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Mapping of scientific research on ecotoxicological analysis with *zebrafish* (Danio rerio) in textile effluents between 2011 and 2021

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ABSTRACT

The high load of pollutants in textile industrial effluents makes it necessary to carry out an ecotoxicological analysis. Mapping these analyses in animal models can help clarify the possible toxicity that these textile effluents have. Thus, the present study aimed to map the evolution of scientific publications regarding the use of zebrafish (Danio rerio) as a bioindicator animal model for environmental quality analysis in the ecotoxicological analysis of textile effluents over a ten-year horizon (2011 to 2021). Three methodological steps were established: a sampling of articles, scientometric and bibliometric analyses, and a systematic literature review. It was observed in twelve documents that ecotoxicological studies of textile effluents using zebrafish are a recent and understudied but promising trend. Among the works, those originating from the Asian continent stood out. The Environmental Science and Pollution Research journal had only two publications. The similarity analysis generated a word tree with seven groups (halos). It was understood that industrial textile effluents have a direct connection with toxicity caused by dyes, and this toxicity can be detected by analysis carried out with the zebrafish bioindicator. It was observed that ecotoxicological assessments with zebrafish could be carried out through different methodologies. However, some proved more complex and presented more robust results, such as embryonic and larval analyses. These analyses were considered beneficial compared to other animal models because they are low cost, require a short period, and comply with an internationally imposed standard (OECD 236). Therefore, it concluded that zebrafish is a promising model for ecotoxicological analysis of textile effluents.

KEYWORDS: Toxicity, Industrial effluents, Bioindicator.

1 INTRODUCTION

The textile industry stands out among the industrial sectors that may degrade the environment. The environmental impacts generated by this sector affect aquatic ecosystems and the population in direct contact with these waters. It is, therefore, one of the industrial sectors leading environmental and social issues (DIAS et al., 2018).

The dumping resulting from the textile industry consists of synthetic chemical compounds (PIZATO et al., 2017) and natural chemical compounds such as detergents, sodium hydroxide, polyacrylamide, phosphonic acid, dyes, sodium carbonate, sodium chloride, detergents, and softeners, as well as fabric fibers (MARINHO, 2019). Dyes are considered toxic to the environment because of the changes they can cause in the receiving bodies, such as color variation, turbidity, and disturbance of aquatic life; toxic intermediates generated by the degradation of dyes can be considered carcinogenic compounds (AHIRWAR et al., 2016).

Some biological organisms can be used as bioindicators of toxicity in the aquatic environment (SÁ et al., 2019), highlighting some species of algae such as Charophyceae spp. and Phanerochaete chrysosporium (RYBAK et al., 2017; HUANG et al., 2018); fish such as tilapia (Oreochromis niloticus) and zebrafish (Danio rerio) (AMÉRICO-PINHEIRO et al., 2019; GOMES et al., 2020); species of is such as Acropora Aspera, Platyga and Digita (GISSI et al., 2017) and microcrustaceans such as Ceriodaphnia dubia (NETO et al., 2022).

Fish have demonstrated efficiency in indicating environmental quality because they enable the assessment of the ecotoxicological effects of substances inserted in water bodies (AMÉRICO-PINHEIRO, 2019). Among fish, Danio rerio, known as paulistinha or zebrafish, is a species widely used in ecotoxicological tests to determine environmental contamination and

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assessment of water quality, presenting itself as an efficient bioindicator in environmental studies (AMÉRICO-PINHEIRO; MARKET, 2022). This species presents responses through morphological, genetic, cytological, tissue, and biochemical evaluations (TRIGUEIRO et al., 2020), as well as changes in embryonic, teratogenic, and behavioral development (CADENA et al., 2020), including an international standard for toxicity testing known as FET Test contained in OECD 236 (2013).

Zebrafish is a vital animal model accepted internationally for ecotoxicological analysis because it provides results in a short period and presents high traceability using few resources, compared to other animal models, such as rodents (LOPES-FERREIRA, 2018; CANEDO et al., 2022). In addition to respecting the principles of 3Rs, referring to animal welfare (replacement, reduction, and refinement), this animal model also allows the adoption of other 7Rs, referring to scientific principles (registration, report, robustness, reproducibility, and relevance) and conduct (responsibility and respect) (CANEDO et al., 2022). Zebrafish analyses may occur in the embryonic, larval, and adult stages (SILVA et al., 2019).

The large load of existing pollutants in textile industrial effluents makes it necessary to perform ecotoxicological analysis to observe the possible toxic effects and interferences that these effluents can cause in the aquatic environment (SÁ et al., 2019). In this context, the state of the art of ecotoxicological assessments of textile effluents using Danio rerio as a bioindicator can help clarify the toxicity of this type of effluent and understand the current problem.

The mapping of scientific research, or determination of state of the art, seeks to deepen knowledge about specific themes, elucidating the guidelines for theoretical-methodological reflections and enabling the in-depth discussion of academic production (RODRIGUES et al., 2019). Thus, scientometric and bibliometric analyses consider the quantitative aspects of science and scientific production (GUEDES et al., 2022), content demonstration, and statistical validation (MANNARELLI et al., 2022). In line with the scientometric and bibliometric analyzes, the systematic review of the literature presents the qualitative aspects of the theme studied, through the synthesis and study of publications on the subject, allowing a critical evaluation of the results (PFEIFF et al., 2020).

2 OBJECTIVES

To map the evolution of scientific publications concerning zebrafish (Danio rerio) as a bioindicator of environmental quality for ecotoxicological analysis of textile effluents in water bodies in the ten-year horizon (2011 to 2021).

3 METHODOLOGY

The methodology was structured following the procedures performed by Guedes et al. (2022); three stages were established: article sampling, scientometric and bibliometric analysis, and systematic literature review.

3.1 Sampling (Step 1)

Sampling was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (PAGE et al., 2022). This procedure takes place in four phases: identification, composed of the total of the works found; screening, where criteria are applied for inclusion and exclusion of the works; eligibility, in which the dynamic reading and the removal of duplicate works occurs, that was carried out through the Mendeley application (Mendeley et al.); and, finally, the inclusion of works that are following the research objectives (PAGE et al., 2022; GUEDES et al., 2022).

The identification and screening of the works occurred through the choice of keywords, the determination of the databases, and the analysis of the data. The keywords were chosen considering the theme under study and the problem raised; for greater comprehensiveness of the data, the words were placed in English (DONTHU et al., 2021). Notably, the study problem is related to the identification of the level of toxicity that textile effluents can cause in the environment, using zebrafish (Danio Rerio) as a bioindicator.

The keywords were chosen based on the phases of zebrafish development and analysis with textile effluent. The research was conducted using the keywords: "zebrafish," "zebrafish Embryo," "zebrafish larva," "Danio rerio," "Danio rerio Embryo," "Danio rerio larva," and "Textile effluent." Keyword combinations were established, using the AND connective, often one of the words related to zebrafish and "Textile effluent," to narrow the results and delimit the theme.

The selected words were inserted into the data platforms, and the results obtained were directed to bibliographic data processing software. The data was collected through four databases: Pubmed, Scopus, Web of Science, and Nature. They were accessed through the Capes Periodical Portal (Capes Cafe). The time interval chosen comprises the period from 2011 to 2021, and it is possible to analyze the scientific papers published in the last ten years.

The inclusion and exclusion criteria were applied after identifying the works and removing duplicates. The inclusion criteria were: articles in English inserted in the chosen research platforms, published between 2011 to 2022, within the thematic axis of study. Moreover, the exclusion criteria were: documents in other languages, outside the given time interval, not characterized as an article, and inconsistent with the theme. The eligible publications underwent the entire reading procedure and were evaluated according to the research's problem and objectives.

3.2 Scientometric and bibliometric analyses (Step 2)

The scientometric and bibliometric analyses are quantitative studies (GUEDES et al., 2022). This stage was divided into three processes: data organization, map production, and statistical analysis. With Microsoft Excel 365 are performed the analysis of information, organization of data, and preparation of charts and tables. In addition to temporal analysis, journals, publication sites, SCImago Journal Rank (SJR), Quartiles, Impact Factor, and Qualis/Capes of each journal were observed.

The second process refers to the map production demonstrating the worldwide incidence of publications, which occurred through the application Qgis 3.24.3 (QGIS, Boston, USA). Finally, the third step corresponded to the statistical analyses performed through the Iramuteq 0.7 application (Iramuteq, Boston, USA). This program uses the R interface and Python for multidimensional text analysis (IRAMUTEQ, 2022). For the analyses with Iramuteq, it was necessary to construct a corpus (text base) in which the articles' titles, keywords, and abstracts were included. Using the Iramuteq was performed the analysis of similarity was. This analysis generated a word tree whose ramifications represented their relationships in the corpus (KLAMT; SANTOS, 2021).

3.3 Systematic literature review (Step 3)

The Systematic Literature Review (SLR) is a qualitative and descriptive analysis that critically and observationally evaluates the work on the subject (NASCIMENTO et al., 2019). For this, the PRISMA method performed the complete reading, interpretation, evaluation, and correlation of works selected in step 1. (LIMA et al., 2018). Based on the following question: "Are the methodologies used to determine the toxicity by the zebrafish bioindicator (Danio rerio) efficient in identifying the toxicity of textile effluents?".

Spreadsheets containing the main points of each article were prepared to organize the information (NASCIMENTO et al., 2019). The selected articles were organized according to the zebrafish development phase and the methodological procedures applied. These criteria helped in the identification and structuring of toxicity data of this Bioindicator. Finally, the articles consulted were organized according to thematic similarities, which guided the propositions of improvements and the indication of tests for future analysis.

4. RESULTS

The first stage of the results refers to data sampling. The second stage presents the scientometric and bibliometric analyses, composed of three subsections: temporal analysis of publications, distribution of publications, and textual statistical analysis. The third and final stage pertains to the systematic literature review.

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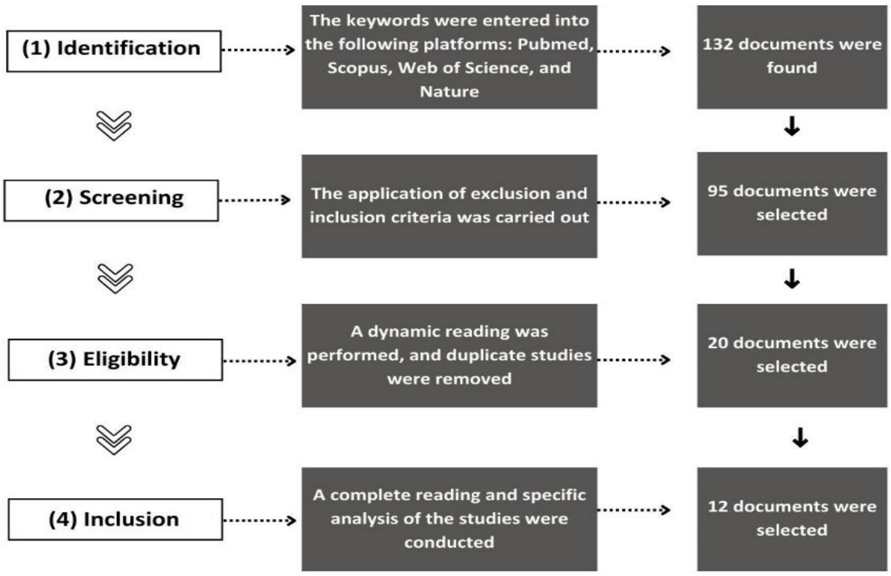
4.1 Sampling of articles (Step 1)

The results regarding the initial selection of articles allowed for the inclusion of 132 studies (Figure 1). It is important to note that articles evaluating textile dyes, recurrent chemical compounds in the textile industry, were also considered.

Based on the inclusion and exclusion criteria, 95 manuscripts were obtained, representing 72% of the initial sample. Removing duplicates resulted in 20 articles (15% of the total). Finally, after the full-text reading, 12 articles were selected, representing 9% of the initial sample. The narrowing down of the initial sample streamlines the evaluation of the found manuscripts, aiding in investigating the state of the art of the studied topic (PACHECO et al., 2018).

Figure 1 - Results found in the application of the PRISMA methodology.



Source: Prepared by the authors (2022)

4.2 Cienciometric and bibliometric analysis (Stage 2)

4.2.1 Temporal Analysis of Publications

A gradual temporal evolution of publications was observed between 2011 and 2021 (Figure 2).

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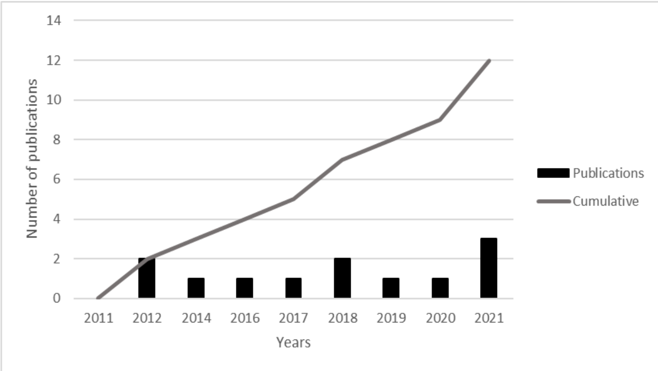
Figure 2 - Temporal evolution and quantity of publications between the years 2011 and 2021.



Source: Prepared by the authors (2022)

The annual average literary production output was around 1.3 published works, with a publication percentage of 11% per year. There was no published work in 2011; between 2012 and 2020, 1 to 2 articles were published annually, representing an average of 1.28 papers per year (10.6%). In 2021 there was a more significant number of publications when three manuscripts were registered, representing a percentage of 25%, that year, the publications were above the established average.

With these observations added to the cumulative evaluation, it can be said that the evolution of the publications was increasing; however, it was identified that the theme needs to be explored since few works were published annually. Despite this, the increase in the percentage of publications in 2021 showed that the theme is on the rise, considered promising for future studies.

A survey by Lopes-Ferreira et al. (2021) demonstrated that zebrafish have been used in environmental studies since 1977. According to the authors, there has been considerable growth in the analysis of zebrafish pollutants, particularly concerning bioaccumulation, toxicity, and interaction with other environmental contaminants, up until 2019.

4.2.2 Distribution of Publications

It was found that seven countries were responsible for the 12 publications on the subject, namely: Brazil, Germany, India, China, Portugal, Mexico, and Zimbabwe. Among these, India and China have stood out with the most significant number of publications, each contributing three articles. In addition, recent publications in India took place between 2020 and 2021, while China had two publications in 2012 and only 1 in 2021. Brazil published two articles on the subject in 2016 and 2018. Germany, Zimbabwe, Portugal, and Mexico had a single publication each in 2014, 2017, 2018, and 2019, respectively (Figure 3).

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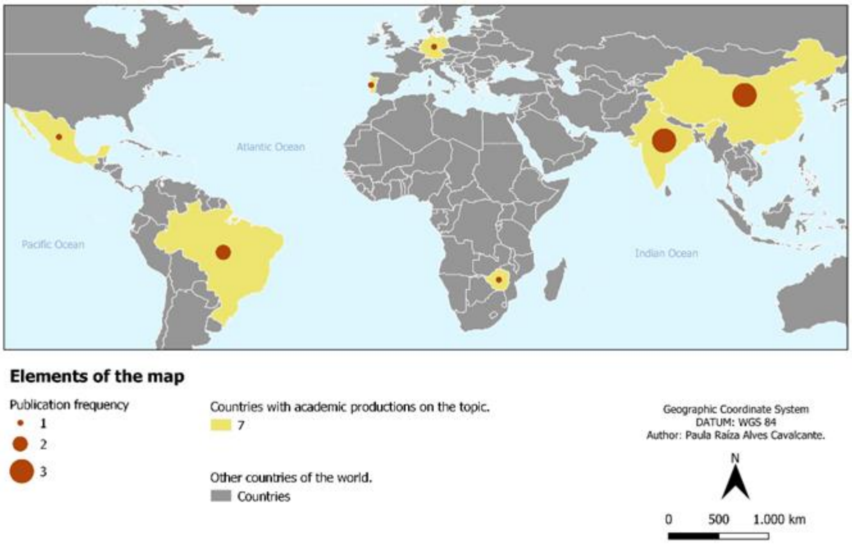
Figure 3 - Frequency of publications with their respective countries between 2011 and 2021.



Source: Prepared by the authors (2022)

Regarding the number of publications by continent, it was observed that Asia stood out with six articles, followed by South America and Europe with two articles. These results are consistent with global textile production. According to data from the United Nations Industrial Development Organization (UNIDO, 2018), Asia is the continent with the highest textile production. China ranks first in this ranking, with annual production reaching approximately $421 billion, while India ranks second, with production exceeding $67 billion. Brazil ranks 10th, representing 3% of China's production (MENDES JUNIOR et al., 2021).

The articles were published in 11 journals (Table 1). It was found that the journal "Environmental Science and Pollution Research" stood out in the publications, as it had two articles published.

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Table 1 - Scientific Journals in which the papers were published and their classifications

Scientific Journal	Number of publications	SJR	Impact factor (JCR)	Qualis (CAPES)
Environmental Science and Pollution Research	2	0,831	5,19	A2
Journal of Environmental Management	1	1,481	8,91	A1
Journal of Environmental Sciences	1	1,205	6,796	A1
Fibers and Polymers	1	0,445	2,347	A2
Environmental Pollution	1	1,954	9,988	A1
Ecotoxicology and Environmental Safety	1	1,239	7,129	A1
Toxicology Reports	1	0,807	4,807	A3
Environmental Toxicology and Chemistry	1	0,887	4,218	A2
Frontiers in Microbiology	1	1,314	6,064	A2
Chemosphere	1	1,505	8,943	A1
Chemico-Biological Interactions	1	0,857	5,168	A2

Source: Prepared by the authors (2022)

SJR - SCImago Journal Rank is a database composed of Scopus data and uses the weighted average of citations received by the journal over the past three years (SCIMAGO, 2022). The highest SJR indicator among the evaluated journals was 1.954, attributed to the journal Environmental Pollution, with emphasis on the categories: Health, Toxicology, and Mutagenesis; Pollution; Toxicology. This journal also had the highest impact factor among the evaluated journals (9.988). The Impact Factor quantifies scientific publications based on the citations received by articles published in the core collection of Web of Science in the two preceding years (UFRJ, 2020).

Qualis varied between A1, A2, and A3. While 45% of the journals were classified as A1 and A2, considered the highest classification strata, only 10% remained in category A3. The classification performed by Qualis refers to the analysis and quantification of the bibliographic production of teachers and students, serving as an evaluation tool of intellectual production correlating quantitative and qualitative aspects (BARATA, 2016).

The joint analysis of bibliometric indexes allows the impartiality and precision of the established results (THOMAZ et al., 2011). Through Table 1, it is possible to confirm this statement because the journals with higher SJR and JCR also had the best Qualis Capes classifications. Guedes et al. (2022) emphasize that journals with high bibliometric indexes are considered of good quality because they correspond to the rigor of the evaluation processes to which the works are submitted to maintain established impact metrics. Regarding the authors

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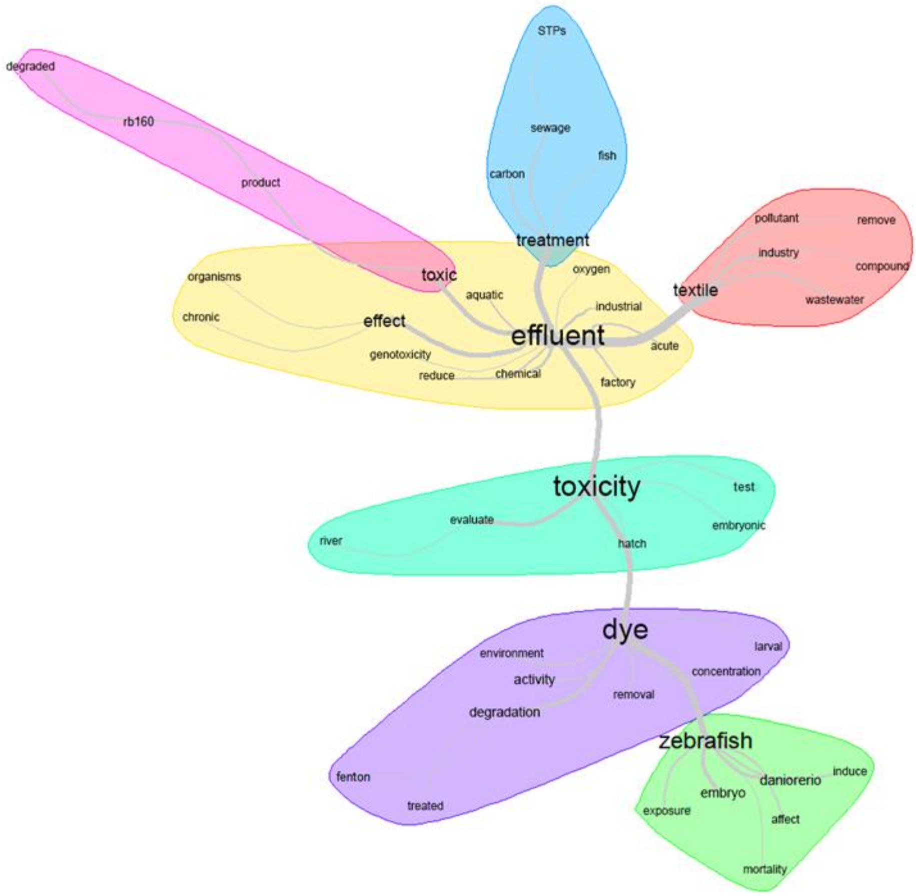
of the publications, heterogeneity was observed, with no predominance of authors in this study area.

4.2.3 Textual statistical analysis

By analyzing the similarity (Figure 4), it became possible to understand the texts' structure and the topics' relevance.

Figure 4 - Similarity Analysis of Words



Source: Prepared by the authors (2022)

The word tree formed generated seven groups, each group containing a primary word (core) presented in bold and with a font size larger than the others. These groups were called "halos" and grouped similar words in different colors (MANNARELLI et al., 2022). The connections between the halos were made by connecting lines, and the line thickness represented the strongest or weakest connections between the halos and the words (CARMO et al., 2018). The yellow halo contained the primary root, focusing on the word "affluent," from

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it, other connections and groups were formed. This halo relates to terms related to aquatic pollution, effluent discharge, organisms present in the aquatic environment, and toxic effects. It was directly linked to four other halos: rose, with a predominance of the term "toxic," which referred to products that may be toxic and degrade the environment; blue, focusing on treatment, treatment types, and fish as an indicator of local toxicity; the red, with the predominance of the term "textile," highlighting the pollutants generated by this industry; and the green-water, focusing on toxicity and methods of evaluation of toxic effects in the aquatic environment. Finally, the water-green halo was connected to two others: purple and light green. Purple focused on the term "dye" and addressed the concentrations of this substance in the environment, possible treatment methods, and tests with specific concentrations that could affect aquatic organisms. In the same segment, the light green halo, with the predominance of the word "zebrafish," represented the exposure of fish to dyes and their possible reactions. Thus, it is understood that industrial textile effluents have a direct link with the toxicity caused by dyes; this toxicity can be detected by analysis with the Bioindicator through exposure of animals to textile effluents or direct exposure to dyes. Regarding the stage of zebrafish development, tests with embryos and larvae were considered, with particular emphasis on the embryonic phase, where affected animals and mortality were observed.

4.3 Systematic literature review (Stage 3)

Based on the Systematic Literature Review (SLR), it was possible to evaluate the approaches of the identified studies (Chart 1).

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Chart 1 - Articles obtained through a systematic literature review after exclusion criteria

Reference	Stage of zebrafish development	Methodologies used with zebrafish
Fang et al. (2012).	Adult	The acute toxicity test of 96 hours was conducted according to the procedure described in ISO (1996). The sample was diluted to five concentrations (100, 80, 60, 40, and 20 percent). Mortality was recorded at 24h, 48h, and 96h intervals.
Zhang et al. (2012).	Adult	The fish were exposed to water samples for four days. Mortality was observed at various exposure concentrations, and the maximum tolerated concentration was determined. Blood and liver samples were collected from the fish for the genotoxicity test. For the micronucleus assay, the caudal section was removed.
Thellmann et al. (2014)	Embryo	The toxicity test was conducted according to OECD 236 at 6, 12, 24, 48, 60, 72, 84, and 96 hours post-fertilization (hpf). The following parameters were observed: mortality, developmental delays and abnormalities (such as spinal deformities, yolk and pericardial edema, pigmentation failure or absence), and heart rate frequency.
De Oliveira et al. (2016)	Embryo and larvae	The tests were conducted according to Lammer et al. (2009) and OECD 212 guidelines. The embryonic development was evaluated at 8, 24, 48, 72, 96, 120, and 144 hours post-fertilization (hpf). The observed lethal effects included coagulation, absence of somite formation, failure of tail detachment, and absence of heartbeat. Sublethal outcomes included embryonic malformations and hatching success.
Teta et al. (2017)	Adult	The eggs were collected daily. The reproductive performance of the fish was monitored and recorded daily for seven days. After seven days, the exposure was initiated by replacing clean water with textile effluent and wastewater treatment plant (WWTP) effluents. The reproductive performance was monitored for 21 days of exposure. After the 21-day exposure period, the vitellogenin (Vtg) content was determined, and histological analysis was conducted.
Fernandes et al. (2018)	Embryo	The acute toxicity test was conducted according to OECD 236 at 24, 48, 72, and 96 hours post-fertilization (hpf). Both lethal and sublethal effects were observed. Lethal effects included egg coagulation, absence of somite formation, failure of tail detachment from the yolk sac, and absence of heartbeat. Sublethal effects included effects on eye and body pigmentation, yolk sac absorption, and hatching rate.
Abe et al. (2018).	Embryo and larvae	After 96 hours post-fertilization (hpf), the following parameters were observed: available consumed and cellular energy. Behavioral analyses were performed on 144 larvae at 144 hpf, and the tests were conducted in four light/dark cycles of 10 minutes each to stimulate/inhibit larval movement.
Hernández-Zamora et al. (2019)	Embryo	The protocol proposed by OECD 236 was followed. Observations were made at 24, 48, 72, 96, 120, and 144 hpf. Lethal outcomes included coagulation, lack of tail detachment, absence of somite formation, and absence of heartbeat (measured after 48 hours). Sublethal outcomes included deformities in the yolk sac, gas bladder, and skeleton and delayed larval hatching rate.
Barathi et al. (2020)	Embryo	The collected embryos were divided into three groups: the control group, embryos treated with 250 µg/ml of RB 160, and embryos treated with a degraded product of RB 160. After treatment, the following observations were made at specific time intervals: phenotypic deformities, hatching rate, survival rate, and heart rate.
Wang et al. (2021)	Adult	The mortality rate was observed. For morphological analysis, body length and body weight were measured. The fish's livers, muscles, and intestinal tissues were evaluated for biochemical analysis. Intestinal content samples were scraped for subsequent microbial DNA extraction.
Raj et al. (2021)	Adult	The swimming activity and behavior of the fish (regular, erratic swimming, lethargy, immobility) were observed, recorded, and compared to the control group for 15 days. Additionally, an analysis of biochemical markers was performed in two crucial tissues (liver and brain tissue)
Suryamathi et al. (2021).	Embryo	The survival and developmental stages of the embryos post-fertilization were observed at 0, 6, 12, 24, and 48 hours. Mortality and teratogenic effects (not specified) were analyzed.

Source: Prepared by the authors (2022)

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It was found that studies on effluents or textile compounds were mainly conducted with zebrafish in the embryonic stage (n=7), followed by the adult stage (n=5), as well as embryonic and larval stages (n=3). Toxicological analyses with this species in the embryonic stage are becoming more frequent, as it is considered an alternative model that is as complex as adult fish and shares cellular similarities with mammals (STRAHLE et al., 2012). The OECD 236 (2013) internationally regulates toxicity tests with embryos, and the standard proposes four observations for indicating lethality: egg coagulation, absence of somite formation, lack of detachment of the tail bud from the yolk sac, and absence of heartbeat. Among the studies that evaluated zebrafish in the embryonic stage, four followed the OECD procedures: Thellmann et al. (2014), De Oliveira et al. (2016), Fernandes et al. (2018), and Hernández-Zamora et al. (2019).

The tests with zebrafish embryos and larvae (ABE et al., 2018) contribute to environmental protection as they have demonstrated efficiency in determining environmental toxicity (SURYAMATHI et al., 2021) and highlight the importance of this animal model. This recommendation elucidates the anthropogenic impact of textile effluents and directly contributes to the sustainable protection of aquatic biota and the pursuit of minimizing toxic levels while respecting environmental regulations (THELLMANN et al., 2014).

The toxicity of textile dyes using zebrafish has been demonstrated by Hernández-Zamora et al. (2019), Barathi et al. (2020), De Oliveira et al. (2016), and Fernandes et al. (2018). Hernández-Zamora et al. (2019) reported that Congo red dye exhibited significant toxicity not only to zebrafish but also to the microalga Pseudokirchneriella subcapitata and cladocerans. The authors found that this type of dye affected organisms at different trophic levels.

Barathi et al. (2020) assessed the textile dye Reactive Blue 160 (RB160). They reported that a concentration of 500 µg/mL already exhibited toxicity to the environment, causing both lethal and sublethal effects on zebrafish embryos. De Oliveira et al. (2016) determined the toxicity of textile dyes Direct Black 38 (DB38), Reactive Blue 15 (RB15), Reactive Orange 16 (RO16), and Vat Green 3 (VG3); all dyes caused malformations during the embryonic and larval stages. The authors emphasized the need for reducing concentrations to levels that do not cause significant effects on biota. Fernandes et al. (2018) studied the dye Disperse Red 343, and its ecotoxicity was assessed using lettuce seeds, Artemia salina, and zebrafish at the embryonic stage. This article established the LC50 corresponding to 100 mg/L; higher concentrations did not significantly affect the organisms.

Abe et al. (2018) correlated the energy balance of zebrafish with the stress conditions caused by dye pollution in water bodies. The authors demonstrated that energy consumption and allocation are related to impaired locomotor activity in the early life stages of zebrafish, which also compromises the energy required for other processes, such as hatching.

Tests on adults have also proven efficient for determining toxicity (ZHANG et al., 2012; FANG et al., 2012; TETA and NAIK, 2017; RAJ et al., 2021; WANG et al., 2021). The conducted tests considered parameters such as lethality, swimming activity, animal behavior (regular, erratic swimming, lethargy, immobility), morphology, biochemical markers, and tests to indicate the presence of endocrine disruptors and their effects on zebrafish gonads and fecundity.

Through the reported evaluations, it was possible to identify the toxic effects of textile effluents and dyes. It was observed that these toxicological assessments could be carried out through different methodologies. However, some methods were more complex and provided more robust results, such as embryonic and larval analyses, which indicated toxic effects in the early post-fertilization days. According to Fernandes et al. (2015), it is possible to establish a correlation between the effects analyzed in zebrafish embryos and human embryos (during the first trimester of development). The authors studied neurobehavioral responses. With these assessments, it becomes possible to identify the impacts on the early life stages of fish and the need for treatment of effluents based on the observed toxicity.

The analyses conducted directed the studies to two observations: 1 - Toxicological studies of textile effluents using zebrafish (Danio rerio) as Bioindicator is still a recent and little-studied strand; 2 - The increase in publications in 2021 may indicate that this line of research is on the rise and tends to be the subject of future research. Among the studies evaluated, those from the Asian continent stood out, linked to the fact that this region is the largest producer of textiles in the world; therefore, they were pioneers in research and published the most considerable amount of articles. The statistical and textual analysis showed that the researchers focused on evaluating the water quality of the water bodies that receive the textile effluents and their components. In addition, it was identified that the toxicity of the effluent is related to the dyes used in this industrial sector.

5. CONCLUSION

It was observed that the ecotoxicity analysis with zebrafish produced satisfactory and significant results to indicate environmental toxicity, assisting in determining concentrations that do not affect the aquatic environment and do not harm water bodies. The tests performed during the early stages of life (embryo and larva) were the most used and were related to OECD 236. These analyses were considered beneficial compared to other animal models as they are cost-effective, require a short period, and adhere to an internationally accepted standard.

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