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Phytoremediation technique on the rehabilitation of contaminated areas and the application of *Zantedeschia aethiopica* (L.) in this process: a narrative review

A técnica de fitorremediação na reabilitação de áreas contaminadas e a aplicação da *Zantedeschia aethiopica* (L.) nesse processo: uma revisão narrativa

La técnica de fitorremediación en la rehabilitación de áreas contaminadas y la aplicación de *Zantedeschia aethiopica* (L.) en este proceso: una revisión narrativa

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Abstract
Phytoremediation is an innovative, efficient and eco-friendly technique for the treatment of contaminated areas. This method consists in the use of plant species for extraction, degradation, containment or immobilization of pollutants/xenobiotics. Recently, ornamental plants have been gaining spotlight in remediation studies, precisely because of their aesthetic value and their ability to develop in environments contaminated with heavy metals, textile dyes and pesticides. An important ornamental species for these studies is *Zantedeschia aethiopica* (L.) Spreng. popularly known as calla lily. The objective of this narrative review is to report up-to-date studies on the use of phytoremediation to clean up contaminated areas and highlight the use of ornamental plants of the genus *Zantedeschia* in this process, especially the species *Zantedeschia aethiopica*. For this, articles indexed between 2015 and 2022, written in Portuguese and English, were selected and the searches were carried out through three electronic databases, Google Scholar, Web of Science and SciELO. The papers were selected through the association between the words *Zantedeschia* spp., *Zantedeschia aethiopica*, ornamental plants and phytoremediation with several other related topics. This review aims to emphasize the gaps found in phytoremediation of contaminated environments studies, specially mediated by *Z. aethiopica*, indicating paths for further research.
Keywords: Calla lily; Remediation; Soil; Sustainability; Water.

Resumo
A fitorremediação é uma técnica inovadora, eficiente e ecologicamente correta para o tratamento de áreas contaminadas. Este método consiste na utilização de espécies vegetais para extração, degradação, contenção ou imobilização de poluentes/xenobióticos. Recentemente, as plantas ornamentais vêm ganhando espaço nos estudos de remediação, justamente por seu valor estético e por sua capacidade de se desenvolver em ambientes contaminados com metais pesados, corantes têxteis e agrotóxicos. Uma espécie ornamental importante para esses estudos é a *Zantedeschia aethiopica* (L.) Spreng. popularmente conhecido como copo de leite. O objetivo desta revisão narrativa é reportar estudos atuais sobre a fitorremediação de áreas contaminadas e enfatizar o uso de plantas ornamentais do gênero *Zantedeschia* nesse processo, em especial a espécie *Zantedeschia aethiopica*. Para isso, foram selecionados artigos indexados entre 2015 e 2022, escritos em português e inglês e as buscas foram feitas por meio de três bases de dados eletrônicas, Google Scholar, Web of Science e SciELO. Os trabalhos foram selecionados por meio da associação entre as palavras *Zantedeschia* spp., *Zantedeschia aethiopica*, plantas ornamentais e fitorremediação com diversos outros temas relacionados. Esta revisão tem o intuito de enfatizar as lacunas encontradas nos estudos de fitorremediação de ambientes contaminados mediadas pela *Z. aethiopica*, indicando caminhos para novas pesquisas.
Palavras-chave: Copo de leite; Remediação; Solo; Sustentabilidade; Água.

Resumen

La fitorremediación es una técnica innovadora, eficiente y ecológicamente correcta para el tratamiento de áreas contaminadas. Este método consiste en utilizar especies vegetales para la extracción, degradación, contención o inmovilización de contaminantes/xenobióticos. Recientemente, las plantas ornamentales han ido ganando terreno en los estudios de remediación, precisamente por su valor estético y su capacidad para desarrollarse en ambientes contaminados con metales pesados, tintes textiles y pesticidas. Una especie ornamental importante para estos estudios es *Zantedeschia aethiopica* (L.) Spreng. conocido popularmente como vaso de leche. El objetivo de esta revisión narrativa es reportar estudios actuales sobre el uso de fitorremediación para limpiar áreas contaminadas y resaltar el uso de plantas ornamentales del género *Zantedeschia* en este proceso, especialmente la especie *Zantedeschia aethiopica*. Para eso, se seleccionaron artículos indexados entre 2015 y 2022, escritos en portugués e inglés y las búsquedas se realizaron a través de tres bases de datos electrónicas, Google Scholar, Web of Science y SciELO. Los trabajos fueron seleccionados a través de la asociación entre las palabras *Zantedeschia* spp., *Zantedeschia aethiopica*, plantas ornamentales y fitorremediación con varios otros temas relacionados. Esta revisión tiene como objetivo enfatizar los vacíos encontrados en los estudios de fitorremediación de ambientes contaminados mediados por *Z. aethiopica*, indicando caminos para futuras investigaciones.

Palabras clave: Vaso-de-leche; Remediación; Terrestre; Sustentabilidad; Agua.

1. Introduction

In order to meet human needs, industries began to consume more natural resources, which consequently increased the inappropriate disposal of toxic waste, such as heavy metals. One of the alternatives for the recovery of contaminated areas with these metals and other xenobiotics is phytoremediation, a bioremediation technique that consists of the extraction, degradation, containment or immobilization of pollutants in contaminated environments, through plant metabolism, and can be associated with the local microbiota (Pinto et al., 2015).

The determination of the bioremediation strategy is defined by the contaminant's nature; organic compounds are processed by plants through phytoextraction, rhizofiltration, phytostabilization and phytovolatilization, whereas inorganic compounds are processed mostly through phytostabilization, phytostimulation and phytotransformation (Glick, 2003; Muthusaravanan et al., 2018; Steliga & Kluk, 2020). The variety of plants that can be used in this technique is vast (e.g., macrophytes, trees, agricultural crops, grasses and ornamental species), besides that, this strategy is considered simple, with reduced costs and environmentally friendly, without causing any negative impacts on the soil (Kaushal et al., 2021).

Although the productive sector of flowers and ornamental plants has been in decline in recent years (Beckmann-Cavalcante, 2021), this exuberant class of plant is highlighted in phytoremediation for having a fast life cycle (which facilitates monitoring) and for improving the aesthetic quality of the environment, encouraging tourism in the region (Rocha et al., 2022).

Among the various ornamental plants used in the decontamination of environments, the genus *Zantedeschia* spp. is highlighted in phytoremediation studies. This commercial interest genus is composed of plants native to the African continent, and *Zantedeschia aethiopica* (L.) Spreng., popularly known as "calla lily", is the most popular species within this group (Resnik et al., 2021).

Considering the above, the objective of this review is to report studies on the use of phytoremediation to clean up contaminated areas and highlight the use of ornamental plants of the genus *Zantedeschia* spp., especially the species *Zantedeschia aethiopica*.

2. Methodology

This literature review has a narrative perspective based on Correia e Mesquita (2014). This review consists of a critical analysis of the phytoremediation process, focusing on the use of *Zantedeschia aethiopica* for treatment of contaminated soil, aiming to provide up-to-date knowledge about how this species is being used in this remediation method. For the elaboration of this review, papers indexed between 2015 and 2022, in Portuguese and English, were prioritized, however quantitative research was not used in this methodology. For conceptual rescues, we also selected articles from previous years.

Searches were carried out in three electronic databases, Google Scholar (https://scholar.google.com.br/), Web of Science (https://www.webofscience.com) e Scientific Electronic Library Online (SciELO) (https://scielo.org/en/). There were no specific criteria to filter the papers, articles were selected through the association between the words *Zantedeschia* spp., *Zantedeschia aethiopica*, ornamental plants and phytoremediation (phytoremediation), with the words contaminated soil, contaminated water, heavy metals, copper (Cu), lead (Pb), cadmium (Cd) and chromium (Cr), in both Portuguese and English.

3. Results and discussion

3.1 Phytoremediation

Phytoremediation is a form of alternative treatment for extraction, degradation, containment or immobilization of pollutants in contaminated environments (terrestrial or aquatic), in order to recover them in whole or in part (Pinto et al., 2015). In the soil, this recovery is promoted by increasing the amount of organic carbon present, increasing its porosity and infiltration capacity (Merkl et al., 2006). Contaminants can be heavy metals, inorganic substances or organic substances derived from petroleum. In Brazil, several studies have been carried out to treat soils contaminated with herbicides through this strategy (Galon et al., 2017; Ferreira et al., 2021; Vasconcelo et al., 2020) and, the diversity of plants that can be used for phytoremediation is wide, ranging from ornamental specimens, macrophytes, woody trees, agricultural crops and grasses (Kaushal et al., 2021).

The phytoremediation process depends on the nature of the contaminant. Heavy metals and inorganic compounds are processed by plant metabolism, through the mechanisms of phytoextraction, rhizofiltration, phytostabilization and phytovolatilization (Fig. 1). The contaminants are removed from the soil through absorption by the roots and aerial vegetative organs and, later, incorporated into the cells in both roots and shoots (phytoextraction); absorbed and accumulated in root tissues (rhizofiltration); stabilized and has its mobility reduced in the root area (phytostabilization); or released into the atmosphere after being degraded (phytovolatilization/phytoevaporation), this mechanism includes mainly volatile contaminants that contain mercury (Hg) or arsenic (As), this mechanism occurs through the leaves. For organic compounds, phytoremediation occurs through phytostabilization, but also through the processes of phytostimulation and phytotransformation (Muthusaravanan et al., 2018; Steliga & Kluk, 2020).

Phytotransformation or phytodegradation is described as the absorption of organic contaminants by plants, followed by its degradation through enzymes or cofactors and can occur in both roots or shoots. Phytostimulation occurs in the rhizosphere (place in the soil where the roots and microorganisms are arranged), and increases the level of biodegradation. It's a biological transformation of the contaminants through a symbiotic relationship between plants and the microbiota. Usually, plants that have the potential to degrade organic molecules in the rhizosphere have long fibrous roots, which increase the contact surface, like grasses. (Glick, 2003; Khan, 2005; Muthusaravanan et al., 2018; Steliga & Kluk, 2020).

Rhizodegradation consists in the interaction of the plant root with the soil microbiota. The plant releases amino acids and carbohydrates into the soil through the root, which are used by microorganisms (rhizobacteria) in their aerobic metabolism as a source of oxygen (Ashraf et al., 2019). Among the rhizospheric bacteria with remediation potential, *Bacillus thuringiensis*, *Bacillus pumilus* and *Rhodococcus hoagii* stand out (Viesser et al., 2020). Mycorrhizas also play an essential role in the rhizosphere microflora, aiding in the degradation processes of contaminants (Ashraf et al., 2019) and increasing the plants tolerance of contaminated soils (Karimi et al., 2018).

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Figure 1 - Processes that contemplate phytoremediation.

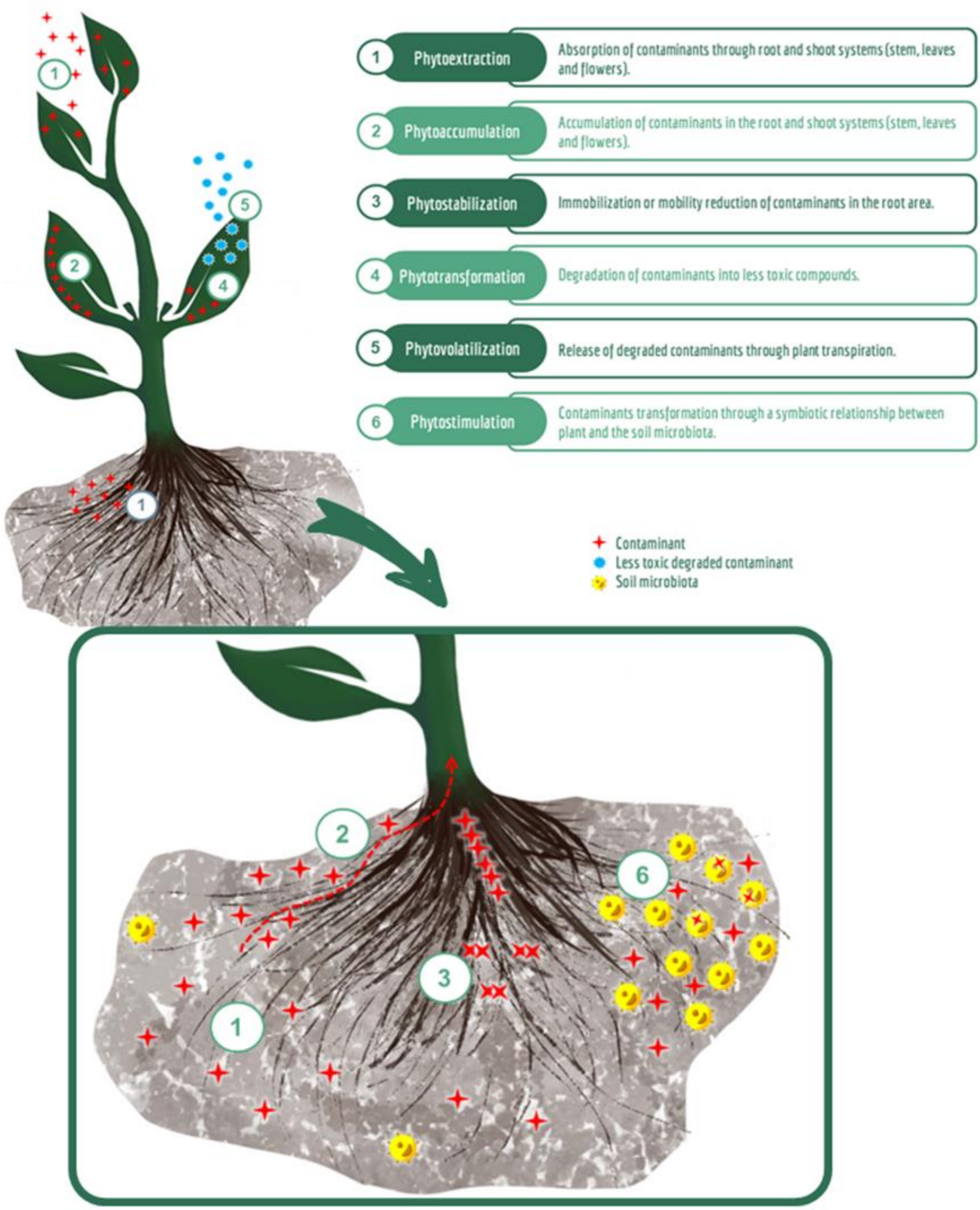

Illustration made by the author and adapted from the studies of Muthusaravanan et al. (2018).

Even though it is a slow strategy of remediation, phytoremediation is highlighted for preserving the soil, depending solely on solar energy to maintain photosynthetic processes, plants can reach adequate biomass at high levels of soil contaminants with low maintenance costs (Glick, 2003). Besides that, this technique can effectively remove organic pollutants and heavy metals from the environment without producing byproducts (Kanwar et al., 2020).

Although advantageous, the use of this technique is limited due to the sensitivity of some plant species to certain contaminants, such as polycyclic aromatic hydrocarbons (PAH's), which limit plant metabolism and interfere with its growth. Thus, it is essential to associate the cultivation of plants with phytoremediation potential to soil bacteria and fungi (mycorrhizae). This symbiotic relationship favors not only plant growth, but also its accumulation of biomass, increases its survival, reduces the dry weight when compared to fresh weight and also effectively promotes the removal of PAH's (Glick, 2003).

In terrestrial environments, some requirements must be understood before the assertive choice of plant species to mediate remediation. The chosen plant must: have accelerated growth, tolerance to pollution, rapid biomass production, high capacity to absorb nutrients, high ecological competitiveness, have a high rate of translocation, accumulate large amounts of reserve substances, be adaptable to climate and soil, present high transpiration capacity and be easily acquired (Silva et al., 2019; Quedinho, 2021).

The effectiveness of this technique depends on several factors, including the type and properties of the contaminant (as mentioned before), the plant specimen and environmental conditions, among which the type and size of the population of microorganisms present in the rhizosphere prevail. Before applying this strategy, it is necessary to verify its viability. It is first necessary to understand if the contaminated site is viable for the growth of plants, but not only that, it is essential to evaluate specimens that can tolerate the contaminant. An example of this is contamination by hydrocarbons, where the phytotoxicity index of Total Petroleum Hydrocarbons (TPH) present in the soil can make phytoremediation unfeasible as an immediate alternative for treatment, in these cases, before applying this technique it is recommended to remove the layer of volatile compounds through air sparging, a strategy that promotes the volatilization of the contaminant through the mechanical aeration of the soil (Collins, 2007; Odoh et al., 2019; Steliga & Kluk, 2020).

The tolerance of plants to contaminants is determined through their defense mechanism, which can be enzymatic or non-enzymatic, reducing the oxidative stress promoted by contact with the xenobiotic. The phytotoxicity of heavy metals is verified by the physiological, histological and chemical changes they induce in plants. Among them, alterations in the permeability of the cell membrane, damages in the functionality of the photosynthetic apparatus and excessive production of reactive oxygen species (ROS), which can promote irreversible oxidations in the DNA and RNA (Verma & Dubey, 2003; Steliga & Kluk, 2020).

In aquatic environments, remediation is promoted through macrophytes, floating plants found mainly in lentic environments, such as swamps, and acting in the removal of pollutants through roots or leaves that remain submerged and can accumulate 100,000 times the amount of heavy metals present in water (compared to its biomass). The presence of these plants in contaminated environments indicates their resistance and possible use for remediation of the area. The primary way that aquatic plants remove heavy metals from the water is through phytostabilization, which in turn can be carried out in both groundwater and surface water (Kanwar et al., 2020)

In order for a macrophyte species to be used in this strategy in an economically viable way, some criteria must be met: (1) the species must have rapid growth; (2) have a high biomass content; (3) have extensive root systems; (4) be easy to handle and prune; and (5) tolerate certain concentrations of trace metals in the vegetable portions to be removed. Some of the species that show high efficiency in the extraction of heavy metals are *Pistia stratiotes* L., *Eichronia crassipes*, *Azolla pinnata* e *Spirodela polyrrhiza* (Miretzky, 2004; Yang et al., 2005; Pinto et al., 2015; Muthusaravanan et al., 2018; Mendonça et al., 2019; Nazir et al., 2020).

The treatment of water contaminated with industrial waste can be carried out through constructed wetlands (CW). These are ingenious systems designed to establish a controlled environment for phytoremediation, mediated mainly by aquatic macrophytes. These systems rely on the association between filter material, macrophytes and microbiota, and are classified according to the type of flow, corresponding to wetlands built with vertical flow (VF CWs) and horizontal flow (HF CWs) (Vymazal, 2010). The author also points out the use of ornamental species *Zantedeschia aethiopica*, *Strelitzia reginae*, *Anthurium andraeanum* and *Agapanthus africanus* in wetlands.

The effectiveness of phytoremediation can be evidenced by associating it with other strategies. Using *Festuca arundinacea* Schreb and associating it with basic bioremediation techniques through fertilizers that stimulate the microbial flora of the soil, Steliga & Kluk (2020) proved the potential of this plant in the biodegradation of hydrocarbons derived from petroleum. Furthermore, the authors found that *F. arundinacea* was effective in the phytostabilization of other heavy metals such as cadmium (Cd), nickel (Ni) and lead (Pb), these metals were retained in the roots and their transport to the shoot system was interrupted.

3.2 Ornamental plants in phytoremediation

Ornamental plants are highlighted for their colors, fragrances, textures, shapes, attractive patterns and are widely used in the decoration and landscaping of internal and external spaces. The use of these plants by men for decorative purposes precedes modern society, especially exotic plants (not native to the region) (Heiden et al., 2006; Vera-Puerto et al, 2021). In Brazil, the productive sector of flowers and ornamental plants has consolidated itself as relevant and growing within agribusiness, especially aimed at supplying the domestic market (Junqueira & Peetz, 2014). From 2006 to 2019, floriculture in the country had a growth of 5% to 8%, however the industry had a fall with the emergency of COVID-19 and the constant lockdowns. Weeks after the start of the pandemic in Brazil, the sector estimated a loss of R$ 297.7 million (Beckmann-Cavalcante, 2021).

Studies involving phytoremediation technologies are well known, however this technique applied with the mediation of ornamental plants has gained prominence in recent years. In parallel with the accumulation of pollutants that are removed from the food chain, ornamental plants promote an aesthetic improvement of the environment, especially herbaceous plants. One of the main advantages of using ornamental plants is the incentive to tourism in the recovery site. The aesthetic charm of the specimens attracts tourists from different places and the money produced can be invested in the maintenance and monitoring of the area (Rocha et al., 2022).

Herbaceous ornamental plants are indicated for phytoremediation due to their shorter life cycle, allowing to more easily and accurately assess the stress on the plant promoted by the contaminant, especially heavy metals (Liu et al., 2018). Some herbaceous species used in phytoremediation and present in several landscape gardens are: *Catharanthus roseus* (L) G. Don (Madagascar periwinkle) and *Dendranthema grandiflora* Tzevelev (Chrysanthemum). When introducing *C. roseus* into soils contaminated with heavy metals, Barbosa (2020) observed that this species acted as a phytoremediation unit, mainly through the phytostabilization of the metals Cd, Cu and Zn present in the sewage sludge. In addition, it showed a high tendency for the phytostabilization of Ni and As and the phytoextraction of the metals Ba, Cd, Cu, Ni, Se and Zn, present in the commercial substrate. Subjecting chrysanthemums (*D. grandiflora*) to Cu contaminated soil, Menegaes et al. (2017) observed that this species showed tolerance to high rates of this metal and stands out for its ability to retain this element in its roots. However, the authors point out that the aesthetic quality was affected, which jeopardizes its commercial value.

Although the use of herbaceous ornamental plants is indicated, soil remediation is not limited by them and can be promoted by woody-stemmed shrubs, such as *Duranta erecta* L. (popularly known as golden dewdrop). Investigating the remediation potential of this species in oil contamination, Amaral & Martins (2017) observed that the introduction of *D. erecta* contributed in the elimination of large amounts of residual oil, possibly promoting an increase in the biodegradation activity of preexisting microorganisms in the soil (phytostimulation).

In heavy metal contamination, Liu et al. (2018) point out the species *Calendula officinalis*, *Celosia cristata* *pyramidalis*, *Melastoma malabathricum*, *Iris lactea* var. *chinensis*, *Euphorbia milii* and *Tagetes patula*, as suitable for soil decontamination. In fact, the *T. patula* species has the ability to promote the phytotransformation of contaminants present in wastewater from textile industries, along with other species such as *Aster amellus*, *Petunia grandiflora* and *Grindelia grandiflora*. As a result, these species are known as remediation of textile dyes (Chandanshive et al., 2018). In lead (Pb) contamination, Rodrigues (2016) highlights the phytoremediation potential of ornamental plants: *Tradescantia pallida* (purple queen), *Ophiopogon jaburan* (lilyturf), *Sansevieria trifasciata* (snake plant) and *Cuphea gracilis* (false erica).

Contaminants are not just limited to the terrestrial and aquatic environment, atmospheric phytoremediation can be promoted indoors. Pollutants such as formaldehyde and benzene are found in domestic environments and pose risks to human health. Both formaldehyde and benzene are part of the group of compounds known as volatile organic compounds (VOCs). Ornamental plants can act as air quality indicators and promote uptake of VOCs through stomata. The absorption rate of these compounds can be limited by several factors, among which: the plant species, the light intensity, the concentration of VOCs in the environment, the duration of opening and closing of the stomata and the type of metabolism of the specimen (C3, C4 and CAM plants) (Cruz et al., 2014).

Among the ornamental plants present in domestic environments that have the ability to reduce the amount of VOCs in the place, Rocha et al. (2022) highlight *Chamaedorea elegans* Mart. (bella palm), *Schefflera arboricola* (hayata) Merr. (Umbrella tree), *Dracaena sanderiana* Sander ex Mast. (Lucky bamboo) and *Spathiphyllum wallisii* Regel (peace lily).

3.3 *Zantedeschia* spp.

Plants of the genus *Zantedeschia* spp. belong to the family Araceae, a monophyletic clade composed of monocotyledonous angiosperms. This family currently has 117 genera and approximately 8,106 species. (The plant list, 2013). The species of this family are found predominantly in tropical territories and present terrestrial and epiphytic ways of life, being usually herbaceous. Although predominantly terrestrial, this family has an aquatic genus *Pistia* (Corrêa et al, 2005). The most (visually) characteristic portion of this family is its spadix-like inflorescence (Ribeiro, 2007).

In the genus *Zantedeschia*, one of the most known and commercialized species is *Zantedeschia aethiopica* (L.) Spreng. popularly known as calla lily (in Portuguese, “copo-de-leite”). This plant native to southern Africa, has white flowers with yellow spadix inflorescences, which give it its aesthetic exoticity and economic interest (Resnik et al., 2021), this species has georeferenced records throughout the American continent.

Most of the accumulation of macronutrients occurs on the aerial parts of *Z. aethiopica*, especially in the period before flowering, which indicates the ideal time for fertilization (Carneiro et al., 2015). In its leaf blade, petiole and spathe there are idioblasts and calcium oxalate crystals, these structures when ingested present some toxicity to the organism, promoting kidney, gastrointestinal and hepatic lesions. Accidents with domestic animals involving ingestion of this plant are common (Perin & Aquino, 2019).

3.4 Phytoremediation of pollutants mediated by *Zantedeschia aethiopica*

Copper (Cu) is an essential metallic micronutrient for plants, especially when it is associated with sulfur (copper sulfide) (Rodrigues, 2016). Copper deficiency in plants is observed through leaf chlorosis and necrosis (Mota et al., 2013).

For years, copper was used in agriculture as a fungicide and bactericide through the compound called Bordeaux mixture (Amarante et al., 2015). Bordeaux mixture consists of a mixture of copper sulfate pentahydrate, calcium oxide and water. Copper ions act on the pathogen's enzymatic system, inhibiting its protein synthesis (Junior, 2018). Soils contaminated with high levels of copper are carefully investigated, since this metal poses risks to the local biota due to its ability to bioaccumulate in the food chain (Ciaca, 2016). In plants, excessive amounts of Cu promote changes in histological and tissue levels, inactivating cytoplasmic enzymes that result in oxidative stress and interfere in the metabolism of macro and micronutrients (Rodrigues, 2016). At high concentrations, Cu can induce plant resistance to pests, reducing crop productivity (Sediyama et al., 2014).

The calla lily presents tolerance to high levels of Cu in the soil, so its cultivation is viable in soils contaminated with this metal. This species absorbs and retains Cu mainly in the tuber, making it a potential phytoaccumulator. However, high concentrations of Cu promote yellowing and necrosis on the leaf edges, this effect gets gradually worse as the concentration of this metal increases. Due to these flaws in the aesthetic quality of the plant, its commercialization in flower shops after remediating contaminated soils becomes unfeasible (Menegaes, 2015).

Lead (Pb) in its organic form (Pb-tetraethyl, triethyl and diethyl) is extremely mobile and rapidly assimilates into plant roots. In plants, this heavy metal accumulates in the cell walls of plant tissue, inducing chlorosis and darkening of the roots, inhibiting the process of photosynthesis, interfering with the water balance and consequently, preventing plant development. In the detoxification strategy of this metal, plants sequester Pb to the vacuole and restrict it in the cell wall (Sharma & Dubey, 2005). Some species used in Pb phytoremediation are *Mentha crispa* L. (Sá et al, 2015), *Macadamia integrifolia* (Vilas Boas et al, 2015), *Euphorbia hirta* L. (Ullah et al., 2019), *Tagetes erecta* L. (Minisha et al., 2021; Bardiya et al., 2017), *Tradescantia pallida*, *Ophiopogon jaburan*, *Sansevieria trifasciata* and *Cuphea gracilis* (Rodrigues, 2016).

The species *T. pallida*, *O. jaburan*, *S. trifasciata* and *C. gracilis* act on Pb retention through their root systems. Among the species mentioned, the species *C. gracilis* has a high retention potential (Rodrigues, 2006). Pb in phytoremediation studies is essential, however, the use of species belonging to the genus *Zantedeschia* spp. for remediation of soils contaminated with this metal remains scarce.

Chromium (Cr) is a heavy metal and an essential soil micronutrient. In the environment, this element is found in trivalent (Cr^{+3}) and hexavalent (Cr^{+6}) forms (Barbosa, 2020). Its toxicity indices are mainly associated with its valence, stability and concentration. The trivalent form of this metal is relatively stable, having low mobility and low solubility in water (Maronezi et al., 2019). The hexavalent form is the most toxic, presenting high reactivity and water solubility. Usually, the hexavalent species has an anthropic origin and acts by denaturing proteins and precipitating nucleic acids, demonstrating relationships with the development of neoplasms in humans (Dávalos et al., 2019). The removal of Cr from contaminated environments can be performed by bryophytes, the species *Sphagnum perichaetiale* Hampe and *Ricciocarpos natans* (L.) Corda, have a high removal potential, which corresponds to 78 and 70% respectively between the species (Torres, 2018).

The phytoremediation and phytostabilization capacity of Cr^{+6} of *Z. aethiopica* was investigated by Dávalos et al. (2019), the authors qualified it as promising in the rehabilitation of areas contaminated with this metal, especially when its soil concentrations are below 118.96 mg/kg, since it corresponds to the LC_{50} of this species. Higher doses of Cr^{+6} reduce root growth and promote absence of flowering in the 20-week interval, in which the bioassays were performed.

Another metal widely studied in phytoremediation assays is cadmium (Cd). This non-essential element, even at low concentrations, is toxic, mainly because it has enzymatic inhibitory activity. The high toxicity of Cd can lead to protein denaturation and oxidative stress (Guimarães et al., 2008), and the effects of its accumulation in vegetables are observed in:

- Roots: affects water absorption, interferes with enzymatic activity, impairs the transport of macroelements (Ca, P and K) and limits root growth. It is worth mentioning that the absorption of Cd by the roots is associated with two main factors: root morphology and the concentration of this metal in the soil (Kabata-Pendias & Szteke, 2015; Cogo et al., 2020);

- Aerial vegetative plant parts: induces chlorosis (interveinal and generalized) in young leaves, chlorotic spots on leaf margins, purplish spots, tissue necrosis and inhibition of photosynthesis. This inhibition can occur by changes in the electron transport chain, in the Calvin cycle or by a reduction in the concentration of chlorophyll (Guimarães et al., 2008; Kebata-Pendias & Szteke, 2015; Cogo et al., 2020);

● Seeds: reduces α and β amylase activity, inhibits embryonic and root axis growth (Guimarães et al., 2008).

Most plants have low tolerance to Cd. However, a tolerance strategy for this metal developed by plants is through intracellular complexation. The exposure of plants to Cd rapidly induces the production of phytochelatins (PCs) accompanied by the induction of transcription of genes aimed at absorption, with this the compartmentalization of Cd associated with chelating substances, forming a Cd-chelator complex. This complex is later stored in cellular and subcellular structures, contributing to the reduction of Cd concentration in the cytosol. This process was explored through genetic manipulation to produce transgenic plants with greater tolerance to Cd (Guimarães et al., 2008).

However, as previously observed with Cb, although the relevance of Cd in phytoremediation studies is high, the use of species belonging to the genus *Zantedeschia* spp. in the remediation process of soils contaminated by this metal remains scarce so far.

4. Conclusion

Phytoremediation has a lot of advantages in environmental cleanup of contaminated areas. However, the use of this technique alone still has limitations in terms of protocols. Furthermore, exploring the remedial capacity of plants does not guarantee quick results, as it is a process that occurs slowly and relies on other variables that can determine its effectiveness, such as: soil pH, the climate of the region, the composition of the contaminant, the plant species and the local microbiota. To maintain an ecological balance on the site, it is necessary to evaluate and apply ornamental plants that are native and can tolerate the contaminants. For this to occur, biotechnological techniques such as genetic engineering programs have been applied, in order to alter the biomass production and the visual quality of ornamental species, which increases their remedial potential and their aesthetic beauty.

However, we report a scarcity in studies involving the phytoremediation of lead and cadmium, by species belonging to the genus *Zantedeschia* spp, the exposition to these two contaminants can be toxic, even to human health. Therefore, we advise that further in-depth studies be carried out so that the remediation potential of this species is extended to lead, cadmium and other contaminants.

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