Past and present pest mitigation: insights from an international survey of practices

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Abstract: Through a knowledge exchange network, many countries have established similar timelines for the use of chemical substances, such as pesticides and fungicides, in the preservation of collections in museums, libraries, and archives. To profile the use of toxic and non-toxic treatments across different types of collections, an international survey was developed to gather data on past conservation methods and current pest control practices. This survey was directed at professionals working in libraries, archives, and museums, focusing on the strategies employed to mitigate pest-related issues. The study aims to understand whether traditional chemical treatments, widely documented in the literature and recommended by conservation manuals, have been adopted by institutions of various profiles and how professionals are currently addressing pest mitigation in cultural heritage collections. The findings reveal that, although institutions have increasingly transitioned to non-toxic treatments driven by concerns over sustainability and workplace safety, the legacy of pesticide-treated collections continues to present significant challenges. Furthermore, while non-toxic methods are gaining traction, some regions still need to reassess traditional chemical treatment practices to align with contemporary conservation guidelines Through a knowledge exchange network, many countries have established similar timelines for using chemical substances to preserve collections in museums, libraries, and archives. A survey was conducted among professionals in cultural heritage preservation to gather data on past treatment methods and current pest control practices. The study aimed to profile the use of toxic and nontoxic treatments across different types of collections, examining whether traditional chemical methods recommended by conservation manuals were widely adopted and how current practices address pest-related issues in cultural heritage. The results reveal that, although institutions have increasingly transitioned to nontoxic treatments driven by sustainability and workplace safety concerns, the legacy of pesticide-treated collections continues to pose significant challenges. Furthermore, while nontoxic methods are gaining traction, some

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regions still need to reassess traditional chemical treatment options to align with contemporary conservation practices.

Keywords: Survey; Pesticides; Toxic treatments; Nontoxic treatments; Conservation.

Introduction

In 1887, Walter Hough, an entomologist and chief curator of the Anthropology department at the Smithsonian National Museum of Natural History, wrote that due to the abundance of materials in large museums, frequent examination of each specimen was impractical, so each one must be poisoned in advance to prevent loss (Hough 1887: 529). This author provides several recipes for destroying moths and xylophagous insects. His experimental recipes included arsenic, carbolic acid, strychnine, naphtha, and benzine, with different application methods suggested depending on the fragility of the item treated (Hough 1887: 553).

The same treatments that became popular for specimens in natural history collections were also applied to ethnological collections made from organic materials such as feathers, fur, and leather.

During the second half of the nineteenth century and the beginning of the twentieth century, there was a growing interest in preserving these collections. This period saw an intensification of studies in entomology, with the scientific community dedicating significant time and effort to describe and identify new insect families and species, including those that damage collections (Farber 1976: 94-95).

The use of volatile compounds increased in museums during the early twentieth century with the introduction of closed cabinets (Goldberg 1996: 33). To control insects considered "enemies of books," substances like camphor, benzine, thymol, tobacco smoke, turpentine essence, and aromatic plants were used (Houlbert 1903: 232) Museum pest control manuals mention the efficacy of carbon disulfide (Goldberg 1996: 33), but due to its explosive properties and associated risks, this compound became less appealing than other volatile fumigation agents. Additionally, hydrocyanic acid gas, used to eradicate pests in the preservation of plants, seeds, and fruits, was also commonly used in museum collections (Goldberg 1996; Pool *et al.* 2005).

In the 1940s, the chemical industry began to synthesize different compounds more quickly, increasing the supply of pesticides available, which led to the development of organochlorine, organophosphate, carbamate, and pyrethroid pesticides as new synthetic organic compounds were discovered. These synthetic compounds, capable of preventing, repelling, or killing insects, were developed by the chemical industry (Tello 2021: 4), which had also been involved in the development of chemical weapons during the First World War. After the war, these companies shifted to producing civilian products (Arndt 2022: 290).

Organic compounds such as hexachlorobenzene (HCB), dichloro-diphenyl-trichloro-ethane (DDT), lindane(γ-HCH), naphthalene, paradichlorobenzene (PDB), permethrin and deltamethrin were widely used in collections to prevent damage or losses caused by pests (Odegaard & Sadongei 2005; Angelova *et al.* 2023). The use of fumigating agents, such as ethylene oxide, formaldehyde, carbon tetrachloride, and other compounds, has also been mentioned in some conservation manuals (Plenderleith & Werner 1971; Kathpalia 1973).

As promising products for controlling urban pests, these compounds were well received in museums as potential preservation agents. Neither the objects nor those applying them were initially considered to be at risk. This apparently viable and safe alternative, combined with strong commercial advertising, led to the incorporation of organic synthetic pesticides

into the pest control routine of the museum (Tello 2021: 5).

Due to the limited number of experts in this field, institutions shared their experiences via exchanges between professionals. During this period, scientific publications became an important means of communicating and institutionalizing professional practices in the context of preserving collections (Almeida 2021: 50). Tello (1921) also notes that participation in congresses and consultation of specialized literature helped strengthen a unique network of knowledge that extended beyond national boundaries.

Museums used both traditional recipes and commercially available chemicals with different formulations for preserving their collections. As a result of routine and successive treatments, objects may have been contaminated with multiple chemical substances (Tello 2021: 8). There are few institutional records of these treatments because they were considered routine care in museums (Goldberg 1996; Hawks & Makos 2000; Omstein 2010). In consequence, there are collections that have been subjected to different chemical processes, and few records to document these processes.

Many entomologists, taxidermists, collectors, curators, and other professionals shared these treatments, contributing to a network of information exchange concerning biological threats and pest control strategies. According to this knowledge exchange network, chemical substances were applied in a similar manner in many countries (Pool *et al.* 2005: 11). Could this network of knowledge also influence regions outside the traditional developed countries?

An international survey was developed to collect information on toxic and nontoxic treatments used in different types of collections. To move beyond the traditional Anglo-Saxon axis, the questions were prepared in English, Spanish, and Portuguese to make them accessible to a wider audience, which is not always actively engaged in international conservation surveys.

This article presents the results of a survey designed to identify traditional treatments used for disinfecting objects and assess the level of acceptance of more sustainable methods for preserving cultural heritage in different countries.

Methods and analysis

A questionnaire created in Google Forms, consisting of 20 questions, was divided into four main sections. The first section, with four questions, collected general information about the participant's profile, including the type of collections they worked with, their level of experience, employment status, and country of residence. Museum professionals, archivists, and librarians were the target audience for the research, with no specific academic background required. Participants needed only to have professional experience in collection preservation and integrated pest management.

During the development of this questionnaire, we decided to include professionals working in private practice, as many conservators operate independently on projects and are not formally employed in institutions. These professionals often run their own studios, and their insights could contribute to understand pest control methods used in projects and private work.

The second part of the questionnaire addressed preventive conservation, with four questions about current pest control measures, the most common types of pests threatening heritage objects, and the impacts of recent infestations. Private practice professionals were asked to consider the information and procedures adopted in their workplaces.

The third section focused on toxic treatments applied to objects in the past, with seven questions exploring personal experiences with the use of chemical substances in both institutional and private practice settings. Institutional professionals were asked to consider old records, information from previous employees, visual evidence on objects (such as old tags or signs of past treatments), or scientific analyses conducted on collections. Private practice professionals were asked to mention any evidence of contamination in objects treated in their studios or specific projects.

The fourth and final section inquired about alternatives for nontoxic treatments, asking whether they were applied and which methods were used. This section included four questions. At the end of the survey, participants had the option to leave their email addresses for future contact or follow-up research.

The questionnaire featured multiple-choice questions complemented by some open fields to increase response rates. The survey was available from September to November 2022, and results were compiled using Microsoft's Power Bi® software. Responses were grouped by geographic region, with contributions from professionals in Europe, Latin America, the United States, Canada, and Africa. Participants from Asia and Oceania were grouped together due to low participation rates in these regions.

The questionnaire was widely distributed on professional lists and conservation forums, such as the Global Conservation Forum and ConsDistList. It was also shared on social media, where the post was shared 87 times and reached 1,177 accounts. The survey aimed to reach as many participants as possible, but the organic dynamic reach of social media and forums made it difficult to measure the precise audience reach. Consequently, it is not possible to calculate the sample percentage, margin of error, and confidence level of this survey. However, the 192 completed questionnaires provide valuable information for this study.

Results and discussion

The first part of the questionnaire aimed to identify the participants' professional profiles. A total of 192 professionals from 30 countries[1] participated in the survey **(Fig. 1)**. The majority of participants were from Latin America, followed by Europe, the United States, and Canada, with only a small number from African, Asian, and Oceanian countries.

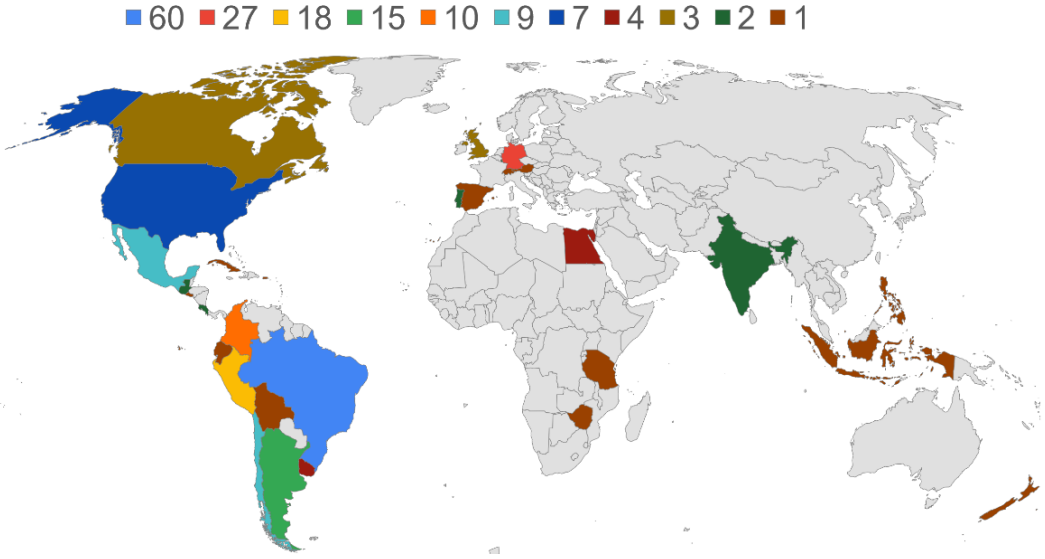

Fig. 1. The geographic distribution of questionnaire participants and the number of respondents.

1 Participants in this survey reside in the following countries: Argentina, Austria, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Ecuador, Egypt, El Salvador, Germany, Guatemala, India, Indonesia, Luxembourg, Mexico, New Zealand, Peru, Philippines, Portugal, Puerto Rico, Spain, United Kingdom, United States, Switzerland, Tanzania, Uruguay, Zimbabwe. Source: The authors.

A total of 169 participants (88%) indicated that they had at least five years of experience in cultural heritage conservation. Among them, 126 participants (65.6%) reported working full-time at an institution, while the remainder worked in private practice in their own studios or as freelancers on specific projects (**Fig. 2**).

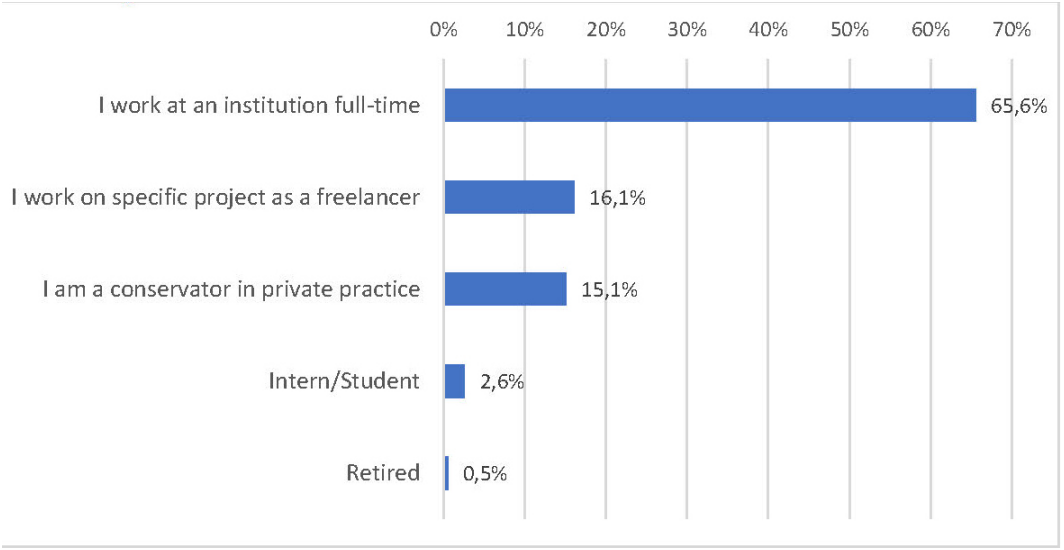

Fig. 2. Participants' current employment status. Source: The authors.

Participants reported working with archival and bibliographic materials (39.6%), historical collections (39.6%), and archaeological and ethnographic objects (37.5%) (**Fig. 3**). Multiple answers were allowed for this question, indicating that the research covered a comprehensive set of materials. Historical, archaeological, and ethnographic objects are composed of various organic materials, such as wood, textiles, plant fibers, feathers, and leather, among others.

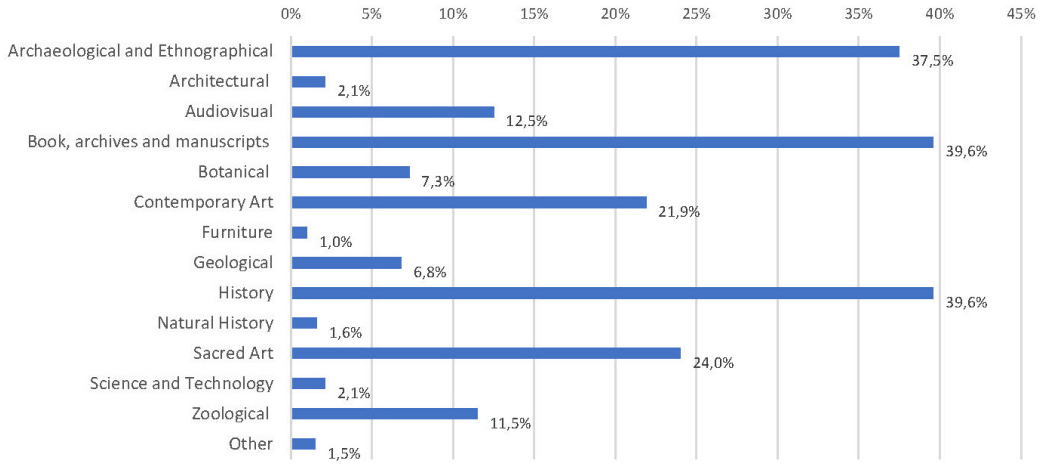

Fig. 3. The categories of collections that participants worked on. Source: The authors.

In the topic of preventive conservation, 99.5% of participants indicated that their institutions currently maintain practices related to the preventive conservation of collections, including climate monitoring, integrated pest management policies, and periodic inspections.

Participants from different countries provided varying answers about the types of biological threats recently recorded in their collections, with multiple answers allowed for this question. Latin American professionals reported frequent problems with mold (37%), moths (32.3%), woodborers (28.6%), and termites (28.1%). In contrast, participants from the United States and Canada reported woodborers (4.2%), moths (3.6%), mold (2.6%), and silverfish (2.6%) as their primary biological threats. In Europe, woodborers (15.6%), moths and silverfish (13% each), and mold (10.9%) were predominant.

Participants from Africa reported occurrences of silverfish (2.6%) and woodborers (2.1%). In Asia and Oceania, termites and silverfish were mentioned with equal frequency (2.1%), followed by mold (1.6%). The following figure presents a comparative table for all participants by geographic region (**Fig. 4**).

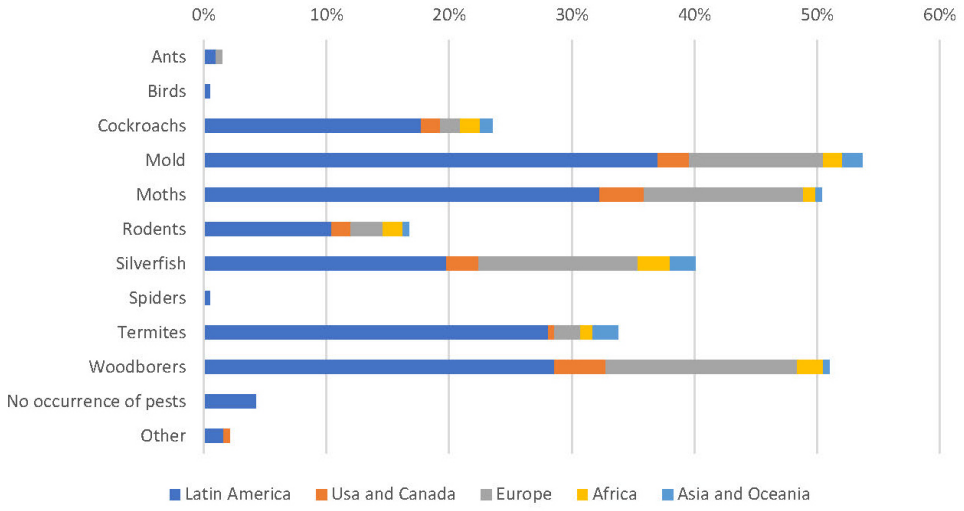

Fig. 4. Geographical comparisons of pest occurrences in recent years. Source: The authors.

In the topic of toxic treatments, 38.5% of participants reported having personally used chemical substances to eliminate pests from objects.

Geographical analysis results (**Fig. 5**) show that naphthalene was most commonly used in Latin America (10.4%), followed by cypermethrin (8.9%) and thymol (7.8%). Participants from the United States and Canada primarily used thymol (0.5%), dichlorvos (0.5%), and heavy metals such as lead, arsenic, and mercury (0.5%). In Europe, participants indicated personal use of permethrin (3.1%), thymol (1.6%), and naphthalene (1.0%). Asian participants reported the use of paradichlorobenzene (0.5%), while African participants noted the use of other non-listed toxic products (0.5%).

In comparison, Latin American regions show a higher propensity for using these chemical substances. Participants in this region reported personal experiences with synthetic pyrethroids, fumigants, organophosphates, and organochlorines that have already been banned from use and commercialization. A significant incidence of fungicides, such as thymol and

pentachlorophenol, was also noted. This scenario aligns with the prevalence of the most common types of biological threats in the participants' countries of residence, as shown in **Fig. 4**.

Among participants who admitted using toxic products, 20.8% cited reasons such as fast treatment, effectiveness, and familiarity with the product (Fig. 6). For others, these toxic methods persist due to their affordability, low complexity, and traditional treatment status. According to two participants (from Brazil and the USA), the use of chemical substances was suggested by project-specific guidelines. There could be more than one answer to this question.

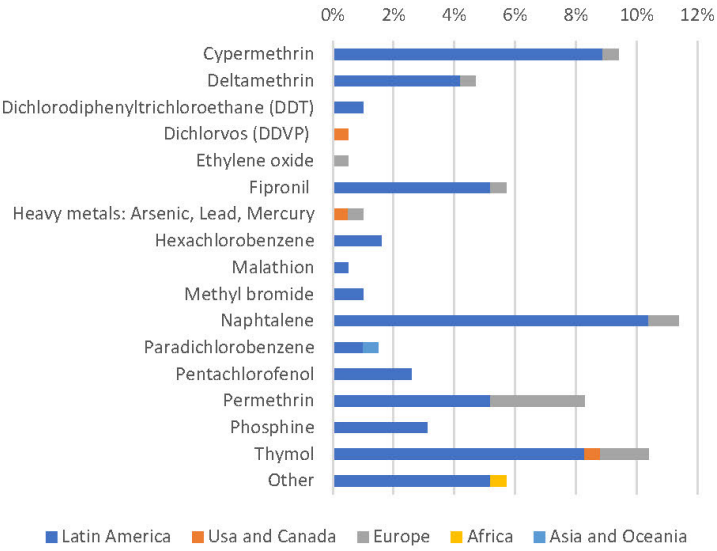

Fig. 5. A comparison of the chemicals personally used by participants based on their geographic location. Source: The authors.

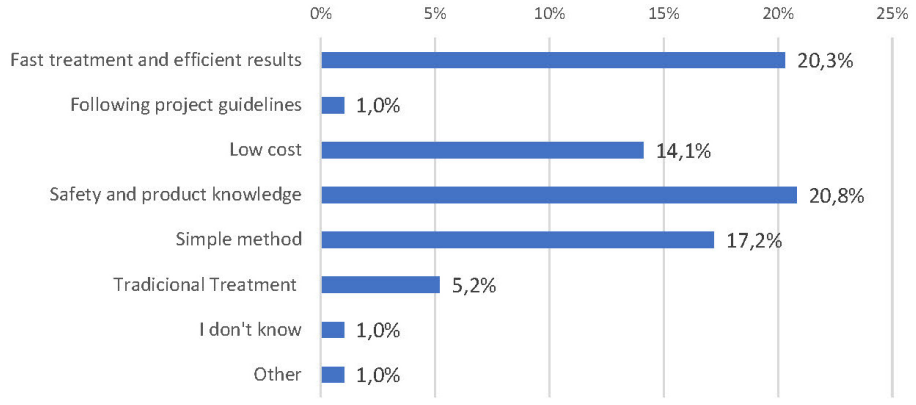

Fig. 6. Justifications for the current use of toxic products. Source: The authors.

Regarding the use of toxic products, participants reported experiencing side effects from chemical exposure, either personally or via colleagues (**Fig. 7**). The most frequently mentioned reactions included headaches (25.5%), respiratory tract irritation (16.7%), and eye irritation (16.7%).

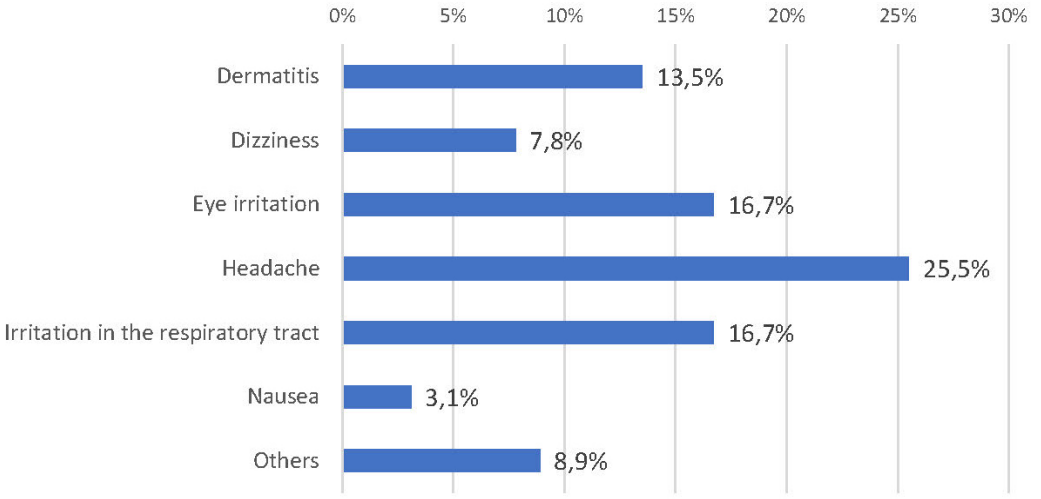

Fig. 7. Experiencing side effects as a result of the use of toxic products. Source: The authors.

The responses regarding historical treatment records were almost evenly divided (**Fig. 8**). Only 34.9% of responses indicated the presence of historical treatment records, while 32.3% stated that such records were unavailable. As noted in literature reviews, accurate documentation of past pesticide treatments in cultural collections poses significant challenges (Goldberg 1996; Hawks & Makos 2000; Omstein 2010).

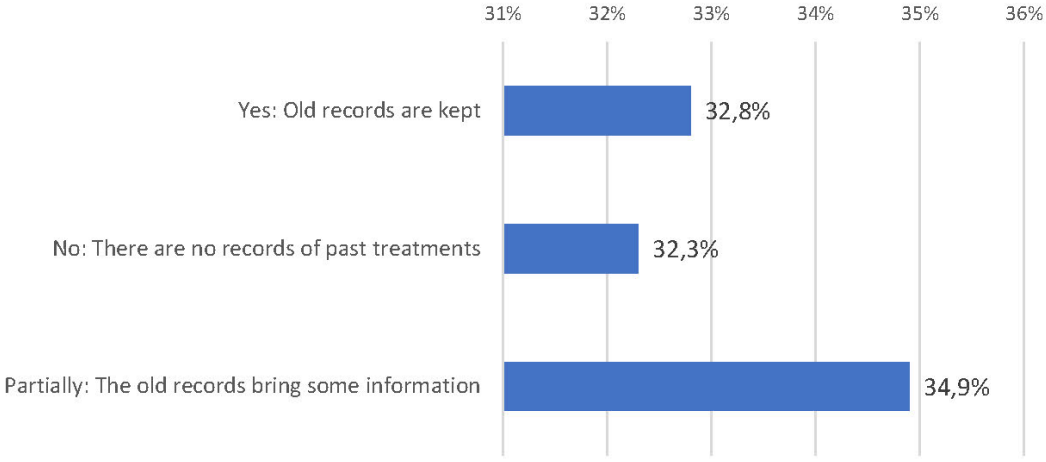

Fig. 8. Documentation of past pest control treatments. Source: The authors.

Geographic grouping provides valuable insights into past chemical treatments **(Fig. 9)**. Naphthalene was predominantly used in Latin American countries (28.1%). Thymol was cited by 14.6% of participants, followed by cypermethrin (12%) and deltamethrin (7.3%). Only 6.3% of respondents mentioned Dichlorodiphenyltrichloroethane (DDT) as a historical treatment. Additionally, 14.6% of participants were unaware of the products used in historical treatments. There appears to be significant continuity in these countries, as the most commonly used historical products (naphthalene, thymol, and synthetic pyrethroids) continue to be frequently applied recently.

In Canada and the United States, heavy metals (3.6%) and pesticides like DDT, dichlorvos, and paradichlorobenzene (2.1% each) were most frequently mentioned as historical treatments. In Europe, chlorinated pesticides were commonly reported, with lindane accounting for 11.5% of all treatments, followed by DDT (10.4%), permethrin (9.4%), and heavy metals (8.9%).

In Asia, DDT was most commonly cited (1.0%), followed by paradichlorobenzene (1.0%) and other substances. African participants reported fewer records of old treatments but indicated the presence of DDT, paradichlorobenzene, heavy metals, and other pesticides (0.5% each).

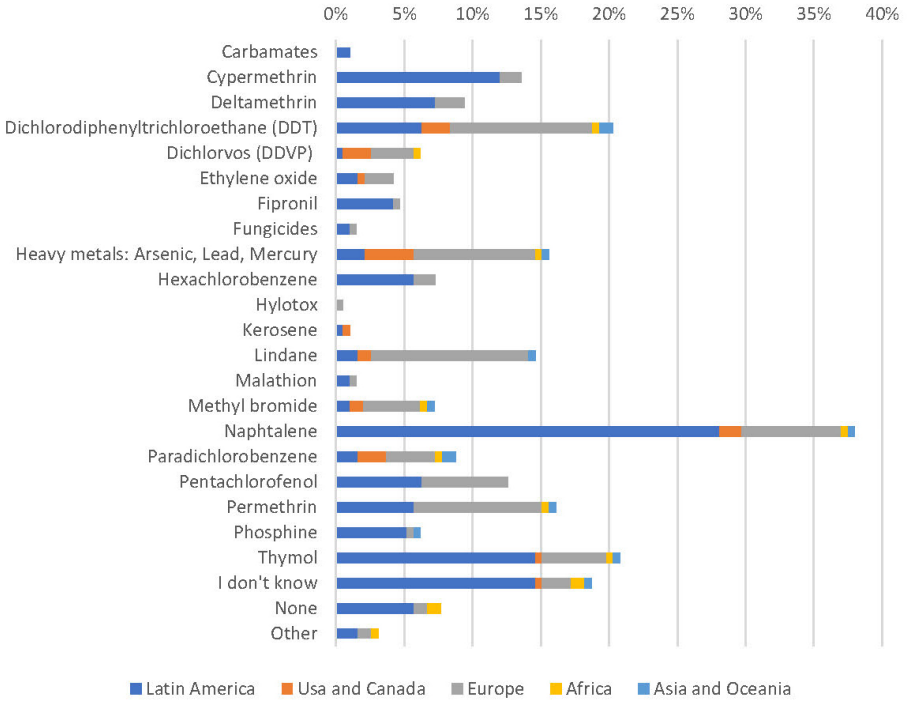

Fig. 9. Geographically based past treatment records. Source: The authors.

The responses align with findings from literature reviews. Naturalists and collectors in the nineteenth century employed recipes containing arsenic, mercury, and lead to control infestations (Hough 1887: 552-57), as documented in reports and publications from natural history museums. By the latter half of the twentieth century, with the advancements

in the chemical industry, new solutions began to be applied and exchanged (Tello 2021).

Post-war Europe saw the widespread use of organochlorine pesticides, with lindane and DDT preferred in countries like Austria, Germany, Luxembourg, and Switzerland. The use of chlorinated products extended to other countries, possibly influenced by European colonial practices, aimed at preserving documents and materials in tropical climates (Angelova *et al.* 2023).

In 1940, scientists at Imperial College London began research to find a substitute for pyrethrum, as its supply was affected by the war in Japan (Clarke 2012: 135). Research with DDT proved so successful that production licenses were swiftly instituted in the United Kingdom. Subsequently, DDT was employed in British colonies to control disease vectors such as malaria and yellow fever (Gay 2012: 90). This historical moment of colonial productivity enhancement justified the presence of organochlorines in Asia and Africa. It is challenging to trace the extent to which these substances were implemented in these colonial countries before and after their independence (Clarke 2012: 134). These substances were used to combat disease vectors, like malaria and yellow fever, but were not limited to this purpose. Angelova *et al.* (2023), for instance, mention the presence of chlorinated pesticides in English colonial archival records in African countries and instructions for the preservation of these administrative documents.

In the realm of nonchemical treatments for collections, participants in our survey indicated a shift towards sustainable techniques. Of these professionals, 39.1% reported using inert atmospheres for pest control, notably prevalent among participants in the United States, Canada, and Europe. Other methods mentioned include freezing (27.1%), heating (8.9%), gamma ionization (9.9%), and the application of essential oils and local plants (16.1%). Of all participants, 30.2% state that they currently do not use any nontoxic techniques.

Geographical comparisons **(Fig. 10)** reveal distinct preferences: Latin American participants prefer to use anoxia (16.7%), freezing (12.5%), and traditional techniques involving spices, local plants, and essential oils (10.9%). Gamma radiation is mentioned by 9.4% of participants for pest control in this region, with special emphasis on Brazilian professionals. However, 29.7% of participants overall indicated that none of the listed nontoxic techniques are used in their institutions, possibly indicating ongoing reliance on toxic chemicals.

Freezing is the predominant technique in the United States and Canada (4.7%), followed by anoxia (3.6%). In Europe, anoxia leads (16.1%), followed by freezing (8.9%). Traditional materials are more commonly employed in Africa (2.1%), Asia, and Oceania (1.6%).

There is a considerable level of trust in nontoxic techniques among 50% of participants, with 47.9% expressing full confidence in these methods, while 2.1% indicate distrust in nontoxic treatments. Latin American participants exhibit the lowest confidence levels in these techniques compared to participants from other geographic regions **(Fig. 11)**.

Regarding the level of trust in nontoxic techniques, there is a notable geographical disparity. Latin American countries exhibit a higher propensity to rely on traditional chemical methods for pest control and show lower confidence in nontoxic alternatives. In contrast, in Europe, the United States, and Canada, negative responses regarding confidence in alternative techniques are minimal, with a noticeable decrease in reasonable confidence compared to positive responses.

Several factors contribute to this scenario. Limited conservation training opportunities in Latin American countries may contribute to a lack of awareness about the adverse effects of chemical treatments on collections. Financial constraints also limit access to nontoxic alternatives, such as anoxia and freezing methods, making commercial chemical products more attractive due to their accessibility and immediate efficacy.

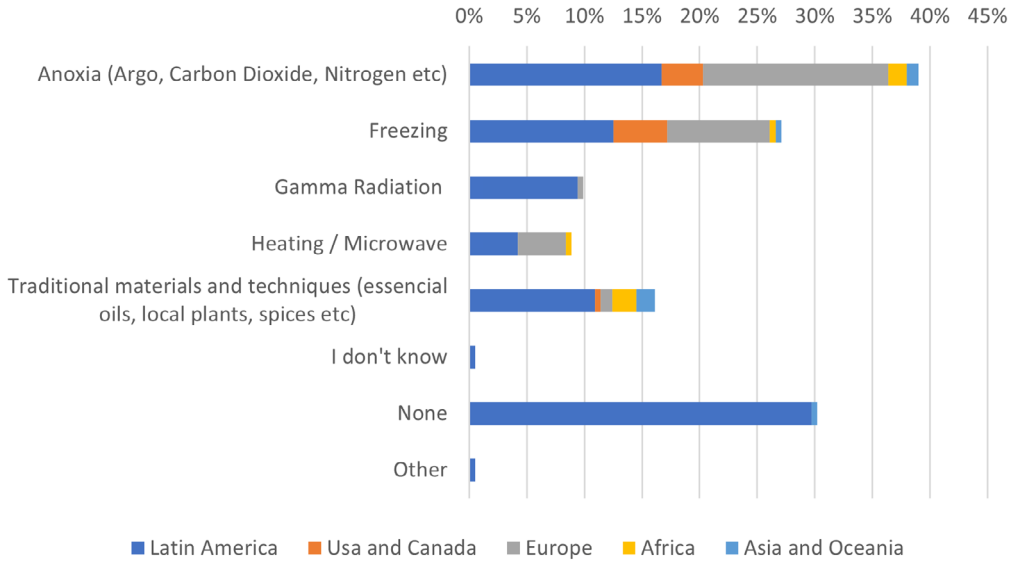

Fig. 10. Comparison of nontoxic techniques currently being used by the participants in different regions. Source: The authors.

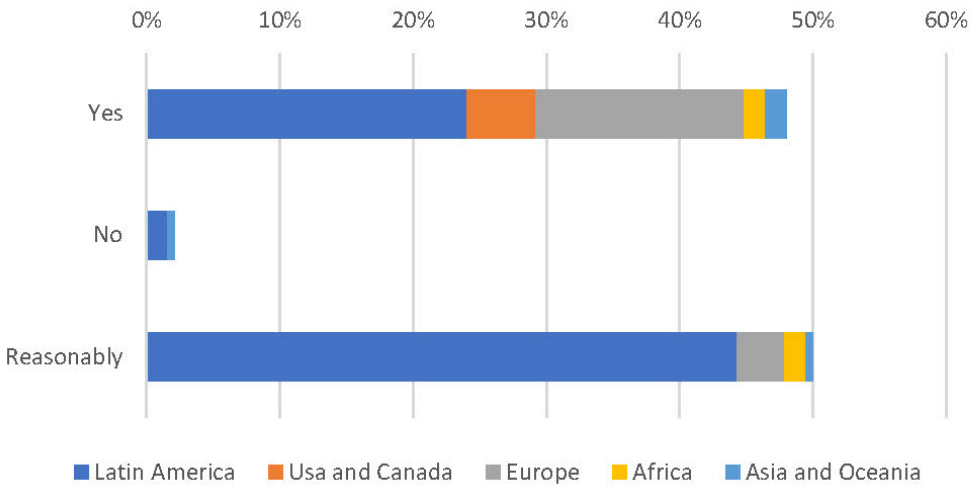

Fig. 11. Comparison of the level of confidence in nontoxic treatments across different geographic regions. Source: The authors.

Additionally, a language barrier could hinder the dissemination of information, as much of the literature on the subject is published in English, potentially excluding Spanish and Portuguese-speaking professionals from accessing critical information.

Despite the limited participation from Asia, Oceania, and Africa in this survey, it is noteworthy that professionals in these regions demonstrate a preference for sustainable pest control methods, including the use of essential oils and native plants. This choice

reflects their awareness of health risks and commitment to preserve cultural heritage by using nontoxic means.

Conclusion

Over the past few decades, the conservation discipline has made substantial progress. As a result of new international regulations and national legislation in countries that have restricted the availability and use of biocidal products, these changes have been implemented. Sustainability topics related to cultural heritage, as well as a heightened awareness of the harmful effects of chemicals on cultural heritage collections, can also result in significant changes in behavior (Arndt 2022: 295).

Beginning in the 1990s, conservators increasingly turned to nontoxic treatment alternatives, driven by a desire to promote workplace safety and sustainability. Methods such as freezing, treatment with inert atmospheres, ionizing radiation, and integrated pest management practices, aimed at early insect detection, gained prominence (Pinniger 2001: 72-78).

Despite contemporary shifts towards nontoxic treatments in institutions today, the legacy of collections treated with pesticides remains significant. Persistent residues of these chemicals have resulted in documented cases of contamination in modern collections (Carrasco 2004; Cunha & Mattos 2015). Exposure to these substances can lead to a range of health issues, including eye and skin irritation, digestive system damage, headaches, dizziness, infertility, loss of consciousness, and even death (Waxman 1998; ATSDR 2023).

The risks of contamination are not limited to professionals who handle these objects, such as conservators, curators, and researchers. Indigenous communities' involvement in museological processes has become a key driver for the renewal of traditional treatments in museums. In this new context, indigenous groups visit museum storage areas and work directly with the collections housed in these institutions. Often, members of these communities request the use of certain items for ceremonial purposes. In such cases, potential contamination of these objects restricts their use and poses health risks to those who physically interact with them. Additionally, this contamination can threaten the environment, especially when objects are reintegrated into daily life, used in religious ceremonies, or buried in the ground by Indigenous community leaders (Sadongei 2001).

The involvement of stakeholders in activities such as research, exhibitions, and other curatorial actions has helped strengthen the identity of some groups. It has also contributed to transforming traditional institutions into democratic and empowering spaces. Due to this new social dynamic, chemical treatments must be reassessed, especially in countries where professionals still have little confidence in nontoxic methods.

This survey, while representing a limited and specific group of participants, provides insights that align with geographic trends observed in professional practices both historically and presently. The findings corroborate the existing literature on the challenges associated with past chemical treatments and underscore the widespread adoption of pest mitigation strategies informed by conservation manuals and global knowledge-sharing networks. Responses from Latin American, Asian, and African participants provided specific insights. Online surveys in multiple languages could serve as crucial tools for data collection, addressing the underrepresentation of these regions in conventional research.

Future research in this area could benefit from expanding surveys and conducting personal interviews, particularly in regions with low questionnaire participation. The comprehensive survey results are accessible

through provided links[2] or by scanning the QR code below **(Fig. 12)**, allowing readers to explore diverse responses using specific filters on the interactive website.

Fig. 12. QR-Code for survey results.

Acknowledgments

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DELGADO VIEIRA, A. C.; VÁSQUEZ SALVADOR, P. A.. O passado e o presente da mitigação de pragas: resultados de uma pesquisa internacional sobre práticas. *R. Museu Arq. Etn.* 43: 114-128, 2024.

Resumo: Por meio de uma rede de troca de conhecimento, muitos países estabeleceram cronogramas semelhantes para o uso de substâncias químicas, como pesticidas e fungicidas, na preservação de coleções em museus, bibliotecas e arquivos. Com o objetivo de traçar o perfil do uso de tratamentos tóxicos e não tóxicos em diferentes tipos de coleções, foi elaborado um questionário internacional para coletar dados sobre métodos de conservação utilizados no passado e práticas atuais de controle de pragas. Esse questionário foi aplicado a profissionais de bibliotecas, arquivos e museus, com foco nas estratégias adotadas para a mitigação de pragas. A investigação busca compreender se os métodos tradicionais de tratamento químico, amplamente descritos na literatura e recomendados por manuais de conservação, foram adotados por

2 English version of the website: https://app.powerbi.com/view?r=eyJrIjoiYzc2MGY5YWUtZmNjOS00Nj I3LTk2YWUtMGIwZWMyMjIyNjFjIiwidCI6IjdlOTNlMjg2LWIyOWEtNDQ1NC1hNDFhLWU4NDE5ZWM5ZGViNSJ9

Portuguese version of the website: https://app.powerbi.com/view?r=eyJrIjoiZWRmMmRlZDktMzVmMC00NDIwLWJiMDAtOWQ2MzhhMDcyYjdkIiwidCI6IjdlOTNlMjg2LWIyOWEtNDQ1NC1hNDFhLWU4NDE5ZWM5ZGViNSJ9

instituições de diferentes perfis e como os profissionais atualmente realizam tratamentos para mitigar pragas em bens culturais. Os resultados indicam que, embora as instituições tenham adotado cada vez mais tratamentos não tóxicos, motivadas por preocupações com sustentabilidade e segurança no ambiente de trabalho, o legado de coleções tratadas com pesticidas continua representando desafios significativos. Além disso, embora os métodos não tóxicos estejam ganhando popularidade, algumas regiões ainda precisam reavaliar as práticas tradicionais de tratamento químico para se alinhar às diretrizes contemporâneas de conservação.

Palavras-chave: Questionário; Pesticidas; Tratamentos tóxicos; Tratamentos não tóxicos; Conservação.

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