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Biology Genetics

An ecotoxicological approach for criteria and standards of sanitary effluent control in Brazil

Uma abordagem ecotoxicológica para critérios e normas de controle de efluentes sanitários no Brasil

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ABSTRACT

Brazil is noteworthy in South America due to several laws concerning effluent ecotoxicological assessments. Due to the growing demand for sanitary effluent toxicity control in urban settings, this study carried out a comprehensive assessment of current ecotoxicological criteria and standards for effluent release in receiving water bodies in Brazil. The findings reveal that states mostly apply federal legislation, with only six states (SP, RJ, MG, PR, SC, RS) establishing more protective laws. These results aid in establishing environmental legislation adjustments, aiming at greater environmental safety and preventing contamination by contaminants of emerging interest, such as microplastics, certain drugs, and nanocomposites, which are not removed by conventional sewage system treatment.

Keywords: Ecotoxicology; Sanitary effluents; Legislation

RESUMO

O Brasil se destaca na América do Sul devido a diversas legislações referentes à avaliação ecotoxicológica de efluentes. Devido à crescente demanda por controle de toxicidade de efluentes sanitários em ambientes urbanos, este estudo realizou uma avaliação abrangente das normas vigentes quanto aos critérios e normas ecotoxicológicas para lançamento de efluentes em corpos receptores de água no Brasil. Os resultados indicam que a legislação federal é aplicada majoritariamente nos estados, sendo que apenas seis estados (SP, RJ, MG, PR, SC, RS) possuem legislações estaduais mais protetivas. Estes resultados podem auxiliar no estabelecimento de ajustes das legislações ambientais, visando maior segurança ambiental e evitando a contaminação por contaminantes de interesse emergente, como

microplásticos, certos medicamentos e nanocompósitos, que não são removidos pelo tratamento convencional de esgoto sistemas.

Palavras-chave: Ecotoxicologia; Efluentes sanitários; Legislação

1 INTRODUCTION

Physicochemical analyses only, such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), suspended solids and pollutant determinations, do not distinguish between inert and biologically active compounds and are, thus, not sufficient to characterize potential environmental risks (Costa et al., 2008). Ecotoxicity tests are, therefore, required to determine biological pollutant effects.

The term "ecotoxicology" was coined in 1969 through French researcher René Truhaut, from the derivation of the words "ecology", the science that deals with the relationship between living beings and the environment they inhabit, and "toxicology", the science that analyzes potential harmful effects caused by a given dose of chemicals in a given organism (Walker et al., 2001, p.13). This term reflected the growing concern at the time regarding the adverse ecological and human effects of natural or man-made chemicals, and its consolidation led to the development of a field of study that assesses the toxic effects, acute or chronic (Brasil, 2005), of natural or synthetic chemicals on both biotic and abiotic ecosystem components (Zagatto & Bertoletti, 2014).

In this sense, ecotoxicological assessments comprise effective tools in assisting licensing evaluations, in defining laws, limits, regulations and technical standards concerning physical, biological, and chemical parameters of natural and synthetic elements and in the inspection and monitoring of environmental chemical inputs (Azevedo & Chasin, 2003; Brasil, 1988). Ecotoxicological effects, however, vary according to exposure time and environmental and biological contaminant behaviors (Azevedo & Chasin, 2003). Therefore, contaminant physicochemical properties, magnitude and frequency of exposure, exposure routes and organism sensitivity must all be considered in ecotoxicological assessments.

In this context, although water quality analyses worldwide have traditionally focused on nutrients, bacteria, metals, and priority organic pollutants that negatively impact human health, such as pesticides, industrial chemicals, and petroleum hydrocarbons (Pal et at., 2014), advances in technical research have increasingly contributed to the detection of many other contaminants present in wastewater and surface water in urban areas, even following treatment of raw sewage by Sewage Treatment Plants (STP). The stages of this type of treatment comprise, briefly comprising preliminary treatment, for the removal of coarse solids and sand, primary treatment, in which particulate, floating, and sedimentable materials are removed, secondary treatment to remove organic matter by means of biological processes, either aerobic or anaerobic and, if necessary, the removal of non-biodegradable materials and nutrients, such as nitrogen and phosphorus (Secretaria Nacional de Saneamento/ Ministério do Desenvolvimento Regional [SNS/MDR], 2021).

Sewage Treatment Plants, however, are inadequate in the removal of several classes of pollutants, such as Emerging Contaminants (ECs) or emerging pollutants, also called Contaminants of Emerging Concern (CEC) (Sauvé & Desrosiers, 2014). The term “emerging” is related to their recent detection in the environment as a result of improved analytical techniques (Soares et al., 2020). These contaminants comprise several classes of compounds, such as microplastics, antibiotics, personal care products, synthetic hormones, artificial sweeteners, certain metals and several drugs and pharmaceuticals, noteworthy due to their diversity and potential to cause adverse aquatic ecosystem and human health effects (Tran et al., 2018; Vélez et al., 2019).

Despite Brazil boasting of the highest volume of freshwater resources among all nations worldwide, this valuable natural asset is progressively depleting due to continuing pollutant inputs, among others, resulting in significant water quality degradation (Mello et al., 2020). Brazilian Federal Law n. 9.433/1997 defines one of the goals of the National Water Resources Policy as assuring current and future generations of the necessary availability of water, at quality standards adequate to

their respective uses (Brasil, 1997). Therefore, the right to dispose of sewage and other effluents, treated or not, into water bodies for dilution, transportation, or final disposal must be granted by the Public Power.

However, according to the Brazilian Federal Constitution (Brasil, 1988), Brazilian states must exercise full legislative competence to attend to their peculiarities in the absence of federal law on general norms, including but not limited to forests, hunting, fishing, fauna, nature conservation, soil and natural resource defenses, environmental protection and pollution control, liability for damage to the environment, tourism and landscapes. In this context, this study aimed to analyze state laws in force in Brazil concerning ecotoxicological assessments.

2 METHODOLOGY

The narrative review presented herein was conducted in an exploratory and descriptive manner. A literature search was carried out from 2007 to November 2022 to identify relevant articles and documents. Databases such as Pub-Med, Scopus, Science Direct, Google Scholar, as well as legislation documents, were used in the search. Articles were considered eligible for inclusion in this review when meeting the following criteria: (1) original research articles published in peer-reviewed journals, as well as laws, standards, agreements, and policies; (2) published in Portuguese, English and Spanish, for articles, and in Portuguese for normative documents; (3) focusing on water legislation; (4) comprising ecotoxicological approaches, legislation and the presence of contaminants of emerging concern in aquaria and humans.

3 RESULTS

3.1 Brazilian legislation on effluent release into receiving water bodies

In Brazil, water quality evaluations and potential pollutant effects are regulated by the Brazilian National Environmental Council (Conselho Nacional do Meio Ambiente

[CONAMA]), established by Federal Law n. 6.938/81, Article 6, item II. The CONAMA is the advisory and deliberative body of the National Environmental System (Sistema Nacional de Meio Ambiente [SISNAMA]), and its competencies comprise the establishment of norms and criteria for the licensing of effective or potentially polluting activities, to be granted by the Union, Brazilian states, the Federal District, and municipalities, as well as the establishment of norms, criteria, and standards associated to environmental quality control and maintenance aiming at the rational use of environmental resources, especially water resources (Brasil, 1981, Art.8, clause VII).

The enactment of CONAMA Resolution n. 357/2005 established public provisions for the classification of surface water bodies and environmental guidelines for their framing, as well as establishing effluent discharge conditions and standards. This Resolution defined that sanitary effluent should not cause or present the potential to cause toxic effects to aquatic organisms in the receiving body considering toxicity criteria, including employed method, test organisms, analysis frequency, and tolerated toxicity established by the competent environmental agency (Brasil, 2005). The CONAMA Resolution n. 430/2011 determines that sanitary sewage treatment system effluents may be subject to ecotoxicity testing in the case of interference of effluents with potentially toxic characteristics to the receiving body, at the discretion of the competent environmental agency (Brasil, 2011).

Law n. 6.938/1981 defines that Brazilian states within the sphere of their competence and in the areas of their jurisdiction should elaborate supplementary and complementary rules and standards related to the environment, observing those established by CONAMA (Brasil, 1981, Art. 6, VI, § 1º). This condition was revoked in 2011, as most environmental agencies in different Brazilian states failed to establish standardized ecotoxicity methods and criteria, also lacking definitions on degree of tolerated toxicity and test species.

Brazilian legislation is, therefore, still deficient with regard to its water quality standards and criteria (Montagnera et al., 2017). For example, among the thousands

of emerging contaminants known today, only some pesticides are cited in the Brazilian Ministry of Health Ordinance n. 888/2021 and CONAMA Resolution n. 357/2005, both of which address water quality. This represents less than 10% of the approximately 380 pesticides authorized for use in Brazil, which is the largest pesticide consumer in the world.

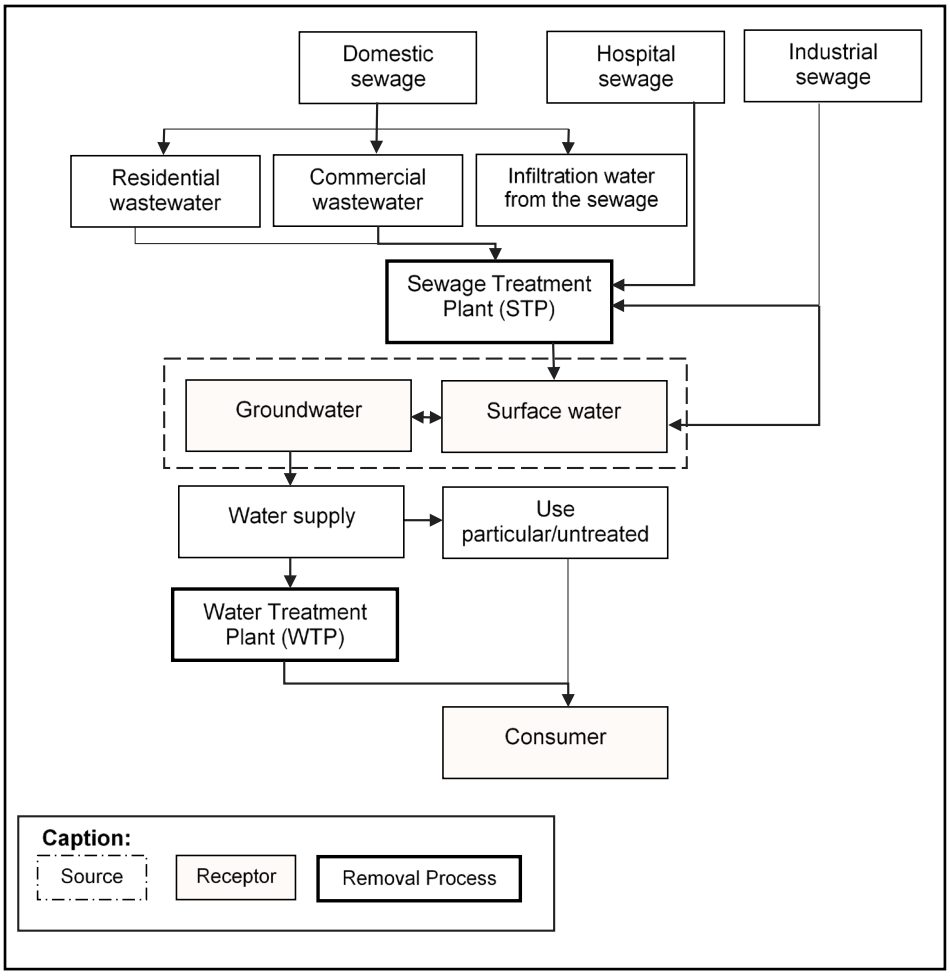
The CONAMA Resolution n. 430/2011 partially amends CONAMA Resolution n. 357/2005, providing conditions, parameters, standards, and guidelines for the management of effluent discharges into receiving water bodies. This Resolution was intended to assist Brazilian states that, until then, did not have their own regulations for effluent toxicity control, and defines that effluents resulting from sanitary sewage treatment systems must meet specific conditions and standards (Brasil, 2011). This Resolution, does not, however, establish conditions to identify emerging pollutants in receiving water bodies, although the current legislation lists more than 200 chemical parameters for water quality standardization.

Figure 1 illustrates the main sources and pathways of the effluent discharge into the water body (adapted from Stuart et al., 2012).

The support offered by the Brazilian Federal Constitution, through Article 225, establishes the right of everyone to have an “ecologically balanced environment, an asset for the common use of the people and essential to a healthy quality of life” (Brasil, 1988), so that the government and the community have the duty to defend and preserve it for present and future generations.

The Ministry of Health, through the Consolidation Ordinance MS n. 5/2017 and CONAMA Resolution n. 430/2011 set the legal need for conservative actions regarding aquatic environments and the quality of water to be used for human consumption. This is strongly shared by the “One Health” vision, in the health of humans, domestic and wild animals, plants, and ecosystems are interdependent. Therefore, setting parameters for wildlife and ecosystem protection primarily protects humans (Dye, 2022).

Figure 1 – The main sources and pathways discharge of effluents into the water body



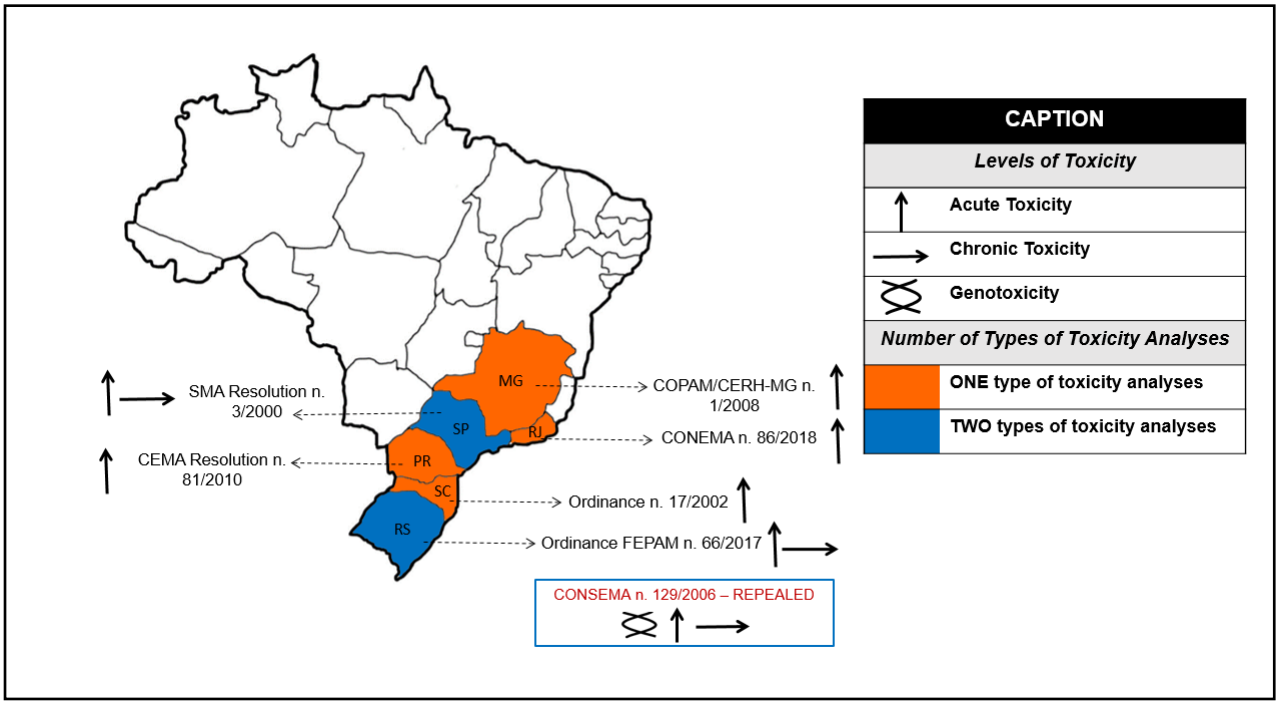
Source: Adapted from Stuart et al. (2012)

However, despite the development of resolutions and standards that classify and define guidelines for the management of effluent discharges into receiving water bodies in Brazilian territory, such as the determination of the Median Lethal Concentrations-CL50 or Median Effective Concentrations-CE50, i.e., effluent concentrations that causes acute effects (lethality or immobility) to 50% of exposed organisms within a certain exposure period (usually for 96 hours) under specific test conditions (Brasil, 2011), Brazilian law does not expressively establish limits and parameters based on ecotoxicological analyses in sanitary effluents in a countrywide manner.

In fact, as Brazil is a continental-sized country, each state has the flexibility to apply distinct effluent controls. Some Brazilian states are noteworthy for enacting

more restrictive laws that fill constitutional gaps in supplementary competence to CONAMA Resolution n. 357/2005 by applying ecotoxicological analyses, as depicted in Figure 2, comprising the states of Rio Grande do Sul, Paraná, Santa Catarina, São Paulo, Minas Gerais and Rio de Janeiro. These states are all located in the highly industrialized Southern and Southeastern regions of the country.

Figure 2 – Brazilian states with laws that include ecotoxicological tests



Source: Authors (2022)

3.2 Brazilian state legislation on effluent release into receiving water bodies and ecotoxicological assessments

3.2.1 São Paulo

The ISO/TC – 147/SC – 5 WG3 model established by International Organization for Standardization in 1975, with the participation of the Environmental Company of the state of São Paulo (CETESB), introduced technical procedures standards for the performance of tests and analysis of the acute toxicity of toxic substances worldwide

(Bertolleti et al., 1989). This model was then adopted in Brazil, under the proposal of defining an analytical screening of chemicals and products causing acute toxicity to freshwater fish. Since then, the CETESB has developed methodologies for application in short and long-term tests, for the determination of acute and chronic toxicity of toxic substances or effluents (Pereira et al., 1987).

Similarly, the Brazilian Association of Technical Norms (ABNT) has established standards such as the NBR 12648: Aquatic Ecotoxicology – Chronic toxicity – Test method with algae (Chlophyceae) (2018) and NBR 12713: Aquatic Ecotoxicology – Acute toxicity – Test method with Daphnia spp. (Crustacea, Cladocera) (2022) to aid in ecotoxicological assessments in Brazil.

State Decree n. 8,468/1976 establishes that the environmental pollution prevention and control system of in the state of São Paulo is governed in alignment with current regulations, thus making the release or discharge of pollutants into the water, air, or soil subject to prohibition (São Paulo, 1976). This Decree approves Regulation n. 997 of May 31, 1976, which provides for the prevention and control of environmental pollution, while the SMA Resolution n. 3/2000 complements previous legislations, defining ecotoxicological control limits for liquid effluents in the state. Considering potential interactions between effluent substances, this Resolution determines that these should not cause or display the potential to cause toxic effects to aquatic organisms in the receiving body, according to the relations that set permissible toxicity levels. The organisms used in the toxicity tests, as well as the test methods, are defined by São Paulo's Environmental Sanitation Technology Company (Companhia Ambiental do Estado de São Paulo [CETESB]) (São Paulo, 2000).

In 2012, the São Paulo branch of the Brazilian Association of Sanitary and Environmental Engineering (Associação Brasileira de Engenharia Sanitária e Ambiental [ABES]) developed and published the "Potability Guide for Chemical Substances", to offer technical-scientific subsidies so that public and private entities in the state of São Paulo would be able to dialogue about the complex process of prioritizing chemicals to

be regulated in the state, criteria to be adopted, technological limitations, and tools to protect the health of populations that consume water not within potability standards or from contaminated areas (ABES, 2012). Accordingly, the Environmental Company of the state of São Paulo (CETESB) presented a diagnosis of the contamination of surface water, groundwater, and sediments by pesticides in 2019, directed to the state. The intensive use of pesticides in agriculture can cause significant damage to the quality of water resources, directly affecting aquatic ecosystems and human health (CETESB, 2019). Both ABES and CETESB standards are directed to water used for human consumption.

3.2.2 Rio Grande do Sul

The definition of criteria and emission standards for the toxicity of liquid effluents discharged into surface waters in Rio Grande do Sul was established through a Resolution created by the State Council of the Environment (CONSEMA) n. 129/2006. This resolution also indicates the need for behavioral (Thoré et al., 2021) and genotoxicity (Bhat et al., 2019) assessments, as well as acute and chronic toxicity tests (Rio Grande do Sul, 2006). However, CONSEMA Resolution n. 334/2016 revokes the previous Resolution under the justification of updating and revising criteria and emission standards for the toxicity of liquid effluents discharged into surface waters (Rio Grande do Sul, 2016).

In 2017, the State Foundation for Environmental Protection (FEPAM) Ordinance n. 66/2017 was published in the state, establishing the frequency of toxicity monitoring of emission sources that discharge their effluents into surface waters in the state's territory. This Ordinance establishes the duty of liquid effluent-generating sources which have been released in surface water bodies to perform ecotoxicological analyses employing at least two trophic levels, assessing both acute and chronic toxicity effects, according to criteria established in Paragraph 3°, Art. 18 of CONAMA Resolution n. 430/2011 (Rio Grande do Sul, 2017).

3.2.3 Santa Catarina

Through Ordinance n. 17/2002, the Santa Catarina Environmental Foundation (FATMA) establishes the maximum acute toxicity limits for effluents from different sources and defines other provisions. This regulation defines that effluent substances cannot cause or display the potential to cause toxic effects capable of altering the behaviour and physiology of the aquatic organisms present in the receiving body. In addition, maximum acute toxicity limits are established for effluents belonging to different categories (Santa Catarina, 2002).

3.2.4 Paraná

CEMA Resolution n. 81/2010 provides criteria and standards of ecotoxicity for the control of liquid effluents discharged into surface waters in the state of Paraná. This Resolution sets criteria and emission standards associated to the ecotoxicity of liquid effluents for generating sources that discharge their effluents into fresh, saline, and brackish waters, for licensing and self-monitoring purposes required by the competent Paraná environmental agency (Paraná, 2010).

3.2.5 Minas Gerais

Through the State Council of Environmental Policy (COPAM) and in the use of the attributions of the State Council of Water Resources of the State of Minas Gerais (CERH-MG) the Joint Normative Deliberation COPAM/CERH-MG n. 1/2008 provides for the classification of water bodies and environmental guidelines for their framing, also establishing conditions and standards for effluent discharges in the state of Minas Gerais, in consideration of the conditions of the federal Resolution CONAMA n. 357/2005, which provides the classification of water bodies and environmental guidelines for their framing and establishes the conditions and standards for effluent discharges.

Therefore, the quality of aquatic environments in the state of Minas Gerais must be assessed by biological indicators, using aquatic communities, with criteria to be defined by joint COPAM and CERH-MG deliberation (Minas Gerais, 2008). This deliberation defines physicochemical water quality standards for classes 1 and 3 and specifies water body classification in cases of fishing or organism cultivation for intensive consumption. The toxicity criteria regarding effluent discharge conditions and standards are outlined in § 1° of the normative ruling, which must be based on the results of standardized ecotoxicological tests using aquatic organisms.

3.2.6 Rio de Janeiro

The State Council of Environment (CONEMA) Resolution n. 86/2018 (Rio de Janeiro, 2018) was instituted in the state of Rio de Janeiro in 2018. The resolution revokes technical standard NT 213.R4, which defines toxicity control criteria and standards for industrial liquid effluents, published on October 18, 1990, and establishes ecotoxicity criteria and standards for the release of liquid effluents into surface water sources in the state using ecotoxicological tests as an integral part of the environmental licensing system.

Among the established conditions, licensed activities must meet progressive targets for reducing acute ecotoxicity, associated with deleterious effects, lethal or non-lethal, on specific test organisms, aiming at with effluent quality improvement. The test organisms recommended by the resolution for the control of acute ecotoxicity in wastewater effluents for this state are presented in Table 1.

Rio de Janeiro laws defines that ecotoxicological tests must be performed with aquatic organisms belonging to at least two different trophic levels, referring to an organism's position in the ecological chain (Rio de Janeiro, 2018). Thus, the Resolution maintains the minimum trophic level conditions established by CONAMA Resolution n. 430, thus not exercising a more restrictive responsibility than that of the federal regulation. Developers of licensed activities may request the substitution of the test

organisms recommended by regulations, provided that sampling and toxicity tests are performed by an accredited laboratory using ABNT methods or, in their absence, international standard methods, in their latest version (Rio de Janeiro, 2018).

Table 1 – Test organisms recommended by the Rio de Janeiro State Council of Environment concerning sanitary effluent ecotoxicity control

	Test organisms
Effluents presenting: a) Salinity ≤ 0.5% or b) Conductivity ≤ 1066 µS cm^{-1}	Fish (*Danio rerio* and *Pimephales promenales*), Crustaceans (*Daphnia* spp.) Luminescent bacteria (*Vibrio fischeri*)
Effluents presenting: a) Salinity > 0.5% or b) Conductivity > 1066 µS cm^{-1}	Mysid crustaceans (*Mysidiopsis juniae* and *Mysidium gracile*), Luminescent bacteria (*Vibrio fischeri*) Branchiopoda crustaceans (*Artemia* sp.)

Source: CONEMA Resolution n. 86/2018 (Rio de Janeiro, 2018)

The Rio de Janeiro state CONEMA Resolution n. 86, which establishes ecotoxicity criteria and standards concerning the discharge of industrial and sanitary liquid effluents into surface watersheds. However, on February 8, 2021, CONEMA Resolution n. 90 approved the Standard Operational Norm NOP-INEA-45, which establishes criteria and standards for the discharge of treated sanitary sewage into receiving bodies for the state of Rio de Janeiro.

Sanitary sewage is termed generically in Resolution n. 90 as residential and commercial liquid discharges and infiltration waters in the collecting system. Thus, liquid waste, treatment plant effluents, generated by percolation of effluents (lixiviates), from external sources or from the decomposition of waste itself, located in sanitary and/or industrial landfills, industrial and/or non-sanitary effluents, are not specified in this Resolution. It, therefore, applies to the disposal of effluents on the soil, in which environmental license conditions must be set to prevent the surface and underground water contamination.

This standard fully alters the DZ 215-R4 (guideline for the control of biodegradable organic load in liquid effluents of sanitary origin, republished on November 8, 2007) and NT 202 R10 (technical standard published on December 12, 1986, which establishes criteria and standards for the discharge of liquid effluents), regarding sanitary sewage discharge standards. Therefore, the standards established in NOP-INEA-45 apply to sewage generated in any building, such as residential, commercial, industrial, ports, airports, concessionaires (public and private) of sewage treatment systems, as well as sewage treatment plants connected to the public network (Rio de Janeiro, 2021).

By not implying in changes in Resolution n. 86/2018, Resolution n. 90 advocates that effluents from sanitary sewage treatment systems may be subject to ecotoxicity tests in case of interference of effluents with characteristics potentially toxic to the receiving body, at the discretion of the competent environmental agency, as long as there is compliance with what is established in current state legislatures. Therefore, despite recent updates in the Rio de Janeiro laws establishing sanitary effluents criteria and standards, this state still lacks chronic toxicity analyses requirements.

4 DISCUSSION

Considering that the Brazilian states must exercise full legislative competence to meet their peculiarities in the absence of federal law, this study aimed to analyze the legal regulations in force throughout Brazil concerning the ecotoxicological control of water bodies that receive sanitary effluents. The findings reveal that the standards, parameters, and ecotoxicological criteria set forth for the discharge of sanitary effluents into receiving water bodies defined in the state of Rio de Janeiro, and the other states addressed, in supplementary competence to federal laws (CONAMA Resolution n. 357/2005 and n. 430/2011), require re-evaluations regarding the use of ecotoxicological analyzes as an effective tool for aiding decision-making.

Brazil has one of the most progressive environmental legislations compared to other countries. In fact, it holds the state and society responsible for maintaining a

healthy environment for current and future generations (Sanchez Ocamp et al., 2022). However, Brazilian legislation still makes little use of chronic exposure assessment methodologies, such as biomarkers (Handy et al., 2003; Lomartire et al., 2021) and more detailed risk assessments, such as the Adverse Outcome Pathway (AOP) approach. This approach, for example, can be employed to evaluate compounds that inhibit aromatase, the enzyme responsible for the transformation of androgens into estrogens, expressed in various vertebrate tissues, such as brain, adipose and placental tissue (Rocha & Umbuzeiro, 2022; Merlotti et al., 2011), to obtain a comprehensive view of mechanisms of action of certain pollutants.

The findings reported herein also indicate that no Brazilian state is required to perform genotoxicity effluent analyses to assess damages to DNA structure or function. As traditional sewage treatment systems are usually not capable of removing mutagenic and/or carcinogenic micropollutants, the need for further studies in this regard is clear (Machado, 2016).

Finally, in order to meet adequate emerging pollutants regulation, it is clear that several society sectors (political, economic, social and environmental) should act through coordinated actions by public managers (Sanchez Ocamp et al., 2022). Furthermore, environmental information and education programs have bene proven effective tools in significantly affecting environmental regulation compliances, and should, therefore, also be implemented (Sanchez Ocamp et al., 2022).

5 CONCLUSIONS

Few Brazilian states have established laws that require the application of ecotoxicological analyses to monitor pollutant exposure in industrial and/or sanitary effluents, and none states include genotoxicity analyses. Furthermore, Brazilian federal regulations state that, at the discretion of the competent state environmental agency, sanitary effluents can be subject to ecotoxicity testing as long as they interfere

with potentially toxic characteristics of the receiving body. However, in practice, not all sanitary effluents are monitored through ecotoxicological approaches throughout the country. This reveals considerable and imminent contamination risks from emerging pollutants from anthropogenic sources to both aquatic biota and humans.

REFERENCES

Azevedo, F. A., Chasin, A. A. M. (2003). *As bases toxicológicas da ecotoxicologia*. São Paulo: Rima.

Bertolleti, E., Goldstein, E. G., & Zagatto, P. A. (1989). Variabilidade de testes de toxicidade com peixes. *Revista Ambiente*, 3(1), 52–58.

Bhat, S. A., Cui, G., Li, F., & Vig, A. P. (2019). Biomonitoring of genotoxicity of industrial wastes using plant bioassays. *Bioresource Technology Reports*, 6, 207-216.

Brasil. (1981). *Lei n. 6.938, de 31 de agosto de 1981.* Dispõe sobre a Política Nacional do Meio Ambiente, seus fins e mecanismos de formulação e aplicação, e dá outras providências. Brasília: Senado Federal.

Brasil. (1988). *Constituição da República Federativa do Brasil de 1988*. Brasília: Senado Federal.

Brasil. (1997). *Lei n. 9.433, de 8 de janeiro de 1997*. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. Brasília: Diário Oficial [da] República Federativa do Brasil.

CETESB. (2019). *Diagnóstico da contaminação de águas superficiais, subterrâneas e sedimentos por agrotóxicos*. São Paulo: Companhia Ambiental do Estado de São Paulo.

CONAMA. (2005). *Resolução n. 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. Brasília: Diário Oficial [da] República Federativa do Brasil.

CONAMA. (2011). *Resolução n. 430, 13 de maio de 2011*. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução n° 357, de 17 de março de 2005, do Conselho Nacional do Meio Ambiente. Brasília: Diário Oficial [da] República Federativa do Brasil.

Costa, C. R., Olivi, P., Botta, C. M. R., & Espindola, E. L. G. (2008). A toxicidade em ambientes aquáticos: discussão e métodos de avaliação. *Química Nova,* 31 (7), 1820-1830.

Dye, C. (2022). One Health as a catalyst for sustainable development. *Nature Microbiology*, 7(4), 467-468.

Handy, R. D., Galloway, T. S., & Depledge, M. H. (2003). A proposal for the use of biomarkers for the assessment of chronic pollution and in regulatory toxicology. *Ecotoxicology*, 12, 331-343.

Lomartire, S., Marques, J. C., Gonçalves, A. M. M. (2021). Biomarkers based tools to assess environmental and chemical stressors in aquatic systems. *Ecological Indicators*, 122, 107207.

Machado, C. S. (2016). *Quantificação do risco à saúde humana pela exposição a poluentes químicos e potencial carcinogênico às comunidades adjacentes ao Rio Pardo, Brasil.* [Tese Doutorado em Enfermagem em Saúde Pública, Escola de Enfermagem de Ribeirão Preto]. Repositório da Universidade de São Paulo. https://doi.org/10.11606/T.22.2017.tde-30032017-195037

Mello, K., Taniwaki, R. H., Paula, F. R., Valente, R. A., Randhir, T.O., Macedo, D. R., Leal, C. G.,... & Hughes, R. M. (2020). Multiscale land use impacts on water quality: Assessment, planning, and future perspectives in Brazil. *Journal of Environmental Management*, 27(15), 110879.

Minas Gerais. (2008). *Deliberação Normativa Conjunta COPAM/CERH-MG n. 1, de 05 de maio de 2008*. 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. Minas Gerais [Belo Horizonte]: Secretaria Executiva do Governo do Estado de Minas Gerais.

Montagnera, C. C., Vidala, C., & Acayabab, R. D. (2017). Contaminantes emergentes em matrizes aquáticas do brasil: cenário atual e aspectos analíticos, ecotoxicológicos e regulatórios. *Química Nova*, 40(9), 1094-1110.

NBR ISO 12648. (2018). *Ecotoxicologia aquática – Toxicidade crônica – Método de ensaio com algas (Chlophyceae)*.

NBR ISO 12713. (2022). *Ecotoxicologia aquática — Toxicidade aguda — Método de ensaio com Daphnia spp (Crustacea, Cladocera)*.

Pal, A., He, Y., Jekel, M., Reinhard, M., & Gin, K. W. H. (2014). Emerging contaminants of public health significance as water quality indicator compounds in the urban water cycle**.** *Environment International*, 71, 46–62.

Paraná. (2010). *Resolução CEMA n. 81, de 19 de outubro de 2010*. Dispõe sobre Critérios e Padrões de ecotoxicidade para o Controle de Efluentes Líquidos lançados em águas superficiais no estado do Paraná. Paraná: Conselho Estadual do Meio Ambiente.

Pereira, D. N., Goldstein, E. G., Zagatto, P. A., & Sassi, R. (1987). Bioensaios: um programa a serviço do controle da poluição – Resultados iniciais. *Revista Ambiente*, 1(1), 32–36.

Rio de Janeiro. (2018). *Resolução CONEMA n. 86, de 07 de dezembro de 2018.* Aprova a NOP-INEA-08-REV00 – critérios e padrões para controle da ecotoxicidade aguda em efluentes líquidos. Rio de Janeiro: Conselho Estadual de Meio Ambiente do Rio de Janeiro.

Rio de Janeiro. (2021). *Resolução CONEMA n. 90, de 08 de fevereiro de 2021.* Aprova a NOP-INEA-45, que estabelece critérios e padrões de lançamento de esgoto sanitário. Rio de Janeiro: Conselho Estadual de Meio Ambiente do Rio de Janeiro.

Rio Grande do Sul. (2006). *Resolução CONSEMA n. 129, de 24 de novembro de 2006*. Dispõe sobre a definição de Critérios e Padrões de Emissão para Toxicidade de Efluentes Líquidos lançados em águas superficiais do Estado do Rio Grande do Sul. Rio Grande do Sul [Porto Alegre]: Conselho Estadual do Meio Ambiente.

Rio Grande do Sul. (2016). *Resolução CONSEMA n. 334, de 13 de dezembro de 2016*. Revoga a Resolução CONSEMA 129/2006, que dispõe sobre a definição de Critérios e Padrões de Emissão para Toxicidade de Efluentes Líquidos lançados em águas superficiais do Estado do Rio Grande do Sul. Rio Grande do Sul [Porto Alegre]: Conselho Estadual do Meio Ambiente.

Rio Grande do Sul. (2017). *Portaria FEPAM n. 66, de 19 de dezembro de 2017.* Dispõe sobre o estabelecimento da frequência de monitoramento de toxicidade para fontes de emissão que lancem seus efluentes em águas superficiais no território do Estado do Rio Grande do Sul, e dá outas providências. Rio Grande do Sul [Porto Alegre]: Fundação Estadual de Proteção Ambiental Henrique Luiz Roessler.

Sánchez-Ocampo, E. M., Téllez-Lópes, A. M., Islas-Flores, H., Gómez-Oliván, L. M. (2022). Environmental laws and politics, the relevance of implementing regulation of the presence of emerging pollutants in Mexico: a systematic review. *Water Emerging Contaminants & Nanoplastics*, 1(6).

Santa Catarina. (2002). *Portaria n. 017/02 – FATMA, de 18 de abril de 2002*. Estabelece os Limites Máximos de Toxidade Aguda para efluentes de diferentes origens e dá outras providências. Santa Catarina: Fundação do Meio Ambiente.

São Paulo. (1976). *Decreto n. 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. São Paulo: Assembleia Legislativa do Estado de São Paulo.

São Paulo. (2000). *Resolução SMA n. 3, de 22 de fevereiro de 2000*. O Secretário do Meio Ambiente, no uso de suas atribuições legais e, em face da deliberação da Diretoria Plena da CETESB – Companhia de Tecnologia de Saneamento Ambiental que provou a necessidade de implementar o controle ecotoxicológico de efluentes líquidos no Estado de São Paulo. São Paulo: Secretaria de Estado do Meio Ambiente.

Sauvé, S., Desrosiers, M. (2014). A review of what is an emerging contaminant. *Chemistry Central Journal*, 8(15), 1-7.

Secretaria Nacional de Saneamento/Ministério do Desenvolvimento Regional [SNS/MDR]. (2021). *Panorama do Saneamento Básico no Brasil 2021.* Brasília: Secretaria Nacional de Saneamento do Ministério do Desenvolvimento Regional.

Soares, A. F. S., & Souza, L. P. S. (2020). Contaminação das águas de abastecimento público por poluentes emergentes e o direito à saúde. *Revista de Direito Sanitário*, 20(2), 100-133.

Stuart, M., Lapworth, D., Crane E., & Hart, A. (2012). Review of risk from potential emerging contaminants in UK groundwater. *Science of the Total Environment*, 416, 1-21.

Thoré, E. S. J., Philippe, C., Brendonck, L., & Pinceel, T. (2021). Towards improved fish tests in ecotoxicology-efficient chronic and multi-generational testing with the killifish Nothobranchius furzeri. *Chemosphere*, 273, 129697.

Tran, N. H., Reinhard, M., & Gin, K. Y. H. (2018). Occurrence and Fate of Emerging Contaminants in Municipal Wastewater Treatment Plants from Different Geographical Regions-a Review. *Water research*, 133, 182–207.

Vélez, V. P. P., Hernández, G. E., Avila, I. C., Abril, E. M. Cisneros, J. F., Alvarado, A., & Ulloa, V. A. (2019). Emerging Contaminants in Trans-American Waters. *Revista Ambiente &* Água, 14(6), 1-26.

Walker, C. H., Hopkin, S. P., Sibly, R. M., & Peakall, D. B. (2001). *Principles of ecotoxicology*. 2nd ed. New York (USA): Taylor & Francis.

Zagatto, P. A., & Bertoletti, E. (2014). *Ecotoxicologia aquática: Princípios e Aplicações*. 2nd ed. São Paulo: Rima.

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