Hair Care Products Manufacturing Wastewaters: Toxicity and test Organism Sensitivity

Elisa Dias de Melo (elisadias@yahoo.com.br)  
UninCor  https://orcid.org/0000-0001-7675-8684

Ann Honor Mounteer  
UFV: Universidade Federal de Vicosa

Research Article

Keywords: contaminants of emerging concern, industrial effluents, hazard/risk assessment

DOI: https://doi.org/10.21203/rs.3.rs-283342/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Wastewater from two (A and B) small-scale hair care product manufacturers located in the state of Minas Gerais were characterized, with regard to physical, chemical and ecotoxicological parameters. Wastewater characteristics typical for this industrial sector were found in three samples collected at each manufacturing plant, with high levels of both particulate and dissolved organic matter (soluble and total COD), oils and grease and acute toxicity to the microcrustacean *Daphnia similis* (EC$_{50}$ < 0.5 %). Strong positive correlations between turbidity, oils and grease and acute toxicity were observed. It is worth mentioning that only one of the manufacturers operates a wastewater treatment plant, while the second discharges untreated wastewater to a local sewer system. Furthermore, neither of the two cities where the enterprises are located has a municipal sewage treatment plant, aggravating environmental impacts of the industrial contributions to sewage discharges in receiving waters. A battery of tests was performed with species from three trophic levels (primary producers and primary and secondary consumers) to select the most sensitive test organisms to the wastewaters evaluated. The microcrustacean *Ceriodaphnia dubia* is indicated for use in routine monitoring, since it exhibited the highest sensitivities to hair care products wastewaters, for both acute and chronic effects.

Highlights

- Hair care products manufacturing generate highly toxic effluents.
- Sensitivity of test organisms to cosmetics industry wastewaters compared.
- Local sewer system not connected to municipal sewage treatment plant.
- Positive correlations between turbidity, oils and acute toxicity observed.
- *Ceriodaphnia dubia's* highest sensitivities to hair care products wastewaters.

1 Introduction

Water scarcity and rationing in several Brazilian cities has become an alarming reality in recent years. Despite the media's emphasis on this issue, it is not the only water related problems faced by the population. Unplanned urban growth, increasing demands for consumer goods and precarious sanitation conditions all contribute to the degradation of already compromised water supplies. Preservation of aquatic environments should be a goal of all, and both producers and consumers should be aware of their responsibility to minimize environmental degradation arising from production and use of consumer goods.

To assess the real impact of any industrial sector on the aquatic environment, it is essential to characterize the entire production chain, with special attention to wastewater generation points. Wastewater characterization should not be restricted to physical and chemical parameters but should also include ecotoxicological evaluation. Decision-making regarding treatment processes to be implemented should be based on both physical-chemical and ecotoxicological aspects.
Quality control during characterizations is fundamental for reliable data interpretation and is required by legal regulations to certify laboratories issuing reports to environmental agencies. A further requirement in ecotoxicological characterization is the need to evaluate the sensitivity of species from different trophic levels to wastewater samples, since not all organisms respond in the same way to the same concentration of a toxic agent, and it is important to know what the trophic chain levels will be impacted by wastewater discharge to receiving waters.

The Brazilian cosmetics industry is recognized for its economic importance, but little attention has been paid to the environmental impacts associated with wastewater discharge from the hundreds of small-scale manufacturers throughout the country, many of which do not operate wastewater treatment plants (Melo et al. 2013; Melo and Mounteer 2017; Melo et al. 2018). Wastewater composition depends on raw materials and products, but typically is characterized by high chemical oxygen demand (COD) and concentrations of organic compounds with low biodegradability, such as preservatives, surfactants, oils and greases (O & G), dyes and fragrances (Bautista et al. 2007; El-Gohary et al. 2010).

Several studies have already evaluated the comparative sensitivity of test organisms to complex chemicals mixtures, such as industrial effluents (Walsh et al. 1982; Rojieková-Padrtová et al. 1998; Liguoro et al. 2010; Ribeiro 2008; Rosal et al. 2010; among others). However, to the best of our knowledge, no studies have been conducted to select test organisms sensitive to cosmetics industry wastewaters, in particular from hair product factories. Therefore, the goal of this study was to perform physicochemical and ecotoxicological characterization of wastewaters from small-scale hair care product manufacturers and select the most sensitive test organisms for ecotoxicological evaluation of these wastewaters.

## 2 Material And Methods

### 2.1 Hair care product manufacturers

After an initial screening of hair care products manufacturers, two representative small-scale hair care products manufacturing plants were selected for this study, hereafter denominated Plant A and Plant B (Table 1), respecting the confidentiality agreement as a condition of their participation. Plant A employs 48 people and has an average monthly water consumption for industrial processes of 50,000 liters. Sanitary sewage and industrial effluents are treated separately. The industrial effluents come from production activities such as reactor washing, packaging and laboratory wastes, together with raw materials and products past their shelf-life, as well from the purge of the compressors and the solutions used in regeneration of ion exchange columns used to prepare the deionized water that is incorporated into products.

At plant A wastewater is treated in a 1300 L stainless steel tank by conventional physicochemical batch process of coagulation, flocculation and sedimentation, followed by passage through an activated carbon filter. Physicochemical sludge is sent to a drying bed and then collected by a third party for incineration. The treated wastewater is discharged to the municipal sanitary system and released without further treatment to the receiving water body.
Factory B has five employees and an average monthly industrial water consumption of 20,000 liters. There is no wastewater treatment system installed in the plant and wastewater is discharged in the municipal sewage system and released without any treatment to receiving waters.

Table 1. Hair care products manufactures at plants A e B

| Product              | Plant A | Plant B |
|----------------------|---------|---------|
| Shampoo              | X       | X       |
| Conditioner          | X       | X       |
| Capillary Mask       | X       | X       |
| Finisher             | X       | X       |
| Split end repair     | X       | X       |
| Keratin              | X       | X       |
| Extract              | X       |         |
| Hair ointment        |         | X       |
| Silicone cream       | X       |         |
| Oil                  |         | X       |
| Combing Cream        |         | X       |
| Curl Activator Fluid |         | X       |

2.2 Wastewaters sampling and physicochemical characterization

Both plants operate batch production processes and therefore grab samples of raw wastewater were collected at each once a month, for three months. Wastewater samples were stored in polyethylene bottles after coarse sieving (0.1 cm sieve) and mixing. Physicochemical characterization was performed according to standard methods (APHA 2017) and included the following parameters: pH (method 4500-H⁺ B, Hach HQ40d pHmeter), electrical conductivity (method 2510 B, Tecnopro mCA-150 conductivity meter), turbidity (method 2130 B, TD-300 turbidity meter), total COD (tCOD) and soluble (sCOD) (method 5220 D, Hach DR3800 spectrophotometer), dissolved organic carbon (DOC, method 5310 B, Shimadzu TOC-V CSH) and O&G (method 5520 B). Samples were filtered through 0.45 μm sterile membranes for sCOD and DOC quantification.

All analyzes were performed at the Laboratory of Sanitary and Environmental Engineering (LESA) of the Universidade Federal de Viçosa (UFV), except O&G analyses, which were carried out by a private laboratory.

2.3 Organism maintenance
Toxicity tests were carried out in the ecotoxicology laboratory, Aquatox / LESA / UFV, in which the test organisms *Daphnia similis, Ceriodaphnia dubia, Hyalella azteca* and *Raphidocelis subcapitata* were maintained, according to Brazilian technical standards (ABNT NBR 12713: 2016, NBR 13373: 2016, NBR 12648: 2018 and NBR 15470: 2013), which are similar to international standards. The organisms were maintained in water collected at the UFV’s water treatment plant prior to the disinfection process. Quality of each batch of water was monitored by measuring pH, electrical conductivity and total hardness (method 2340 D, APHA 2017). Water was aerated for at least 12 hours before use.

Test organisms were held in beakers under controlled temperature and photoperiod, as specified for each species. The cladocerans *D. similis* and *C. dubia* were transferred to fresh water and fed three times a week with Tetramin® fish meal, yeast (*Saccharomyces cerevisiae*) and a suspension of *R. subcapitata*. The amphipod *H. azteca* water was changed once a week. They were fed daily with a mixture of fish meal, yeast and primrose oil, while solid food consisting of rabbit food (Rói, Guabi, São Paulo) and Tetramin® fish food was supplied three times a week. Nylon screens and *Elodea* were used as substrate for *H. azteca* growth. The green microalga *R. subcapitata* was cultivated in LC Oligo medium under aseptic conditions.

The fish *Danio rerio* was not maintained in the Aquatox laboratory but was obtained from a commercial breeder and transported to the Laboratory of Fish Biology, Department of Veterinary Medicine, UFV, where the necessary structure for testing was made available. Test protocols were duly approved by the UFV animal ethics committee (CEUA), Process 09/2016. After receiving the fish, they were kept for seven days in a 250-liter aerated aquarium, respecting the maximum body mass per volume ratio of water, 1 g.L⁻¹. During the seven days adaptation period, fish were fed with Presence Nutripiscis (Campinas, SP), with a minimum content of 450 g.kg⁻¹ crude protein. No obvious signs of stress, such as abnormal behavior, bleeding, excessive mucus or lethality greater than 5% of fish during the adaptation period were observed and they were considered fit for toxicity testing.

Sensitivity of the different test organisms to the reference substance sodium chloride (NaCl) was determined periodically, following the methodologies defined in the respective standards, detailed in the following item. Organism sensitivity can be found in supplementary information.

### 2.4 Toxicity tests

A comparative sensitivity analysis was performed using representative test organisms of three trophic levels, primary producers (*R. subcapitata*), primary consumers (*C. dubia, D. similis, H. azteca*) and secondary consumers (*D. rerio*) in the raw wastewater from the second sample collected at both manufacturing plants.

Before starting all toxicity tests, sample pH was monitored and adjusted to pH 6-8 if necessary. Initial characterization of raw wastewater samples was carried using the static *D. similis* acute immobilization assay (NBR 12713, ABNT 2016). Neonates aged six to 24 hours were exposed to serial dilutions of the samples, for 48 hours, at 22 ± 2 °C under a 12 h light/dark cycle. Four replicates of each dilution and the
control (culture water) were included, each containing 10 mL of test solution and five organisms. The number of immobilized organisms were counted at the end of the assay.

For the semi static *C. dubia* survival and reproduction assay (NBR 13373, ABNT 2016), neonates (6 - 24 hours old) were exposed to serial dilutions of wastewater for eight days at 22 ± 2 °C under a 12 h light/dark cycle. Ten replicates containing one organism and 10 mL test solution were included for each wastewater dilution and the negative control (dilution water). At 48 hours intervals, surviving adults and neonates were counted and the adults were transferred to new test solutions and fed. The number of surviving adults and the cumulative number of neonates in each test solution was tallied after eight days to determine chronic effects. Mortality of adults within the first 48 hours of exposure was quantified as an acute effect.

For the static *H. azteca* survival and growth assay (NBR 15470, ABNT 2013), seven to 14-day-old organisms were exposed to serial dilutions of the samples for 96 hours at 22 ± 2 °C under a 12 h light/dark cycle. Ten replicates containing 20 mL of test solution and one organism were included for each dilution and the control. In each replicate, 0.05 mL of compound food was added at the start of the assay and again after 48 hours. Dead organisms were counted at the end of the assay.

For the *R. subcapitata* growth inhibition assay (NBR 12648, ABNT 2018), test solutions (100 mL sample diluted in LC Oligo medium and inoculum of $10^5$ cells.mL$^{-1}$) were prepared in triplicate under aseptic conditions in 250 mL erlenmeyers capped with a cotton stopper. The erlenmeyers were randomly arranged in shakers (Brand New Ethics, Model 109) and held at 22 ± 2 °C, under constant illumination (4,500 lux) and stirring (100-175 rpm) for 72 hours. At the beginning and at the end of the test the number of algal cells in each test solution was counted.

Acute toxicity to *D. rerio* (NBR 15088, ABNT 2016) was carried using fish with total length of 2.0 ± 1.0 cm in homogeneous lots exposed to serial dilutions of samples for 48 hours at 22 ± 2 °C under a 12 h light/dark cycle. Ten fish were exposed to each dilution and the control (dilution water). At the end of the exposure period dead fish were counted and the survivors were euthanized by immersion in a benzocaine solution.

Acute toxicity assay results (*D. similis C. dubia, D. rerio, H. azteca*) were reported as the half maximal effective or lethal initial concentration (EC$_{50}$ or LC$_{50}$, %). Chronic toxicity results were reported as the half maximal inhibitory (IC$_{50}$, %), of cell growth (*R. subcapitata*) or organism reproduction (*C. dubia*). Toxicity indices were quantified by the Trimmed Spearman Karber, Probit, Dunnett or linear interpolation methods, using software made available free of charge by the US Environmental Protection Agency (USEPA, 2006).

Correlations between physical, chemical and ecotoxicological data were determined after confirming the normality of the data by the Shapiro Wilk test, using the Action Stat system (Estatcamp, Campinas, SP).

### 2.5 Comparative sensitivity of test organisms
Comparison of sensitivity among different organisms was evaluated using the method proposed by Zagatto and Bertoletti (2006), which takes into account the confidence intervals obtained for the EC$_{50}$ or LC$_{50}$ indices of the organisms to be compared. Initially, the G statistic was calculated using Eq. 1:

$$G = \sqrt{\left( \log \left( \frac{UL_1}{EC_{50,1}} \right) \right)^2 + \left( \log \left( \frac{UL_2}{EC_{50,2}} \right) \right)^2}$$

where: $UL_1 =$ upper confidence interval for test organism 1

$UL_2 =$ upper confidence interval for test organism 2

$EC_{50,1} =$ Effective concentration for test organism 1

$EC_{50,2} =$ Effective concentration for test organism 2

The H and Z values were then calculated using equations 2 and 3:

$$H = 10^G$$

$$Z = \frac{\text{higher } EC_{50} \text{ value}}{\text{lower } EC_{50} \text{ value}}$$

and test organisms exhibited significantly different sensitivities to the wastewater when $Z > H$.

### 3 Results And Discussion

#### 3.1 Wastewater characterization

All wastewater samples collected at hair care products manufacturing plants A and B presented characteristic odor and were white to lightly colored. The wastewaters contained high levels of organic matter (Table 2), including O & G, typical of wastewaters of this industry (Bautista et al. 2007, El-Gohary et al. 2010). Although total COD was much higher in plant B samples, dissolved organic matter (sCOD and DOC) levels were not as markedly different. High turbidity values in all samples were related to high suspended organic solids contents as evidenced by the differences between tCOD and sCOD values. The higher organic matter contents of plant B samples suggests lower dilution of wastewaters during the washing process.

Sample pH values varied from acid to basic at plant A, which may be a result of purging of the regeneration solution from the process water ion exchange columns.
All samples exhibited very high acute toxicity to *D. similis*, especially from plant B, in agreement with this effluent’s more concentrated organic content. Cosmetics industry wastewaters are known to contain many substances toxic to aquatic organisms such as surfactants, dyes, preservatives and phenol derivatives (PERDIGÓN-MELÓN et al. 2010) and therefore the high acute toxicity is not surprising, but should certainly be a concern to the manufacturing plant and environmental enforcement agencies.

Only a few significant positive correlations were found among wastewater physicochemical properties (Table 3), notably pH with conductivity, O & G with turbidity, and soluble COD with DOC, while significant negative correlations were only found between soluble COD, DOC and conductivity, DOC and turbidity and total COD and O & G.

Acute toxicity indices had strong negative correlations with turbidity and O & G, that is the higher the values of these latter parameters, the lower the EC\textsubscript{50} values, and the more toxic the wastewater was. On the other hand, toxicity indices were positively correlated with DOC, meaning the higher the dissolved organic carbon content, the lower the toxicity (higher EC\textsubscript{50} value).
### 3.2 Comparative sensitivity of test organisms

Test organisms remained healthy and consistently sensitive to the reference toxicant (Supplementary Data), which permitted their use to evaluate toxicity of the hair care products wastewaters (Table 4). Wastewater storage slightly lowered toxicity to *D. similis* (lower EC<sub>50</sub> in Table 2 than Table 4). However, all tests reported in Table 4 were performed in parallel with wastewater samples stored for the same time period. Wastewater from plant B was more toxic to all organisms, except *C. dubia*, but with a slight difference.

### Table 4

Raw wastewater toxicity to different test organisms of samples collected at plants A and B (values in parentheses are 95% confidence intervals)

| Effect   | Test organism | Index    | Plant A (%)        | Plant B (%)        |
|----------|---------------|----------|--------------------|--------------------|
| Acute    | *D. similis*  | EC<sub>50</sub>, 48h | 0.49 (0.34–0.69)  | 0.04 (-)           |
|          | *C. dubia*    | EC<sub>50</sub>, 48h | 0.17 (0.13–0.22)  | 0.04 (0.03–0.05)  |
|          | *H. azteca*   | LC<sub>50</sub>, 96h | 0.12 (0.07–0.20)  | 0.04 (-)           |
|          | *D. rerio*    | LC<sub>50</sub>, 48h | 2.67 (1.67–4.28)  | 2.50 (-)           |
| Chronic  | *C. dubia*    | IC<sub>50</sub>, 168h | 0.017 (0.014–0.106)| 0.018 (0.014–0.033)|
|          | *R. subcapitata* | IC<sub>50</sub>, 96h | 0.54 (0.46–0.61)  | 0.08 (0.07–0.09)  |

(-) no confidence interval could be calculated
Test organism sensitivity to acute effects varied decreased *C. dubia* and *H. Azteca*, which exhibited equally high sensitivities to the wastewaters (Table 5). Organism sensitivity decreased in the following order: *C. dubia* = *H. azteca* > *D. similis* > *D. rerio*. Greater sensitivity of daphnids than fish has previously been reported for a wide variety of chemicals (Martins et al. 2007) and industrial effluents (Rodgers et al. 1996). Despite the lower sensitivity *D. rerio* compared to the other organisms evaluated, very high toxicities were still observed, especially considering that the effluent from plant B is discharged without undergoing any treatment. Fish occupy the aquatic high trophic levels and are likely to accumulate high levels of substances by bioconcentration (Mackay et al. 2016) and, therefore they useful in environmental monitoring programs because organic fish systems are more histologically and physiologically similar to humans than invertebrates, allowing for more reliable extrapolations.

**Table 5**
Comparison of acute toxicity indices for different test organisms to hair care products wastewater collected at plant A

| Organism 1 x Organism 2 | H   | Z   | Sensitivity            |
|--------------------------|-----|-----|------------------------|
| *C. dubia* x *H. azteca* | 1.77| 1.42| *C. dubia* = *H. azteca* |
| *D. similis* x *C. dubia* | 1.53| 2.88| *C. dubia* > *D. similis* |
| *D. similis* x *H. azteca* | 1.85| 4.08| *H. azteca* > *D. similis* |
| *D. similis* x *D. rerio* | 1.79| 5.45| *D. similis* > *D. rerio* |
| *C. dubia* x *D. rerio* | 1.71| 15.70| *C. dubia* > *D. rerio* |
| *H. azteca* x *D. rerio* | 2.00| 22.25| *H. azteca* > *D. rerio* |

*C. dubia* was found to be a more sensitive indicator than the alga *R. subcapitata* to wastewaters from both manufacturing plants (Table 6). Geis et al. (2000) cite a review of the US Toxic Substances Control Act databases, in which algae were found to be more sensitive than invertebrates and fish species in 50% of observations and less sensitive in 30%.

**Table 6**
Comparison of chronic toxicity indices of different test organisms to hair care products wastewaters (plants A and B)

| Plant | Organism 1 x Organism 2         | H   | Z   | Sensitivity          |
|-------|---------------------------------|-----|-----|----------------------|
| A     | *C. dubia* x *R. subcapitata*   | 6.26| 31.8| *C. dubia* > *R. subcapitata* |
| B     | *C. dubia* x *R. subcapitata*   | 1.85| 4.44| *C. dubia* > *R. subcapitata* |

Controversies exist in the scientific literature regarding the choice of test organisms. Some authors argue that the use of sensitive species is more relevant than the use of native species, but there are suggestions that the use of standardized organisms is more important than the use of sensitive or native species (Rojiecková-Padrtová and Marsalek 1999). In general, conditions must be found that meet the highest
number of requirements in the choice of test organisms, considering data reliability for the greater objective of protecting aquatic life.

All species tested showed high sensitivity to the hair care products manufacturing wastewaters and use of the microcrustaceans *D. similis* and, or *C. dubia* can be recommended for routine analyses of acute and chronic toxicity, respectively, since the methodologies for maintenance and toxicity testing with these test organisms is relatively simple and well established in many ecotoxicology laboratories.

### 4 Conclusions

Raw wastewaters from two small hair care products manufacturing plants (A and B) presented similar characteristics, with high levels of organic matter, including oils and greases, and acute toxicity to *D. similis*, indicating the need for appropriate treatment prior to discharge, which should be based on techniques capable of reducing both organic matter and toxicity. Wastewater turbidity, oils and grease contents correlated strongly and with increased toxicity.

Test organism sensitivity to the wastewaters was compared and found to decrease in the following order for acute effects: *C. dubia* (cladoceran) = *H. azteca* (amphipod) > *D. similis* (cladoceran) > *D. rerio* (fish), while *C. dubia* was found more sensitive than the alga *R. subcapitata* for chronic effects. However, although all species tested showed high sensitivity to the wastewaters, with toxicity indices of < 1 to 3%. Use of *C. dubia* for routine monitoring of these industrial wastewaters is recommended since evaluation of the acute and chronic toxicity for this sensitive species will help guarantee the protection of other aquatic organisms.

### References

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (2016). NBR 15088: Ecotoxicologia aquática: toxicidade aguda: método de ensaio com peixes. Rio de Janeiro

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (2011) NBR 12648: Ecotoxicologia aquática: toxicidade crônica: método de ensaio com algas (Chlorophyceae). Rio de Janeiro

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (2013) NBR 15470: Ecotoxicologia aquática: toxicidade em sedimento: método de ensaio com Hyalella spp (Amphipoda). Rio de Janeiro

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (2016) NBR 12713: Ecotoxicologia aquática: toxicidade aguda: método de ensaio com Daphnia spp (Crustacea, Cladocera). Rio de Janeiro

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (2016) NBR 13373: Ecotoxicologia aquática: toxicidade crônica: método de ensaio com Ceriodaphnia spp (Crustacea, Cladocera). Rio de Janeiro

APHA - AMERICAN PUBLIC HEALTH ASSOCIATION, AWWA - AMERICAN WATER WORKS ASSOCIATION, WEF - WATER ENVIRONMENTAL FEDERATION (2017) Standard Methods for the Examination of Water
Wastewater, 23 ed. Washington: American Public Health Association.

BAUTISTA P, MOHEDANO AF, GILARRANZ MA, CASAS JA, RODRIGUEZ JJ (2007) Application of Fenton oxidation to cosmetic wastewaters treatment. J. Haz. Mat. https://doi.org/10.1016/j.jhazmat.2006.09.004

CASTRO AAS (2008) Avaliação ecotoxicológica de efluentes industriais utilizando Danio rerio Hamilton-Buchanan, 1822 (TELEOSTEI, CYPRINIDAE). Dissertation, Federal University of Rio Grande do Norte

EL-GOHARY F, TAWFIK A, MAHMOUD U (2010) Comparative study between chemical Coagulation/Precipitation (C/P) versus Coagulation/Dissolved Air Flotation (C/DAF) for pre-treatment of Personal Care Products (PCP) wastewater. Desalination. https://doi.org/10.1016/j.desal.2009.10.016

GEIS SW, FLEMING KL, KORHALS ET, SEARLE G, REYNOLDS L, KARNER DA (2000) Modifications to the algal growth inhibition test for use as a regulatory assay. Environ Toxicol Chem. https://doi.org/10.1002/etc.5620190105

HOLANDA JN, MACIEL AP, SANTOS RL (2012) Avaliação ecotoxicológica da água de lavagem da purificação de biodiesel de soja metílico utilizando Danio rerio como organismo-teste. Boletim do Laboratório de Hidrobiologia. 25(1), 13-20.

LAMEIRA V (2012) Estudo dos efeitos ecotoxicológicos dos fármacos paracetamol e dipirona sódica para organismos aquáticos. Thesis, University of São Paulo

LIGUORO M, LEVA V, GALLINA G, FACCIO E, PINTO G, POLLIO A (2010) Evaluation of the aquatic toxicity of two veterinary sulfonamides using five test organisms. Chemosphere. https://doi.org/10.1016/j.chemosphere.2010.07.003

MACKAY D, CELSIE AKD, ARNOT JA, POWEL DE (2016) Processes influencing chemical biomagnification and trophic magnification factors in aquatic ecosystems: Implications for chemical hazard and risk assessment. Chemosphere. https://doi.org/10.1016/j.chemosphere.2016.03.048

MARTINS J, TELES LO, VASCONCELOS V (2007) Assays with Daphnia magna and Danio rerio as alert systems in aquatic toxicology. Environ. Int. https://doi.org/10.1016/j.envint.2006.12.006

MELO ED, MOUNTEER AH, LEÃO LHS, BAHIA RCB, CAMPOS IMF (2013) Toxicity identification evaluation of cosmetics industry wastewater. J. Haz. Mat. https://doi.org/10.1016/j.jhazmat.2012.11.051

MELO ED, MOUNTEER AH (2017) Panorama da indústria de cosméticos e efluentes líquidos gerados. Sustentare. http://dx.doi.org/10.5892/st.v1i1.4512

MELO ED, MOUNTEER AH, REIS E, COSTA E, VILETE A (2018) Screening of physicochemical treatment processes for reducing toxicity of hair care products wastewaters. J. Environ. Man. https://doi.org/10.1016/j.jenvman.2018.02.036
PERDIGÓN-MELÓN JA, CARBAJO JB, PETRE AL, ROSAL R, GÁRCIA-CALVO E (2010) Coagulation–Fenton coupled treatment for ecotoxicity reduction in highly polluted industrial wastewater. J.Haz. Mat. https://doi.org/10.1016/j.jhazmat.2010.04.104

PEREIRA MPC (2013) Efeitos do agrotóxico Vertimec® 18EC para o zooplâncton e fitoplâncton: análises laboratoriais com o produto comercial e amostras de mesocosmos artificialmente contaminados. Dissertation, University of São Paulo

PORTELA CMS (2002) Avaliação ecotoxicológica do Arroio Sapucaia, RS, com a utilização de diferentes metodologias em água superficial e sedimento. Dissertation, Federal University of Rio Grande do Sul

RIBEIRO EN (2008) Avaliação da sensibilidade dos organismos utilizados em testes de toxicidade nos efluentes das indústrias de explosivos: seleção de uma bateria de testes na busca dos "organismos ideais". Thesis, University of São Paulo

RODGERS DW, SCHRODER J, VEREECKEN SL (1996) Comparison of Daphnia magna, rainbow trout and bacterial-based toxicity tests of Ontario Hydro aquatic effluents. Clean Water. https://doi.org/10.1007/978-94-009-0299-2_11

ROJIEKOVÁ-PADRTOVÁ R, MARŠÁLEK B, HOLOUBEK I (1998) Evaluation of alternative and standard toxicity assays for screening of environmental samples: Selection of an optimal test battery. Chemosphere. https://doi.org/10.1016/S0045-6535(98)00065-4

ROJIEKOVÁ-PADRTOVÁ R, MARŠÁLEK B (1999) Selection and sensitivity comparisons of algal species for toxicity testing. Chemosphere. https://doi.org/10.1016/S0045-6535(98)00566-9

ROSAL R, RODEA-PALOMARES I, BOLTES K, FERNÁNDEZ-PIÑAS F, LEGANÉS F, PETRE A (2010) Ecotoxicological assessment of surfactants in the aquatic environment: Combined toxicity of docusate sodium with chlorinated pollutants. Chemosphere. https://doi.org/10.1016/j.chemosphere.2010.05.050

SANTOS PIM (2009) Avaliação da toxicidade aguda do inseticida metomil e o seu efeito sobre a atividade da acetilcolinesterase do peixe Danio rerio. Dissertation, Federal University of Rio Grande do Norte

SILVA EMF (2012) O uso da alga clorofícea Pseudokirchneriella subcapitata e análises limnológicas para avaliação da qualidade ambiental dos sistemas lóticos e lênticos da bacia hidrográfica dos rios Itaqueri/Lobo (Itirapina/Brotas-SP). Dissertation, University of São Paulo

USEPA - UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (2006) Statistical Analysis for Biological Methods. www.epa.gov/nerleerd/stat2.htm#. Accessed 02 dec. 2018

WALSH G, DUKE KM, FOSTER RB (1982) Algae and crustaceans as indicators of bioactivity of industrial wastes. Wat. Research. https://doi.org/10.1016/0043-1354(82)90017-3
Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.jpeg
- SupplementaryData.docx