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A review of biological deterioration of library materials and possible control strategies in the tropics

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Abstract

Purpose – The purpose of this paper is to review the current state of research on the various biological agents that could cause deterioration of paper materials and possible intervention strategies against these biotic agents in the tropics.

Design/methodology/approach – Recent literature in the tropics is reviewed to gain insight into the problems that confront libraries in the tropics as regards the biological deterioration of library materials.

Findings – The paper identifies moulds as the most important biodeteriorating agents of library materials. In addition to destroying, disfiguring and staining books, the moulds have been linked to numerous adverse human health effects that fall into three categories: allergic, toxic and infectious. The other biological agents include bacteria, insects and rodents. The important insects in tropical environment are cockroaches and termites. The warm humid tropical conditions and dirty environment trigger/promote biodeterioration processes and make book deterioration to be more pronounced in the tropics than in the temperate regions.

Research limitations/implications – Physical visits to the libraries were not carried out and the conclusions reached were based on evidence from scientific literature on the subject in the tropics.

Practical implications – A very useful source of information on how to curb the menace of biological agents against the destruction of library materials in the tropics. These include training programmes for library staff on conservation and preservation of library collections, the creation of awareness on the issue among library users, the adoption of good house keeping practices and modification of storage environment to make them unsuitable for the biodeteriogens. It is recommended that libraries and archives in tropical countries should have preservation guidelines and integrated pest management teams and should also cooperate with scientists in relevant disciplines to be able to find lasting solutions to the problem of biodeterioration of library materials.

Originality/value – This paper looks into the neglected area of biological deterioration of papers which is the main information carrier in libraries. It provides very useful and practical suggestions that libraries in the tropics could adopt to tackle the menace of biological agents.

Keywords Biological hazards, Fungi, Paper, Conservation, Collections management, Libraries

Paper type General review

Introduction

The library collects, organizes, makes available and conserve for future use the record of human knowledge. These library collections represent the priceless heritage of man as they store facts, ideas, thoughts, accomplishments and evidences of human development from generations to generations. The history of the past in written documents are indispensable for now and future generation and according to Akussah (2002), the records of today constitute the heritage of tomorrow. With a view to safeguarding the world's documentary heritage, UNESCO in 1992 cited by Majumdar (2005) launched the programme "Memory of the Word". The consequences of the loss of such materials are unimaginable and it is an obligation that the librarians and other information professionals in charge of these repositories take every necessary

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steps/precautions to ensure that the materials are in stable and usable conditions. In contrast to museum items that are rarely handled, library materials are meant to be used; they have to be conserved and stored in an ideal and secure environment to arrest their decay, but such condition must also be comfortable for library users. In the words of Varlamoff (2005), preservation carried out for the sake of preserving is of no value, while as well as allowing access to all documents lavishly without giving considerations for preservation measures will, sooner than expected, results in the document becoming inaccessible for future generations. Thus library preservation is faced with the double tasks of making information accessible and at the same time ensuring its ultimate survival. As the IFLA-PAC China Centre (2006) put it: the core activity of preservation and conservation is to ensure that significant library and archive materials, published and unpublished, in all formats, will be preserved in accessible form for as long as possible. However, the medium on which the written cultural heritage is recorded determines the durability.

Deterioration refers to a change of state of any material from the original form caused by interplay between the object and the agents of destruction. Biodeterioration is vital for the recycling of organic matter in nature, and if not for this, the whole earth crust would have been filled with organic matter; however, it becomes detrimental when it affects materials with cultural or economic value (Cappitelli and Sorlini, 2005). Virtually, all materials including even the seemingly resistant stones and metals are subject to natural forces of deterioration with time.

Paper has been the main medium for recording human knowledge worldwide, and its degradation or deterioration has been one of the most unappreciated serious issues for library and archival materials. Though, nowadays, readers have access to electronic resources, but most of the past records are on paper and many users still prefer to read the print materials, and in a recent survey, 86 per cent of 100 individuals including office workers, students, scientists and administrators indicated that they will not discard paper documents even when they had an electronic copy of the same document (Hart and Liu, 2003). Paper is liable to biodegradation which leads to loss of aesthetic values and sometimes its irreversible damage. Up till the end of eighteenth century, papers were produced from carefully selected cotton rags, and the papers then were of good quality. However, the change of paper raw materials to wood pulp have resulted in the poor quality of papers kept in libraries, archives and museums. Paper is composed primarily of cellulose and other substances such as lignin, hemicelluloses, pectins, waxes, tannins, protein and mineral constituents depending on the origin of the raw materials. The chief component cellulose could be likened to a chain and the fibre chain gives paper its strength.

According to the National Library of Australia (2004), deterioration of library materials is one of the major crises facing libraries throughout the world. The rate of book deterioration is particularly high in tropical countries where factors that aggravate deterioration are at optima. According to Mwiyeriwa (1988), all the factors that cause paper deterioration: physical (acid, heat, humidity, light), biological (moulds, insects, rodents) and careless handling methods are more pronounced in Africa than elsewhere in the world. Of the 2,511 total book acquisition of the University of Ghana in 1986, up to 600 physically disintegrating books were taken to the bindery section for repairs; and that there were still many more disintegrating books on the shelves that have not been identified (Akussah, 1991). Mwangi (1994) reported that about 33.3 per cent of bibliographic collections in selected Kenyan libraries have pH less than 4, and thus stand the risk of acid hydrolysis. In the recent survey of the National Archives

of Ghana, 51.1 per cent of the documents had deteriorated, thus in need of urgent treatment (Akussah, 2006). According to Zyska (1997), while considerable efforts have been devoted to research on degradation of library materials in Europe, there is paucity of such information on library materials in Africa. Sekete (2004) opined that the rate of deterioration of documents is more alarming in developing countries particularly in sub-Saharan Africa due to the interplay of factors not very prominent in developed countries. The sharp drop in the rate of acquisition of books and journals by African institutions due to declining financial resources in recent years require that libraries must preserve what they already have in their collections. Majumdar (2005) contended that the cultural and literary heritage on India in different libraries and institutions are becoming victims to deterioration and are disappearing day by day. Ojo-Igbinoba (1993) posited that African Universities must begin to view seriously the issues of preservation and conservation for them to play the expected roles of preserving the cultural heritage of the continent and support research. A search through literature shows that little attention has been paid to research on biological deterioration of library materials in tropical countries particularly in sub Africa, while the bulk of the few studies carried out were on the abiotic or non-biological causes of paper deterioration (Alegbeleye, 1996; Ngulube, 2005; Olatokun, 2008). There is the need for detailed studies of biological agents of degradation of library materials in tropical countries in order to device cheap and effective methods of prevention/control against the ravages of the biotic agents. This article reviews the various biological agents that could cause deterioration of paper materials and the possible intervention strategies against these biotic agents.

Causes of deterioration

Regardless of the chemical constituents, all library materials will decay since the organic matter of which most libraries are made of decay with time. Deterioration of paper-based object is essentially the degradation of cellulose. However, even fragile papers that are well handled could have durability (Akussah, 1991). Generally, the high temperature and relative humidities of the tropics contribute greatly to accelerating the rate of various kinds of deterioration. Paper deterioration could be grouped into four categories:

(1) Chemical deterioration due to natural ageing occurs in paper, made with wood pulp sized with rosin in an acidic medium resulting in yellowing and rapid loss of their original structure.

(2) Mechanical deterioration entails changes in the structure (size and shape) resulting in cracking, splitting and warping, for example, when bindings become broken or warped resulting from improper handling.

(3) Incidental deterioration occurs due to accidents such as flooding, fire, vandalism, etc.

(4) Biological deterioration is when living agents are involved in the degradation of library and archival materials.

The causes of deterioration listed above could also be grouped into two types: the abiotic and biotic factors. The first three causes constitute the abiotic factors while biological deterioration is caused by biotic or living agents. However, it is pertinent to point out that chemical, mechanical and biological agents act in co-associations, ranging from synergistic to antagonistic to deteriorate paper materials. The focus of

this paper is on the biological agents of book deterioration. The biological agents survive and proliferate on the organic constituents of library materials. The biotic factors stand as the most important cause of deterioration in tropical countries, due to the high ambient temperature and relative humidity that provide excellent condition for their proliferation and destructive ability (Bansa, 1981).

The biological agents could be divided into two groups:

(1) Macroorganisms, i.e. those living agents that could be seen with the naked eyes and these include insects and rodents.

(2) Microorganisms, i.e. the living agents that cannot be visualized with the unaided eye, but only with the microscopes, and these include fungi (moulds) and bacteria.

Moulds (fungi) and bacteria

Moulds are opportunistic microorganisms of ubiquitous nature and the number of identified fungal (mould) species is well over one million (Mueller and Schmit, 2007). Mould spores, which are the means through which fungi are disseminated, are always present in the air, but sufficient moisture may remain in dormant state for long periods provided the environment is kept dry by maintenance of low relative humidity. However, the fungi will grow on any organic material provided there is sufficient moisture fungal spores are found in both indoor and outdoor air samples, with the two main reservoirs being organic debris and soil (Domsch *et al.*, 1980; Lugauskas and Krikstaponis, 2004). Mould growth on paper materials often result in the profuse production of spores, thus making them to be visible as blackish, greenish, bluish, etc. on the surfaces of deteriorating materials depending on the colour of the asexual fruiting structures (spores). The presence of moulds on library collections is second only to the problem of acidic papers (Southwell, 2002). The factors that influence the mycological (fungal) contamination of buildings and the level of contamination of books include installations and overall maintenance of premises, temperature, humidity, air circulation and the number of visitors (Godds *et al.*, 1973; Lugauskas and Krikstaponis, 2004). The other factors listed by the authors are age of books, materials used in the manufacturing, extent of use and mechanical damage. The availability of moisture is a prerequisite for biological decay to occur in paper materials, and it is a common observation that moisture alone causes significant reduction in the strength of papers. As such moulds proliferate in situations where conditions indoors are very moist, precisely when the relative humidity exceeds 70 per cent, which may arise from condensation of airborne water vapour on building surfaces or from leakage of water as a result of rain or run off entering the building or from pipes and taps inside buildings (Small, 2003). As a general rule, higher relative humidity correlates with high mould growth. Wetting of collections which may arise for instance from water disasters increases susceptibility of papers to mould growth and makes conservation for the future problematic (Aziagba and Edet, 2008). In storage premises where the larger proportion is filled with books and other related materials, there is little air flow and air is almost stagnant; such conditions aggravate the mould contamination because the propagules of fungi in the air settle slowly on surfaces and start to grow (Lugauskas and Krikstaponis, 2004). Dust may constitute source of nourishment for fungi and even insects(Korpi *et al.*, 1997), it could form a microenvironment on surfaces thereby hindering normal airflow over them, and the large surface areas of small dust particles could absorb moisture (Maggi *et al.*, 2000). If the growth of mould is observed

in the collection, and immediate steps are not taken to alter environmental conditions or halt its proliferation, the mould will profusely ramify and digest the material on which it has started to grow.

The fungi isolated from deteriorating library materials at Olabisi Onabanjo University using the microbial culture dependent method are shown in Table I. They include *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Cladosporium* sp., *Neurospora* sp. and *Penicillium* sp. In an earlier related study, Nwokedi and Nedosa (1999) also isolated *A. niger*, *A. fumigatus*, *Chaetomium thermophile*, *C. globossum*, *Mucor pusillus*, *Trichoderma viride*, *Penicillium digitatum*, *Rhizopus oligospous* and *R. stolonifer* from deterioration books at the University of Jos. A study carried out in Indonesia recovered 32 species of moulds belonging to *Aspergillus*, *Penicillium*, *Humicola*, *Curvularia*, *Syncephalastrum* and *Trichoderma* (Gandjar *et al.*, 1989). Singh *et al.* (1995) in their study titled "Fungal spores are an important component of library buildings" found the major contributors to library air as *Cladosporium*, *Aspergilli*, *Penicillia*, *Alternaria*, *Drechslera* and *Curvularia*. The authors also found significant increase in the concentration of fungi in libraries after agitation of books.

The mould isolation studies show that irrespective of geographical locations, fungi in the genera *Aspergillus*, *Penicillium* and *Cladosporium* are the ones often associated with book deterioration. Lugauskas and Krikstaponis (2004) isolated 174 fungal species belonging to 52 genera from three library premises in Vilnius. However, Michaelsen *et al.* (2006) observed that only 5 per cent of fungal communities involved in paper deterioration have been accurately described owing to limitation of isolation methods and misidentifications and the incomplete knowledge of the deteriorative agents has accounted for the problems encountered in the restoration and conservation of written heritage (Michaelsen *et al.*, 2006). Mesquita *et al.* (2009) working on the mould flora of the historical documents on the archive of the University of Coimbra, Portugal found that the most frequent genera were *Cladosporium*, *Penicillium* and *Aspergillus*, and the other less frequent genera, such as *Alternaria*, *Botrytis*, *Chaetomium*, *Chromelosporium*, *Epicoccum*, *Phlebiopsys* and T*oxicocladosporium* were also present. Zielińska-Jankiewicz *et al.* (2008) found the following moulds *Aspergillus*, *Penicillium*, *Geotrichum*, *Alternaria*, *Cladosporium*, *Mucor*, *Rhizopus*, *Trichoderma* and *Fusarium* in air samples collected in a library and archive storage facilities.

Table I.
Frequency of microorganisms isolated from various deteriorating library materials at Olabisi Onabanjo University, Ago Iwoye, Ogun State

Fungi	Total isolates
Aspergillus niger[a]	29
Aspergillus flavus[a]	27
Aspergillus fumigatus[a]	*11*
Cladosporium sp.[a]	25
Neurospora sp.[a]	9
Penicillium sp.[a]	20
Rhizopus sp.[a]	*5*
Bacillus sp.[b]	*23*
Streptococcus sp.[b]	*7*
Pseudomonas sp.[b]	8
Staphylococcus sp.[b]	7
Flavobacterium sp.[b]	7

Notes: [a]Fungi (mould) isolates; [b]bacteria isolates
Source: Bankole and Abioye (2005)

Moulds by their saprophytic nature could utilize virtually any substrate as carbon source. The moulds secrete extracellular enzymes that digest papers and book bindings, thereby weakening them (Nitterus, 2000). According to Rojas *et al.* (2006), among environmental microorganisms, fungi constitute the biggest problem in micro deterioration of paper stored in archives and that the ability of fungi to degrade this and other substrates is mainly due to the production of powerful arsenal of enzymes such as cellulases, amylases and proteases. Fungal degradation of paper causes various kinds of damage depending on the organisms responsible for the attack. Some moulds frequently found on papers through the action of cellulolytic enzymes dissolve cellulose fibres in papers resulting in rapid loss of strength, or produce pigments or weak acids which causes discolouration and disfigurement of library materials (Michaelsen *et al.*, 2009). One type of mould deterioration found on books is paper foxing appearing in the form of small, brown or rusty coloured, irregular spots, sometimes having dark spots resulting from the reaction of mould spores with trace metals found in paper (Meynell and Newsam, 1978; Arai, 2000).

Bacteria are prokaryotic microorganisms that require high water activity in a slightly alkaline or near neutral pH for their metabolic activities. Ogbonna and Ejekwu (1990) reported the involvement of three bacterial species *Bacillus* sp., *Staphylococcus aureus* and *Streptococcus lactis* in the degradation of newsprints. Nwokedi and Nedosa (1999) reported the isolation of *Bacillus* sp., *S. aureus* and *Pseudomonas* sp. from deteriorating library books in Jos. The bacterial isolates obtained from deteriorating library materials in OOU include *Bacillus* sp., *Streptococcus* sp., *Pseudomonas* sp., *Staphylococcus* sp. and *Flavobacterium* sp. (Bankole and Abioye, 2005). It was established that the fungi in decreasing order of ability: *A. niger*, *A. flavus*, *A. fumigatus*, *Penicillium* sp. and *Cladosporium* sp. developed and formed fructifications from mycelia inoculated onto Whatman filter papers, which is an indication of their ability to cause degradation of paper materials. It should be noted that the mere association of a microorganism with paper or any other organic substrate does not prove its involvement in the destruction of the substrates. The two bacterial isolates *Bacillus and Pseudomonas* sp. grew mildly pointing to their minor role in the degradation of paper materials. While the results confirmed that fungi play active roles in the deterioration of paper materials, it also implies that bacteria isolated from deteriorating books may have arrived at the surfaces as contaminants from dusts, and that they do not play important role as causative agents of degradation(Bankole and Abioye, 2005). Indeed Akussah (2006) found that 86 per cent of books surveyed in the National Archives of Ghana had evidence of mould deterioration. However, the genus *Bacillus* have also been implicated as causative agent of foxing of papers, though this fungal damage has often been ascribed to fungi (De Paolis and Lippim, 2008).

Apart from the destruction of materials, the presence of these fungi on book materials and invariably in the library environment may constitute potential risks to the health of library users. According to literature, all mould species that have been isolated from paper materials are tonophilic, though to different degrees. In developed countries, exposure to moulds and their related health problems in agricultural farms, homes, offices and public buildings including school libraries have gained recognition as one of the most common indoor environmental issues (Jarvis and Miller, 2005: Gniadek *et al.*, 2005; Singh, 2006). Mould exposure could have adverse effect on the health of man through three processes: allergy, infection and by mycotoxin production (Singh, 2006). Most of the fungi that have been associated with paper deterioration have been characterized as potential allergens and inhalation of their spores may

provoke immune responses resulting in diseases such as allergic rhinitis(sneezing attacks, nasal discharge or blockage), eye irritation, cough, bronchial asthma or hypersensitivity pneumonitits or farmer's lung depending on the nature of fungi, the dosage of exposure and the health status of the individuals (Pieckova and Jesenska, 1999; National Academy of Sciences, 2004). Nilsson *et al.* (2004) found greater number of mould species in airborne dust samples from damp than in control residences with the major moulds being *Aspergillus*, *Cladosporium* and *Penicillium*. The residents of damp residences also had more compliants of allergic symptoms in the form of irritations of skin, eyes and respiratory tract. Meklin *et al.* (2002) and Cho *et al.* (2006) also reported adverse health outcomes in adults and children associated with the presence of dampness and/or mould in indoor environments. *A fumigatus*, one of the prominent fungi isolated is known to cause a respiratory disease known as "aspergillosis" with the symptoms resembling that of tuberculosis and is also known to produce the mycotoxin gliotoxin. *A flavus* produces numerous spores, which can contaminate food and produce very potent secondary metabolites such as aflatoxins and cycolpiazonic acid. Aflatoxin is a strongly carcinogenic metabolite classified as a class 1 carcinogen (IARC, 1993), and it has also been shown to cause immunotoxicity and growth retardation in West African children (Gong *et al.*, 2002). Though the principal mode of infection of mycotoxins is by ingestion of contaminated food, however, they have been proposed to cause adverse human health effects after inhalation exposure to mould in indoor residential, school and office environments (Kelman *et al.*, 2004). According to Aziagba and Edet (2008), water damaged buildings provide a moist environment for moulds to flourish and produce hazardous effect such that library users with preexisting conditions such as allergies and asthma find it difficult to stay in such places. Thus, from the health point of view, the presence of microbes on books could constitute potential source of health hazards to those working in the libraries and the users, especially those that are used to putting their hands in the mouth before flipping through the pages of books.

Insects and rodents

Insects frequently cause extensive and often irreversible destruction of books in dark (nocturnal), humid, dirty and cluttered environments. Such environments provide ready food source where they can feed, lay eggs and pupate silently (Shuhaimi, 1986). Insects can hide in cracks in bookshelves or inside books where the eggs settle in the gutter between pages. Worldwide, the important insects reported to be responsible for paper damage include silverfish (bookworm), book louse, cockroaches and termites. However, from our own observation which is also supported by literature, the danger to book by bookworm and booklouse is insignificant in the tropics. However, the termites and cockroaches have their habitation in the zones of hot climate like ours. If insects such as woodlice and weevils are found in a library, this gives the indication that the condition in the library is too humid for book storage.

The role of insects in damaging books has attracted the attention of few investigators in West Africa. Ighinosa (2000) observed that insects constitute the major problem to library development in Nigeria and that they do irreversible damage fast and secretly. Dike (1953) identified insects as the sole cause of deterioration of historical records, while Harris (1956) indicated that insects are the major factor in the deterioration of bibliographic records. Plumbe (1964) reported that tropical countries swarm with insects and pests, and that majority of the over 1,200 identified cockroaches were found in the tropics. Ighinosa (2000) noted that cockroaches are found in all libraries in the tropics

and they bring about destruction of library materials in their insatiable demand for food. Termites are capable of devouring a whole library, and could do so rapidly and so completely than the librarian becomes aware. Wet or damp conditions of tropical countries create conducive atmosphere for termites, and the damage they cause are irreparable. The termites also produce mud encrustations on the damaged material. Termite could be recognized on the library by the mud tunnels formed on the walls, book cases and library furniture. Indeed, Plumbe (1964) described Africa as the headquarters of termites. Plumbe (1964) was of the opinion that book pathology centre ought to be set up in several locations in the tropics where insects found on books could be promptly identified, and control measures proffered. Termites feed on cellulose, which is the major constituent in papers.

The rodents such as rats, mice and squirrels eat and thereby destroy binding materials, adhesives and related materials in library collections. The rodents are attracted to confined dark places, and they cause much damage to collections that are infrequently handled before the destruction is noticed. The rodents could utilize library materials as food or they can soil and permanently disfigure the collections by urinating and defecating on them. Mice and rats also usually shred and chew paper materials to make nests. It is also pertinent to note that rodents' invasion of library materials could expose users to diseases.

Measures against biological deterioration of papers

The term preservation is used to encompass all activities applied to retard the rate of deterioration of library and archival materials whether biological or abiotic. The importance of paper preservation can be summarized by the quotation of Williams Blades (1980) quoted by Walker (2008) that:

> The surest way to preserve your books in health is to treat them as you would your own children, who are sure to sicken if confined in an atmosphere which is impure, too hot, too cold, too damp or too dry.

Preventive steps could considerably prolong the useful life span of library collections and are cost effective compared to measures taken after deterioration had occurred.

Controlling moulds

Knowledge of the microclimates in library stacks and the viability of the mould airspora are two key factors in evaluating the risk of infections to which books are exposed (Galo, 1993). In modern library facilities in developed countries, the library environment with sealed windows, automated heating, cooling and ventilation systems create safe conditions for the preservation of library materials (Turner, 1985). The control of biodeterioration processes should begin with the adoption of strategies that will present unconducive environmental condition for growth of fungi. Since high temperature combined with high humidity prevailing in humid tropics facilitate fungal deterioration of paper, it should therefore be possible to prolong the life span of paper by modifying the environment to make it unsuitable for growth of moulds agents but however comfortable for library users. According to Forde (2002), climate control and monitoring is one of the keys to sustainable collection management in libraries and archives. This could be achieved by installation of air conditioners that will function round the clock in all parts and rooms of the library, because many of the microorganisms causing deterioration proliferate well under room conditions of the tropics, but have significantly reduced growth and activities under reduced

temperature (Badu, 1990). Relative humidity and temperature should be monitored on a regular basis.

Singh *et al.* (1995) found that air-conditioned libraries have lower fungal spore concentrations than naturally ventilated buildings. The practical application of installation of air conditioners may be very difficult in some tropical countries such as Nigeria due to costs and the epileptic power supply. In such situations, fans could be installed to circulate air which will remove pockets of high moisture that may occur in "dead spaces" in stacks and collections. It should be noted too that an environment with fluctuations in temperature and humidity level is the most harmful, because under these conditions, materials expand and contract, thus causing their weakening. Mould spores are carried in dusts and dirty materials, thus collections should be kept in enclosures that will keep them dust free as much as possible and foodstuffs should not be brought into areas where books are kept. Florian (1994) recommended that the optimum temperature for this purpose should be between 18 and 22 °C and humidity should be adjusted below 55 per cent.

There should be good ventilation within the library premises because an active air flow partially reduces the ability of microorganisms to function, dries the environment, destroys their structures and remove their propagules from the premises (Lugauskas and Krikstaponis, 2004). In advanced countries, equipments are available for sampling airborne allergens and airborne mycotoxins. It is vital that any standing water be mopped as soon as it is noticed, and the use of dehumidifier is recommended. Practically, library materials could be stored for long durations by putting them in zip lock or heat sealed bags or polythene bags. Polythene bags resist changes in temperature and humidity and the chances of mould damage within is minimal except the materials going into the bags have high moisture content. Apart from controlling moulds, the bagging will also control insects and make the library materials to be dust free.

Library materials showing traces of deterioration due to microorganisms should be removed immediately from circulation and quarantined because these organisms cause diseases that pose risk to human health. In addition, such deteriorating books provide inocula that could contaminate and deteriorate other paper materials in its vicinity. It is important that devices which could be used for early detection of fungal spores in library environments will permit us to intervene at the infection site at the right moment and also to detect the micro-environments where climatic parameters are not suitable for conservation purposes. The methods that could be routinely used for routine inspection to detect early mould contamination include the macroscopic and microscopic inspection (Shamsian *et al.*, 2006) and the culture method (Bankole and Abioye, 2005). Recent studies have shown that electronic nose technology could be used for effective monitoring in an indoor environment and for the detection of fungal contamination of library papers, especially if linked to a real time neural network that has information on the volatile patterns from non-spoiled paper material (Canhoto *et al.*, 2004; Orosa and García-Bustelo, 2009). Burton *et al.* (2008) reported the use of polymerase chain reaction (PCR) assays for monitoring total fungi and bacteria in indoor air.

When mould contamination has occurred inevitably such as in flooding, there are technologies for the remediation of the resulting mould and bacterial contamination. One such technology is the use of gaseous chlorine (ClO_2) for the remediation of libraries and other indoor air environment impacted by microbial growth (Southwell, 2002; Burton *et al.*, 2008).

Controlling insects and rodents

The control of insects and rodents in libraries can be accomplished by following good house keeping practices: keeping food away, screening windows and doors, screening air intakes and louvers and killing any insect or rodents found in the house. Akussah (2006) found little evidence of insect and rodent damage to books in the National Archives of Ghana due to the maintenance of clean environment and strict regulations on non-eating repositories. Adequate lightning of buildings also ensures that insects are not attracted. Insecticide formulations can be used to kill insects but the drawbacks are that it could be harmful to man if regulations are not properly followed and it can cause damaging reactions with paper artefacts. Thus, while there are many chemical available that will efficiently deal with biological agents, care must be taken to ensure that the ones used do not have destructive effect on library materials and that they do not pose hazards to the health of library staff and users. The library buildings should regularly be inspected all round, and if necessary use traps could be used to kill rodents. There are also glue boards which could be used to control rodents within library premises. Rodent baits could also be used to control rats, but the use should be restricted to the exterior of library buildings because carcasses of rats if not detected early inside library buildings will breed large insect populations.

Training of staff on preservation methods

Education represents a low cost preservation activity that the libraries in developing countries should embark upon. Akussah (1991) identifies lack of training and awareness as a major factor that contributes to deterioration of archives and public records in Ghana and recommended the training of information professionals and patrons of libraries. Nwokedi and Nedosa (1999) opined that the knowledge of factors causing deterioration on library materials is vital to understanding why certain activities must be carried out on a long-term basis to retard degradation of library materials. Kanyengo (2009) contended that though some libraries have preservation departments, but their activities are restricted only to book and journal binding. The survey carried out by the Joint IFLA/ICA on conservation and preservation facilities showed that up to 2000, no formal training was offered on conservation in Africa, though several courses which were just of short durations were provided (Coates, 2000). Akussah (2005) and Alegbeleye (2008) recommended that the library, archival and information schools should provide formal education and training on conservation and preservation of library materials. Akussah (2005) posited that the training could be carried out through in-house and continuous education programmes such as workshops and seminars. Olatokun (2008) opined that for the successful implementation of conservation and preservation programmes, there should be adequate and trained manpower who are information professionals that understand the physical and chemical nature of the materials in the library holdings. In addition to training staff, there is also the need for the regular training of users on proper handling methods, and in situations where the latter is not realistic; Walker (2008) recommended that library staff must be available to keep watch to intervene when harmful practice is noticed. Gaba (1995) reiterated the inculcation of a preservation culture in both staff and users, and that library staff and management should consider the preservation of library materials as an integral part of library practice.

Preservation criteria should be incorporated into collection decisions by academic libraries. Libraries should employ collection conservation librarians whose duty will be the physical care of various library materials.

As it is practiced in developed countries, there is the need for tropical countries to set up in each library a unit to carry out inspection and evaluation of possible mould and insect infestations and other visible pests in library environment. The inspection represents a cost effective method within an integrated pest management programme (IPM). The IPM means the control of pests using integrated and environmentally friendly methods such as biological control and raising awareness and educating the public along with minimal use of relatively safe chemical control methods. The IPM plan monitors, identifies the pest, provide good sanitation, modifies the environment to make them unfriendly to pests, and also embarks on treatment action when deemed fit. The inspection team should regularly look for harbours of insects, improper storage methods, moulds and other conditions that could promote the proliferation of biological agents of deterioration. More importantly, older documents acquired through donations or purchase should first be assessed, and if need be quarantined and examined by specialists. It is important that personnel to carry out this assignment must have been well trained on biological agents of library materials, their habitats, and the hazards they constitute to collections. Finally, in line with the practice in the developed world, there is the need for libraries in the tropics to set up Preservation Department where cases involving biological infestations of library materials could be handled by experts. Also, libraries should collaborate with scientists in relevant discipline such as entomologists to deal with insects and mycologists to deal with moulds to be able to devise appropriate preventive and treatment strategies against paper deterioration.

Policy formulation and financial commitment

The libraries in the tropics should have preservation and conservation policies that will include biological management policies which will serve as guide to library personnel in maintaining a pest- and mould-free environment in the libraries. Wamukoya and Mutula (2005) reported that most African countries do not have preservation and conservation policies in their libraries and information centres. However, the survey of Olatokun (2008) showed that the libraries in Nigeria have preservation policies, though the provision in the guidelines are seldom adhered to. Foot (1996) argued that though human resources, knowledge, common sense, time and energy are vital, but that adequate funding is even much more important for successful implementation of storage policy. Olatokun (2008) identified inadequate funding as the greatest constraint against effective preservation and conservation of library materials in Nigeria.

Conclusions

This paper has given an overview of biological agents that degrade library materials especially papers which has remained the main carrier of recorded information. It also highlights various possible approaches that could be applied to curb the detrimental effects of the biodeteriogens in the tropics. The warm and humid tropical climate provide conducive conditions for the proliferations of biological agents especially moulds, thus making the problem to be more prominent in the tropics than in temperate regions. In addition to their roles in the deterioration of library holdings, the biological agents mostly fungi could be hazardous to the health of staff and library users. It is naturally not possible to have an environment free of mould spores, and the most cost effective action to make them remain inactive or dormant is to properly monitor the temperature and relative humidity of library environment and have good air-conditioning system/ventilation, and good hygiene. Interestingly, all the practices

listed above will also prevent insect infestation and to some extent control rodent encroachment. The health and safety concern should take first priority, thus mould contaminated objects should be promptly removed and quarantined as soon as they are noticed. There is the urgent need for countries in the tropics to have national policy for preservation of library materials as at present; such policies are non-existent in most libraries in developing countries.

References

Akussah, H. (1991), "The preservation of library and archival materials in the harsh Ghanaian environment", *African Journal of Library, Archives and Information Science*, Vol. 1, pp. 19-28.

Akussah, H. (2002), "Records management and preservation in government ministries and departments in Ghana", *African Journal of Library, Archives and Information Science*, Vol. 12, pp. 155-65.

Akussah, H. (2005), "Preservation of public records in Ghana: the training, education and awareness factors", *Information Development*, Vol. 21, pp. 295-302.

Akussah, H. (2006), "The state of document deterioration in the National Archives of Ghana", *African Journal of Library, Archives and Information Science*, Vol. 16 No. 1, pp. 1-8.

Alegbeleye, B. (1996), "A study of book deterioration at the University of Ibadan Library and its implications for preservation and conservation in African university libraries", *African Journal of Library, Archives and Information Science*, Vol. 6 No. 1, pp. 37-45.

Alegbeleye, G.O. (2008), "Past imperfect, present continuous, future perfect: the challenges of preserving recorded information in Nigeria", *An Inaugural Lecture at the University of Ibadan, 24 January.*

Arai, H. (2000), "Foxing caused by fungi: twenty five years of study", *International Biodeterioration and Degradation*, Vol. 46, pp. 181-8.

Aziagba, P.C. and Edet, G.T. (2008), "Disaster-control planning for academic libraries in West Africa", *The Journal of Academic Librarianship*, Vol. 34 No. 3, pp. 265-8.

Badu, E.E. (1990), "The preservation of library materials: a case study of University of Science and Technology Library in Ghana", *Aslib Proceedings*, Vol. 42 No. 4, pp. 119-25.

Bankole, O.M. and Abioye, A. (2005), "Evaluation of deterioration of library materials at Olabisi Onabanjo University Library, Ago-Iwoye, Nigeria", *African Journal of Library, Archives and Information Science*, Vol. 15 No. 2, pp. 99-108.

Bansa, H. (1981), "The conservation of library collections in tropical and sub-tropical condition: the problem of increased dangers of damage and decay in areas of high temperature and humidity", *IFLA Journal*, Vol. 7 No. 3, pp. 264-7.

Burton, N.C., Adhikari, A., Iossifova, Y., Grinshpun, S.A. and Reponen, T. (2008), "Effect of gaseous chlorine dioxide on indoor microbial contaminants", *Journal of Air and Waste Management Association*, Vol. 58 No. 5, pp. 647-56.

Canhoto, O., Pinzari, F., Fanelli, C. and Magan, N. (2004), "Application of electronic nose technology for the detection of fungal contamination of library paper", *International Biodeterioration and Biodegradation*, Vol. 54, pp. 303-9.

Cappitelli, F. and Sorlini, C. (2005), "From papyrus to compact disc: the microbial deterioration of documentary heritage", *Critical Reviews in Microbiology*, Vol. 31, pp. 1-10.

Cho, S., Reponen, T., LeMasters, G., *et al.* (2006), "Mold damage in homes and wheezing in infants", *Annals of Allergy, Asthma and Immunology*, Vol. 97 No. 4, pp. 539-45.

Coates, P.R. (2000), *JICPA Survey of Conservation and Preservation Facilities and Experts in Africa*, available at: www.epa.prema.net/jicpa/survey.htm (assessed 21 September 2007).

De Paolis, M.R. and Lippim, D. (2008), "Use of metabolic and molecular methods for the identification of A *Bacillus* strain isolated from paper affected by foxing", *Microbiological Research*, Vol. 163, pp. 121-31.

Dike, K. (1953), *Report on the Preservation and Administration of Historical Records and Establishment of Public Record Office in Lagos*, Government Printer, Lagos.

Domsch, K.H., Gams, W. and Anderson, T.H. (1980), *Compendium of Soil Fungi*, Vol. 1, Academic Press, New York, NY, p. 959.

Florian, M.L.E. (1994), "Conidial fungi (mould, mildew) biology: a basis for logical prevention, eradication and treatment for museum and archival collections", *Leather Conservation News*, Vol. 10, pp. 1-28.

Foot, M.M. (1996), "Housing our collections: environment and storage for libraries and archives", *IFLA Journal*, Vol. 22, pp. 11-114.

Forde, H. (2002), "Overview of collections information and advice in the archives domain", Council on Library and Information Resources, available at: www.clir.org/pubs/reports/pub89/contents.html (accessed 10 October 2004).

Gaba, B.S.A. (1995), "Preservation practices in the University of Cape Coast Library: an appraisal", *Aslib Proceedings*, Vol. 47 No. 5, pp. 127-9.

Galo, F. (1993), "Aerobiological research and problems in libraries", *Aerobiologia*, Vol. 9, pp. 117-30.

Gandjar, I., Abdis, D.N.D. and Wardasasmita, S. (1989), "Moulds isolated from old archive materials in Indonesia", *World Journal of Microbiology and Biotechnology*, Vol. 5, pp. 387-9.

Gniadek, A., Macura, A.B., Oksiejczukc, E., Krajewska-Ku"ak, E. and Łukaszuk, C. (2005), "Fungi in the air of selected social welfare homes in the Malopolskie and Podlaskie provinces – a comparative study", *International Biodeterioration and Biodegradation*, Vol. 55, pp. 85-91.

Godds, L.N., Hiss, A. and Buch, S.I. (1973), *Materials and Technology Wood, Paper, Textiles, Plastics*, Longman, London, pp. 137-203.

Gong, Y.Y., Cardwell, K.K., Hounsa, A., Eggal, S., Turner, P.C., Hall, A.J. and Wild, C.P. (2002), "Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: a cross-sectional study", *British Medical Journal*, Vol. 325, pp. 20-1.

Harris, J. (1956), "Notes on book preservation in West Africa", *Walas News*, Vol. 2, pp. 1-25.

Hart, P.E. and Liu, Z. (2003), "Trust in the preservation of digital information", *Communications of the ACM*, Vol. 46 No. 6, pp. 93-7.

IARC (1993), "Some naturally occurring substances: food items and constituents, heterocyclic amines and mycotoxins", IARC Monographs on Evaluation of Carcinogenic Risk to Humans, International Agency for Research on Cancer 56, Lyon.

IFLA-PAC China Centre (2006), *Strategic Plan 2006-2008,* available at: www.nlc.gov.cn/en/services/iflapac_chinacenter/strategem.htm (accessed 17 March 2008).

Ighinosa, I.O. (2000), "Insect control in libraries: a case study of cockroaches in the tropics", *Nigerian Libraries*, Vol. 34, pp. 64-9.

Jarvis, B.B. and Miller, J.D. (2005), "Mycotoxins as harmful indoor air contaminants", *Applied Microbiology and Biotechnology*, Vol. 66, pp. 367-72.

Kanyengo, C.W. (2009), "Managing digital information resources in Africa: preserving the integrity of scholarship", *The International Information & Library Review*, Vol. 41 No. 1, pp. 34-43.

Kelman, B.J., Robbins, C.A., Swenson, L.J. and Hardin, B.D. (2004), "Risk from inhaled mycotoxins in indoor office and residential environment", *International Journal of Toxicology*, Vol. 23, pp. 3-10.

Korpi, A., Pasanen, A.-L., Pasanen, P. and Kalliokoski, P. (1997), "Microbial growth and metabolism in house dust", *International Biodeterioration and Biodegradation*, Vol. 40 No. 1, pp. 19-27.

Lugauskas, A. and Krikstaponis, A. (2004), "Microscopic fungi found in the libraries of Vilnius and factors affecting their development", *Indoor and Built Environment*, Vol. 13, pp. 169-82.

Maggi, O., Persiani, A.M., Gallo, F., Valenti, P., Pasquariello, G., Sclocchi, M.C. and Scorrano, M. (2000), "Airborne fungal spores in dust present in archives: proposal for a detection method, new for archival materials", *Aerobiologia*, Vol. 16, pp. 429-34.

Majumdar, S. (2005), "Preservation and conservation of literary heritage: a case study of India", *The International Information and Library Review*, Vol. 37, pp. 179-87.

Meklin, T., Husman, T., Vepsäläinen, A. *et al.* (2002), "Indoor air microbes and respiratory symptoms of children in moisture damaged and reference schools", *Indoor Air*, Vol. 12, pp. 175-83.

Mesquita, N., Portugal, A., Videira, S., Rodríguez-Echeverrı, A.A., Bandeira, A.M.L., Santos, M.J.A. and Freitas, H. (2009), "Fungal diversity in ancient documents. A case study on the Archive of the University of Coimbra", *International Biodeterioration & Biodegradation*, Vol. 63 No. 5, pp. 626-9.

Meynell, G. and Newsam, R.J. (1978), "Foxing, a fungal infection of paper", *Nature*, Vol. 274, pp. 466-8.

Michaelsen, A., Pinae, G., Montanari, M. and Pinzari, F. (2009), "Biodeterioration and Restoration of a 16th-century book using a combination of conventional and molecular techniques: a case study", *International Biodeterioration and Biodegradation*, Vol. 63, pp. 161-8.

Michaelsen, A., Pinzari, F., Ripka, K., Lubitz, W. and Pinar, G. (2006), "Application of molecular techniques for identification of fungal communities colonizing paper material", *International Biodeterioration and Biodegradation*, Vol. 58, pp. 133-41.

Mueller, G.M. and Schmit, J.P. (2007), "Fungal biodiversity: what do we know? What can we predict?", *Biodiversity Conservation*, Vol. 16, pp. 1-5.

Mwangi, K.M. (1994), "Book longevity: chemistry or the librarians responsibility?", *Nigerian Archives*, Vol. 4, pp. 10-14.

Mwiyeriwa, S. (1988), "The development of archives in Africa: problems and prospects", in Michael, W. (Ed.), *Aspects of African Librarianship*, Mansell, London, p. 258.

National Academy of Sciences (2004), *Damp Indoor Spaces and Health*, National Academies, Washington, DC, available at: www.nap.edu

National Library of Australia (2004), "Preservation policy", available at: www.nla.gov.au/policy/pres.html (accessed 10 December 2007).

Ngulube, P. (2005), "Environmental minitoring and control in national archives and libraries in Eastern and Southern Africa", *Libri*, Vol. 55, pp. 154-68.

Nilsson, A., Kihlstrom, E., Lagesson, V., Wessen, B., Szponar, B., Larsson, L. and Tagesson, C. (2004), "Microorganisms and volatile organic compounds in airborne dust from damp residences", *Indoor Air*, Vol. 14, pp. 74-82.

Nitterus, M. (2000), "Fungi in the archives and libraries", *Restaurator*, Vol. 21, pp. 25-40.

Nwokedi, V.C. and Nedosa, P.S. (1999), "Studies on microorganisms associated with the deterioration of some library book materials in Jos, Nigeria", *African Journal of Library, Archives and Information Science*, Vol. 9 No. 1, pp. 75-88.

Ogbonna, C.I.C. and Ejekwu, E.O. (1990), "A comparative study of the microbiology of made in Nigeria toilet rolls and used newspapers", *University of Jos Faculty of Science Research Communications*, Vol. 1, pp. 47-50.

Ojo-Igbinoba, M.E. (1993), "The practiseof conservation of library materials in sub Saharan Africa", Monograph of Africana Librarianship No. 3, African Studies Program, Indiana University, Bloomington, IN.

Olatokun, W.M. (2008), "A survey of preservation and conservation practices and techniques in Nigerian University Libraries", *LIBRES Library and Information Science Research Electronic Journal*, Vol. 18 No. 2, available at: http://libres.curtin.edu.au/

Orosa, J.A. and García-Bustelo, E.J. (2009), "Ashrae standard application in humid climate ambiences", *European Journal of Scientific Research*, Vol. 27 No. 1, pp. 128-39.

Pieckova, E. and Jesenska, Z. (1999), "Microscopic fungi in domestic dwellings and their health implications in humans", *Annals of Agriculture and Environmental Medicine*, Vol. 6, pp. 1-11.

Plumbe, W.J. (1964), *The Preservation of Books in Tropical and Subtropical Countries*, Oxford University Press, London.

Rojas, A., Mikan, J., Villalba, L. and De Garcia, M.C. (2006), "Partial purification of proteases from filamentous fungi that cause deterioration of industrial paper", *Phytopathology*, Vol. 96 No. 6, p. S99.

Sekete, S.S.P. (2004), "Records preservation in developing countries with special reference to Tanzania", *Dar es Salaam Library Journal*, Vol. 6 No. 2, pp. 108-23.

Shamsian, A., Fata, A., Mohajeri, M. and Ghazvini, K. (2006), "Fungal contaminations in historical manuscripts at *Astan Quds*Museum Library, Mashhad, Iran", *International Journal of Agriculture and Biology*, Vol. 8 No. 3, pp. 420-2.

Shuhaimi, H. (1986), "The effects of environmental factors on library and archival materials and services", *Environmental Information*, p. 5.

Singh, J. (2006), "Toxic moulds and indoor air quality", *Indoor Built Environment*, Vol. 14 Nos 3/4, pp. 229-34.

Singh, A., Ganguli, M. and Singh, A.B. (1995), "Fungal spores are an important component of library buildings", *Aerobiologia*, Vol. 11 No. 4, pp. 231-7.

Small, B.M. (2003), "Creating mould free building. A key to avoiding health effects of indoor moulds", *Archives of Environmental Health*, Vol. 58 No. 8, pp. 523-7.

Southwell, K.L. (2002), "The use of chlorine dioxide as a mould treatment and its effect on paper acidity: a case study", *The Journal of Academic Librarianship*, Vol. 28 No. 2, pp. 400-5.

Turner, S. (1985), "Mould-The silent enemy", *The New Library Science*, Vol. 4, pp. 1-21.

Varlamoff, M. (2005), "The first step in preservation: building the right building", paper presented at the World Library and Information Congress: 71st IFLA General Conference and Council "Libraries – A Voyage of Discovery", 14-18 August 2005, Oslo, available at: www.ifla.org/IV/ifla71/papers/100e-Varlamoff.pdf (accessed 6 September 2008).

Walker, A. (2008), *Basic Preservation Guidelines for Library and Archive Collections*, 3rd revision, National Preservation Office, London.

Wamukoya, J. and Mutula, S.M. (2005), "E-records managament and governance in East and Southern Africa", *Malaysian Journal of Library and Information Science*, Vol. 10 No. 2, pp. 67-83.

Zielińska-Jankiewicz, K., Kozajda, A., Piotrowska, M. and Szadkowska-Stańczyk, I. (2008), "Microbiological contamination with moulds in work environment in libraries and archive storage facilities", *Annals of Agriculture and Environmental Medicine*, Vol. 15, pp. 71-8.

Zyska, B. (1997), "Fungal types isolated from library materials: a review of the literature", *International Biodeterioration and Biodegradation*, Vol. 40 No. 1, pp. 43-51.

Further reading

Eckardt, J. (2004), "Indoor moisture and mould related problems", *Allergie et Immunologie*, Vol. 36 No. 2, pp. 182-5.

International Federation of Library Associations (2002), *The Joint IFLA/ICA Committee on Preservation and Conservation in Africa (JICPA) Report 2002*, available at: www.ifla.org/VII/s25/p1/jicpa02.htm (accessed 5 June 2009).

Proietti, N., Capitani, D., Pedemonte, E., Blumich, B. and Segre, A.L. (2004), "Monitoring of paper: non-invasive analysis by unilateral NMR: part 11", *Journal of Magnetic Resonance*, Vol. 170, pp. 113-20.

Zotti, M., Ferroni, A. and Calvini, P. (2008), "Microfungal biodeterioration of historic paper; preliminary FTIR and microbiological analyses", *International Biodeterioration and Biodegradation*, Vol. 62, pp. 186-94.

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