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Review article

Relationship between the biohazard in Cuban archives and libraries and the occurrence of disasters

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ABSTRACT

Archives and libraries contain environmental microorganisms, in particular fungi, that are typically found in the air, associated with dust, and on preserved documents surfaces. Under appropriate conservation conditions these fungi are inactive and cannot damage documents, but they can affect the health of workers because they are constantly inhaled. For this reason, personnel in these institutions are exposed to biohazard circumstantially or involuntarily. The objective of this work is to explain how this biohazard is accentuated when disasters occur, whether small or large, related to intense vibrations or the presence of water in materials, which leads to a significant increase in the environmental fungal load. An exhaustive search was carried out in Internet, principally in publications indexed in databases, and no reference was found that relates biohazard in archives and libraries to disasters. Results previously obtained in our researches indicate that with adequate Biosafety measures and procedures as well as appropriate Preventive Conservation, Integrated Pest Management and Disaster Risk Reduction Plans, this problem can be mitigated.

Keywords: biohazard; fungi; disasters; archive; biosafety; health

Relación entre los riesgos biológicos en los archivos y bibliotecas cubanas y la ocurrencia de desastres

RESUMEN

Los archivos y las bibliotecas contienen microorganismos ambientales, en particular hongos, que se encuentran normalmente en el aire, asociadosal polvo y sobre la superficie de los documentos preservados. Bajo condiciones apropiadas de conservación estos hongos están inactivos y no pueden dañar los documentos, pero si pueden afectar la salud de los trabajadores porque son inhalados constantemente. Por este motivo, el personal en estas instituciones está expuesto a riesgo biológico de forma circunstancial o involuntaria.El objetivo de este trabajo es explicar cómo este riesgo biológico se acentúa cuando ocurren desastres, ya sean de pequeña o gran magnitud, relacionados con intensas vibraciones o la presencia de agua

en los materiales, lo que propicia un aumento significativo de la carga fúngica ambiental. Se realizó una búsqueda exhaustiva en Internet principalmente en publicaciones indexadas en bases de datos, y no se encontró ninguna referencia que relacione el riesgo biológico en archivos y bibliotecas con los desastres. Los resultados obtenidos previamente en nuestras investigaciones indican que, con adecuadas medidas y procedimientos de bioseguridad, así como con apropiados Planes de Conservación Preventiva, de Manejo Integrado de Plagas y de Reducción de Riesgo de Desastres esta problemática se puede mitigar.

Palabras clave: riesgo biológico; hongos; desastres; archivo; bioseguridad; salud

INTRODUCTION

Archives and libraries contain documents in various materials and formats that deteriorate over time due to the aging of the media, pigments and inks. But the deterioration process is accelerated by the effect of physical agents (light, temperature, relative humidity, etc.), chemicals (atmospheric pollution), particulate matter (dust, soot) and biological agents (microorganisms, insects, etc.) present in the environment.

Temperature (T) and relative humidity (RH) are among the environmental parameters most analyzed in these institutions since they are involved in the chemical processes that occur during the aging of materials, inks and pigments. The same occurs with light intensity and in particular Ultraviolet (UV) radiation. [1] However, the incidence of the settleable dust and biological agents, particularly filamentous fungi, on the collections preserved in these institutions is not always monitored with equal rigor and systematicity.

The existence of fungi in the indoor environment of archives and libraries is due to their introduction from the outdoor through the air and together with the dust that penetrates through windows and doors, ventilation or air conditioning systems with poor hygiene, through cracks and other openings in walls, etc. [2,3] They can also be introduced into buildings through dirt dragged by shoes and adhered to people's clothing and skin and even by insects and mites present in dust or that can reach the repositories. [4,5] It is important to note that the fungal propagules concentration can increase inside these institutions as a result of their dispersion from internal sources of contaminationsuch as documents, other objects and infected surfaces that are moved or manipulated. Dust also constitutes an element that contributes to fungal contamination in the indoor environment of premises and particularly in archives and libraries. [4,6,7]

Dust contains numerous elements that come from natural and anthropogenic sources, of biotic origin (mites, pollens, fungal propagules, etc.) and abiotic origin (chemical substances from industries and automobiles, as well as different sugars), [8] therefore, serves as a source of nutrients for some insects and fungi, and creates a microenvironment on the surfaces of the collections, preventing the normal flow of air over them, which makes it easier for the surface areas to absorb a large amount of humidity, favoring the proliferation of pests. [9] Likewise, dust contributes to the dispersion of aeroallergens that affect human health, such as fungal propagules and mites. [10] Furthermore, it constitutes a secondary source of environmental microbial contamination if it is agitated or shaken. [6,7,11] In this way, dust constitutes a potential danger for documents of heritage value and for human health. [12,11,13]

Fungi are among the microorganisms that can be found in the indoor air of archives and libraries as well as in the dust settled on documents and other surfaces. [14] These agents use these materials as nutrients for their growth and development, causing serious effects on their chemical composition and altering their physical-mechanical structure, in addition to inducing aesthetic damage that affects the appearance and in many cases, the correct reading of their message. [15] Besides to damaging the documentary heritage preserved in these institutions, fungi can severely affect human health since they have different structures and pathogenic mechanisms that cause specific health effects, therefore, some are considered primary pathogens, such as *Candida albicans*, *Stachybotrys chartarum* and *Aspergillus fumigatus*; other fungi are opportunistic or secondary pathogens since they would only affect the human organism if it presents immunological problems. [16,17]

According to some experimental results obtained in Cuba, not only on the diversity and physiology of fungi isolated from air and dust collected in various archives, but also from allergological studies, it is kwon that the mycological quality of these environments plays an important role in the health of workers. [18,19,20,21,22,23,24] This coincides with studies carried out in archives, libraries and museums in other countries. [25,26] These environments are characterized by sometimes having more or less high concentrations of dust and fungi that can trigger allergies and other health problemssince personnel are

exposed to these allergens during the work day. [27,24] However, currently having preventive actions is vital to maintain the sustainability of work in archives and libraries, even more so when increasingly severe health conditions are foreseen fundamentally due to Climate Change (CC) that is causing emerging infections and "storms of asthma" and the occurrence and intensity of disasters is favored. [28]

The objective of this work is to explain how this biohazard is accentuated when disasters occur, whether small or large, related to intense vibrations or the presence of water in materials, which leads to a significant increase in the environmental fungal load.

DEVELOPMENT

Methodology used in the review process

A review search was carried out for reports from the last 10 years on biohazard in archives and libraries, as well as the incidence of disasters in increasing this risk. They were taken into accountall articles found on the Internet in general, the publications made by the Preventive Conservation laboratory of the National Archive of the Republic of Cuba, in national and international journals and otherpublicationsindexed in the following databases: Biological Abstract, Chemical Abstract, CIRC, Emerging Sources Citation Index (ESCI), Latindex, PubMed, REDIB, Redalyc, SciELO, Science Direct and Scopus.

Several terms and their combinations were used to carry out the searches, which were: fungi, molds, microorganisms, archive, library, air, dust, paper, biohazard, biosafety, biohazard in archives, biohazard in libraries, biosafety in archives, biosafety in libraries, biohazard during disasters.

Results of the search performed

The search carried out allowed us to find only some reports related to the biohazard in archives and libraries during the COVID-19 pandemic, [29,30,31] but no information was found linked to other types of disasters that can occur in these institutions. However, studies previously performed in Cuban archives on environmental fungal contamination, [18-22] as well as allergy studies made on personnel working in these institutions [23,24] have shown that the time of exposure to archive environments significantly affects the health of personnel, so they are exposed to biological risk circumstantially or involuntarily. [10]

Biohazard in Cuban archives and libraries

When biohazard is taken into account in any institution, it is essential to handle two important concepts. One of them is biosafety and the other is biohazard. Biosafety is defined as the set of preventive measures, aimed at maintaining control of occupational risk factors from biological, physical or chemical agents, achieving the prevention of harmful impacts, ensuring that the development of said procedures does not threaten health and safety of workers, visitors and the environment. [32] It has a strategic and integrative approach that encompasses the normative and regulatory frameworks (including instruments and activities) for the analysis and risks management related to the life and health of people, animals and plants as well as risks partners with the environment. [31] For its part, biohazard is defined as all those living beings, whether of animal or plant origin, and all those substances derived from them, present in the workplace and that may be susceptible to causing negative effects on the workers' health. These negative effects can be combined into infectious, toxic or allergic processes. [31]

The biohazard concept indicates that there are several biological agents that can affect document repositories and other spaces within heritage institutions. It has been known for years that bibliophagist insects can cause severe damage to documentary collections, generating pests [5] and that their exoskeletons and detritus can trigger allergic states in people more or less severe depending on the immunological characteristics of the individuals. [33] On the other hand, the existence of fungal propagules (spores, fragments of spores and hyphae from filamentous fungi) is also known to be dangerous not only for documents but also for human health, since they can cause allergies and other diseases such as infections or mycoses which can be superficial (skin, nails, hair and mucous membranes) or deep (in the respiratory system); there are also the mycotoxicoses, effect caused by mycotoxins that can penetrate through the skin and the respiratory tract, affecting even its lower part, that is, the bronchi and alveoli. [15,34,14,26,35,36,37] Likewise, mites and pollens are associated with the dust that penetrates these spaces, which constitute important allergens for humans. [38,39]

Unfortunately, in archives and libraries the presence of biological agents and their remains are so high that for their study they can be divided into animated and inanimated (figure 1). Among the animated biological agents are living forms of bacteria, fungi, arthropods (insects and mites), etc., which can be found in the air, dust and affected documents (figure 2), as well as different types of viruses among which the influenza virus can be mentioned (which is transmitted by contagion between people mainly) or SARS-Cov-2. [2,20,40,5,31] Among the inanimated forms of biological agents are poisons, toxins and volatile organic compounds (VOCs) excreted by bacteria and fungi, detritus and exoskeletons remains of mites and insects, as well as human and animal hair, wool remains, waste of fibers and resins, many of which are potent allergens for humans. It should be

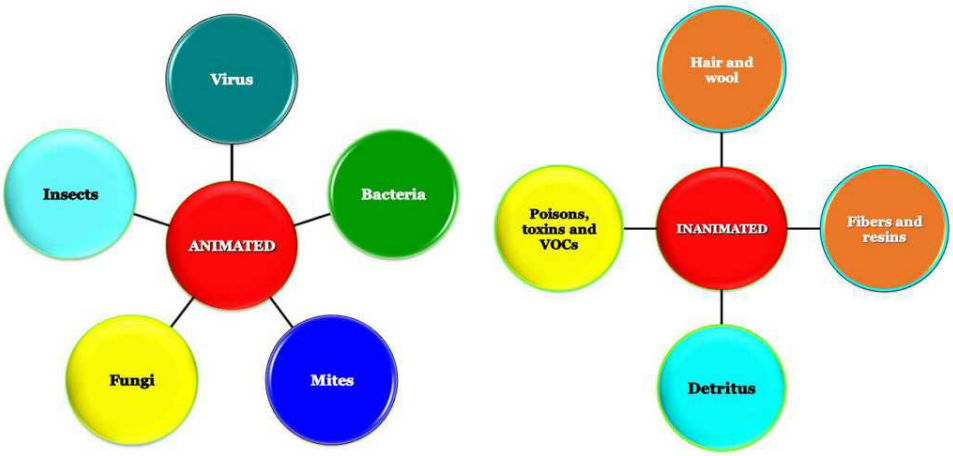

Fig. 1. Types of biological agents that can be found in heritage institutions. VOCs: Indicate volatile organic compounds

noted that most of these inanimate elements are moved by air and dust, and many of them can be found in dust collected in archives, libraries and museums. [41,42]

A high percentage of the documents preserved in archives and libraries are on paper, although there may also be other materials such as textiles, metal, parchment, plastics, glass, etc. All of them during the manufacturing process can become contaminated with microorganisms (bacteria and fungi) from the environment or from the raw materials used, remaining retained within the material. In many cases, microbial structures, and in particular fungi, can lose viability during the manufacturing of the different documentary supports, but in other cases, such as paper or film materials in general, they can become latently trapped between the structures, fibers or gelatin that make them up and begin to develop once appropriate conditions of T and RH appear for their growth. [43] On other occasions, documents become infested during storage, display or handling and, under favorable thermohygrometric conditions they form extensive and strong biofilms that irreversibly damage the document (figure 3). If these biofilms are agitated or moved, either because an affected document is rubbed over inside the repository or because it is manipulated, a resuspension of the fungal spores occurs in the air, increasing the fungal concentration in the indoor environment. [7,11] Furthermore, as many of these spores are extremely small (≤ 3 µm) they can be easily inhaled and breathed by personnel, and can be deposited in the different areas of the respiratory tract, including the lungs and alveoli (figure 4), which can even trigger deep mycoses if the individual's immune system is depressed. [44,36]

The existence of fungal growth on surfaces, including document surfaces, can in turn lead to an increase in the produc-

Fig. 2. Different types of documents damaged by biological agents; A, Books affected by fungus; B, Fragment of cinematographic film damaged by bacteria; C, Documents damaged by two types of insects (silverfish and dry wood termites)

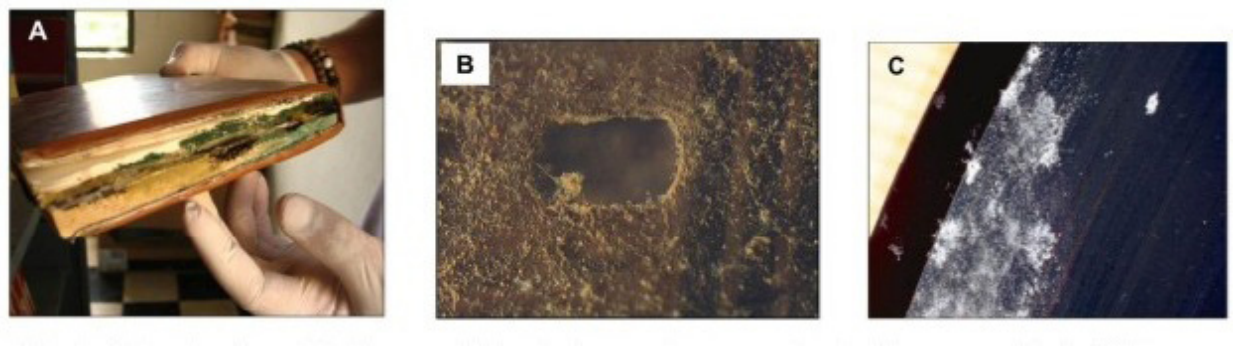

Fig. 3. Extensive fungal biofilms on different documentary supports; A, Over a paper book; B, Over a cinematographic film; C, On a polyvinyl acetate disc

tion and excretion of VOCs by some environmental fungi, as well as mycotoxins that can be inhaled or enter in contact with the skin causing respiratory or dermal damages. [14]

Various fungal genera have been isolated from archive and library environments around the world (table 1), but Aspergillus, Cladosporium and Penicillium tend to be the most abundant, mainly due to the large amount of organic materials that are conserved and that serve as nutrient. [2,3,20,26,45,46,4,7] These three genera are characterized by having a cosmopolitan distribution and include a large number of species that form small, dry spores that can be easily dispersed by the effect of air. [47] These spores can be quite numerous in the air indoor of the occupational environments particularly the archive repositories, so they can be easily inhaled. [47,48] They can also be deposited on materials if the RH is high and grow on paper, leather, textiles and other substrates, forming extensive biofilms. [49] These biofilms on the documents compromise the structural cohesion of paper, and book bindings, irreversibly deteriorating them. [46]

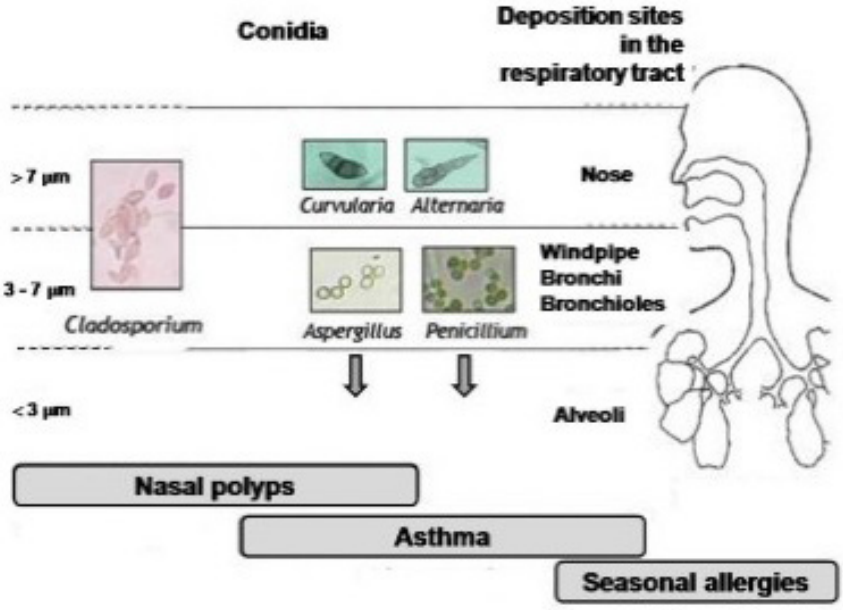

Fig. 4. Deposition of fungal spores or conidia in the respiratory tract. Most of these spores can be retained in the upper tract, i.e. they are inhalable because they do not reach the lungs, while those that do reach the lungs are respirable (dimensions ≤ 3 µm), such as the case of Aspergillus and Penicillium spores [44]

Table 1. Some fungal genera and species found in the air and dust of libraries and archives [20,26,45]

Genera		Species	
Acremonium a	Acrothecium	Acremonium alabamense *	Epicoccum nigrum
Acremoniella	Alternaria a	Acremonium strictum *	Fusarium avenaceum
Aspergillus a	Arthrinium a	Alternaria alternata *	Fusarium dimerum *
Aureobasidium a	Bispora	Alternaria citri	Fusarium graminearum
Basipetospora	Botrytis a	Aspergillus awamorii	Fusarium oxysporum *
Bipolaris a	Candida a	A. candidus *	Geotrichum candidum
Ceratosporum	Chrysonilia	A. clavatus *	Mucor mucedo
Chaetomium a	Chrysosporium a	A. flavipes *	Mucor racemosus *
Cladosporium a	Cryptococcus a	A. flavus *	Paecilomyces variotii *
Coprinus a	Curvularia a	A. fumigatus *	Paecilomyces lilacinus *
Dactylella	Dreschelera	A. glaucus *	Penicillium citrinum *
Emericella	Epicoccum	A. japonicus *	P. chrysogenum *
Eurotium	Fonsecaea a	A. nidulans *	P. commune *
Fusarium a	Geotrichum a	A. niger *	P. corylophilum
Gliocladium	Graphium	A. ochraceus *	P. decumbens *
Gonytrichum	Hansenula	A. oryzae *	P. digitatum
Harpographium	Helminthosporium	A. penicillioides **	P. griseofulvum *
Hormonema	Humicola	A. terreus *	P. oxalicum
Monascus a	Macrophomina	A. versicolor *	P. simplicissimum
Monosporium	Mortiriella	Aureobasidium pullulans *	P. spinulosum *
Myrothecium	Mucor a	Bipolaris spicifera *	Rhodotorula mucilaginosa *
Neoscytalidium	Neurospora	Botrytis cinerea	Rhizopus microspores *
Nigrospora	Oidiodendron a	Candida albicans *	Rhizopus oryzae *
Paecilomyces a	Pestalotia	Candida glabrata *	Rhizopus stolonifer *
Pestalotiopsis	Phialophora a	Chaetomium elatum	Saccharomyces cerevisae *
Penicillium a	Phoma a	Chaetomium globosum *	Scedosporium prolificans *
Rinocladiella	Rhizoctonia	Chrysonilia sitophila *	Scopulariopsis brevicaulis *
Rhizomucor a	Rhizopus a	Chrysosporium fastidium	Sporobolomyces roseus
Rhodotorula a	Saccharomyces a	Cladosporium cladosporioides *	Stachybotrys equinata
Scedosporium [a]	*Syncephalastrum* [a]	*Cladosporium delicatulum*	*Stemphylium botryosum*
Sepedonium	*Scopulariopsis* [a]	*Cladosporium elatum* *	*Talaromyces purpurogenus*
Sporobolomyces [a]	*Stachybotrys* [a]	*Cladosporium herbarum* *	*Talaromyces funiculosus*
Stemphylium [a]	*Talaromyces* [a]	*Cladosporium macrocarpum*	*Trichoderma longibrachiatum* *
Trichocladium	*Trichoderma* [a]	*Cladosporium sphaerospermum* *	*Trichoderma roseum*
Trichosporon [a]	*Torula*	*Cladosporium tenuissimum*	*Trichoderma viride* *
Tritirachium [a]	*Ulocladium* [a]	*Cryptococcus laurentii* *	*Ulocladium alternariae*
Verticillium	*Wallemia* [a]	*Curvularia eragrostidis*	*Ulocladium botrytis* *
Sterile mycelium or non-sporulating mycelium [b]		*Curvularia lunata* *	*Wallemia sebi* *

Note: * Indicates that they are pathogenic species according to de Hoog et al. (2000); ** Indicates that it is pathogenic according to Klich (2006); a Reveals genus that have pathogenic species; b Specifies that some of these mycelia that are pathogens have been found. [35,50,35,51]

Within these three genera, Aspergillus species always prevail. It is reported that it is because many of them are considered part of the indoor mycobiota and that the small size of their spores allow them to stay long periods of time in the air; in addition, many species are xerotolerants (they require low water activity (aw) to grow, that is aw ≤ 0.7) which is equivalent to growing to a lower RH of 70% so they are considered as primary and secondary colonizers of the materials that they degrade. [52,53,54,55] Of the Aspergillus genus, the species A. flavus and A. niger are the ones that turn out to be predominant. [3,26,56] However, a good number of species of these and other genera are toxigenic, primary pathogens or opportunistic pathogens, even classifying some of them with a biohazard level 2, such is the case of Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Aspergillus terreus and Aspergillus penicillioides and even in Cuba, Aspergillus species are considered with biohazard level 2. [57,58,59] On the other hand, it is known that fungi, not yet viable, can be harmful to the health of personnel working in archives and libraries, since the chemical substances that make up their propagules are powerful allergens. Besides, mycotoxins and VOCs that excrete can be inhaled affecting the organism. [60,61] This implies a high biohazard for the personnel working in these heritage institutions, because their function is to work with documents and not with microorganisms, so it has recently been raised that file and library workers are exposed to biohazard in a circumstantial way. [21] It is noteworthy that the species Aspergillus fumigatus and Aspergillus niger in addition to being xerotolerants, are also thermotolerants (they can grow between 40ºC and 52ºC) what could have an important impact on health in situations of significant increases in ambient temperature as is happening with the CC. [62,63]

Disasters and biohazard in Cuban archives and libraries

When a disaster related to intense vibrations occurs, whether of little magnitude, such as the fall of a shelf, or of great magnitude such as the occurrence of an earthquake, there is a sharp detachment of both the dust sedimented on the surfaces and of the fungal propagules that may have developed in a biofilm on various surfaces, including contaminated documents, increasing the fungal environmental load and therefore the risk of rapidly inhaling spores and other propagules of allergenic, toxigenic or opportunistic pathogenic species. If on the contrary, the disaster that occurs is associated with the water either by a broken pipe, the rupture of air conditioners, heavy rains, hurricanes, etc., there is a significant increase of the fungal growth on the surfaces, due to the high environmental humidity or to the increase the water in the materials that can be kept humid or wet for several days, and thereby it is stimulated the environmental fungal load. [64]

With disasters the biohazard caused by fungi increases significantly, due to a considerable increase in the load of their spores and other propagules in the air facilitating its rapid inhalation. On the other hand, the high RH can also contribute to the proliferation of mites and insects whose eggs are nested in the dust and remain settled on the surface of documents and other objects, generating pests that can become difficult to control if they are not detect in time. [5,65,66]

The COVID-19 pandemic caused by the new Coronavirus Sars-COV-2, is an epidemiological disaster whose fundamental affectation occurs in humans. However, it could be demonstrated that this virus, although it does not damage documentary supports and therefore does not affect the documentary heritage treasured in archives and libraries, remains viable for several days on the surface of the different kind of documents (2 to 9 days depending on the materials that make up the infected document) constituting a source of propagation which increases the biohazard of the personnel working in these institutions. [31] Therefore, adequate measures and procedures of biosafety and appropriate preventive conservation plans, integrated pest management and disaster risk reduction plans, contribute to mitigate the impact of disasters and the biohazard on the documents and the personnel.

In Cuba, for years, it is mandatory that all institutions have disaster risk reduction plans. In particular, the legal framework of Civil Defense (organization of the country's defense system), always improving and updating, includes the care and protection of the nation's cultural heritage in its different versions since 1983 and even until 2030. [67] Therefore, the archives and libraries not only have these plans but also carry out disaster risk reduction, including actions to mitigate the impact of the CC, in an updated, systematic and coordinated manner with other entities (including heritage institutions) of the municipality. Hence, these plans are updated annually as established in Resolution No. 201 of the CITMA (2020), [68] and are controlled and checked with this same periodicity by the Civil Defense that has coordination offices and specialists to the municipal level.

Conclusions

Among the existing risks in Cuban archives and libraries is the biohazard to which the staff is exposed during the workingday. As the incidence of this risk is given by the environment characteristics where the documentation is preserved or where the personnel perform their systematic manipulation and continues for years, exposure to this risk is circumstantial.

Disasters caused by large vibrations or water exacerbate the environmental fungal load facilitating rapid inhalation of fungal

propagules, which increases the biohazard that these biological agents cause. Likewise, the increase in the environmental RH permanently also facilitates the trigger for mites and insect's pests.The impact mitigation of disasters on the personnel biohazard is achieved with correct measures and procedures of biosafety and with appropriate Preventive Conservation, Integrated Pest Management and Disaster Risk Reduction Plans.

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Interests Conflicts

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