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Environment and passive climate control chiefly in tropical climates

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Introduction. This presentation will focus on some of the effects of climate on library and archives collections in tropical climates, and will discuss some prudent alternatives to the mechanical and chemical approaches commonly used to control climate and its immediate effects. One of the most important factors affecting the longevity of library and archival materials is the environment in which they are stored, used, and displayed. Substantial research has demonstrated the profound effects of temperature, humidity, light, air circulation, and pollution, and controlling these effects is the highest priority of any preservation program.

THE MAIN FACTORS IN CONTROLING ENVIROMENT

I will review some of the main factors that affect environment, namely temperature, humidity, light, and atmospheric pollution, as all combine to shorten the life of library and archives materials.

Temperature. The higher the temperature, the more rapidly materials will deteriorate because heat accelerates the chemical reactions that cause deterioration. Conversely, the lower the temperature the longer the materials will last. However, as most library and archival materials must coexist with humans, there is clearly a practical limit to how much the temperature can be lowered and maintained. If temperature can be closely controlled, it should have a practical range of 20 degrees centigrade to 21 centigrade (68F to 70F), consistently maintained in all areas of a library or archives facility. These levels are regarded as tolerable to staff and users and appropriate for most materials. However, it is important to remember that the soc-called "standards" for both temperature and relative humidity are based on conditions and resources in temperate climates, and may be unattainable in humid tropical areas. If temperature cannot be controlled because of a lack of adequate mechanical systems, other measures should be considered to ameliorate the situation.

Humidity. Humidity is present in all air, and the term relative humidity (RH) refers to the given percentage (amount) of water vapor in the air at a given temperature. When temperature is high, air can absorb and contain a great deal of moisture, but when temperature is low, the moisture is deposited from the air onto surfaces. Clearly, in this way, temperature is closely linked to the level of relative humidity as cooler temperatures cannot hold as much humidity as warmer temperatures, thus a rapid lowering of temperature can result in condensation on non-hygroscopic (non-absorbent) surfaces while hygroscopic (absorbent) materials such as paper become damp. For example, a daytime temperature of 20 degrees centigrade (70 F) with a relative humidity of 50% can change conditions very rapidly if the overnight temperature drops to 13 degrees centigrade (60 F), as this causes the relative humidity to drastically increase to 70%.

Most paper expands and contracts with fluctuations in RH and this fluctuation helps to shorten the life of paper and binding materials because of stresses that occur within their structure. In general, the consequences of low RH are much less serious than for high RH. High humidity can cause mold to develop, especially when linked to poor air circulation. High humidity also provides a hospitable environment for insects, which must have moisture in order to survive and flourish. A range of 35% RH to 40% RH is acceptable and achievable in tropical climates with the right equipment, but failing this, RH should be lowered as much as possible through natural means, perhaps by increasing the rate of air flow in the building.

Light. Exposure to high levels of light causes fading (especially of inks and colors), darkening and yellowing (especially of paper containing wood and lignin), and the weakening of fibers. Both sunlight and artificial light (especially fluorescent) are sources of ultra-violet, which is the most harmful of the light wavelengths. However, all direct light is damaging to some degree. Materials are at their most vulnerable when exposed on long-term display or when stored under strong constant light, in front of a window for example.

The amount of light is measured in lox or foot-candles, with one lux (or lumen) equivalent to 0.09 foot-candles. A 150 watt incandescent light bulb will produce 50 lux at a distance of one meter. In storage areas, lights should always be turned off when the area is not in use, but should be limited to 100 lux unless materials are covered. Materials on exhibition display should generally not be subjected to light stronger than 80 lux. In addition, ultra-violet shields should be employed if the lights are fluorescent. Light entering through windows should be filtered through screens or blinds.

Atmospheric Pollution. Pollutants are generally in the form of gases and particulates. While most pollution enters a building from outside, pollution can also be caused by construction materials, paints, cleaning solvents, untreated wood, particle board, and plastics, which can emit gases that are harmful to paper. Gases that are harmful include nitric oxide, sulfur dioxide, carbon monoxide, formaldehyde, and a wide variety of industrial gases. Particulates consist of small solids, such as grit, dust, and smoke. Heating, ventilating, and air cooling systems (HVAC) are the primary methods by which conservation environments are maintained. The purpose of HVAC is to establish and maintain humidity (add or remove moisture), and temperature (add or remove heat), filter incoming air to remove particulates and gaseous substances, circulate air to spread heat/cooling, to suppress mold growth, and perform these tasks constantly and evenly throughout the collection storage areas.

When libraries and archives have HVAC available, they have found that good conditions are best met by constant-volume all-air systems with central air-handling stations where filtration, dehumidification, humidification, maintenance and monitoring, are at a central location rather than distributed. If libraries and archives are constructed with HVAC systems built into them, or are able to retrospectively install HVAC, it is important to consider specifications that will produce a continuous conservation environment.

Some library materials require much more exacting storage conditions than are required for paper-based material. Motion picture film, colour film, and microfilm, for example, must be kept in a cool, dry, environment, so even if HVAC is not practical or affordable for a larger storage space, a small vault or cabinet with good controls should be used. Such a cabinet should maintain low temperatures---around 20 degrees centigrade---but more important is the level of relative humidity, which should not exceed 35 percent. This can only be achieved through a dehumidification system or through the use of a desiccant such as silica gel. Silica gel can be conditioned to maintain a low RH by absorbing humidity within a tightly closed cabinet. As the silica gel becomes saturated, it can be reconditioned by heating out the humidity and reused indefinitely.

PASSIVE CLIMATE CONTROL

Because of high energy costs and the impracticability of HVAC for many libraries and archives, there is now a great deal of interest in passive climate control systems. In tropical climates, HVAC can have indirect but serious detrimental effects, especially if it cannot be operated on a continuous basis. Generally, HVAC can be very effective in cooling spaces, but in climates with extremely high levels of humidity it does not function well enough as a dehumidifier to ensure effective climate control, and must often be used in combination with dehumidifiers. This is because the cooler temperature obtained by HVAC can actually increase the relative humidity. When HVAC cannot be used on a continuous basis---as when it is shut down at night or weekends for example---it has the effect of cooling the collection, but as the air heats up, condensation is formed on the colder surfaces of books, shelves, and walls resulting in mold growth.

It is also a common mistake to use HVAC to try to maintain low temperature and relative humidity only in an isolated area of the library or archive, such as a rare book storage vault. When “cold” objects are brought from the vault to an uncontrolled area with high temperature and relative humidity, condensation forms on the objects, and on the outside of the cold wall of the vault causing mold growth as well as structural damage to the wall.

Passive climate control is closely associated with the movement towards sustainable buildings, and there has been considerable interest in this area over the last several years as energy costs have risen and more attention has been paid to environmental issues. In essence, sustainable buildings apply specific climate design and construction materials to create a structure that achieves both energy saving and a tolerable internal climate. These buildings are designed to: reduce heat gain during the day and increase heat loss at night, locate on sites that offer a good microclimate, control solar radiation, regulate and improve air circulation. With a new sustainable building, issues of importance are: site selection (away from areas of possible flooding, orientation to prevailing winds and sun position), natural shading (trees, hills, other buildings), shelter (from tropical storms, destructive high winds), structural materials and design (open lightweight wall structures in humid tropical areas, thick walls in arid tropical areas).

Unfortunately, many libraries and archives are in existing buildings of poor design, but steps can be taken to reduce heat intake and light damage, and significantly improve the rate of air circulation. In some cases, buildings of a traditional design, constructed in an age before HVAC, are being replaced with sealed buildings based on standard Western design. The traditional building design often functions well and is responsive to local conditions, but the “modern” Western style building with a large number of sealed windows often cannot accommodate local conditions in the face of a poorly functioning or inconsistently operating HVAC.

Good air circulation is often the key to maintaining a tolerable climate, as moving air helps to dry humidity and greatly reduces the incidence of mold. In some cases, existing buildings have other design faults resulting in serious environmental problems. A common problem is “rising damp,” a condition where ground moisture is conducted upwards through (a), a masonry wall, or (b) through a concrete floor slab. In the case of (a), paint and the underlying plaster become damp and flake off the wall. In the case of (b), the concrete slab seems always to be damp, which damages shelving and contributes to the overall levels of humidity in the building.

Rising damp is usually the result of the lack of a damp course in the case of a masonry wall. A damp course is a waterproof barrier placed across the section of the wall just above ground level to prevent moisture rising through the porous masonry. In the case of a damp concrete slab, dampness results from the lack of a waterproof membrane between the soil and the concrete. The following steps can be considered when attempting to improve the climate of a building without the use of HVAC.

Reduce heat gain by covering windows to the East and West by screens or curtains to control direct sunlight, alternating according to the time of day.

Reduce heat through the use of surrounding vegetation, such as shade trees.

Increase air circulation by taking advantage of breezes, especially to the South and North, keeping windows open but screened to prevent the entry of insects and birds. Outdoor obstacles to ambient breezes should be removed, and in some cases, outdoor baffles can be erected to divert breezes through windows.

Improve air circulation by opening up any vents or small windows close to the ceiling to stimulate the circulation of air through open windows at floor level upwards through the room. Enhance circulation with ceiling fans if available.

Reduce heat intake by using reflective colors on roof surfaces.

Reduce heat radiating through from the roof by installing false ceilings.

.Reduce extreme humidity with dehumidifiers if available.

Damp courses can be set in place in the base of masonry walls by progressively removing bricks and inserting a waterproof layer, such as slate or asphalt. In the case of cavity walls, air bricks or vents can be installed at the base of the wall to permit air to circulate through the air space.
Where buildings are raised, ensure that air is permitted to circulate fully beneath the structure by removing any obstructions, and by taking steps to ensure dry conditions.

MONITORING

The continuous monitoring of temperature and relative humidity is extremely important whether or not the library/archive has climate control systems. Where an HVAC system is in place, monitoring provides the opportunity to evaluate its performance and take corrective action when needed. If the library does not have an HVAC system, an accurate record of temperature and relative humidity through all seasons and conditions can provide the essential data from which to design a system in the future, and can indicate where and when some remedial action can be taken. Monitoring at its simplest level can mean taking regular sightings of a thermometer and a hygrometer, noting the changes throughout the day. Although there are now quite sophisticated instruments for checking the temperature and relative humidity—such as hand-held electronic hygrometers that measure both, the disadvantage of this method is that in the long term it is extremely labour-intensive and usually accounts for readings taken only when the library/archive is open, generally failing to record night-time or holiday conditions. This is also the disadvantage of using basic thermometers, dial-type hygrometers, and humidity strips. The most effective use of staff time and the most accurate test of climate conditions is through the use of automatic monitors, such as recording hygrothermographs, calibrated with a psychrometer, and electronic data-loggers.

RESULTS OF POOR CLIMATE CONTROL

The environment that is the most damaging to library and archives collections---high humidity, low air circulation, combined with poor housekeeping---is the most beneficial for mold and insects. As mold and insect infestations have commonly been addressed with questionable and expensive chemical treatments, it seems pertinent to examine some alternative approaches.

Mold

One of the most common problems in libraries and archives in humid tropical regions is mold (mould). Mold is a general term given to a wide variety of fungi, and practically all types are common to all parts of the world. Mold grows through the propagation of its spores, which are always present in the air waiting for the right opportunity to germinate. Moisture provides the necessary conditions for mold germination, whether or not the moisture is the result of high relative humidity, condensation, or direct wetting, as in the case of water-damaged materials. The visible signs of mold result from the “flowering” of the spores into mycelium, the familiar velvet-like surface covering. The mycelium, in turn, becomes powdery and generates more mold spores that become airborne to continue the cycle. At this point, mold spores are at their most dangerous to human health, and the treatment of mold-infected material must be handled with great care to avoid inhalation.

It is important to remember that mold is the result of bad environment, usually high humidity and poor air circulation. Temperature is less of a factor, except, of course, as it affects relative humidity, with low temperatures resulting in higher humidity and readier dew point (i.e. when moisture forms on surfaces). Mold can grow on any moist surface, such as a plastic shower curtain, but it can also feed on hygroscopic materials such as paper, leather, and book coverings, causing disfiguring multi-coloured stains and greatly reducing their strength. The characteristic brown spots---“foxing”--- on some types of paper is the result of high humidity and a particular form of mold.

Prevention. Mold grows in conditions of high relative humidity, direct wetting, and poor air circulation. The only way to resolve a mold growth problem is by altering these conditions. For example, if paper collections are stored in a basement area with low temperature, high relative humidity, little light, and very low air circulation---ideal mold conditions--- it seems sensible to reverse the conditions, perhaps by storing the materials elsewhere. Even if a successful remedial mold treatment programme is undertaken, the material will quickly mold again if it is returned to the environment in which the mold first developed.

Sometimes mold can develop in small areas that serve as micro-environments, even in an otherwise stable environment. In these cases, a survey of the area will usually reveal air circulation problems in an area of the storage in which there is little or no air circulation. In some cases, a closed micro-environment, such as an exhibit case, can be conditioned to control humidity through means of a desiccant. Certain mites (commonly known as book lice) can be a useful indicator of mold, as these tiny grey/white mites will inhabit the inner margins of a damp book and feed on microscopic mold embedded in the paper. Hidden molds can be detected through the use of ultraviolet lights as mold fluoresces when exposed. Mold can also be detected by the musty odour that is common to many damp basement areas.

If mold is discovered, immediate steps should be taken to discover the cause. Check for water infiltration (wet floors, ceiling, or walls), whether or not the HVAC is functioning correctly (appropriate level of air flow, whether or not the pre-heat coil or misting unit is working), and if there is a structural problem (rising damp, condensation, etc). Although not all molds are toxic to humans, it is important to regard all infestations as possibly toxic and take the appropriate precautions (respirator and gloves) when entering an infested area.

When the cause has been traced, take immediate steps to correct it. Vacuum or mop up standing water, adjust the HVAC, and/or activate electric fans to speed up the circulation of air. If dehumidifiers are available, they should be employed in tandem with both HVAC and fans.

Mold is the prime enemy of film materials as it attacks the surface and emulsion. If film is unprocessed and in a proven moisture-proof container, it is usually safe from mold damage. However, when the package is broken, mold threads or filaments develop and immediately become apparent when the film is exposed. Film left in a camera in humid conditions is especially susceptible to mold. Coating microfilm during processing is regarded as a useful preventative measure, as this reduces the risk to the emulsion layer and allows the mold to be removed before serious damage is caused. Examples of such coatings include polysulfide, a protective coating developed by the Image Permanence Institute of Rochester, New York, United States of America.

Treating Mold Infected Books. In the past, a variety of chemical procedures was used for "killing" mold spores, including the use of ethylene oxide in a vacuum chamber (now effectively banned because of health concerns) and heated thymol and para-dichlobenzine (now recognized as ineffective as fungicides but with possible application as fungistats in some circumstances). No matter what chemicals are used to kill mold, materials would again become molded if returned to the same environment as there is little residual effect. If a large number of books are wet or damp, freezing is a way of quickly stabilizing the infestation until appropriate treatment can be dispensed.

At its most basic, the treatment of mold infected books requires that they be taken to a well-ventilated area with electric fans to increase air movement. A good arrangement is to have a fan blow across the infected books through an open window or, if available, handle the books inside a running fume hood (cupboard). The rapidly moving air will dry out the moisture in the books and desiccate the mold spores, effectively rendering them "inactive." If necessary, take the books outdoors and place in the sun and a mild breeze for a short time, and if possible, work to remove the mold outdoors if the conditions permit. Ultra-violet rays from the sun can kill mold. In handling infected books, staff should wear HEPA face masks or respirator and wear plastic or rubber gloves.

When the books are dry, a HEPA filter vacuum cleaner should now be used to remove as much of the inactive and dry mold from the covers of the books as possible. If the library does not have a HEPA filter vacuum available, activated dusters (i.e. dusters with an electrostatic charge or containing a mild adhesive) can be used. The dusters should be laid over the infected area and the mold spores gently picked up. The objective of these measures is to avoid releasing the mold spores into the air.

When the soft mold has been removed, the outside of the book covers can be wiped with a solution of ethyl alcohol. This acts as a mild solvent to remove some of the outer staining. Care must be taken not to overly wet the area.

The inside of the books can now be examined. In many cases, mold stains will be seen on the inside of the binding near the joints and at the head and tail. The stains can be gently swabbed with the ethyl alcohol but it is unlikely that the stains will be completely removed. Although mold stains can be bleached out with chemical bleach, this is not a method that can be recommended, as bleach can rapidly deteriorate the paper, especially in humid conditions.

Returning Treated Books. Books should not be returned to the original shelf locations until the space is declared completely free of mold and the cause identified and rectified. Affected surfaces in the room can be washed down with a liquid bleach (Lysol), but this should be completely dry before the room is again occupied.

Following the return of the books to the shelf, the room should be inspected periodically to ensure that the mold problems have not returned. HVAC components should be checked, especially vent areas, and HVAC filters changed on a regular basis. In the absence of HVAC, ensure that improvements are made to the rate of air circulation.

Mold: Wrong Steps. Unfortunately, there are numerous rough and ready approaches that have been taken in the past to remove mold. Here are a few measures that must not be taken.

Do not brush off dried-out mold spores. This will launch them into the air with risk of inhalation.

Do not spray or swab the books with bleach of any kind. This can cause severe damage.

Do not use a chemical fumigant without checking its possible toxicity.

Do not inhale mold spores when cleaning off books, and do not enter a mold-infested area without an approved face-mask.

Mold Damage to Non-Book Materials. Art works, prints, maps, framed items, etc, need to handled with great care, as careless vacuuming or dusting can damage fragile surfaces. A useful mold removal method is place a piece of fiberglass insect screening over the piece then vacuum through the screen to remove as much of the inactive mold as possible. If working outdoors and wearing a respirator, a soft brush may be employed to gently remove the mold, taking care not to grind the spores into the medium or the paper fibres. If framed materials show signs of mold on the inside of the frame enclosure, the artifact should be unframed, treated, and reframed using new mat board and with the frame structure thoroughly cleaned and dried.

Insects

In humid tropical areas, insects pose a serious threat to collections of all types. Most insects need moisture to survive, thus they are much less of a problem in arid tropical areas. Insects (as well as rodents, bats, and birds) invade buildings for food, water, and shelter, and libraries and archives can provide these if the building is open and accessible to them and conditions welcoming. If insect damage is evident in a library collection, a careful survey should be conducted using sticky traps to see what types of insects are causing the problem. A variety of sticky traps are available, many featuring specific sexual attractants.

A wide variety of insecticides and other devices has been used to try to eradicate insect infestations in the past, including ethylene oxide (ETO), methyl bromide, formaldehyde, and, more recently, gamma radiation. Most chemical fumigants require that the materials be enclosed, a vacuum chamber in the case of ETO and plastic sheeting or tarpaulins in the case of others. Gamma radiation, used to deal with both insect and mold infestations, has the advantage of no residual effects---a major disadvantage with chemicals---but studies have demonstrated that at moderate to high levels of radiation there may be damage to cellulose, the basis of all paper. More recently, tests have shown the advantage of using both freezing and heat to kill harmful insects, and these methods are to be preferred to the more toxic exposures of chemicals.

As with climate control, the building itself can be made one of the main control factors by developing it as an inhospitable environment to insects. The following sensible precautionary steps can be taken to reduce the incidence of most insects, and if scrupulously followed, can have a major impact on insect control.

Building Exterior

Do not plant shrubs or trees to be in contact with a building, and avoid flowering species.

Remove vines, ivy, or other climbing plants from the walls or roof.

Use a wide gravel or paving surround to the building, ensuring that there are adequate and effective drains to prevent water entering the structure.

Do not attach lights to buildings as they will attract flying insects. Insects tend to be attracted by ultra-violet so lights close to a building should be sodium or similar with low ultra-violet output. Lights mounted away from the building should be mercury vapour type with high ultra-violet output.

All garbage and rubbish, including garden and library waste, should be kept in a vermin-proof container away from the building.

Ensure that all roof drains and downspouts are kept clear of debris and in good condition.

Bird and other nests should be removed from the building.

Building Construction

To deter the entrance of insects buildings should be ideally of solid and impermeable construction (brick, stone, concrete, steel, etc).

Seal all unnecessary entrance holes into the building. Where electrical cables, water pipes, telephone connections, waste pipes, etc. enter the building, ensure that the entry holes around the service are completely sealed and caulked.

Doors and windows should be tight-fitting and kept closed at all times, and insect screening of an appropriate small mesh size should cover every opening.

When designing a new building consider the installation of a revolving door.

Building Space Configuration

All food consumption and preparation should be kept away from collection storage areas, ideally in a separate building.

If a food preparation area must be part of the library building, the entrance should be directly to the outside to avoid carrying food and waste through the building.

HVAC systems create wet and moist areas, and central systems have condensate drains. HVAC should be located in a basement area rather than the roof and steps should be taken to ensure that there is no standing water and that condensate drains are always clear.

Restrooms, janitors closets, and workrooms are sources of water and drainage and should be segregated from the collection storage areas.

Condensation forming on cold water pipes can be avoided by wrapping them with an insulation material.

A quarantine room for the inspection of newly acquired material should be established as close to the goods entrance/loading dock as possible. Incoming materials should be placed in the room and unpacked, the cardboard cartons (especially corrugated board) should be disposed of immediately. If an incoming group of materials appears to have some form of insect damage, the entire group should be covered tightly with plastic sheeting and insect sticky traps placed under the plastic to monitor any insect infestation.

Housekeeping

The building interior should be well maintained and kept clean, removing dirt and dust that could provide nutrients for insects.

Water spills should be immediately mopped up, and care must be taken when washing windows and floors that excess water does not permeate the structure through cracks in the walls or floor.

It is preferable that food and drink should not be consumed in reader and staff areas, although this is often difficult to control. However, spills and food debris should be carefully removed and waste receptacles emptied regularly.

Receptions and events involving food and drink should not be held in a reading room or adjacent to a collection storage area.

Refrigerators and similar appliances are popular habits for insects as they combine heat and moisture. Areas under and around these appliances should be regularly cleaned, and sticky traps placed if necessary.

Inside Fittings

For insects that have secured a foothold within the building, their mobility needs to be impeded by securing inside doors, especially those leading to vulnerable areas, such as a kitchen or restroom. Consideration might be given to fitting these doors with a weather seal.

Cracks and crevices in the inner building structure walls or floor should be filled in to prevent insects entering and infesting the cavity areas.

Exhibit cases and special storage cases should be fitted with gaskets to ensure a tight-fitting seal.

Fittings, cases, and room corners should be regularly vacuumed and the vacuum bags checked for insects. Filled paper vacuum bags should be disposed of outside the building immediately after removal.

Killing Insects

A freezer can be used to kill insects by freezing at temperatures at or below minus 20 degrees centigrade (minus 3 F). Exposure should be for three to four days. Books should be placed in plastic bags and on removal from the freezer at the end of the cycle, be allowed to become conditioned while under a constant air current from a fan. Freezing is generally used for occasional infestations when insect are discovered, and should not be used for routine treatment. A simple chest freezer can be used.

Heat can also used to kill insects in infested materials. In this instance, temperatures of 50 degrees centigrade (120 degrees F) will dry out insect bodies. In tropical areas, infested books can be placed in a metal container wrapped in black plastic and left in direct sunlight for a few hours to attain the desirable heat.

Because of the possible health risks, insecticides should be used with great care and with full knowledge of the effects on humans and library materials.

Research is being conducted on safe and natural insect repellents, such as compounds made from the n*eem* tree, which will help to render collections safe and less palatable to insects. It is hoped that the research will suggest a method of combining a neem powder with a solvent to allow application directly into parts of the text block of books. Using a repellent that is not harmful to humans combined with a safe method of killing insects would seem to be a worthwhile strategy to pursue. Freezing and heat treatment for small infestations, adopting an integrated pest management approach, and using natural repellents, can help substantially to control insects while maintaining an environment that is safe for humans.

Relevant Readings on Environment

IFLA Principles for the Care and Handling of Library Material. IFLA, PAC, CLIR: International Preservation Issues, Number One. **Error! Bookmark not defined.**

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