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Analysis of Bioindicators Species of Wastewater of the Productive System, an Option of Environmental Monitoring for the Production Engineering

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Abstract: The production system seeks in the environment resources for the use as raw material or operational input. In this process there is the dumping of residues with potential for contamination of the medium. For the control of the environmental quality, monitoring is relevant and is an expensive process. With the use of indicator species, this procedure can be made cheaper, however, the analysis of the species on crityriasis is necessary. The present study analyzed three species: Selenastrum capricornutum, Daphnia magna and Keratella tropica, under 10 criteria, and the first two species were considered good for bioindication, especially in laboratory work. It is recommended that analytical work with species with bioindicator be developed to assist in the orientation of species both in the laboratory, in bioassays, and in field work, in biomonitoring and bioindication. The development of the use of environmental indicators of environmental quality may greatly help the maintenance of environmental quality, with the dissemination of knowledge to other researchers and to the community at large.

Keywords: Environmental Quality; Indicator; Biomonitoring

1. Introduction

There is a pressure of the production system on the natural resources through the obtaining of the raw material, for the production of goods (BOIRAL; HERAS-SAIZARBITORIA; BROTHERTON, 2019). However, this system, even with generation of resources for production, returns garbage that are released into the environment (HE et al., 2019). The wastewater of these systems undergoes changes in their biotic parameters (physical and chemical) that can denote the compromise of environmental quality indicators, requiring treatment systems even before the production system, which increases production costs.

Several techniques can assess changes in the environment (COLOMBO et al., 2018; ROTARU, 2014), some of which include living organisms, bioindicators (PAKZAD; OSMOND, 2016, FAUZI; MISNI, 2016). These can respond physiologically, metabolically and / or ethologically the changes in the environment, being, therefore, species that indicate the occurrence of modifications of environmental parameters. They are of great importance because they indicate imperceptible alterations without instruments or laboratory measurements, being able to be alert to future damages to the habitats.

In this way, the monitoring of wastewater is an important aspect of environmental management and production engineering (HITAM; BORTHAN, 2012). Bioindicators are important tools for detecting changes in the environment and have the potential for assessing the health of ecosystems before their functionality was compromised, by providing biological responses that can guide policy makers and environmental managers (BONANNO; ORLANDO-BONACA, 2018)

This work aims to discuss the use of bioindicators of environmental quality as a mechanism for environmental monitoring of wastewater, aiming at the water security necessary for the industrial procedures of Production Engineering.

2. Quality of Water Resources

Degradation of ecosystems implies the reduction or loss of the biological or economic productivity of the land, as well as changes in the quantity and quality of available fresh water, being associated with the impoverishment and loss of quality of life of the populations living in these regions (SOUSA, 2007; BOHUŠOVÁ; FAIZ et al., 2012; SVOBODA, 2016).

Human activities generate several adverse effects on the environment, which can cause changes in ecosystems (GHASEMI et al., 2015). The processes of industrialization, mining, increased food production, coupled with the increase in population density and the constant need for human consumption, have significantly increased the release of residues in water resources. On the other hand, water quality is a constant concern in ensuring human health and in the safety of production systems (MABAHWI et al., 2014)

Goulart and Callisto (2003) has observed an expressive decrease in water quality and loss of aquatic biodiversity due to the destructuring of the physical and chemical environment and alteration of the natural dynamics of biological communities. The process of industrialization has contributed in this process, especially the sectors that present a low degree of environmental commitment, with reactive posture the legal determinations (KELES, 2012; KORDOS; VOJTOVIC, 2016).

As for amount of water, tanks are built for purpose of storing water for multiple uses (THORNTON; RAST, 1993, LIAO et al., 2019; BARAKOTI; MOORHEAD; APUL, 2019). These tend to exhibit high concentrations of nutrients and suspended solids in the water, favoring eutrophication and silting, which contribute to reducing the quality and quantity of stored water (TUNDISI et al., 1999; MARTTILA et al., 2018). The quantity and diversity of chemicals increase the likelihood of risks in these environments (ZAGATTO, 2006). Frequent changes in trophodynamics and salinity in reservoirs are selective factors of the species potentially colonizing these environments, which influences the composition and relative abundance of species of the aquatic communities of these (SOUSA, 2007; HAN et al., 2011). For this reason, the study of bioindicators of environmental quality may help to increase the efficiency of the monitoring of these environments, seeking to provide reliable information regarding potential problems in the water bodies, reducing this insecurity (AZERÊDO et al, 2015).

Magalhães and Ferrão Filho (2008) claim that chemical analyzes do not portray the environmental impact caused by pollutants because they do not demonstrate the effects on the ecosystem. Only biological systems (parts or organisms) can detect the toxic effects of substances (TIAN et al., 2019; RIBEIRO et al., 2019. For Callisto et al. (2005), the development of an adequate biomonitoring program depends on criteria, standards and risk assessment of occurrences of environmental impacts, as registered in programs in various locations (WATTIGNEY et al., 2019; HAYS; KIRMAN, 2018; AYLWARD, 2018).

3. Environmental Quality Bioindicators

According Neumann-Leitão e El-Deir (2009), bioindicators are species, groups of species or biological communities that through their living conditions, presence and abundance reveal biological parameters of a given environmental condition. For Bonanno and Orlando-Bonaca (2018), bioindicators are living organisms which provide information on the quality of the environment.

For Callisto et al. (2005) and Li et al. (2010), the use of bioindicators is more efficient than the instantaneous measurements of physical and chemical parameters used to assess water quality. In the field, it can help identify the effects caused by natural and anthropogenic agents. Biomonitors may replace automated measuring equipment or supplement information. (LOPES et al., 1998; FRANCK et al., 2011).

The advantage of using bioindicators over conventional methods of environmental quality assessment is low cost and can be used for the cumulative evaluation of events occurring over a certain period of time, recovering a non-detectable environmental history of detection or measurement by other methods, as pointed out by the Environmental Company of the State of São Paulo (CETSB, 2013).

In order to work with bioindicators, criteria for their selection must be previously established, as well as the degree to which the indicators meet the criteria, through laboratory tests and bioassays. The choice of a bioindicator should be well-founded (HEINK; KOWARIK, 2010), with primary and secondary data, observations and experiments. Thus, it begins with the understanding of what would be an ideal bioindicator, characterized by being a taxonomically well defined species, easily recognized by non-specialists, presenting broad geographical distribution, being abundant, having low genetic and ecological variability, preferably having a size large and long life cycle, have well-defined and known ecological characteristics and be able to be used in laboratory studies, in addition to low mobility (JOHNSON, 1993; NEUMANN-LEITÃO; EL-DEIR, 2009). Is also understood as the species that has potential for bioaccumulation, wide distribution, narrow range of motion, short lifespan and ease of collection (TANABE; SUBRAMANIAN, 2006).

The use of bioindicators to monitor environmental quality in reservoirs is the object of research in some centers (GOULART; CALLISTO, 2003; COSTA et al., 2009; PERBICHE-NEVE et al., 2016; OVASKAINEN et al., 2019). However, Ecotoxicology allows to study the adverse effects of selected chemical products on the whole ecosystem, by exposing representative organisms to environmental exposures (COSTA et al., 2009; COSTA; DALBERTO, 2010; CAMPANA; WLODKOWIC, 2018), being able to evaluate the potential of risk to human health (CHEN et al., 2018), as determined by the Resolution of the National Council of the Environment of Brazil n. 357 (CONAMA, 2005).

In order to work and identify various effects of pollutants on aquatic organisms, a series of criteria should be considered in choosing the test organism: sensitivity among species, availability, being representative of the ecosystem under study, ease of maintenance and adequate information on the species under study. However, the organisms should be used to make an ecologically true extrapolation of results from studies of the effects of pollutants in the aquatic environment (JONSSON et al., 2010).

Matthews et al. (1982), Oertel; Salánki (2003) and Li et al. (2010) present the definition of biomonitoring as the systematic use of the responses of living organisms to evaluate changes in the environment caused by anthropogenic actions. Biomonitoring at the pollutant level can be done through the bioindicators present in the ecosystem (passive monitor) or by introducing test organisms in the environment (passive monitor) (NEUMANN-LEITÃO; EL-DEIR, 2009). The study of species as bioindicators requires an analysis under criteria, in this way the present paper sought to perform this analysis in three species.

4. Methodology

From Descriptive Ecology (POORE, 1962), seeking to understand the water quality of reservoirs for industrial systems, a survey of secondary data was carried out with exploratory research. Bioindicator species were chosen through their relationship with the aquatic ecosystem. Biological data, Ecology and environmental needs, as well as procedural optimum and specific lethality limits were raised. By means of a spreadsheet developed by Neumann-Leitão and El-Deir (2009), these species were analyzed under the focus of bioindication in order to identify the most appropriate ones for monitoring environmental quality. After selecting three species (*Selenastrum capricornutum*, *Daphnia magna* e *Keratella tropica*), it was possible to search for specific data, identifying analytical precepts according to Jonsson (2005), Neumann-Leitão and El-Deir (2009) to verify if the species are good bioindicators, being carried out the typification of each species and the assembly of a spreadsheet for a qualitauantitative analysis.

To better classify the species, values between 1 and 5 were determined for each parameter of the ideal bioindicator, 1 being for irrelevant characteristics going to 5 as a very relevant characteristic. Weight was also determined from 1 to 3 for each characteristic, according to the importance for the determination of the ideal bioindicator (Table 1). Of the 10 characteristics, two were identified as the most relevant in the analysis of a species as a bioindicator: have a well-defined taxonomy and well-known ecological characters, being assigned 3 to ponder these parameters. Two other characteristics were identified as irrelevant for this analysis, that is, to be easily recognized by experts and have a large size, assigned 1 to ponder these parameters. The other characteristics were assigned with 2 to ponder these parameters. From this analysis it was possible to list the species in order of preference for the research through its ecological importance.

Table 1. Ponder attributed to each of the characteristics of a bioindicator.

Characteristics of the bioindicator	Ponder
taxonomically well defined	3
well-known ecological characters	3
use in laboratory studies	2
have a significant geographical distribution	2
be abundant	2
low genetic and ecological variability	2
long life cycle	2
have low mobility	2
easily recognized by experts	1
preferably of large size	1

5. Systematic and Biology Data of the Species Studied

The Theory of Evolution by Natural Selection says that the individuals who were most able to survive the risks and catastrophes as well as those who survived were favored reproductively by the environments where they lived, showing the importance of the relationship between organisms and environments (TOWNSEND et al., 2010; DESMOND, 2018; SALAS, 2019).

According Moore (2011) “animals sharing the same body plane are grouped on the same Phylum. Within each phylum, there are usually well-defined classes with characteristics that equip animals for some particular environment or way of life, and within each class the original form of the organism will have changed as they explore different habitats”. There is a complex discussion regarding the definition of species (ALEIXO, 2007; FERRER, 2009; TOWNSEND et al., 2010). To Mayr (1982), the biological concept of species defines a group of organisms or a population of organisms reproductively isolated from other groups or populations. Thus, the three species of the present study follow this definition.

a) Selenastrum capricornutum Printz, 1914

The *Selenastrum capricornutum* Printz, 1914, belongs to the Protist Kingdom, Phylum Chlorophyta, Class Chlorophyceae, Order Sphaeropleales, Family Selenastraceae, Genus *Selenastrum*. For the class Chlorophyceae, one of the characteristics of the cells is to have external, radial or near radial symmetry. S. apricornutum is cited in 1,626 references on the ScienceDirect website, with 23 articles being 2019 and 78 being 2018 (research on January 10, 2019). It is a unicellular microalga. It has starch (polysaccharide) as its stock. Many of the species have flagella in some phase of life, contain two membranes and reproduce by conjugation or mitosis (simple division). It inhabits the aquatic ecosystem and has no capacity of locomotion.

This species is recommended internationally for studies evaluating the ecotoxicity of chemical agents (USEPA, 1994; RODRIGUES, 2001, BLANCO, LLASERA, 2016; ZHAO et al., 2018). Studies with exposure to tetracycline (TC) on the freshwater were investigated by determining a battery of parameters, including algal biomass, chlorophyll fluorescence index Fv / Fm, superoxide dismutase (SOD) and malonaldehyde (MDA), as demonstrated by Yang et al. (2013). Sun and Simsek (2017) studied dissolved organic nitrogen (DON) using bacteria and this algae, showed DON was bioavailable. Toxicity studies were developed by Zhao et al. (2018), and the results indicated that the increase in toxicity caused by mixtures of these herbicides could, at suitable concentrations, pose a significant hazard to this microalgae in the aquatic environment. Torgan (2002) points out as a probably cosmopolitan species, being a characteristic to be a good bioindicator.

b) Daphnia magna Straus, 1820

The *Daphnia magna* Straus, 1820, belongs to the Animalia Kingdom, Phylum Crustacea, Branchiopoda Class, Cladocera Order, Daphniidae Family, Daphnia Genus. The brachiopods class is a very diverse group of crustaceans, mainly freshwater, characterized by small or vestigial cephalic appendages (except, generally, the antennas), because they do not have any segment of the trunk fused to the head. They have other foliaceous appendages, being used in swimming or filtering food. Many species exhibit paternogenic reproduction and incubate their eggs. They are divided into four orders, which differ considerably as to the shape of the body. They are: Anostraca; Notostraca; Conchostraca and Cladocera. The cladocerans present the circular body, locomotor antennas, claw-shaped furcation and dorsal incubator camera inside the compressed carapace laterally (BARNNES et al., 1995; RUPPERT et al., 2005; MOORE, 2011). The organisms of the order Cladocera are mostly planktonic, having benthic species and also related to the coastal zone, presenting reduced size and limited locomotion capacity. They live almost exclusively in freshwater and are representative of the secondary production of aquatic ecosystems (BARNNES et al., 1995).

Within zooplanktonic organisms, the genus Daphnia occupies a central position in the trophic chains of the aquatic system, in small pools of water. In the ecological function, it acts as consumer of lower order, between the detritivores (bacteria) and primary producers as (algae). In the life cycle there are successive changes. D. magna reaches adulthood after 6 to 10 days, during which time it changes carapace 5 to 6 times. It has a reproductive cycle every 3 days, changing carapace after release of each litter (CARVALHO et al., 2000). Daphnia is sensitive to some chemistry compounds, they are sometimes used to test of water quality (HEGER et al., 2018). According Serra et al. (2019), this remove small particles, reduce microbial loads and polish nutrients in secondary effluents, their applicability in wastewater treatment plants might be complicated under the presence of some chemical compounds.

Daphnia magna is cited in 9,459 references on the ScienceDirect website, with 30 articles being 2019 and 832 being 2018 (research on January 10, 2019). Among the most significant studies, this species are the establishment of filtration, swimming and mortality under ammonium, nitrite, nitrate and phosphate (SERRA et al., 2019). A study of the effects of swimming and physiological responses on different levels of lambda-cyhalothrin has done for Bownik, Kowalczyk and Bańczerowski (2019). The effects of lomefloxacin on survival, growth and reproduction under simulated sunlight was done by Luo et al. (2018) and effects of aquatic toxicity of biofuel, by Heger et al. (2018). This specie is distributed worldwide in the northern hemisphere (GELAS, MEESTER, 2005). The USEPA. (1994) lists factors for choosing this test organism: a) easy laboratory manipulation; b) reproduce parthenogenetically, ensuring uniformity of genotypic sensitivity response in ecotoxicological evaluations; c) have a short life cycle.

c) Keratella tropica Apstein, 1907

The *Keratella tropica* Apstein, 1907, belongs to the Animalia Kingdom, Rotifera Phylum, Class Eurotatoria, Order Ploima, Family Brachionidae, Genus Keratella. The rotifers are multicellular, ranging in size from 50 to 2000 μm. It lives in the aquatic ecosystem in reservoirs, they are microscopic and zooplanktonic. In order to control the plutonic communities, the study of rotifers is relevant, since they are important components of these biocenosis. They present a rapid heterogenic reproduction, fact that places them in numerical and reproductive advantage when compared to the other zooplanktonic groups. These are the first metazooplanktons that have a significant impact on the phytoplankton pasture process. Rotifers are microscopic herbivores, common in freshwater plankton, which feed on unicellular algae and bacteria. In addition, rotifers influence various interactions within the microbial trophodynamic process, which occurs at different trophic levels (ARNDT, 1993). They are found in temperate regions. Their abundance reflects eutrophication.

Keratella tropica is cited in 36 references on the ScienceDirect website, with 1 articles being 2019 and 3 being 2018 (research on January 10, 2019). Used as a bioindicator in an environmental impact study in the Mediterranean Sea, in El-Mex Bay, by Ezz et al. (2014), it was found that the genus Keratella was present in the collections, with relative significance seen the frequency in the samples. In a study developed by Azerêdo et al. (2000), in two reservoirs, Potions and Camalaú, were selected for study, which are located in the Paraíba River basin, northeastern Brazil, were found total of 28 taxa, the most represented being Rotifers (13 rotifers, 11 cladocerans and 4 copepods). It is observed that rotifers were usually the most abundant group found in eutrophic environments, being bioindicators for such conditions. Among these, the Keratella were represented.

6. Score Attributed To Each Specie

The use of bioindicators to monitor environmental quality in reservoirs has been investigated through several studies (GOULART; CALLISTO, 2003; COSTA et al., 2009). In addition to pointing out that consumed vegetables raw and irrigated with contaminated water constitute risks to the health of consumers. Knowledge about species taxonomy or ecology and analytical precepts are of fundamental importance for testing hypotheses related to aquatic environmental pollution. As well as information and habitat assessments, hydrological investigations and knowledge of land use, such as irrigation and its technology, are useful for providing information about water quality.

In the comparative study between the focus species, it´s observed that there is a variation between the scores attributed to each of the characteristics (Table 2). In the two characteristics considered most relevant, with ponder 3, the scores ranged from 5 to 3, demonstrating that the three species are close to these aspects. On the other hand, in the characteristics considered with less relevance, with 1 being weighted, all the species had the lowest score in relation to the size, whereas in relation to being easily recognized by specialists, ranged from 1 to 5 the assigned score. In the intermediate aspects, with ponder 2, in two aspects all the species had maximum score, that is, in the attributes used in laboratory studies and to have low mobility.

Table 2. Weighted analysis of the criteria for bioindicators of the species S. capricornutum, D. magna and K. tropica

	S. capricornutum			*D. magna*			*K. tropica*		
Characteristics of the bioindicator	note	ponder	punctuation	note	ponder	punctuation	note	ponder	punctuation
taxonomically well defined	4	3	12	4	3	12	3	3	9
well-known ecological characters	4	3	15	5	3	15	3	3	6
use in laboratory studies	5	2	10	5	2	10	5	2	10
have a significant geographical distribution	5	2	10	5	2	10	2	2	4
be abundant	4	2	8	5	2	10	3	2	6
low genetic and ecological variability	5	2	10	5	2	10	3	2	6
long life cycle	1	2	2	1	2	2	1	2	2
have low mobility	5	2	10	5	2	10	5	2	10
easily recognized by experts	5	1	5	5	1	5	4	1	4
preferably of large size	1	1	1	1	1	1	1	1	1
Sum			84			85			58
Mean			8,4			8,5			5,8
Medium			10			10			6

As a final result, the analysis indicated *S. capricornutum* and *D. magna* as good to be bioindicators, whereas *K. tropica* did not score near the others, being considered a species with limitations to the bioindication process. This result is consistent with the number of articles on each species in bioindication studies.

The analysis of *S. capricornutum* as a good bioindicator is confirmed by the literature, through the Bassfeld (2001), Rodrigues (2001), Costa et al. (2009) Blanco, Llasera (2016); Zhao et al. (2018), among others. It should be noted that as test organisms, it can be used to assess acute toxicity to aquatic organisms (BASSFELD, 2001), as well as to evaluate the potential of human health risk (BRASIL, 2005). The highest scores were given by the characteristics (i) use in laboratory studies (USEPA, 1994; RODRIGUES, 2001); (iii) have a significant geographical distribution (TORORGAN, 2002); (iv) low genetic and ecological variability (ZHAO et al., 2018) and (v) have low mobility (BLANCO, LLASERA, 2016)

Cladocerans, such as *D. magna*, are among the most widely used organisms for bioassays. They are abundant in the aquatic environment and play important roles in the food chain (BARNNES et al., 1995). As a test organism, it may be used to evaluate the toxicity of the aquatic environment, as pointed out by Bassafeld (2001). Cladocerans occupy different trophic levels and, when grown in the laboratory, have a defined sensitivity to the reference substances. It is the most widely used species in the world for toxicity testing due to its sensitivity to toxic and easy-to-use laboratory (USEPA, 1994). The highest scores were given by the characteristics (i) well-known ecological characters (BARNNES et al., 1995; CARVALHO et al., 2000; RUPPERT et al., 2005; MOORE, 2011; SERRA et al. (2019); (ii) use in laboratory studies (USEPA, 1994); (iii) have a significant geographical distribution (GELAS, MEESTER, 2005); (iv) be abundant (GELAS, MEESTER, 2005; HEGER et al., 2018); (v) low genetic and ecological variability (RUPPERT et al., 2005; MOORE, 2011); (vi) have low mobility (BARNNES et al., 1995) and (vii) easily recognized by experts (LUO et al., 2018).

However, the *K. tropica*, despite having a defined system, did not obtain research success in abundant ecological information for the species. Therefore, the third species was not used as an ideal bioindicator. Information on the Ecotoxicology of organisms used as biomonitors of environmental quality can be used in the planning and management, in several locations, to prioritize problems of water quality. It is necessary to continually study these organisms as a way of enriching existing information and discover alternative remediation for problems with environmental impacts.

7. Conclusions

Bioindicators are an option to monitor wastewater from the production system for Environmental Engineering, which can minimize or eliminate impacts that can be generated to the environment. The present study showed that of the three species studied, *S. capricornutum*, *D. magna* and *K. tropica*, only the latter can not be used as an environmental bioindicator, due to the limitations presented. The species *S. capricornutum* and *D. magna* are bioindicators of environmental quality, important for the use of production engineering, allowing the identification of environmental changes that are harmful to humans.

It´s recommended that analytical work with species with bioindicator potential be developed to assist in the orientation of species both in the laboratory, in bioassays, and in field work, in biomonitoring and bioindication. The development of the use of species indicators of environmental quality may greatly help the maintenance of environmental quality, with the dissemination of knowledge to other researchers and to the community at large.

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