TECHNOLOGICAL OVERVIEW OF CONTAMINATION AND BIOREMEDIATION BY NECROCHORUME IN CEMETERIAL SOILS AND AQUIFERS

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ABSTRACT

Purpose: Aiming to map the scientific and technological production involving the contamination and bioremediation of this compound, a technological prospection study was conducted based on articles published in the last 20 years, in the Scopus and Web of Science databases.

Theoretical framework: Necrochorume is a liquid derived from human decomposition, with a high contaminating potential and presenting a serious health hazard.

Method/design/approach: The study was carried out using 5 keywords and their combinations, which were divided into 2 groups and treated using Microsoft Excel. For the first group, the combinations were used: “Necrochorume”, “necrochorume and contamination”, “cemeteries and contamination”, “cemetery leachate and contamination”. For the second group, we used: “Necrochorume and bioremediation”, “cemeteries and bioremediation” and “cemetery leachate and bioremediation”.

Results and conclusion: The keys with the most results were "cemeteries and contamination", with 74 results in the Scopus database and 76 in the Web of Science, where it was analyzed that, of the 74 articles found in Scopus, only 37 alluded to the necrochorume, and in the Web of Science, 59 articles addressed the subject of interest. The only bioremediation keyword combination that found results was “cemeteries and bioremediation”, with 4 articles in the Scopus database and no results in the Web of Science. The VosViewer program was used to survey the occurrences of the main keywords throughout the study period.

Research implications: As a main result, it was observed that there is a scarcity of publications related to its infection and its contaminating potential, as well as its bioremediation.

Originality/value: It is also highlighted, based on the studies found, the extreme need to develop techniques that enable the safe use of soils and aquifers contaminated by necrochorume, as well as preventing the occurrence of contamination by the compost.

Keywords: Biotreatment, Cemetery, Contamination, Necrochorume, Technological Prospecting.

PANORAMA TECNOLÓGICO DA CONTAMINAÇÃO E BIORREMEDIAÇÃO POR NECROCHORUME EM SOLOS E AQUÍFEROS CEMITERIAIS

RESUMO

Objetivo: Visando mapear a produção científica e tecnológica envolvendo a contaminação e a bioremedição desse composto, conduziu-se um estudo de prospecção tecnológica com base em artigos divulgados nos últimos 20 anos, nas bases Scopus e Web of Science.

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Referencial Teórico: O necrochorume é um líquido derivado da decomposição humana, com alto potencial contaminante e que apresenta um sério perigo à saúde.

Metodologia: O estudo foi realizado com a utilização de 5 palavras-chave e suas combinações, que foram divididas em 2 grupos e tratadas com uso do Microsoft Excel. Para o primeiro grupo, foram utilizadas as combinações: “Necrochorume”, “necrochorume and contamination”, “cemeteries and contamination”, “cemetery leachate and contamination”. Para o segundo grupo, utilizou-se: “Necrochorume and bioremediation”, “cemeteries and bioremediation” e “cemetery leachate and bioremediation”.

Resultados e discussão: A combinação de palavras-chave com mais resultados foi “cemeteries and contamination”, com 74 resultados na base Scopus e 76 na base Web of Science, onde constatou-se que, dos artigos encontrados na Scopus, apenas 37 faziam alusão ao necrochorume de fato, e 59 na Web of Science. A única combinação de palavras-chave referentes à biorremediação que encontrou resultados foi “cemeteries and bioremediation”, com 4 artigos na base Scopus e nenhum resultado na Web of Science. O programa VosViewer foi usado para realizar o levantamento das ocorrências das principais palavras-chave ao longo do período estudado.

Implicações da pesquisa: Como resultado principal, observou-se que há escassez de publicações relacionadas à sua infecção e seu potencial contaminante, bem como à sua biorremediação.

Originalidade/Valor: Destaca-se também, com base nos estudos encontrados, a extrema necessidade do desenvolvimento de técnicas que viabilizem o uso seguro de solos e aquíferos contaminados por necrochorume, bem como o impedimento da ocorrência de contaminação pelo composto.

Palavras-chave: Biotratamento, Cemitério, Contaminação, Necrochorume, Prospecção Tecnológica.

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1 INTRODUCTION

According to Resolution No. 335 of the National Council for the Environment (CONAMA), published on April 3, 2003, the decomposition of the human body releases a liquid called "product of coliquation", popularly known as necroslurry. The product has a viscous texture, a reddish-brown color, a strong odor and a high degree of pathogenicity. Its average density is 1.23 g/cm³ and it has a relationship between volume of compound produced and weight of the human body of 0.60L/kg (Aries, 2008).

Knowledge of the mobility of the liquid coming from human decomposition in the soil is fundamental for knowing which physical medium the contaminant is going to percolate to: soil or water. For this it is necessary to analyze not only the liquid, but also the type of soil where the cemetery is installed. The liquid derived from human decomposition has about 60% water, 30% mineral salts and 10% organic substances, such as bacteria and diamines, which are considered toxic, such as cadaverine and putrescine (Campos, 2007). These substances are the main ones related to the contamination caused by the compound, and may be responsible for the transmission of diseases like typhoid fever and hepatitis (Fineza, 2008).

Milk (2009), states that contamination by necroslurry occurs when it percolates the soil, and can reach the groundwater and aquifers. Rainwater infiltrates infected soils causing leaching of organic and inorganic chemicals, as well as pathogens such as viruses and bacteria responsible for the biodegradation of bodies (Betiatto, Souza, & Bini, 2015).

The process of urbanization, too growing, has generated the constitution of cities that have contradictions in providing adequate housing, since several families need to establish residence in areas subject to potential danger (Rocha, 2021). According to the IBGE (2010), in Brazil, about 15.6% of households use underground water for human consumption and for
meeting their needs, and, in general, people do not realize the extent of the problem about cemeteries (Marcomini, & Castro, 2010). According to Espíndula (2004), the results of studies warn of the need to promote systematic investigations, mainly in residential areas close to cemeteries, where there is water exploration through fountains and wells.

One way to minimize the impacts caused by necroslurry contamination is by performing bioremediation. The aim of this method is to induce or accelerate the natural processes of recycling compounds, including organic or inorganic compounds, using the capacity of microorganisms to degrade organic matter to degrade toxic organic compounds, both natural and synthetic (Dias, 2000).

As defined by Faria (2017), this technique is an expanding area of environmental biotechnology and can be defined as the application of biological agents and processes for the treatment of pollution and contamination. Mariano (2006), explains that bioremediation consists of removing pollutants from the environment in question or converting them into less harmful products, using communities of endogenous microorganisms from the infected environment. Moreira and Siqueira (2006), define the technique as a strategy or process that employs microorganisms or their enzymes to detoxify contaminants in the soil or in other environments.

The elaboration of a panorama that shows the contamination by necroslurry and possible bioremediation in soil and cemeterial aquifers will make it possible to identify the trends of research in the area and understand what the authors are discussing on the topic currently, contributing to identify the research gaps and enabling the continuity of research projects on the topic (Araujo, & Scafuto, 2020).

Therefore, considering the potential for contamination of cemeteries and the current pandemic situation, where several burials have occurred inappropriately, this research aims to identify the scientific and technological production involving necroslurry, as well as its contamination and its biotreatment.

2 THEORETICAL GROUNDS

Environmental problems from groundwater can occur through contamination by cemeteries, taking into account that in the projection of most of these necropolises geological and hydrogeological studies have not been carried out. As such, these plants pose a high risk of contamination by necroslurry. The location of cemeteries is usually located in places far from the urban center, but today it is possible to find cemeteries fully integrated with the urban mesh (Hirata, & Suhogusoff, 2004).

Some graves are located near the water table level (about four meters below ground level). These are the most damaging to underground aquifers, especially those with less than a year of installation. Causing a high consumption of oxygen, they generate an increase in the quantity of mineral salts, which raises the electrical conductivity of the water, leading to an increase in the concentration of ions such as bicarbonate, chloride, sodium and calcium. There is also an increase in iron, aluminum, lead and zinc (Macedo, 2004).

In São Paulo, Romanó (2005) identified the presence of the pathogens that cause polio and hepatitis in wells at depths from 40 to 60 meters, evidencing that the contamination can reach great depths and vast extent, implying the contamination of the whole region that is supplied with this water. For example, contamination by cemeteries may lead to changes in the physico-chemical and microbiological quality of water, due to the substances and microorganisms that come from the decomposition of corpses and even from possible agents that cause diseases that may even have killed the buried individual as a cause of death.
2.1 Cemeteries and necroslurry contamination

According to Santos, Silva, Chaves and Camponogara (2007), cemeteries are equivalent to landfills. The main difference is contained in the contaminating residue released by decomposition, which in this case occurs through the putrid dissolution of the bodies giving rise to a foul-smelling and grayish liquid, necroslurry (Silva, Souza, & Rocha, 2006).

Considering the characteristics of this compound, Üçisik and Rushbrook (1998) state that it is useful to examine the residues from cemetery runoff as a potential analogous to the fate of landfill leachates. The necroslurry, being slightly denser than the water, has an excellent mobility and dispersion, running through the aquifer to its impermeable layer, being carried in the direction of the subterranean flow, contaminating the whole region.

Water coming into contact with the compound can absorb microbiological contaminants such as heterotrophic bacteria, proteolytic bacteria, sulfite-reducing clostridia, enteroviruses and adenoviruses. There may also be an increase in oxygen consumption, due to biological decomposition and transformations, especially of compounds with nitrogen, phosphorus and sulfur (Cunha et al., 2008).

Some indicators are used to detect the alteration or contamination of underground aquifers by necroslurry, such as electrical conductivity, chlorides, nitrogen compounds (total and ammoniacal nitrogen), ammonia, nitrates and nitrites, biochemical oxygen demand (BOD) and dissolved oxygen (OD) (Cunha et al., 2008). In addition, bioindicators such as Streptococci, Salmonella, total coliforms, E. coli, sulfite-reducing clostridia such as Clostridium perfringens, and Pseudomonas aeruginosae, proteolytic bacteria (Espíndula, 2004) can be analyzed. Of these, Clostridium spp., E. coli, and enterobacteria are colonizers of human corpses and can represent large evidence of necrochorume contamination (Üçer isik, & Rushbrook, 1998).

Eneterium (2009), believes that water samples with low concentration of fecal pollution pathogens (Thermotolerant Colliforms), however, have a higher number of anaerobic bacteria, such as the sulfite-reducing clostridia (CSR), indicate probable cemeterial contamination.

In relation to bacteria of the genus Clostridium, there are gram-positive anaerobic bacilli, which can inhabit the human intestinal tract and warm-blooded animals (Carrillo, 1998). Such bacteria are pathogenic and can survive for long periods in soil and water longer than enteric pathogens even under unfavorable conditions (Pacheco, 1991)

2.2 Bio-remediation

According to Quintella, Mata e Lima, (2019), bioremediation can be defined as a technique with the aim of biological remediation, and this has been widely used in the reduction or elimination of the impacts generated by hydrocarbon contaminants of long chains and difficult to remove.

The main application of bioremediation is in matrices such as soil, fluids and various other examples of waste water. It can be applied in situ or ex situ (with use of bioremediators). When applied in-situ, the technique has a great advantage over sustainability, and can still have the financial factor as attractive (Zhang, Gendalanga, & Mahendra, 2017).

Furtado (1997) states that the goal of bioremediation technology in contaminated areas can be summarized as the resolution of problems through biological means, either on site, in-situ, or it can be ex-situ, characterized by the removal of soil for destruction/grounding or water for treatment. According to Santos (2008), it is unquestionable that the best option, both in technology, as in costs, and in efficiency, will always be in-situ remediation.

There are different forms of bio-remediation and each one will be applied depending on the technical analysis of the situation and the need that the problem in question presents, as well as the type of contaminant contained in the environment. (Bohrer, 2012). The success of
bioremediation depends on the application of the technique (*in-situ* or *ex-situ*), but it needs a certain control during the process. Berger, 2005.

The *in-situ* techniques have as their main characteristic the treatment of the material in the very place where it is found. In this way, there is no need to collect and transport it to another place, and there is an economy in the logistics of the process. Major in situ bioremediation techniques include natural attenuation, known as intrinsic or passive bioremediation. In this case, the recovery of the area occurs more slowly, and monitoring takes a long time; biostimulation, where the activity of living organisms is encouraged by the introduction of inorganic and organic nutrients into the area; landfarming, which consists of the insertion of oily residue with organic carbon concentrated on the surface of the contaminated soil to promote the biodegradation of the different oil constituents; phytoremediation, which has as its characteristic the action of stimulating the activity of small living beings responsible for degrading the pollutants, which are generally heavy metals, such as zinc, magnesium and copper (in mineral waste); and bioaugmentation, an option for areas with a high degree of deterioration, as the degradation power is optimized by increasing the population of specific organisms. This term is often also used as a synonym for bioremediation (Andrade, Augusto, & Jardim, 2010).

The technique carried out *ex-situ* requires that the material be taken to a different location for carrying out the treatment. It is usually the best choice in a scenario with a high potential for spreading contamination. Among the different techniques, one can highlight composting, where the soil is removed from its original location and placed in batteries. In this case, the organisms inserted/present in it will be responsible for metabolizing the pollutants, transforming them into H₂O water, organic matter and carbon gas (CO₂); and the bioreactors, a process that occurs after sieving the soil, which is then mixed with water in a normally vertical rector (tanks). A sludge is formed with about 10 to 40% of particles in suspension. It is therefore more suitable for soils with fine particles (Andrade et al., 2010).

### 2.3 Existing legislation on cemeteries

On May 28, 2003, CONAMA Resolution No. 335 was passed, which provides for the environmental licensing of cemeteries. It lays down minimum criteria for the establishment of future cemeteries to protect groundwater from infiltration by necroslurry, and from this, horizontal and vertical cemeteries are required to undergo the environmental permit procedure.

Resolution CONAMA nº 368, of March 28, 2006, amends some of the provisions of the previous resolution, prohibiting, for example, the installation of necropolises in areas of permanent preservation (APP) or in others that may generate the deforestation of the Atlantic Rain Forest in areas of regeneration. Furthermore, it is forbidden to install cemeteries on land where there are caves, sinks or underground rivers and in areas where the water table, measured at the end of the rainy season, is less than 1.5 meters from the base of the graves.

In the State of Rio de Janeiro, on May 7, 2020, the State Environmental Institute (INEA) issued Technical Note No. 1, which provides guidance for environmental licensing of cemeteries in the State of Rio de Janeiro, in order to cater for events arising from unforeseeable circumstances and/or force majeure, such as the advancement of the COVID-19 pandemic.

### 3 METHODOLOGY

Bibliometry is a quantitative, statistical, and mathematical method used to analyze and construct indicators about the behavior and evolution of the scientific field, focusing on disciplines, areas, organizations, or countries. The data collection is done on platforms of articles database for academic newspapers and magazines (Soares, Carneiro, Calmon, & Castro, 2016).
The literature review is used as a guarantee of reliability and technical quality of a research, ensuring that the study has a scientific basis. The use of revision methodologies and software as support tools to perform the analysis of scientific progress in a given area has been increasingly applied, as they increase the chances of analyzing the object of study with greater precision (Barbosa, Lira, Neto, Santos L., & Santos I., 2019). Therefore, this article also presents potential guidelines for future research.

The mapping of the articles was carried out using the Scopus and Web of Science databases. The keywords used in the research were divided into three groups: one related to necroslurry, another to contamination in cemeteries, and, finally, one referring to the bioremediation of the contaminated environment. The keywords were searched in the "title", "keyword" and/or "summary". The articles published in Spanish, English and Portuguese were considered for study.

For both groups, qualitative analyzes were carried out, looking for which keywords would be used to obtain more assertive results. To do so, the search was made with synonyms of the main words (necroslurry, bioremediation and contamination), as well as possible combinations. Among the terms assessed were: ‘necroslurry’, ‘necroslurry and contamination’, ‘cemeteries and contamination’, ‘cemeteries and contamination’. For the second group, the following combinations were used: "Necrochorume and bioremediation", "cemeteries and bioremediation" and "cemetry leachate and bioremediation".

The data survey for the implementation of that analysis was carried out between 1 and 25 August 2021. The materials obtained were treated using Microsoft Excel (version 16.0.6742.2048), which was used with the purpose of organizing the data obtained, aiming to facilitate the analysis of the studies found, as well as the exclusion of the articles in duplicity.

The VosViewer program (version 1.6.17.0) was used to survey the main keywords and their occurrences in a period of twenty years (2001 to 2021), as were the main authors involved in the latest publications on the theme.

The articles used in the studies had, as inclusion criteria: they were published between 2001 and 2021; they were available in Spanish, English or Portuguese and; they contain information on factors associated with soil contamination by necroslurry.

As exclusion criteria: articles with topics that do not address the subject proposed in this bibliographic review were excluded, outside the limited publication period and articles with repeated or insufficient data.

4 RESULTS AND DISCUSSION

This step presents the survey performed from the keyword sets that were predefined.

4.1 Prospective survey of articles related to necroslurry contamination

It was noted that the term "necroslurry" is used in Brazilian and English literature. From this, the word was used to find both results. In Table 1, the results of the research concerning the scientific articles can be seen with the keywords related to the term, as well as the innate contamination caused by it.
Table 1- Survey of articles related to necroslurry contamination.

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Scopus</th>
<th>Web of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necroslurry</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>‘Necroslurry and contamination’</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>‘Cemeteries and contamination’</td>
<td>74</td>
<td>76</td>
</tr>
<tr>
<td>“Cemetery leachate and contamination”</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2021).

One can perceive that there is a lack of academic research about the question. Even with the varied use of search terms, the results found are scarce on both platforms.

In the analyzes of the articles on necroslurry, it was found that 4 of the 8 scientific studies found were in duplicity. The keywords with the highest return were "cemeteries and contamination". Of the 74 articles found in the Scopus base, only 37 made an allusion to contamination by necroslurry. Other studies found in this search made reference to soils contaminated by various compounds, such as heavy metals, hydrocarbons, industrial waste and medicines. In the Web of Science database, though, of the 76 publications, 59 did in fact deal with the contamination of cemeteries. The other combinations of keywords used presented few results, but with greater precision in relation to the discussion held and the topic of interest.

Silva and Malagutti (2009), used electrical images in the delineation of areas potentially contaminated by necroslurry in a case study at the municipal cemetery of Vila Rezende, Piracicaba-SP. The results indicate strong signs of contamination, since the contamination plumes found at the site have the same underground flow as the aquifers there. The location of the conductive abnormalities and the likely contamination plumes have shown that the contamination probably exceeded the location of the cemetery site and is directly linked to the depth of the water floor and burial time.

Xavier, Amorim, Valentini, and Faria, (2015), conducted a diagnosis of the current situation of the cemeteries Parque Bom Jesus de Cuiabá and São Gonçalo, in Cuiabá-MT, with the objective of analyzing the number of bodies and the local construction with a perspective of environmental management. After the study, it became evident that the contamination of the cemeteries was not significant from the point of view of the number of burials, but for a validation of this claim would require constant monitoring of the ground water and soil of the sites.

Albuquerque, Cerqueira and de Albuquerque, (2017), conducted a study with the aim of identifying and evaluating the environmental impacts present in the municipal cemetery of Queimadas- PB. The cemetery was found not to comply with the current legislation, presenting a high risk to public health, with the possibility of contamination by necroslurry and microorganisms transported by the runoff.

Antonio et al., (2018), analyzed variations in the chemical properties of soil, which were monitored during the cadaveric decomposition of pig carcasses in a tropical forest area in order to recognize patterns and assess their usability by criminal forensics. Different variations were found according to the decomposition phases observed and also in the way the carcasses were deposited in the study environment (above or below the ground), evidencing the possibility of using these variations in the development of models for the forecast of post-mortem intervals lasting up to 67 days.

VosViewer was also used at this stage, based on the articles found in the research for the keywords "necrochorume" and "cemeteries and contamination" (Figure 1). The software shows the occurrence of a keyword, using the density of the circle that represents the same as an analogy for the volume of publications.
In the research referring to necroslurry, it was possible to analyze that the studies focusing on the area occurred mainly between 2012 and 2017, being the most recent publications aimed at the period of decomposition (post-mortem interval) and the cadaveric soil (cadaveric soil). In Table 2, one can see the keywords with the highest occurrence, as well as the year in which there were more publications on the theme.

**Table 2 - Occurrence of keywords referring to the study of necrochorume.**

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Occurrence No</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necroslurry</td>
<td>5</td>
<td>2012</td>
</tr>
<tr>
<td>Cemetery</td>
<td>2</td>
<td>2009</td>
</tr>
<tr>
<td>Post-mortem interval</td>
<td>1</td>
<td>2018</td>
</tr>
<tr>
<td>Cadaveric soil</td>
<td>1</td>
<td>2018</td>
</tr>
<tr>
<td>Necropolis</td>
<td>1</td>
<td>2017</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors (2021).

In relation to the studies of contamination by cemeteries, as can be seen in the following image (Figure 2), the researches referring to groundwater (groundwater) were highlighted, which were published mainly in the period between 2013 and 2014. A focus on this topic may be justified because the main concerns related to necroslurry contamination are intrinsically linked to infection of local aquifers.
Figure 2: Keywords associated with articles on contamination by cemeteries and their distribution over 20 years. 
**Source:** Prepared by the authors (2021).

The keywords found can also be analyzed separately, and can then visualize the number of times the term appears in the published studies, as well as the year in which there were most publications.

The period with more studies on the theme took place in 2014, where 26 occurrences of the keyword *cemetery* were found. Also in 2014, terms referring to the study of aquifers (*groundwater* and *water contamination*) were found. In 2016, there were 4 publications that aim to study necropolis (*necropoliis*).

After careful analysis of the articles found during the research, it was found that Brazil, together with the United States, is the country that most carried out studies and publications that relate necroslurry to contamination of the cemeterial terrain (Table 4).

<table>
<thead>
<tr>
<th>Countries (Scopus)</th>
<th>No. of publications</th>
<th>Countries (Web of Science)</th>
<th>No. of publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>19</td>
<td>US</td>
<td>14</td>
</tr>
<tr>
<td>US</td>
<td>12</td>
<td>Brazil</td>
<td>11</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>7</td>
<td>Germany</td>
<td>9</td>
</tr>
<tr>
<td>Canada</td>
<td>6</td>
<td>England</td>
<td>7</td>
</tr>
<tr>
<td>South Africa</td>
<td>6</td>
<td>Denmark</td>
<td>6</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors (2021).

It can be concluded, with the use of the computer software VosViewer, that the author with more articles related to the theme is of Brazilian origin. Five publications were found that had as their main author the researcher Silva, R. These data can be visualized in Chart 1.
In their most recent study, Silva R., Malagutti and Moreira, (2009), presented the results of the methods of electrical resistivity in the delineation of the area that were potentially contaminated by liquefaction products, in the municipal cemetery of Vila Rezende, Piracicaba. The results indicate a water table depth between 3.1 and 5.1 m, with two groundwater directional flows, one for SW and one for SE. Due to the contamination plumes, which have the same groundwater flow direction, as well as the conductive anomalies observed in the geoelectric sections, the suspicions of contamination in the area have been confirmed.

Martim, Neto e Silva, (2016), studied, together, the structural characteristics of the tombs and the architecture of the Garden Municipal Cemetery of Maringá, located in the State of Paraná, Brazil. They also published, in the same period, a geological report for the horizontal municipal cemetery of Mandaguari, Brazil, analyzing all the geological characteristics of the region where this enterprise was installed.

Researchers Silva et. al., (2017), conducted a study that determined the natural vulnerability to groundwater contamination in the vicinity of the Municipal Cemetery of Caçapava do Sul-RS, a municipality located in the central region of the State of Rio Grande do Sul. This municipality has a large vulnerable area that covers, besides the surrounding of the cemetery, the city center, because besides being on a fractured aquifer, which has semi-outcropping groundwater levels to outcroppings, the cemetery lacks a structure that prevents possible contamination.

Da Silva, Silva, Leão and Figueiredo, (2018), had as their objective the study to determine the permeability and chemical quality to compare with Resolutions CONAMA n° 335/03 and n° 420/09 (It provides criteria and guiding values of soil quality regarding the presence of chemical substances and establishes guidelines for the environmental management of areas contaminated by these substances as a result of anthropic activities), and to determine the coefficient of infiltration in the soil occupied by the cemetery in the city of Caçapava, in Rio Grande do Sul. The results showed that only cadmium exceeded the levels permitted by the legislation and indicated permeability between $5.87 \times 10^{-6}$ cm.s$^{-1}$ and $1.94 \times 10^{-3}$ cm$^{-1}$, exceeding the limits of the legislation.
Scholars Abia, Alisoltani, Upump-Jaswa and Dippenaar, (2019), used high-yield sequencing techniques to determine bacterial composition and its associated functional profiles in cemetery soil samples collected on and below the cemetery in two South African cemeteries (Maitland Cemetery in Cape Town and Fontein Street Cemetery in Middelburg), to assess the potential threat to the health of neighboring populations through groundwater contamination. The group found that cemeteries may be potential sources of microbial pollution in groundwater, especially in areas with shallow water tables such as Maitland.

Egbimhanlu et. al. (2020) aimed in their study to identify the potential risks of groundwater and sources located around burial sites, and to provide data on the impact of such toxins on water quality and the environment. The results showed that most samples had high salinity (5.5 ± 1.9), slightly acidic pH values (5.23 ± 0.94) and significantly high lead concentrations (0.63 ± 0.27) between the measured parameters. This acidity makes the water more vulnerable to metals dissolving in it. It was not possible to clarify whether the sources of the salts are from the soil itself and/or compounds used to prepare the corpse for burial or the metal accessories and paints used in finishing the coffins, which contribute to lead contamination.

4.2 Prospective survey of articles related to bioremediation of necroslurry contamination

Only the Scopus database returned during the search. Four articles were found, but both had no direct relationship with necroslurry. None of the results found showed Brazilian researchers as authors. The publications of these have taken place over the last four years, which underlines the recent interest of the scientists in this little explored area.

In the article published by Zamani, Montoya and Gabr, (2017), a study was done aiming to provide an overview of microbial precipitation with carbonate use as promising technology for bioremediation. The microbially induced calcium carbonate (MICP) precipitation technology for conservation, considering its purpose, was considered adequate, but studies are still needed to make the medium economically viable.

Researchers Schelkle et. al., (2018), described a two-step approach, aimed at reducing the spore load of *B. anthracis* in soil during laboratory testing, by which germinants and nematodes of *Caenorhabditis elegans* are applied simultaneously. The results of laboratory studies suggest that the combined use of nematodes and germinants could represent a promising approach to remediating soil contaminated by the *B. anthracis* spore.

Burger, Gochfeld and Jeitner, (2019), highlighted the importance of buffer land to determine the risk to ecological resources in contaminated sites, in a case study for Sote Hanford, from the department of energy in Washington, USA.

Already Abdel-Azeem, Held, Richards, Davis and Blanchette, (2019), performed an analysis of the ancient archeological wood in the Middle Cemetery in Abdos, Egypt, with the aim of characterizing the biodegradation of the material in question. The results provide important information about the current condition of the wood and give insights into the identity of the fungi in wood and soils on the site.

VosViewer was used to evaluate the relationship of keywords with the articles found (Figure 3), as well as their occurrence over the last twenty years.
Cyanobacteria and lichens do not have a large body of research, but represent the latest findings in bioremediation research. Publications on bacteria and fungi appear more frequently, but their publications mostly occurred until 2016, data indicated in table 3.

Table 3- Occurrence of keywords referring to the study of bioremediation of necroslurry contamination.

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Occurrence No</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>19</td>
<td>2014</td>
</tr>
<tr>
<td>Bioremediation</td>
<td>15</td>
<td>2018</td>
</tr>
<tr>
<td>Fungi</td>
<td>14</td>
<td>2016</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>4.</td>
<td>2018</td>
</tr>
<tr>
<td>Lichen</td>
<td>4.</td>
<td>2017</td>
</tr>
</tbody>
</table>

It was found that research on bioremediation has gained greater notoriety since 2018, indicating that the technology in question has potential, but more studies are needed for greater knowledge and applicability of the technique.

5 FINAL CONSIDERATIONS

Considering the current pandemic situation in which several burials occurred in inappropriate places and in makeshift ditches, the so-called "shallow graves", together with the potential contaminant of the necroslurry, it is evident the need for research in quantifying and analyzing the study of the impacts caused by this, as well as its possible biotreatments.

In spite of Brazil having a wide collection of studies about the theme, there are found, in the country, several cases of unlicensed cemeteries. Resolution CONAMA n°335/2003, responsible for regulating the essential aspects relating to the environmental permit process for
cemeteries, was recently implemented compared to the period of existence of the necropolises. As a result, there are several places throughout the Brazilian territory where burials occur irregularly, offering risk to public health. Therefore, it was found necessary to comply with the current legislation for the minimally sustainable functioning of cemeteries, as well as the more in-depth study of the methods available for bioremediation aiming at the decontamination of the local soil and the water table. An alternative to traditional burials is also necessary, as the land occupied for cemetery uses is limited and there will be no more room for such practice in the future.

With the carrying out of this research, the scarcity of studies referring to the contamination coming from necroslurry became evident. When we analyze the bioremediation of the compound, it is noted that the results lack even more, indicating that there is still no significant interest in the theme, highly relevant and with great potential for negative socio-environmental impacts. The study carried out is the start of an in-depth research on the theme. The objective is to continue the analysis with the carrying out of other more detailed bibliometric surveys, considering only contamination by cemeteries, fungal treatments and phytoremediation. With the study, it will be possible to identify the research trends in the area and understand what the authors are discussing about the theme currently, contributing to identify the research gaps and enabling the continuity of the research project on the theme.

The conclusion is then drawn from the lack of resources and the existing potential for new studies on the latent contamination by necroslurry, its possible bio-remedies, and even sustainable alternatives for the current burials.

REFERENCES


