: <http://twixar.me/n68m>. Acesso em: 20 mai. 2021.

SÃO PAULO. Companhia Ambiental do Estado de São Paulo. **Emissões do setor de resíduos sólidos e efluentes líquidos (2009-2010)**. São Paulo: CETESB, 2014. 99 p. Disponível em: <http://twixar.me/FQ8m>. Acesso em: 20 mai. 2021.

SÃO PAULO. Companhia Ambiental do Estado de São Paulo. **Fundamentos do controle de poluição das águas**. São Paulo: CETESB, 2018. Disponível em: <http://twixar.me/fV8m>. Acesso em: 01 mai. 2021.

SILVA, A. R. da. et al. A gestão e o monitoramento das águas: uma abordagem das legislações em Portugal e no Brasil. **Revista Brasileira de Geografica Física**, v.11, n.4, p. 1512-1525, 2018. Disponível em: <http://twixar.me/QM8m>. Acesso em: 18 mai. 2021.

SILVA, D. dos. S.; et al. A multibiomarker approach in the caged neotropical fish to assess the environment health in a river of central Brazilian Cerrado. **Science of the Total Environment**, v. 751, 141632, p. 1-12, 2021. Disponível em: <http://twixar.me/hQ8m>. Acesso em: 20 mai. 2021.

SILVA, I. M. da.; et al. Caracterização do efluente da estação de tratamento de esgoto – Unidade Mangabeira – João Pessoa/PB. *In*: CONGRESSO BRASILEIRO DE GESTÃO AMBIENTAL, 7., 2016, Campina Grande. **Anais eletrônicos** [...] Campina Grande: IBEAS, 2016. Disponível em: <http://twixar.me/0Q8m>. Acesso em: 18 mai. 2021.

SILVA, P. R. da. et al. Evaluation of toxixity and estrogenicity in UASB- Treated municipal sewage. **Chemosphere**, v. 268, 128778, p. 1-9, 2021. Disponível em: <http://twixar.me/v28m>. Acesso em: 22 mai. 2021.

SILVA, S. C. da.; BERNARDERS, R. S.; RAMOS, M. L. G. Remoção de matéria orgânica do esgoto em solo de wetland construído. **Engenharia Sanitária e Ambiental**, v. 20, n. 4, p. 533-542, 2015. Disponível em: <http://twixar.me/L78m>. Acesso em: 16 mai. 2021.

ISSN 1980-0827 – Volume 17, número 5, 2021

STORTO, D. et al. Seasonal Dynamics of Microbial Contamination and Antibiotic Resistance in the Water at the Tietê Ecological Park, Brazil. **Water, Air, and Soil Pollution**, v. 232, n. 257, p. 1-18, 2021. DOI 10.1007/s11270-021-05207-y

THAKUR, A. K. et al. Secondary transmission of SARS-CoV-2 through wastewater: Concerns and tatics for treatment to effectively control the pandemic. **Journal of Environmental Management**, v. 290, 112668, p. 1-11, 2021. Disponível em: <http://twixar.me/yN8m>. Acesso em: 17 mai. 2021.

TRAN, H. N. et al. SARS-CoV-2 coronavirus in water and wastwater: a critical review about presence and concern. **Environmental Research**, v. 193, 110265, p. 1-12, 2021. Disponível em: <http://twixar.me/9N8m>. Acesso em: 16 mai. 2021.

UMBUZEIRO, G. de. A.; KUMMROW, F.; REIS, F. F. C. Toxicologia, padrões de qualidade de água e Legislação. **Revista de Gestão Integrada em Saúde do Trabalho e Meio Ambiente**, v. 5, n. 1, p. 1-15, 2010. Disponível em: <http://twixar.me/KQ8m>. Acesso em: 18 mai. 2021.

VON SPERLING, M. **Introdução à Qualidade das Águas e ao Tratamento de Esgotos**. 4. ed. Belho Horizonte: Editora UFMG, 2014. 452 p.

WAN, R. et al. Biochemical responses in the gills of *Meretrix meretrix* after exposureto treated municipal effluent. **Ecotoxicology and Environmental Safety**, v. 111, p. 78-85, 2015. Disponível em: <http://twixar.me/b28m>. Acesso em: 22 mai. 2021.

ZHANG, M. et al. Simultaneous aerobic removal of phosphorus and nitrogen by a novel salt-tolerant phosphate-accumulating organism and the application potential in treatment of domestic sewage and aquaculture sewage. **Science of the Total Environment**, v. 758, 143580, p. 1-12, 2021. Disponível em: <http://twixar.me/g78m>. Acesso em: 16 mai. 2021.