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Compared with the Dutch original, this English version contains a few small changes and some up-dated information.

BUGGY BIZ

INTEGRATED PEST MANAGEMENT IN COLLECTIONS

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CONTENT

INTRODUCTION

The Netherlands Institute for Cultural Heritage (ICN), the Dutch National Archives (NA) and the Dutch Royal Library (KB) are often asked about the control of insects in museums, archives and libraries. Woodborers and 'bookworms', carpet beetles and moths, museum beetles, silverfish and cockroaches all recycle organic material. For them a collection is simply food, just like rubbish is. For centuries man has tried to control insects, a struggle often fought with pesticides. Over the years, these poisonous chemicals have been replaced by better or more powerful ones because insects developed resistance against them, because the chemicals turned out to be to hazardous to humans and the environment, or because they were damage to the collections to which they are applied. Therefore much energy has been spent in the development of clean and safe alternative control methods and on the integration of preventive measures in collection care to prevent insect attack. This has led to the introduction of 'integrated pest management' in collections.

Integrated Pest Management (IPM) is a strategy by which one strives to minimize the use of harmful control substances and methods by applying correct preventive measures, responsible handling of the collections and monitoring. When, in spite of prevention, insects are found that must be controlled, a human, environment and material friendly, non-toxic control method is sought. A toxic treatment is considered only as a last resort.

Integrated pest management comprises five logically consecutive steps: avoid, block, detect, confine, and treat (see diagram on page 13). The emphasis lies on preventive measures and their monitoring. Active control measures are taken only in the last instance. To successfully carry out the integrated approach, it is important that the co-ordination is in the hands of one person who is authorised to impose the measures. In addition, every person who is involved in the care and use of the collection must be informed of the procedures. Explicit agreements should be made with staff and external partners such as cleaners and maintenance personnel. Both the internal and external users of the collection should be engaged. Integrated control appears to create more work, but in practice, it means a reduction in work and expenses that would otherwise be spent in controlling insect attack and conserving and restoring the damaged objects, documents and books, not to mention the accompanying loss of value to the collection.

During the last fifteen years, ICN, NA and KB have built up the necessary experience with 'integrated pest management' in museums, archives and libraries. This knowledge and experience has been brought together in this book in which the same approach has been followed as in the ICN/IADA publication *Fluffy Stuff* (2007) about integrated mould control in archives. It is a feature of the integration that the preventive measures against moulds and insects overlap each other to a large extent.

This book discusses the five steps of the integrated approach. The actions required in every step are accompanied by commentary. Further information about specific subjects or actions is given in the appendices. Practice will show that it is not possible to implement everything at once. Thus it is important to make a risk assessment and make improvements step by step to steadily reduce the greatest risks. The way to prevention lies in being aware of the risks and in recognizing the possibilities for improvement.

With this publication the authors hope to provide those who are responsible for collections care with a helping hand in the prevention and mitigation of insect infestations in collections.

INSECTS

Insects are invertebrates, they have an external skeleton. The skin is hardened to become an armour of chitin that protects the body and serves as an anchor for the muscles. Insects form the largest group within the Arthropoda (legs consist of jointed segments): the so-called Hexapoda. Insects always have six legs and sometimes one or two pairs of wings. When the front wings are hardened they form wing shields such as with beetles.

The body is comprised of three parts:

- head – with eyes, biting or stinging mouth parts and antennae;
- thorax – divided into three segments each having a pair of legs, the rear segment often having one or two pairs of wings;
- abdomen – divided into segments each with two breathing openings through which oxygen is taken up that passes to the organs by way of tubes or a tracheal system.

Conspicuous physical characteristics such as legs, antennae, body shape and size, colour and hair are used for the basic identification of insects.

Insects can be divided into two types according to their development:

- Cockroaches, bristletails (silverfish, paperfish and firebrats), lice, grasshoppers and crickets undergo an incomplete metamorphosis. A small nymph, resembling the adult form, hatches from the egg and grows in stages, shedding its skin several times. After the last moult the insect has full adult characteristics (wings etc.) and is fertile. Both nymph and adult insects feed and cause damage.
- Beetles, moths and butterflies, flies and mosquitoes, bees and wasps undergo a complete metamorphosis. A small larva hatches from the egg, feeds and grows and sheds its skin several times. It is the larva that causes damage (not the adult stage). When the larva is large enough, it changes into a pupa and during a period of apparent rest an entire change of form takes place after which the adult insect emerges from the cocoon. As the only task of the adult insects is the distribution and propagation of the species they do not usually feed and therefore cause hardly any damage.

In order to survive, insects need the following:

Oxygen – Required for the metabolism of food and generation of energy. Insects have no lungs and take up oxygen through openings in the skin.

Nutrients - Insects feed on organic material. Some insects eat everything (cockroaches, drugstore beetles), some prefer plant material (cellulose, for example, woodborers, cigarette beetle), others prefer animal material (proteins, for example, carpet beetles, clothes moths). Dirt, grease, dust, sweat and urine provide extra foodstuff: soiled material is much more attractive than clean material.

Warmth – Activity and development are determined by the external temperature. Insects survive at temperatures (T) of 5-45°C but their optimum development is at 15-35°C.

Moisture - Most insects can develop at a relative humidity (RH) of 50-90%; the optimum is around 70%. Some species have adjusted to dry situations, while others need a high RH (silverfish). Some acquire nearly all the necessary moisture from their food. Woodborers require a wood moisture content of more that 10%. Other species need a high RH because they feed on the mould that grows on moist material.

Light – Light often determines the behaviour of insects. Adult carpet beetles fly towards the light while silverfish and clothes moths avoid it. Such behaviour can play an important role in detection.

Shelter – Behaviour is also determined by the need for shelter. Cockroaches creep away into grooves and cracks. Bristletails seek shelter and move along the plinths of a room.

Amongst the many thousands of insect species, fortunately, there are only about thirty species that are harmful to our collections. When insect damage is detected or when an insect is found in the collection, one should first identify the species. This provides insight into the seriousness of the problem and determines the measures that must be taken. Insects can be divided into four types on the basis of their behaviour and the damage they cause: borers, biters, residents and visitors.

1 Borers

Borers are insects that penetrate deep into an object. The larvae live for some time in the material, mostly wood or paper (cellulose), boring tunnels while they feed until they pupate and fly out through exit holes as an adult beetle. Only adult beetles are usually encountered; larva and pupae are hidden in the object. The first signals of attack are the exit holes and the bore dust that spills out of the tunnels. Size and shape of exit holes and bore dust particles can be used to identify the species. The borers originating in building constructions and furniture often attack other objects. The control of these insects requires a method that penetrates to the core of an object.
Examples of this insect type are woodborers like the common furniture beetle, death-watch beetle, other anobiid beetles, powder-post beetles and longhorn beetles.

2 Biters

Biters are insects that feed in particular on the surface on an object. The larvae live on, and sometimes slightly in, the material. They gnaw through or graze over the material that is mostly of animal origin, sometimes vegetable, but they never bore in wood. Damage is manifested by the presence of holes and bare areas in the material, frass produced by the larvae and webs and cocoons on the object. Larvae, pupae and adults may be found. Control requires treatment of the object.
Examples of this type are carpet beetles and clothes moths. Although drugstore beetles and cigarette beetles belong to Anobiid borer family (they strongly resemble the common furniture beetle) they are often found on collections other then wooden object and treated here as biters.

3 Residents

Residents are insects that live somewhere in the building, creep about and feed on collection material without actually living in the objects. These are mostly animals that undergo an incomplete metamorphosis. They cause gnawing damage and soil the objects with excrement, frass, digestive juices and fat. They often cause odours in the collection. The presence of these insects is mostly dependent on the conditions in the collection area or in the packaging (micro-climates). Apparently they find an attractive climate, sufficient shelter and foodstuff in the form of dirt, rubbish and mould. Often it is only in the second instance that they feed on the collection. Nymphs as well as adults are found although the tiny nymphs will be difficult to see.
Control of this type should concentrate on changing the conditions in the area so that the insects will no longer feel at home (step 1). This usually means lowering the relative humidity (RH), possibly also the temperature (T) and the exclusion of insects from the building (step 2). The objects and area should be well cleaned and eventually treated.
Examples of this type are bristletails (silverfish, firebrats), cockroaches and booklice.

4 Visitors

Visitors are insects that may be found in the building but which do not cause direct damage to the collection. They enter by accident, searching for food or shelter, overnight or for the winter. Their presence is evidence of ‘leaks’ in the building. If they are able to come inside then harmful insects can also. Above all they can cause indirect damage through soiling. When they die, they form a food source for type 2 and 3 insects that may continue with feeding on the collection. The corpses also form a substrate for mould. Mostly the adult insects are found. Control is concentrated on excluding insects from the building (step 2).
Examples of this type of insect are flies, lacewings, wasps and ladybird beetles.

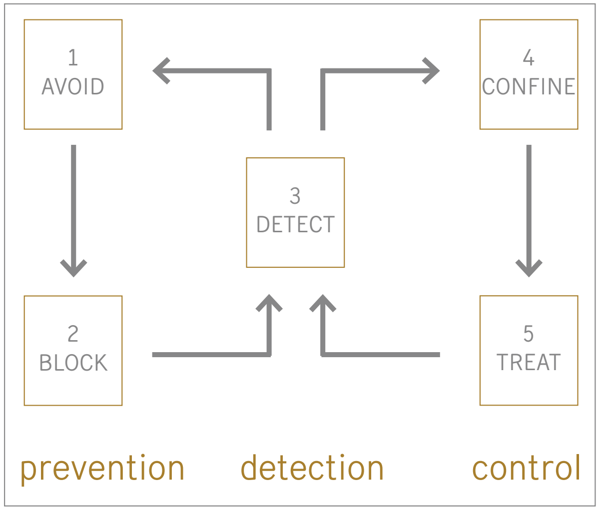
In most cases, the combination of the damage to the collection with the insects (or remains) found provides sufficient evidence to determine the type of insect that must be dealt with. In that case the identification of the exact species is not absolutely necessary for developing a control strategy. Nonetheless it is preferable to identify insects. Especially when they are found somewhere in the building or in insect traps without observing damage to the collection, one should know whether the insects pose a threat or not. For the identification of insects one can use comparative material in the form of illustrations and photos in the various books published on the subject, determination keys and tables, and a self-made collection of examples from found and identified insects. Obviously advice can be sought from experts such as a local natural history museum.

See Appendix I: *Most common insects in collections.*
See Appendix 2: *References and recommended literature.*

See also:
Chinery, M. (1993)
Florian, M-L. (1997)
Pinniger, D. (2001)
Weidner, H. (1993)
Zycherman, L.A. and Schrock, J.R. (1988)

THE 5 STEPS OF INTEGRATED PEST MANAGEMENT

Prevention	1 > Avoid
	2 > Block
Detection	3 > Detect
Control	4 > Confine
	5 > Treat



STEP 1 AVOID

A Keep the relative humidity below 65% and the temperature below 18°C
B Provide sufficient ventilation and avoid micro-climates.
C Keep areas and objects clean and dust-free.
D Place objects 15 cm above floor level.
E Make sure the building is maintained in good condition and free of vegatation

Firstly the storage conditions in the collection areas should be made as unattractive as possible so that insects do not feel comfortable there.

Commentary

A
The lower the temperature, the slower the development and reproduction will become. No mould can grow at an RH lower than 70% whereby the insects that feed on it, such as lice and mites, cannot thrive. It is of course necessary to work within the margins of what is acceptable for the various materials in the collection. The Dutch standards for archives prescribe an RH of 49-55% at a T of 15-18°C. For organic material in museum and library collections the Dutch guidelines recommend an RH of 48-55% and a T of 16-18°C with allowable variations of 3% and 3°C per 24 hours for the most vulnerable materials. See: Nationaal Archief (2001).

B
Provide sufficient ventilation but shield ventilation openings off with a fine mesh (see step 2). Avoid unintentional local differences in climatic conditions. These can occur in places of insufficient air circulation, in packaging or as a result of local sources of moisture, cold or warmth. Near cold outer walls, floors, in and outlets of vents and water pipes the RH can be so high that condensation can form. The T is higher in the vicinity of central heating pipes. Avoid 'dead corners' in rooms. Do not place storage racks and cupboards against outer walls and pillars; place them perpendicular to the wall with space in between so that air circulation is not blocked.

C
Dust and dirt are the icing on the cake for insects. Provide good hygiene in building and collections. Keep the areas clean and dust free. Make sure that the objects are clean within the limits of conservation ethics. Do not bring food into the collections. Ensure that the rubbish depot, especially that of canteens, is far away from the storage areas. Set up a free standing rubbish collection area, for example, closed containers or a small building without window openings and with well closing doors. Do not leave vacuum cleaners in the collection area. Do not place plants, flowers, Christmas trees or firewood in the collection area. See Appendix 9: *Cleaning and disinfestation of the area.* See Appendix 10: *Cleaning and disinfestation of paper collections.*

D
A space of about 15 cm between the floor and the lower shelf of cupboards or racks forms a barrier for crawling insects. In addition, the air circulation is improved, it is less attractive for insects to hide under the cupboards and it is easier to clean underneath. In cases of water incidents the lower objects are not immediately wet.

E
The building should form a protective barrier around the collection (step 2) and not be a source of insects. Remove all (climbing) plants that directly border the building. Prevent and repair water leaks and ensure that gutters and down pipes are clean. Remove bird nests as they form a source of carpet beetles, cigarette beetles and drugstore beetles. Remove all litter in the vicinity of the building.

Prevention - avoid

STEP 2 BLOCK

Having achieved a clean collection area free of insects it must be maintained that way. Insects must be blocked from entering the collection area. Insects mostly come into the building by way of infested objects, with packaging material, via openings in the building and hitching a ride with visitors and personnel.

- A Prevent insects entering because of faults in the building.
- B Prevent insects entering the collection areas by way of visitors and personnel.
- C Do not place packaging materials in the collection areas.
- D Check all incoming objects and collections.
- E Place affected and suspicious objects in quarantine.
- F Check whether suspicious material shows insect activity. Isolate and treat active infestations (steps 4 and 5).

Commentary

A

Seek where insects can enter the building and take measures to prevent that. Be alert to building faults and careless handling. Keep windows and doors closed or fit them with screens. Seal joins, cracks and holes. Block draughts under doors. Fit mechanically strong, fine mesh (20 mesh) on ventilation outlets. Apply good sealing around vents and pipes. Formulate a checklist of all risk factors in and around the building (step 1 and 2 combined), improve what is possible and inspect the building twice a year (in spring and autumn) referring to the list. Extend the list with any newly discovered risks.

B

Visitors and staff can transport insects into the building unintentionally. Do not allow them to bring coats and bags into storage or study areas. A ‘sticky’ mat before the door where people must walk removes soil, mould and insects from shoe soles. In addition, such a mat also prevents insects from crawling inside.

C

Boxes, crates and wooden pallets from elsewhere must not be brought into the storage area without thorough control beforehand. Corrugated cardboard in particular offers hiding places and foodstuff for silverfish and other crawlers. Removals boxes and ‘banana boxes’ must never be brought in because these could have been anywhere. After transport objects should be unpacked in a transito room or quarantine room. This also prevents packed objects staying in the storage area when time is too short for unpacking. Store packaging material (new and for re-use) in a separate, allocated area.

D

Check all incoming objects and collections for insect damage. This could be acquisitions, donations, and new or returning loans. Look for insects (alive or dead), insect remains or insect damage. Often soiling in the form of scales, webbing and mould growth is to be seen; also larval skins, cocoons, wood dust or frass on or under the objects. It is preferable to check the objects at the point of departure; at the archive donator, artist or fellow institution. Transports from abroad bring extra risks.

E

When a quarantine room is not available suspicious objects can be packed in a well sealed box or plastic bag. (Be carefull not to seal damp material, as the risk of mould growth increases.)

F

Wait 2-3 weeks and see if there are any signs of active infestation. A longer period is often necessary with suspected wood borers. The exit holes in wood are often old. Knock as much wood dust out of the tunnels as possible and see if new wood dust is being produced. Plug the exit holes with wax or cover the surface with paper and see if new holes appear in the following spring or summer.

Prevention - block

STEP 3 DETECT

Regular visual inspections and monitoring of areas and collections are necessary to check that the preventive measures of step 1 and 2 (still) suffice. This concerns detection of the presence of insects, remains and damage.

A Carry out regular inspections in the building and in the collections.
B Set up a monitoring system using insect traps.
C Identify the insects found.
D Note all finds and activities in a logbook.

Commentary

A

Carry out visual inspection continually. Be alert for signs of insects every time an object is handled. Walk through the storage area following a fixed pattern. Be particularly alert with sensitive material. Make random checks by taking a box from a rack or opening a cupboard and checking for damage to object or packaging, frass under packaging or cupboards, dead insects, larval skins or cocoons under and around the racks (especially in cracks). Place wooden objects on a piece of black paper to see if new bore dust is being produced. Obviously live insects should be looked for. Many insects are light shy and will hide as the light goes on or the box is opened, that movement gives them away but after that they are invisible. Mostly, one can only rely on trace evidence of their presence. Inspect an area every now and then in the dark with a torch, that may take them by surprise. Insects attracted to lights can be found on window sills in the summer and around lights and lit emergency exit signs. Instruct cleaners, guards, museum staff and users of the collections to be alert to insects (and remains) and to report finds and damage to a particular person. In this manner valuable extra eyes are looking out as well!

B

Insect traps are monitoring aids rather than a control method. They show which insects live in buildings and collection but only if the right trap is placed in the right place. Sticky traps and pitfall traps can be used with or without food or sex attractants (sex pheromones).

UV traps can be used in some cases. The traps should be renewed every two months and the caught insects identified and counted. The results provide an overview of the annual fluctuation of the population and peaks are quickly spotted. There is usually no reason for panic when just a few insects are caught. A problem is certainly indicated when many of the same species or high numbers at one place are being caught.
Monitoring can be contracted out to pest control companies or consultants. The former can react more rapidly to problems but may too gladly sell a pesticide: the latter might be more independent.
See Appendix 2: *Detection with insect traps.*

C

Once insects are found it should be established which type they are and whether they are harmful: only then should a suitable control method be chosen. Precise identification is not always necessary. Often it is sufficient to count the types and seek the cause once an increase occurs.
See Appendix 1: *Most common insects in collections.*

D

In the logbook the types or species of found insects should be noted, their condition, where, when, how, how many were caught, who found them and what action was taken. It is handy to maintain a page per area and to show on a map where the traps are. Also note the cleaning activities in order to record the effects in the short and long term. On the basis of the logbook it can often be established when and where something went wrong.
See Appendix 3: *Logbook.*

Detection - detect

STEP 4 CONFINE

Whenever insects or damaged objects are found somewhere their spread through the building and collection must first be prevented.

A Locate all affected objects.
B Isolate all affected objects.
C Find the source of the infestation and remove it.

Commentary

A
Check the direct vicinity of infested objects (adjacent, under, above, behind, in front). Also check objects that arrived with the same load and that are placed elsewhere in the building.

B
Once an infestation has been determined it must be isolated as soon as possible. If necessary the entire storage area or building must be closed. Crawling and flying insects must have no opportunity to move around. Be aware that they may eat their way out through insulation or other building material. Take care that the insects do not spread through air ducts. If not previously carried out, ensure that all air vents are fitted with fine screens.
Isolate infested objects preferably by transporting them to a quarantine area. Do not let insects escape during the transport. Pack the objects in plastic bags or well closing boxes. (Due to the risk of mould growth, watch out for damp objects!)
With massive, locally concentrated infestations an isolation lock to the exit of the storage area can be made. The infested part of the storage area is sealed off with thick plastic film (polyethylene) and from there a passageway from the same plastic can be made to the door. Look out for the air conditioning in the construction of such a lock. If there is an inlet present then there must also be an outlet otherwise the tent will be inflated. Alternatively, shut off the air conditioning temporarily or disconnect it locally.

C
The source is most often an infested object in which insects have developed. Such an infestation can smoulder away for some time before it becomes conspicuous.
If the source is unknown, try to find it by placing a number of sticky traps around the area where the infestation was detected and try to 'zoom in' on its location.
Often the source can be found in a building problem and if repairs are not carried out immediately, the infestation will repeat itself. Other causes can be attractive (building) material (e.g., certain kinds of insulation material like wool felt) or an attractive environment (high RH>mould>insects).

Control - confine

STEP 5 TREAT

Insects causing problems in objects or collection areas must be treated. Depending on the type of insect it is either the object or the area that must be treated.
The use of safe and clean non-toxic methods should be preferred. Whichever method is chosen, it must be effective and carried out correctly. Insects that survive a treatment can contribute to the development of resistance within the species to that treatment.

A Determine what must be treated.
B Find out the options.
C Make a choice.
D Clean the area.

Go back to step 1
Make adjustments to meet requirements
Return objects to their place

Commentary

A
The borers (type 1) and biters (type 2) that live in or on objects are controlled by treating the infested objects. The residents (type 3) and visitors (type 4) that live somewhere in the area are controlled by treating the area. This often requires the help of professional pest control companies.

B
The various control methods can be divided into two groups:
1 The physical and non-toxic ('alternative') control methods such as low and high temperatures, low oxygen concentrations, high carbon dioxide concentrations and combinations thereof. In some cases gamma radiation is an option.
2 The toxic, chemical control methods such as application of pesticide in solid or liquid formulation, as vapour and as fumigant. The active component and the solvent as well as the additives can react with materials and cause damage to objects.

See Appendix 4: *Non-toxic control.*
See Appendix 5: *Chemical control.*

C
The choice of a control method depends on the type of insect to be controlled, the condition and materials of the object and all kinds of practical considerations such as cost, required equipment, volume or size, need for transport and need to contract a treatment out.
See Appendix 6: *Choice of control method.*

D
Do not return any object to its place without first having found the cause of the infestation and having dealt with it, and without having cleaned that area. There must not be any eggs or small larvae remaining that could spread and cause another infestation. Keep in mind that supplies of packaging material (especially corrugated cardboard) are good hiding places for insects. Remove all signs of infestation from the area and from the object otherwise it will be unclear later whether there is a new infestation or just the remains of the old. After an infestation try to avoid any internal transportation of objects for at least three weeks. In this time it should become clear whether the problem has been completely solved or not.
See Appendix 8: *Personal protection.*
See Appendix 9: *Cleaning and disinfestation of the area*
See Appendix 10: *Cleaning and disinfestation of paper collections.*

E
Once the cause of the problem has been found, determine what should be improved in step 1 and 2. If needed, adjust the detection of step 3. Temporarily, pay extra attention to the area where the problem occurred or adjust some traps to specifically catch the species that caused the problem to see if the treatment was successful.

Control - treat

APPENDICES

APPENDIX 1

Most common insects in collections

The most common harmful insects in collections are given here with short descriptions of their appearance, behaviour (Northen hemisphere), damage, manner of detection and control method options.

Abbreviations

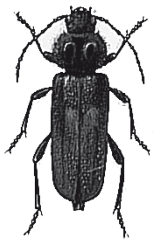
T temperature
RH relative humidity
MC Moisture content
B blunder trap; sticky trap of pitfall trap without lure
F/O sticky trap or pitfall trap with food or odour attractant
P sticky trap or pitfall trap with pheromone lure
L UV or light trap
See also Appendix 2: *Detection with insect traps*

H heat treatment
Fr freezing
PH3 fumigation with phosphine
CO2 fumigation with carbon dioxide
N2 exposure to low oxygen concentration
See also Appendix 6: *Selection of the most appropriate control method.*

1 Borers

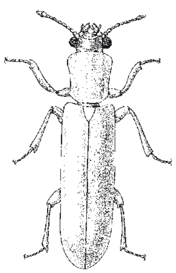
Anobium punctatum – common furniture beetle ('bookworm')

Beetle:	3-5 mm, dark brown with rows of pits in wing shields, head tucked under thorax, bent body with sharp angle between thorax and abdomen
Larva:	6 mm, yellowish-white, crescent shape
Behaviour:	beetles are good flyers
Life cycle:	3-5 years
Emergence:	Apr-Aug, beetle lives 3-4 weeks
Temp:	12-25°C, optimum: 22-23°C
Moisture:	RH>55% - MC >10% optimum: MC 30%
Food:	wood: softwood and hardwood especially sapwood, furniture, books
Damage:	round exit hole, 1-2 mm in diameter, bore dust of one colour, cigar shaped grains
Trap type:	B, P, L
Control:	objects - H, Fr, PH3, CO2, N2, can be treated locally with insecticide.



Hylotrupes bajulus – old house borer

Beetle: 10-20 mm, brownish-black with two grey specks on wing cases, long back swept antennae, thick thighs
Larva: 30 mm, yellowish-white, straight
Behaviour: audible gnawing on warm summer evenings
Life cycle: 3-11 years
Emergence: June-Sept, larvae need high temperatures to pupate, beetles live 3-4 weeks
Temp: 10-35ºC, optimum: 28-30ºC
Moisture: MC>10%, optimum: MC 30%
Food: wood: softwood, especially sap wood, construction timber
Damage: exit hole, 6x3 mm, oval with ragged edges; bore dust of one colour, 1mm long cylinders
Trap type: B, L
Control: dry wood, treat construction with insecticides or heat



Lyctus brunneus – powder-post beetle

Beetle: 5-7 mm, reddish-brown, long and slender, the body tri-segmentation is clearly visible
Larva: 5-6 mm, yellowish-white, crescent form
Behaviour: tropical beetle that arrives with exotic wood
Life cycle: 1 year
Emergence: May-Sept, beetles live one week
Temp: 15-32ºC, optimum: 28-29ºC
Moisture: MC 8-23%, optimum: MC 15%
Food: wood: sapwood of hardwood (oak, tropical), furniture, parquetry flooring
Damage: round exit hole, 1-2 mm in diameter, very fine bore dust like talcum powder
Trap type: B, L
Control: objects - H, Fr, PH3, CO2, N2, can be treat locally with insecticide. See Appendix 6: Selection of the most appropriate control method. Ensure that the RH, also locally, stays under 50%.

Xestobium rufovillosum – death-watch beetle

Beetle: 6-9 mm, dark brownish-grey with yellow specks, head tucked under thorax, bent body with sharp angle between thorax and abdomen
Larva: 11 mm, yellowish-white, crescent form
Behaviour: beetle hibernates in wood, tapping noise, prefers damp wood, rafter tops in contact with cold or damp wall
Life cycle: 4-10 years
Emergence: March-June, larvae pupate in summer/autumn, beetles live 10-11 months including 2 months outside wood
Temp: 10-30ºC, optimum: 22-25ºC
Moisture: MC>22%
Food: wood: especially hardwood, sapwood and heartwood, construction timber
Damage: exit hole round, 3-4 mm in diameter; large, elliptical shaped bore dust
Trap type: B, L
Control: objects - H, Fr, PH3, CO2, N2, alternatively treat locally with insecticide. Appendix 6: Selection of the most appropriate control method. Ensure that the RH, also locally, stays under 55%.
buildings – dry the construction, treat with pesticides or heat.

2 Biters

Anthrenus species – carpet beetles
Anthrenus verbasci – varied carpet beetle
Anthrenus pimpinellae – carpet beetle
Anthrenus museorum – museum beetle

Beetle: 2-4 mm, round, black-white-orange scales
Larva: 4-5 mm, torpedo shaped, white with brownish-black bristles in transverse rows, tail hairs, 'woolly bears'
Behaviour: larvae shed and leave cast skins behind. Beetles fly toward light, need pollen to become fertile except for A. verbasci, which can stay inside. Found on windowsills, often inhabit bird's nests. Beetles are attracted to light.
Life cycle: 9-12 months
Emergence: June –Aug, beetles live 3-4 weeks
Temp: 15-35ºC
Moisture: dry to medium
Food: animal matter, sometimes vegetable matter
Damage: larvae energetically consume wool, fur, hair, feathers. Holes and bare patches, loose hairs on stuffed animals
Trap type: B, L, P (A. verbasci), place traps in the light where the beetles fly about.
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of

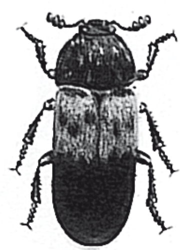
Appendix 1

the most appropriate control method. Insects are fairly tolerant of Fr at -20°C and PH3 so allow longer treatment time or freeze at -40°C.

Attagenus pellio – two spotted carpet beetle, fur beetle

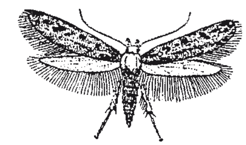
Beetle: 3-6 mm, oval, black with white spot on each wing shield
Larva: 4-10 mm, long torpedo shape, white with brown transverse bristles, long tail hairs (longer than Anthrenus larvae)
Behaviour: larvae inhabit bird nests, shed and leave larvae skins behind. Beetles fly toward light.
Life cycle: 6-12 months
Emergence: Apr-Jul
Temp: 15-35ºC
Moisture: medium
Food: animal matter: dead insects, natural history collections, fur, rarely textiles
Damage: holes and bare patches, loose hairs on stuffed animals
Trap type: B, L, P
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

Dermestes lardarius – larder beetle
Dermestes maculatus – hide beetle



Beetle: 6-10 mm, oval, black scales
Larva: 8-10 mm, torpedo shape, white with black transverse bristles. Large, bristly larvae - larger than carpet beetle larvae
Behaviour: beetles fly towards light
Life cycle: D. lardarius 2-3 months; D. maculatus 2-9 months
Emergence: spring/summer
Temp: 15-35ºC
Moisture: medium
Food: animal matter: bodies of birds and rodents, untanned leather and skin, poorly cleaned natural history specimens
Damage: holes, loose hairs, larvae skins, refuse
Trap type: B, L
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

Endrosis sarcitrella – white-shouldered house moth



Moth: 5-8 mm, white shoulders, speckled wing ends, wings folded over the abdomen when at rest.
Larva: 10 mm long, white, spins a grey tube adhered to wall
Behaviour: larvae inhabit wasp and bird nests, consume dry foodstuffs
Life cycle: 3-8 months
Emergence: spring, summer
Temp: 17-30ºC
Moisture: humid
Food: animal matter: wool, dried fruit, rarely in dry and clean textiles
Damage: grazing tracks, cocoons, much refuse
Trap type: B
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method. Lower RH, keep collection clean and dry.

Hofmannophila pseudospretella – brown house moth

Moth: 7-10 mm, brown with darker specks
Larva: large white larvae, spin tubes around themselves
Behaviour: larvae inhabit bird nests and organic refuse
Life cycle: 3-8 months
Emergence: spring, summer
Temp: 17-30ºC
Moisture: humid environment, 80% RH
Food: animal and vegetable matter, damp textiles, rarely in dry and clean textiles
Damage: holes with irregular edges, bare patches, cocoons
Trap type: B, L
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method. Lower RH, keep collection clean and dry.

Lasioderma serricorne – cigarette beetle

Beetle: 2-3 mm, reddish-brown, smooth and round; similar to drugstore beetle and furniture beetle, but with serrated antennae and without row of pits on wing shields
Larva: small, yellowish-white, crescent shaped
Behaviour: beetle flies towards light
Life cycle: 1-4 months
Emergence: spring, summer

Temp: >21°C
Moisture: medium
Food: omnivorous with preference for vegetable material, tobacco, books
Damage: round exit holes, fine frass and bore dust
Trap type: B, L, P, in warm and light places where beetles fly about
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

Ptinus tectus – Australian spider beetle
Beetle: 3-5 mm, round, brown hairy body, similar to a spider but has only six legs instead of eight
Larva: 3-4 mm, white, crescent shaped
Behaviour: inhabit bird nests and rubbish in attics and cellars
Life cycle: 3-12 months
Emergence: spring, summer
Temp: low, medium, can survive at T<10°C
Moisture: medium
Food: dead animals, vegetable material, textiles, paper
Damage: bore tunnels in which larvae pupate, cocoons
Trap type: B, L
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method. Insects are fairly tolerant of low temperatures.

Stegobium paniceum – drugstore beetle
Beetle: 2-3 mm, oval, reddish-brown, rows of pits on wing shields, resembles furniture beetle
Larva: 3-4 mm, white, crescent shaped
Behaviour: good flyers, especially in warm weather, fly towards light
Life cycle: 1-6 months
Emergence: spring, summer
Temp: medium
Moisture: medium
Food: dry plant material, botanical specimens, paper, dry animal material
Damage: round exit holes
Trap type: B, L, P, in warm and light places where beetles fly about
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

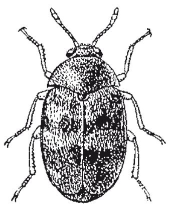
Tinea pellionella – case-bearing clothes moth
Moth: 7-8 mm, gold with two dark specks on wings, pointed 'hairdo', rests with wings folded over abdomen
Larva: 10 mm long, spin tubes around themselves
Behaviour: larvae graze on surfaces; moths are bad flyers, hide in the dark
Life cycle: 3-8 months
Emergence: spring, summer
Temp: 17-30°C
Moisture: medium, humid
Food: animal matter: textile, natural history objects, fur, skins
Damage: grazing tracks, cocoons, much refuse
Trap type: B, in undisturbed, dark places
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

Tineola bisseliella – webbing clothes moth
Moth: 5-7 mm, glistening gold, pointed 'hairdo', rests with wings folded over abdomen
Larva: 10 mm long, naked larvae, silk webs and tunnels on surfaces
Behaviour: bad flyers, hide in the dark
Life cycle: 3-8 months
Emergence: spring, summer
Temp: 17-30°C
Moisture: dry, medium
Food: animal matter: textile, natural history objects, fur, skins, soiled silk
Damage: grazing tracks, holes, webs, much refuse, messy
Trap type: B, P, in undisturbed, dark places
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

Trichophaga tapetzella – tapestry moth, carpet moth
Moth: 8-10 mm, dark shoulders, lighter coloured wing ends
Larva: (10 mm long, naked larvae?) spin a tube around themselves
Behaviour: larvae inhabit horse stables and bird nests
Life cycle: 3-8 months
Emergence: spring, summer
Temp: 17-30°C
Moisture: humid

Appendix 1

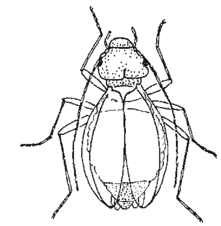
Food: animal matter: textile, hair, wool, silk, skins, tapestries hanging against outer walls, dried meat
Damage: grazing tracks, cocoons, webs, much refuse
Trap type: B
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method. Then lower RH.



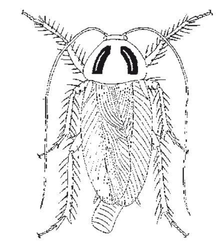
Trogoderma angustum – South American carpet beetle, Berlin beetle, cabinet beetle
Beetle: 2-4 mm, dark with two curved white bands across wing shields
Larva: 4-6 mm, long torpedo shaped, transverse rows of brown bristles, long tail hairs, very active
Behaviour: beetles fly toward light
Life cycle: 5-12 months
Emergence: March-May
Temp: medium
Moisture: medium
Food: animal matter: dead mice, wasp nests, spider webs
Damage: holes, loose hairs, larvae skins, refuse
Trap type: B, L, P,
Control: H, Fr, PH3, CO2, N2. See Appendix 6: Selection of the most appropriate control method.

3 RESIDENTS

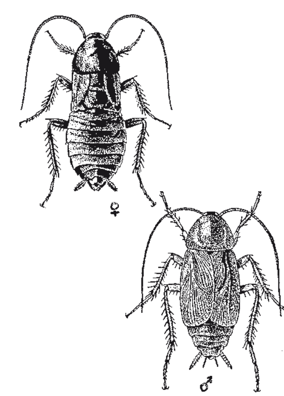
Atropos pulsatoria – winged dust louse
Appearance: 1 mm, silver white, small vestigial wings
Behaviour: move busily around in starts, light shy, prefers to inhabit damp cellars, outer walls, sheds
Life cycle: 1-4 months
Temp: medium
Moisture: humid, RH >75%
Food: mould, starch (size on glazed paper and book binding, herbal specimens, wallpaper), stuffed animals
Damage: grazing tracks on surface, dust/detritus around object
Trap type: B
Control: Lower RH, clean, keep area clean, dry and cool



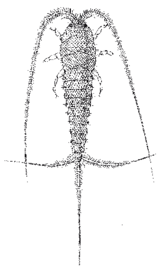
Badonellia titei – winged dust louse
Appearance: 1-2 mm, glassy white, large light brown head; females have wing shield-like, net shaped wings; males are wingless
Behaviour: light shy, inhabit damp buildings and caves
Life cycle: 1 year, hibernate as egg, adults mostly found in July-Nov
Temp: cool - medium
Moisture: humid
Food: mould on paper and other organic material
Damage: grazing tracks on paper and other organic material
Trap type: B
Control: lower RH, clean, keep area clean and dry



Blatella germanica – German cockroach, Croton Bug
Appearance: 10-15 mm, reddish-brown, parchment-like wings covering entire abdomen, two darker stripes on thorax
Behaviour: light shy, active at night (inspect at night), usually inhabits restaurants and kitchens
Life cycle: 6 months – 4 years
Temp: medium, warm
Moisture: medium, humid, wet/water
Food: omnivorous, paper, leather, textile
Damage: holes, stains, odour
Trap type: B, P, F
Control: block, clean, treatment of area by expert

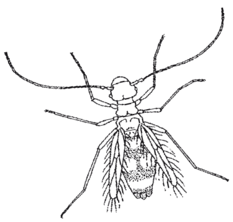


Blatta orientalis – oriental cockroach
Appearance: 15-30 mm, dark brown, males have parchment like wings covering entire abdomen, females have vestigial wing stumps
Behaviour: light shy, active at night (inspect at night), usually inhabit restaurants and kitchens
Life cycle: 6 months – 4 years
Temp: warm
Moisture: medium, humid
Food: omnivorous, paper, leather, textile
Damage: holes, stains, odour
Trap type: B, F
Control: block, clean, treatment of area by expert.



Ctenolepisma longicaudatum – paperfish, giant or gray silverfish

Appearance: 10-15 mm, torpedo shaped, dark grey scales, body length antennae, three long tail hairs, wingless, hair tufts on abdomen
Behaviour: light shy, active at night, similar to fire brat and common silverfish, but inhabits normal indoor climate
Life cycle: 6 months – 5 years
Temp: medium
Moisture: medium
Food: starch, glue, sugars, cellulosic material, paper
Damage: grazing
Trap type: B, F
Control: block, remove all superfluous corrugated cardboard boxes, clean area, lower T to 16-18ºC and RH to <50%, treat area, freeze infested books or boxes.



Dorypteryx domestica – bark louse, book louse, winged louse

Appearance: 1 mm, yellow head and thorax, brownish-red abdomen, speckled back, characteristic veined wings edged with long fringes
Behaviour: inhabits houses, especially storerooms
Life cycle: present all year, peaking in summer
Temp: medium
Moisture: humid
Food: mould on paper and other organic material
Damage: grazing on surfaces, detritus around object
Trap type: B
Control: Lower RH, clean, keep area clean and dry

Lepisma saccharina – common silverfish

Appearance: 10-15 mm, torpedo shaped, small silver grey scales, antennae a little shorter than abdomen, three long tail hairs, wingless, occasional hairs on abdomen
Behaviour: light shy, active at night
Life cycle: 6 months – 5 years
Temp: cool, medium
Moisture: humid, RH>70%
Food: starch, glue, sugars, paper, wallpaper, mould
Damage: surface grazing
Trap type: B, F

Control: block, remove all superfluous corrugated cardboard boxes, clean area, provide dry environment with RH<70%, treat area, freeze infested books or boxes.

Liposcelis sp. – book louse, dust louse

Appearance: <1 mm, transparent, light brown, wingless, large head, no male form
Behaviour: moves actively in starts, light shy, prefer to inhabit damp cellars, outer walls, sheds
Life cycle: 1-4 months
Temp: medium, development accelerates at T>25ºC
Moisture: humid, RH>80% but can survive at 60%
Food: mould, starch (size on glazed paper and book binding, herbal specimens, wallpaper), stuffed animals
Damage: surface grazing, detritus around object
Trap type: B
Control: Lower RH, clean, keep area clean and dry

Thermobia domestica - firebrat

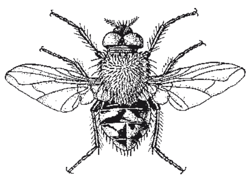
Appearance: 10-15 mm, torpedo shape, dark grey speckled scales, long antennae, three long tail hairs, hairy, wingless, hair tufts on abdomen
Behaviour: light shy, active at night
Life cycle: 3-6 months
Temp: warm optimum: 37ºC
Moisture: dry, medium
Food: starch, can digest cellulose, paper
Damage: surface grazing
Trap type: B, F
Control: block, remove all superfluous corrugated cardboard boxes, clean area, treat area, keep area cool, freeze infested books or boxes.

4 Visitors

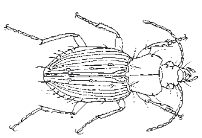
Apis sp - bee

10-15 mm long insects with a hairy body and two pairs of transparent wings; the front pair is larger. Hives are built in cavity walls or under roofs. The entire swarm hibernates in the hive. They do not cause damage but corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Clear away corpses. Call in a recognised pest controller to remove the hive.

Bombus sp. – bumblebee
20-25 mm long insects with a hairy body and two pairs of transparent wings; the front pair is larger. They build their nests in cracks in timber, in cavity walls or under roofs. The queens seek places inside to hibernate and emerge from May onwards. Bumblebees do not cause damage but corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Clear away corpses. Call in a recognised pest controller to remove the hive.



Calliphora sp. - blue bottle, blow fly
10 mm large bluish-black flies with one pair of transparent wings. The female lay their eggs on dead animals and rotting organic refuse. They can smell the odour of flesh from kilometres away. The maggots are light shy while the adults fly towards the light. They do not cause damage in collections but do leave droppings behind ('fly spots'). Flies come inside to hibernate in humid, cool areas. Their corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Clear away dead animals (birds, mice) and insects. Provide good hygiene and removal of refuse.



Carabidae – ground beetle
Different species, 10-25mm long, large, shiny black beetles with long antennae. They do not cause damage but corpses are a food source for other insects. Clear away corpses. As these insects live outside their presence indicates faults in blocking (step 2).

Chrysopa carnea – lacewing fly
10-30 mm large insects with two pairs of equally large, green, transparent, veined wings. They do not cause damage but dead flies are a food source for other insects. The insects live outside but seek places in which to hibernate in cool cellars and attics. Their presence indicates faults in blocking (step 2).

Coccinella sp – ladybird beetle
5-8 mm round beetles. Black thorax with yellowish-white fore-shoulders. Red wing shields with a total of seven black spots. The larva and beetles eat aphids. In winter the beetles seek places in which to hibernate, usually under bark or stones, sometimes inside. They do not cause damage but corpses are a food source for other insects. Groups of beetles can spread an unpleasant odour. Their presence indicates faults in blocking (step 2). Catch living examples and set them free outside, clear away corpses.

Musca domestica – common house fly
5-7mm long insects with one pair of transparent wings. They do not cause damage but do leave droppings behind ('fly spots'). Flies come inside to hibernate in humid, cool areas. These fly larvae live on food and refuse, dead animals and manure. Their corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Clear away corpses. Provide good hygiene and remove rubbish.

Paravespula sp. – wasp
15 mm long insects with a black and yellow striped body and two pairs of transparent wings; the front pair is the larger. The 'wasp waist' is highly recognisable. They build their nests in cavity walls, in attics, or under roofs. The queens seek a place inside to hibernate and emerge from April onwards. Adult wasps live on liquid sugary foodstuffs. They do not cause damage but their corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Wasps can be caught with light traps and wasp traps with sweet food lures. Clear away corpses. Call in a recognised pest controller to remove the nest.

Tenebrio molitor sp. – mealworm beetle
10-15 mm long, large, mat black beetle with short antennae. They move slowly and do not cause damage in collections. The large yellow larvae are found in grain flour and sometimes in bird nests. Sometimes they inhabit insulation material containing starchy filling material. The beetles emerge at the beginning of summer, fly about and are attracted to light. In autumn they die. They do not cause damage but their corpses are a food source for other insects. Their presence indicates faults in blocking (step 2). Clear away corpses.

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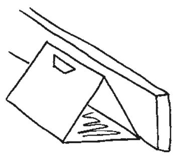
- Mourier, H. en Winding, O. (1975) .
- Illustrations of *E. sarcitrella*, *T. angustum*, *B. orientalis*: Zacher, F. (1927)
- Illustrations *L. bruneus*, *B. titei*, *B. germanica*, *C. longicauzdatum*, *D. Domestica*, *Calliphora sp.*, *Carabidae*: Joanne Porck.

APPENDIX 2 Detection with insect traps

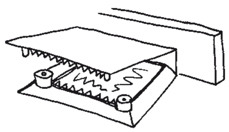
Insect traps can complement visual inspections; they are a useful tool for monitoring insect populations, but are not a disinfestation method. There are various insect traps available for monitoring. By adding an attractant such as a concentrated foodstuff (e.g., cockroach tablet) the effectiveness of a trap can be increased. To trap a particular species a specific attractant can be added such as special foodstuffs, a sexual attractant (sex pheromone) or radiation with a certain wavelength (UV or a certain colour of light). Pheromones are substances that insects give off in order to communicate with each other. Sex pheromones are secreted by females to attract males. As they are species specific, other species do not react to them. Exceptions are the common furniture beetle (*Anobium punctatum*) and the drugstore beetle (*Stegobium paniceum*) that have the same pheromone and there are indications that the case-bearing clothes moth (*Tinea pellionella*) is attracted to the pheromone of the webbing-clothes moth (*Tineola bisseliella*).

1 Sticky traps

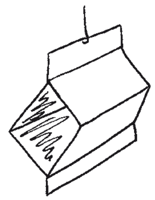
Simple sticky traps are very suitable for general use. They consist of a simple construction of cardboard or plastic with a sticky base that catches everything that enters the trap. A special odourless adhesive is used that does not repel the insects and yet stays sticky for a long time. Due to the cover construction little dust falls on it. Nevertheless, after a few months the glue board loses its adhesion so the trap or base must be replaced. Sticky traps give a general idea of the insects present in the building or collection.
If no specific lure is added to the traps, they catch everything that enters and are referred to as 'blunder traps'.



The *Delta trap* is the best known sticky trap: a cardboard tent with a sticky base. It is placed with both openings in the direction that the insects run, mostly parallel to the plinth or skirting boards. The Delta trap catches wandering insects and moths and has the advantage of being accessible for small insects. The Delta trap has many variations including the Biolock, an asymmetrical shape that is often sold in combination with the sex pheromone for *Tineola bisseliella* as 'clothes moth trap' and gives good results.
The *Cockroach trap* is a larger, flatter and longer trap that is often used in combination with a foodstuff lure. It chiefly traps cockroaches; it is difficult for small wandering insects to climb in over the raised rim.



The *Predator trap* is a more luxurious variety that is often used in archives. The trap comprises a black or white plastic, rectangular or semi-circular box. The lid is hinged to the base and fixed in position with a click system.
The changeable glue boards are slid onto the base. The trap is set directly against the plinth. The insects crawl via a slope into the trap. Boxes, glue boards and attractants are available separately. In the long term, this is a cheaper solution than the Delta traps. The Predator trap is used successfully in archives to trap crawling insects: it is not suitable for trapping moths.



The *Diamond trap* is a larger, hanging sticky trap used for catching flying insects. It comprises a A4 sized sheet of cardboard or plastic folded into diamond shape. It uses a sex pheromone as lure and is successful for catching clothes moths.

The *Window trap* is a sticky trap of corrugated cardboard with a plastic window to show what has been caught. This trap is used in grain stores but gives disappointing results in collections.

2 Pitfall traps

The *Storgard trap* is an example of the type of trap in which insects trip over a rim and fall into a pit where they drown in oil. The trap can be used with attractants and is sometimes used for carpet beetles. It is rarely used in collections.
Hand made pitfall traps can be used to trap silverfish and firebrats. A plastic cup or glass jar is wound in paper enabling insects to crawl up on the outside. After falling into the cup or glass jar they cannot crawl out as the inside surface is too smooth.

3 Electric traps

Many adult insects are attracted by Ultra Violet (UV) radiation (wavelength <400 nm) and sometimes green light (500-550 nm) also. The attracted insects are electrocuted by live wires around the lamp and fall into a collection container or stick to an adhesive strip wound round the lamp. The trap has to be placed so that no insects from outside the area will be attracted. The quality of the lamp deteriorates in time and lamps need to be replaced after a certain number of operational hours. If the lamps are changed in early spring they will burn on full strength in the active insect season. Collections that are not enclosed in cupboards or boxes must be protected against UV radiation by covering with, for example, densely woven (unbleached cotton) fabric. The cheap 'blue light' traps available for domestic use often contain nothing but blue painted lamps with a short lifetime. They neither radiate UV nor attract insects. Furthermore their safety may be questionable.

4 Use

Traps without special attractants spread throughout the building can be used for the general monitoring of insects in buildings or collections. Traps with special attractants can be used to specifically monitor a particular species, for example, in a high-risk collection (textiles, books, furs, stuffed animals) or after treating an insect infestation. Draw a map of the area and fill in the high-risk places and the positions of the traps. Traps are usually positioned in a grid pattern. In normal areas a distance of 10 m apart is sufficient while in high risk areas 2-6 m is recommended. Should that be too expensive, position the traps along the wall and spread a few around the area, especially near high-risk objects.

- Moths (type 2) and residents (type 3) hide away in undisturbed, dark places, so position the traps along the plinths where they crawl, under cupboards and furniture and in quiet corners.
- Clothes moths are fairly poor flyers and are not only caught in hanging traps but also in sticky traps on the floor. They are shy of light and do not fly towards UV radiation.
- Carpet beetles, cigarette beetles and a number of other species are attracted to light, so it is useful to place sticky traps near windows, doors and ligths.

  In historic buildings carpet beetles often come from bird nests by way of the fireplace via the chimney. In that case place a trap near or in the fireplace.

As most insects become adult and move about in spring and summer, these are the times for the most effective monitoring. More generations are able to develop in heated rooms so monitoring should be continued all year round. Depending on the number, check the traps every week to every few months. An interval of longer than three months is not recommended as the seasons are then transgressed. Change the traps after a maximum of one year as the attractants are by then exhausted and the glue boards will have lost their stickiness. Change them earlier in industrial, dusty areas or when they have caught a large number of insects, because a full trap frightens other insects away. After one of two years one has a reasonable impression of the insect population to be expected in the building and the number of insects that are to be caught in the traps. Then one can develop an efficient working practice of performing quick checks of the traps to make sure they are still where they are supposed to be and nothing unexpected is happening, of doing official inspections writing down the numbers in the logbook, and replacement of the traps or the lure. In many instances a routine of placing new traps before the flight season in early spring, then inspecting them mid summer, autumn and winter, provides a good basis monitoring. In times of trouble, frequencies of inspections may have to increase to monthly or even weekly depending on the numbers of insects.

5 Registration and data processing

Examine the trap with a magnifying glass or under a stereo microscope with a magnification of between 10 x and 100 x; the tiny dust lice, mites and spring-tails are also counted. Identify the species and note the number per species or category according to the four types given earlier.
It is useful to make a list of local insects in advance and estimate how harmful they are to the collections. During the examination extraordinary catches can be added to the list. Count the numbers per type per trap and transfer the values to a spreadsheet. Once the two - three monthly

results are set out in a spreadsheet, the developments at the various locations can be easily observed (increase, decrease, equal numbers) and the risk for the collection can be estimated. Indications for trouble are catching more than usual of a particular species or catching more than usual numbers in a particular area. In any case, always try to find the origin of an infestation and eliminate it. An extra cleaning is sometimes enough to return to the normal situation, but treatment of the source or the infestation may be necessary.

Type of trap	Code	Design	Application
Non specific			
Sticky trap or pitfall trap	B	No attractant, 'blunder trap'	random passing insects, spiders, wood lice
Specific			
Sticky trap or pitfall trap	F/O	Food	
		-pill	cockroach
		-sugar, syrup	wasp
	F/O	Odour	house fly, horse fly, blue bottle fly
	P	Sex pheromone	clothes moth, Indian-meal moth, cocoa moth, brown house moth, carpet beetles, furniture beetle, cigarette beetle, drugstore beetle
Electric trap	L	UV radiation. With or without green light	flies carpet beetle, larder beetle cigarette beetle, drugstore beetle

APPENDIX 3

Logbook

Example for a logbook sheet

Date	**Area**	**Inspection carried out by:**	
Location: trap number	**Species:** if species are difficult to determine, record the type of insect; group the visitors to make it simple.	**Number:** also record the development stage and condition	**Action:** record cleaning, changing of traps, treatment of objects
Map of area with locations of traps and detected insects or damage **Notes:**			

Use spreadsheet software to convert the trapping results into graphs in order to follow the progress of the populations in time and location. The empty spreadsheet worksheet can also be used to write down the inspection results.
See for an example of an excell spreadsheet: www.icn.nl

APPENDIX 4 Non-toxic control

There are various methods available for controlling insects in objects. The preference is for the application of non-toxic methods that are both effective and safe and clean for humans, objects and the environment. The most commonly used non-toxic methods are described below.
See also Appendix 5: *Chemical control.*

1 Low temperature *Freezing*

Insects die when exposed to low temperatures for long enough. A minimum of one week's exposure to -20 to -40°C is the general starting point. Freezing is clean and safe, reasonably fast and large quantities of material can be treated simultaneously. The costs of treatment are low after the one-off purchase costs of a freezer. Treatments can be carried out in-house by staff.
Little systematic research has been carried out on the effects of low temperatures on objects. Damage caused by the formation of ice crystals occurs only in wet objects; under normal conditions the material contains little to no free moisture. With inorganic material (glass, metal), condensation can form during freezing because moisture cannot be absorbed. This is not a problem if there is sufficient absorbent material in the surroundings of the inorganic materials. Research on adhesives and adhered joins of wood and leather indicate that freezing does not alter adhesion strength. Tension can occur when materials of varying expansion coefficients are combined in an object, especially when they are restricted in their movement. Examples are marquetry, veneer finish layers and paint on canvas or on wood. Due to the built-up stress between layers, they can de-laminate. Materials that expand differently in the length and width at changes in temperature (anisotropic materials such as ivory, bone and wood) can cause problems as they build up internal stress and may fracture. Experience has shown that organic material with a normal moisture content can be treated without problems. This includes paper (books and archives), textiles (garments, carpets), leather (bookbinding, garments), wood (simple constructions) and natural history collections (stuffed animals, herbal specimens). Alternatives should be considered for delicate and fragile objects as materials are more fragile at low temperatures than at room temperature. It is generally recommended not to freeze wet material except in emergencies to prevent mould growth after water damage. Then freezing in combination with drying under vacuum (freeze-drying) can be carried out.

For a freezing treatment the object is packed in a plastic bag, preferably in a box or crate. As much air as possible is evacuated from the bag. The less air there is around the object, the less danger there is of condensation forming in the bag. Moreover, during thawing condensation will form on the outside of the bag and not directly on the cold surface of the object. While the objects are awaiting their treatment, they should be kept at room temperature so that the temperature shock for the insects is as great as possible. Insects accustomed to hibernate at low temperatures can protect themselves against freezing so they must not get the chance to adjust.
The packaged objects are placed in a freezer or brought to a commercial cold store. The cold air must circulate freely around the objects, so stack them with sufficient space in between. Typically, a freezer can only be filled to about 70% of its capacity. Cooling must occur as fast as possible: 0°C must be achieved preferably within four hours and -20°C within eight hours. Domestic freezers without forced cooling are best pre-cooled to the minimum temperature before loading. The treatment time starts once the objects are at -20°C. A normal load of textiles requires 9-12 hours to cool while boxed archive material requires 48-72 hours.

A double treatment is applied when there are insects present that are tolerant to low temperatures or when the temperature during the treatment is uncertain. The objects are treated as normal, remain packed for 1-3 weeks at room temperature and are then frozen once more. The developmental stages that survived the first treatment are stimulated to undergo further development and are killed in the second exposure to cold. The object is removed from the freezer and slowly warmed up. The packaging is removed only when the objects have reached room temperature and there is no more condensation visible on the outside. If there is no haste, leave the treated objects in the

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bag to check that there are indeed no more living insects inside. Finally the objects may be unpacked and cleaned.

Large objects such as carpets or archive and library collections can be frozen in a commercial cold store. Addresses can be found in the yellow pages. The same rules apply to packaging, temperature and time. Cold stores often provide a temperature of -40°C which is excellent. Help a large carpet to cool down as fast as possible by rolling it from two sides towards the centre so that two thinner rolls are made instead of one thick one.
Always accompany object or collections and instruct the staff of the cold store how to handle them, especially when frozen.

2 High temperature
Heat treatment

High temperatures are also lethal to insects. The development of most insects stops above 35°C and death occurs above 45°C. Causes of death are changes in proteins, fats and ion activity, disturbance of metabolic reactions and dehydration. Factors that play a role in high temperature treatments are insect species and developmental stage, temperature and time. The higher the temperature, the faster death occurs. As a compromise between treatment time and object safety, generally exposure for one hour at 55ºC is carried out. Heat treatment is an effective, clean and safe method for humans and environment that is suitable for treating large quantities of material simultaneously. The method is faster than freezing and can be carried out at relatively low cost.
So far heat treatments have been used only sporadically to control insects in objects. Little research has been done on the effects on different materials and there is still a lot unknown about the disadvantages. One problem with heating is the drying of the material. This can be prevented by making sure that the airspace around the object is minimal and moisture cannot escape. In this way the air will become saturated more rapidly thereby stopping moisture release more rapidly. The simplest way to achieve this is to pack the object in a well sealed plastic bag containing as little air as possible.
Another method is to raise the RH in the air around the object during heating. The argument that a heat treatment accelerates ageing is not entirely true. Calculations show that it makes a difference of only 6 days over a lifetime of 100 years.
The method seems to be suitable for treating unpainted wood, furniture and books. Care is recommended for objects containing materials with different expansion coefficients and layered structures, materials with melting points or glass transition temperatures under 80°C, and (adhesive) joins under tension. Objects containing proteins that should not be altered cannot be treated. Consult a conservator about material heat sensitivity.

High temperatures can be applied in different ways.
The simplest is to place the object, in plastic, in an oven or heating chamber and to slowly raise the temperature to 55°C. Once the core of the object has reached 55°C, maintain that temperature for at least one hour. Allow the object to slowly cool down to room temperature. Try to avoid temperature gradients (warm and cool side). It is best to let the closed oven or chamber cool down before opening it.
It is also possible to adjust the RH of the air during heating and cooling in such a way that the moisture content of the object does not change (*Thermo Lignum*™ method). In the Netherlands hot air treatments have been used for the treatment of borers in wooden buildings such as windmills and roof constructions. The treatment is known as the '*Wijhe method*' or '*Slegten method*'. The whole building is heated under the introduction of moisture until the wood has a minimum internal temperature of 48°C for 24 hours. This method is more effective than injection of pesticide in the wood, yet it requires much energy and is expensive. Therefore it is only considered in cases of large and wide spread infestations.
Another method is 'solarisation' in which heat is generated with sunshine. This method is especially applicable to the treatment of small objects in tropical countries. Instead of an electric oven, the sun heats up an enclosed volume, for example a solar tent. Otherwise the treatment is the same as that in an oven be it a bit rougher as the maximum temperature is more difficult to control. Although controversial, objects can be treated that would otherwise be lost to insect attack.

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Heat can also be generated with microwaves. Compared to a hot air oven, heating objects in a microwave oven has the additional disadvantage that the heating process takes place from the core of the object to the outside. Therefore the outside temperature gives a false impression of the temperature inside the object, it is more difficult to control the heating and overheating of the inside could occur. For buildings microwave treatment of beams and construction wood may offer an attractive alternative to hot air treatments. Methods for localised microwave heating of building elements are being developed in Germany and elsewhere.

3 Low oxygen concentration *Nitrogen fumigation, hypoxia*

Normal air comprises 79% nitrogen (N_2), 20.9% oxygen (O_2), 0.03% carbon dioxide (CO_2) and some other gasses. Insects need oxygen; when the concentration is less than 1% their development ceases and they eventually die. Insects also lose moisture and dehydrate during this process. The higher the temperature, the quicker death occurs. Following published results, a treatment period of five weeks at 20°C and less than 1% O_2 is necessary to kill all developmental stages of the common museum pests. At 25°C it takes 4 weeks, while at 30°C, 3 weeks is sufficient.
Of all the control methods, treatment with low oxygen concentrations is the least harmful for objects, humans and the environment. It is the only treatment in which something is taken from the air instead of added to it.
As nitrogen is an inert gas, no harmful reactions occur, although there are indications that some pigments can undergo a colour change in a reducing air mixture.
After some practice collection staff can carry out this treatment themselves. Objects can be treated individually in special bags, while collections can be treated in special tents or chambers. After the initial purchase costs of equipments (heat sealer, expensive oxygen meter), the cost per treated object is relatively low. However, if treatments are carried out only occasionally then it may be better to contract them out.

Treatments must always be done in a sealed, airtight space such as a purpose built chamber or an airtight tent or bag. Plastic barrier films with a low oxygen diffusion rate are suitable packaging materials. Laminates of polyethylene (PE) and polyester with an interlayer of polyvinylidene chloride (PVDC), polyvinyl alcohol (PVOH), ethylene vinyl alcohol (EVOH) or aluminium are often used. The packaging can be made to any shape by welding the polyethylene side of the plastic laminate with a heat sealer.

Low oxygen concentrations can be achieved by three means:

- adding nitrogen, argon or 'burner gas' from a cylinder, nitrogen generator, or burner;
- sequestering oxygen from a closed environment using an oxygen absorber such as Ageless™ ;
- a combination of both, flushing with inert gas and then sequestering the remaining oxygen.

The first method can be applied in larger rooms (fumigation chambers), in cupboards or to objects packed in bags.
When using nitrogen from a gas cylinder there is a risk of moisture loss from the object when the very dry gas is continually supplied in order to keep the oxygen concentration low. In this case the dry gas should be humidified.
The second method is especially suitable for treating single objects in plastic bags. The object is wrapped in tissue paper and can be placed on a tray or in an open box or crate to avoid any abrasive contact between object and plastic. Yet the volume inside the bag must be kept as small as possible. As long as the bags are not too large an excess amount of oxygen absorber can be added directly into the bag. An oxygen indicator (Ageless Eye™) can be added then the bag is sealed and treatment starts. It will take 1 to 2 days before the oxygen concentration has reached the required less than 1%.
The third method is more advantageous for large volumes, bigger objects or several objects in a bag. The bag is preflushed with nitrogen before the oxygen absorber is added.
The necessary amount of Ageless™ oxygen absorber depends on the volume of the package. The type number tells how many milliliters of oxygen can be absorbed in a given volume: Ageless™ Z500 can absorb 500 ml O_2 and is thus just enough for a volume of 2.5 L of air. An extra 25% should always be added to capture any oxygen that may leak in. When the required treatment time has elapsed, the object is unpacked, cleaned and put back in the collection.
As re-infestation always remains possible, measures must

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be taken to minimise the risk. The object can remain in the oxygen free packing for as long as the danger of re-infestation remains high.
With the banning of the use of methyl bromide, the application of low oxygen concentration, often in combination with raised temperatures, has been developed on a greater scale and is offered on a commercial basis. Entire collections can be treated in fixed fumigation chambers and transportable containers or tents that have been developed for in situ treatment.

4 High carbon dioxide concentrations
CO_2 fumigation

Carbon dioxide (CO_2) is a gas that is released when organic compounds decompose. There is about 0.03% present in normal air. Concentrations higher than 20% cause death in most sensitive insect species. In practice, objects are treated with a CO_2 concentration of 60% in air. The treatment takes place in a sealed room, for example, a fumigation chamber or a special tent ('bubble'). The leaking out of CO_2 or the leaking in of air is no great problem as long as the CO_2 concentration is kept at 60% by adding gas regularly. In the newer, better sealed 'bubbles' gas does not have to be continually supplied; topping up every now and then is enough. The treatment time depends amongst other factors on the temperature and the diffusion rate of the gas through the material (i.e., the density of the material). Thus insects in wood require a longer treatment time than in textiles. For a successful treatment, the starting points are comparable to low oxygen treatments: 5 weeks at 20°C, 4 weeks at 25°C or 3 weeks at 30°C. CO_2 treatment is relatively safe for humans and the environment, although high CO_2 concentrations should not be inhaled. As the gas is barely reactive there are hardly any harmful effects on the objects. However, there are a number of disadvantages. The RH can become too low and the object can dry out when dry CO_2 gas from cylinders is used. In a flow-trough system with continual flushing, the gas must be humidified. The CO_2 gas expands as it emerges from the cylinder and thus becomes very cold. It is important that it does not blow directly at the objects but has time to warm up. Finally, there is a possibility that CO_2 will react with moisture to form carbonic acid (H_2CO_3) but this only occurs when the material is quite wet. Therefore, materials should be air dry (have a normal moisture content) when being treated.

In most countries CO_2 treatments are regulated under the pesticides act and companies need a licence to carry them out. There are many companies that offer this service on a commercial basis but the best known is Rentokil with their CAT method (Controlled Atmosphere Treatment). The company sets up their CAT 'bubble' of the required size in situ. The tent is filled by collection staff then company staff seal the tent and fill it with CO_2. During the treatment they regularly come to check that everything is going well and, if necessary, to add more CO_2. It is important that the temperature and CO_2 concentration is constantly measured so that treatment time can be adjusted to the circumstances. As external personnel are involved, this method is more expensive than freezing and similar in cost to contracting out low O_2 concentration treatments.
The CO_2 treatment is particularly interesting for large infestations and treating a whole collection at once or for large objects that cannot be frozen or heated.
See also *Check list for carrying out a controlled atmosphere treatment* to avoid confusion when dealing with external service providers.

5 Gamma radiation

Gamma radiation is a high energy, electromagnetic radiation with a high penetration ability that is able to kill insects and micro-organisms such as moulds and bacteria. Thus it is the only available method to disinfect objects totally (see *Fluffy stuff*). The radiation is comparable to UV radiation but contains more energy. The radiation is beamed from a radiation source, usually a Cobalt source (^{60}Co) that is radioactive itself but does not cause radioactivity in the radiated material. Only licensed, commercial companies may carry out Gamma radiation treatments. As gamma radiation penetrates deeply, large quantities of material, still packed, can be treated at once.
The control of insects requires a lower dose than control of mould. A dose of 3 kGy (open structured objects) to 5 kGy (dense objects) is effective in killing all developmental stages of museum pests. However, also at this lower dose, gamma radiation affects materials and accelerates ageing

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processes, especially in paper. Wood is less susceptible to radiation. Little systematic research has been done into the effects of different doses on different materials. Yet, like all types of radiation, the damage is accumulative so that each following treatment adds to the further acceleration of the ageing process.
As there are sufficient safer alternatives for insect control in museums, gamma radiation is not a standard treatment option. The method is occasionally applied in archives for bulk treatments or if there is a combined insect and mould outbreak, but then it is regarded as a last resort and one that is used only once.

Check list for carrying out a controlled atmosphere treatment (low O_2 concentration and high CO_2 concentration)

Location of the tent (client)

- minimal 1 m free space on all sides of the tent
- good ventilation
- heating option
- easy access for all equipment
- in principal no-one may enter the room in case of damage to the tent and possible risk of leaks
- leave the door open whenever someone is in the room

Placing objects in the tent (client + provider)

- place the objects with enough space in between so that the gas can penetrate everywhere
- remove all plastic and metal packaging so that the gas can penetrate the objects
- with boxes or cupboards that are being treated entirely, open flaps, doors and drawers so that the gas can penetrate everywhere
- prevent damage to the tent by sharp and protruding parts of objects by covering them (do not use adhesive tape)

Climate in the tent (provider)

- with a high carbon dioxide treatment ensure that the CO_2 concentration is kept above 60% during the entire treatment
- with a low oxygen treatment ensure that the O_2 concentration is kept below 1% during the entire treatment
- ensure that the temperature in the whole tent, both at the gas inlet and elsewhere, is at least 20°C
- to prevent damage to the objects the temperature must not exceed 35°C
- ensure that the relative humidity in the whole tent approximates that to which the objects are accustomed (usually 45-60%).

Length of the treatment (client + provider)

- arrange that the treatment lasts for a minimum of 28 days (>20°C) for biters and residents (types 2 and 3)
- arrange that the treatment lasts for a minimum of 35 days (>20°C) for borers (type 1)
- when the temperature in the tent is below 20°C, consider delaying the treatment until the ambient temperature is higher or extend the treatment for a few weeks
- when the treatment must be carried out in less than 28 days, raise the temperature in tent and room to 30°C (21 days, 28 for borers) or 35°C (14 days, 21 days for borers)

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APPENDIX 5 Chemical control

It is not always possible to treat an insect infestation with non-toxic methods; sometimes it may be necessary to use toxic chemicals. Such control substances consist of the effective ingredient, a poison, which is pure or mixed with other substances such as solvents, emulsifiers and binders to produce the final formula.
A poison can enter the insect in different ways. There are respiratory poisons (via the respiratory system), ingested poisons (via the digestive system) and contact poisons (via the skin). Some chemicals affect a certain biological function in insects that does not exist in mammals, such as hormones that regulate the moulting of larvae. These products should be harmless to humans. They can be useful for the treatment of residents and visitors (type 3 and 4) but are not yet generally available or used in collections.
In many countries only licensed products can be used and then only the formula and method for which the product is authorised. A number of products are available over the counter for the public while others may only be used by specialized pest controllers.

1 Formulae

There are different ways in which a control substance can be applied.

Emulsion sprays - The poison is bound to an oil-like substance so that it stays well distributed in the liquid. The main ingredient of the emulsion is often water. After spraying an oily residue is left on the treated surface or object. The subsequent adhesion of dust to this layer is an extra disadvantage.

Powder sprays - Powdered poison is mixed with water and held in suspension by various additives. A thin layer of powder is left on treated surfaces and objects after spraying.
The use of water based powder sprays can lead to increased humidity in the room with a possible chance of mould growth (against which the toxin is not effective).

Powder dusts - Dry powders are sprayed and the powder is deposited everywhere. They can be used in rooms along plinths and in cracks and crevices but hardly anywhere else.

Spray cans - The solution or emulsion is sprayed using a propellant. Spray cans for crawling and flying insects are available over the counter. As with other liquids, an oily layer of emulsifiers and binders is often left on the treated surface. In addition, stains can be caused by contact with the organic solvents included in the formula. It is very illuminating to spray a little onto a white paper and see what stays behind when it dries.

Vaporisers - The familiar household remedies such as moth cartridges, strips and mosquito plugs use a poisonous substance that evaporates. They only work in a closed room where the concentration of the substance is able to reach an effective level. The vapour can precipitate as an oily layer or crystallise out on surfaces and can be unpleasant for personnel and visitors.

Fumigants - Poisonous gases have the advantage of penetrating deeper in material than fluids or vapours. They are applied in fumigation chambers or special enclosed tents mainly to control food insect pests. Methyl bromide and phosphine were once generally used in collections but fumigation is steadily declining. The fumigation of buildings is no longer carried out, although rooms may sometimes be 'fogged'.

2 Insecticides used in collections

Pyrethoides (*permethrin*, *deltamethrin*, *K-Othrine*™, etc.)
Insecticide solutions based on pyrethoides are often used for the treatment of rooms and for the local control of borers in buildings, furniture and wooden objects. This group of poisons is currently one of the least harmful for people, but they are poisons nevertheless. Professional pest control companies treat buildings by spraying, fogging, or injecting. The collection should be protected from contact with the liquid with plastic sheeting.
Conservators often treat wooden objects by injecting the

solution as deeply as possible in the exit holes and bore tunnels. They should use personal protection and work in a well-ventilated area.

Organophosphates (*dichlorvos, chlorpyrifos*) - Dichlorvos (DDVP; 2,2-dichlorovinyl-dimethylphosphate) is best known for its use in moth strips (Vapona™). Although it is an effective insecticide there are objections to its use in collections. The vapour works like a solvent; softens plastics, resins and adhesives, causes colour changes in textiles, is corrosive at higher RH and penetrates materials poorly. In the past, it was advised to place an infested object in a plastic bag with a Vapona™ strip and let it stand for a time ('bagging'). This method is no longer used due to the negative effects of the vapour. Dichlorvos is also harmful to humans. Its use is not recommended for collections.
Chlorpyrifos is an organophosphate often found as active ingredient in spray cans, cartridges and impregnated paper.

Phosphine (*phosphorus hydride*) - Phosphine (PH_3) is a colourless, flammable gas that is heavier than air and smells of garlic. The gas is released by the reaction of aluminium phosphide or magnesium phosphide with water. Mixed with CO_2 it is also available in cylinders. In the right concentration it is effective against insects in every stage of development. The gas is mainly used in the protection of stored products. Its use is allowed only in fumigation chambers by authorized personnel. The total treatment time, transport, fumigation and off-gassing, requires a few days. Phosphorus hydride is corrosive at high temperature and humidity. Copper and copper alloys are particularly sensitive but iron, aluminium, nickel, steel and silver can also be affected. Application to objects that contain metal is strongly advised against.

Methyl bromide - Methyl bromide (MeBr, CH_3Br) is a very poisonous, colourless nerve gas. It is effective against all developmental stages of insects and has been used much in the past for the control of borers in objects as well as entire buildings. As this gas affects the ozone layer its use in industrial countries has been banned since 2005 (Montreal Protocol).

The great disadvantage of methyl bromide is that it reacts with sulphur bonds thus releasing an unpleasant odour. Its largest supplier (Dow Chemical) has drawn up a list of materials that cannot be treated with methyl bromide. This includes, amongst others: protein containing materials such as leather, parchment, skins, feathers, hair and wool; paper treated with the cellulose dilating sulphite process, paper with a silver finish such as newspaper and all kinds of recent archive material; photographic material; vulcanized rubber. Methyl bromide can also soften natural resins and varnishes and lead containing pigments can darken. It should not be used in collections.

3 Insect repellants

As well as insecticides there are also substances that have no deadly effects but do deter insects; the so-called insect repelling substances or 'repellants'.

Moth balls - The old mothballs consist of naphthalene while the modern type consists of para-dichlorobenzene. The use of mothballs is contentious. The substances have negative side effects, and furthermore, the effectiveness is highly doubtful.
Naphthalene ($C_{10}H_8$) is a cyclic hydrocarbon derived from coal. It sublimates from the solid phase directly into the vapour phase. The vapour is effective against insects only when a very high concentration has been reached which is only achievable in a well sealed room with a large amount of solid naphthalene. It is doubtful whether it can kill eggs. Beetles are less sensitive than moths. The vapour can crystallise out on objects and can dissolve fats, plastics and other polymers. Naphthalene is harmful to humans.
Para-dichlorobenzene (PDCB, $C_6H_4C_{l2}$), also known as Paracide™ and Paradow™, sublimates like naphthalene. It is more effective than naphthalene but also requires high concentrations. PDCB also seems to kill only the adult moths and moth larvae but not eggs. There are doubts about the effectiveness against carpet beetles. PDCB can affect colours and act as a solvent on binding media in painted objects. Plastics, polystyrene in particular, can completely shrivel after exposure to PDCB. The use of mothballs is advised against because they give a false feeling of security, have negative effects on materials and are harmful to humans and environment.

Camphor and cedar wood - Camphor and the essential oils that evaporate out of cedar wood, lavender, onions and other natural products can, in high concentrations, repel insects. In practice these high concentrations are actually difficult to achieve. The commercially available cedar wood blocks are often impregnated with extra cedar oil that eventually seeps out of the blocks and forms an oily layer on the surface: therefore always avoid direct contact with objects. The odour is pleasant but it is better not to rely on these products for pest management.

Nexalotte™ strips, moth paper - The currently available Nexalotte™ strips and other moth papers are strips of paper that are usually impregnated with chlorpyrifos. Insects are killed by contact with the strips and by the pesticide vapour, but only in a closed environment where hopefully a deadly or repellent enough concentration can build up. Experience has shown that the strips are not always effective which introduces the risk of generating insect tolerance and resistance to the pesticide.

4 Alternative chemicals

A special group of pesticides are the non-toxic chemicals. They kill the insects but are harmless to humans and environment. Examples are the insect growth inhibitors (IGI's) or chitin inhibitors, hormones that disrupt the moulting process of the larvae or the growing of nymphs, so that they cannot develop into adults. These compounds can be used to disinfest rooms but are not efficient for the control of insects in or on objects.
Also available are powders of diatomaceous earth, ground stone or clay. The powders contain very small, sharp particles that scratch and damage the outer layer of the skin of the insects, the cuticle, which leads to dehydration of the larvae, nymphs and adults. These powders can be useful to treat rooms against bristle-tails.

5 Tips

Always seek advice from a recognised pest control company for the treatment of rooms and buildings. Choose a company that understands the requirements for the preservation of your collection and the health and safety of personnel, both for the short and the long term.

Also consider new techniques. Work as much as possible following the principles of integrated control. In buildings and in large objects, a local approach is sometimes more appropriate than an overall treatment of the whole building or object.

See also: *References and literature*.

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APPENDIX 6 Selection of the most appropriate control method

The choice of the most suitable control method will depend on the following:

- the condition of the object(s)
- the type of insect that must be controlled
- the material composition of the object(s)
- practical considerations

1 The condition

The condition of the object determines whether it can be treated at once or whether a pre-treatment is first required. The two most important criteria to be met are that the object is strong enough to undergo treatment and that it is dry.
'Strong enough' means that the object must be able to endure the treatment without being damaged.
'Dry' in this case means that the object must not contain more moisture than would be present at an RH at a maximum of 80%. This is because chemical reactions or physical changes may occur when the material contains excessive moisture. Furthermore, with wet material there is a risk of mould growth should an object not be treated immediately. Wet objects must first be dried until they are in equilibrium with an RH<80%. A situation in which this is not necessary is when objects are treated with nitrogen by flushing. By adjusting the RH of the nitrogen to the correct level, drying and control can be combined. Freezing of soaked material after a water emergency is of course allowed.
Always consider the possibility of treating only the affected areas of an object. A painting on canvas in a frame with furniture beetle can always be removed from the frame and the affected legs of a cabinet on display can possibly be detached.

2 The type of insect

One type of control may work better than another depending on the type of insect. Based on the effectiveness and speed of the treatment, one can formulate an order of efficiency. This does not take into account the safety of the object to be treated. A heat treatment is the most efficient for borers (type 1). Heat works fast, efficiently and penetrates well into the objects. Fumigation with phosphorus hydride (phosphine) is also effective but a little slower. Next comes the low temperature treatment. As borers are hidden deep in wood or paper and are fairly resistant to cold, this is a less effective method that requires more time than the first two. Although the carbon dioxide or low oxygen treatments present the least risks, borers are relatively difficult to control with these methods.
The gasses must penetrate the dense material sufficiently and a long treatment time is necessary to achieve good results. It is known from stored grain protection that insects that live inside the grains can be better treated with carbon dioxide than with low oxygen; the order for borers is based on this experience.
Consequently the order of efficiency for borers (type 1) is as follows: heat - phosphine – freezing – carbon dioxide – low oxygen.

Heat is also the most efficient method for biters (type 2). Most biters are less tolerant of cold than borers. Toxic fumigation is effective and fairly fast but because treatment must be carried out in a fumigation chamber, in practice, freezing is faster and more efficient. Low oxygen or high carbon dioxide concentrations provide good results but these methods are more time consuming. Following the experience of the grain pests, in this case low oxygen is probably somewhat more effective than carbon dioxide.
Consequently the order of efficiency for biters (type 2) is as follows: heat - freezing - phosphine - low oxygen – carbon dioxide.

Treatment of the object is usually unnecessary for residents (type 3) unless these insects have nestled in (archive) boxes or book bindings. Usually the space is treated and this does not always have to be with insecticides. For example, it is preferable to control silverfish by ensuring that they cannot find a source of moisture and by lowering the RH while firebrats can be controlled by lowering the temperature. Measures to prevent the intrusion of insects and general good hygiene often render the use of insecticides redundant. If necessary, staff can carry out the spraying of plinths, joints and cracks with a spray can.

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However it is preferable to call in the help of professional pest controllers. In that case strict supervision is necessary to ensure that objects in the area do not come into contact with the insecticide. Cover the lower shelves of storage racks and wall coverings for example with plastic sheeting.

In the case of visitors (type 4), the removal of living and dead insects is the first requirement. The likely source or entry route must be found and, if possible, removed or blocked. Insects from outside should be prevented from entering by means of good preventive measures. Control with insecticides is usually unnecessary. Seek the advice of a recognized pest controller should that well be the case.

3 The composition of the object

When the object is strong enough, air-dry and the type of insect to be controlled is determined, then the material contained in the object should be examined. This may require help of a conservator or other expert. Based on the order of efficiency for the insect to be controlled, the consideration of the object's material then rules out the unsuitable control methods.
Most objects are made of different materials so, in the first instance, the most common material is the starting point. Subsequently, depending on the sensitivity of the additional materials, it is determined whether the risks involved in a treatment are acceptable when weighed against the possible time and cost saving.

- Do not use freezing or heat treatment for fragile objects, objects containing material applied in layers such as paintings, gilding, veneer and marquetry, anisotropic materials or materials under stress.
- Do not use heat treatment for materials with a melting point or glass transition temperature below 80°C. These materials can melt or soften. A heat treatment will certainly lead to malformation when elements are under tension.
- Do not use heat treatment for protein containing materials in which the protein has not yet been analysed. This applies to natural history specimens and perhaps also to archaeological material. Research on seeds suggests for example that the germination of seeds can be disturbed by heat treatment. Should the option to grow plants from the seed in herbarium collections or from excavations be important, then treatments at high temperatures are best avoided.
- Do not use phosphorus hydride to treat objects containing metal. The reaction between phosphorus hydride and pigments has not yet been systematically researched but to be safe treatments of painted objects are not advisable.
- Do not use methyl bromide. If you must, do not use it in combination with protein materials such as leather, parchment, skins, feathers, hair and wool; paper treated with the cellulose dilating sulphite process, paper with a silver finish such as newspaper and all kinds of recent archive material; photographic material; vulcanized rubber and lead containing pigments.

4 Practical considerations

After these considerations only those methods remain that have no harmful effects on the object's material, in the order based on the efficiency for the given type of insect. The final choice will be based on practical considerations. Should one object be treated or a whole collection? What is the available budget for treatment? How much time is available? Are there the facilities available to carry out the treatment in-house? Can the object be transported and what is the insurance situation? Is there a binding contract with a particular company?
In practice it turns out that freezing is the most suitable method for moths and beetles that live on and amongst the material of objects. Most of the objects affected by these insects can withstand freezing treatment. Delicate paintings with borers usually undergo low oxygen or high carbon dioxide treatment, while borers in buildings and large objects may be best controlled with local application of insecticide. When speed is required, heat treatments are gaining popularity.

Whatever decision needs to be made, listen to your (green) conscience but remain realistic and practical.

APPENDIX 7 Previously used control substances

There is a large chance that historical material in the collection has been treated in the past with control substances that have since been banned because of their harmful effects on humans, environment and collection. Residues of these substances can form a health risk.

Stuffed animals, skin and plant specimens were treated in the past with arsenic compounds and mercury salts against rot, mould and insect attack. It is virtually impossible to remove these compounds without damaging the objects. Therefore it is important to formulate protocols for the responsible handling of objects in these collections.
The focus has come to lie on personal protection and personal hygiene in particular. Some institutions have a warning incorporated into their loan contract stating that the object has been treated with poisonous compounds in the past and that residues may be still present.
Ethnographic objects collected in an environment with exotic pests were treated with DDT, Lindane and pentachlorophenol to avoid arriving badly attacked and mouldy at their final destination.
Collections containing much wool and fur such as uniforms in military museums were treated with insecticides against clothes moths and carpet beetles while still in use. The same applies to tapestries and carpets in historic houses. Archives and library collections, especially those in Eastern and Southern Europe, were sometimes treated with 'insect powder' (DDT). This powder can still be present on the pages and in the spine of books.
In the years 1950-1980 many historical buildings were treated against insects and mould by impregnating wood with popular contemporary insecticides and fungicides (DDT, Lindane and pentachlorophenol). Roof constructions, rafters and panelling in churches and monuments can still contain residues of these old control substances, which can even crystallize on the surface.

1 Previously used substances

Chlorinated hydrocarbons - DDT (dichloro-diphenyl-trichloroethane), Lindane (gamma-hexachlorocyclohexane (HCH), benzene hexachloride (BHC)), and PCP (pentachlorophenol) are chlorinated hydrocarbon pesticides often used in the years 1950-1980 in formulae for controlling insects (DDT and Lindane) and mould (PCP). These are contact and ingested poisons that affect the nervous system.
A single, minimum dose is not lethal for humans but repeated exposure has a cumulative effect because the substances break down very slowly and accumulate in fat tissue. They have proven to be very persistent in the environment. The pesticides are applied as a powder or dissolved in an organic solvent.
As DDT, Lindane and PCP are poorly soluble in water and are not volatile, it was thought that there was little chance that the active ingredient could detach from treated material. Practice has shown otherwise. The active ingredients are not bound to the substrate and so, in principle, can migrate. In wood especially there are various low volatile compounds that slowly evaporate to the wood surface. These compounds appear to be able to carry pesticides with them. In the case of DDT, the saturation concentration at which the substance crystallises out on the surface is quickly achieved. First a white bloom can be detected on the surface and later needle shaped crystals start to grow. Lindane and PCP are more volatile than DDT and achieve their saturation concentration more slowly. They can evaporate directly into a space without crystallising on the surface.

Thymol - Thymol (2-hydroxy-l-isopropyl-4-methylbenzene) is a phenol compound that was used for controlling insects and mould. Thymol crystals were sublimated by heating (above a lamp) and the object was then exposed to the vapour. Due to the vapour's low penetration ability and the harmful effects on objects (dissolving of oil paint, inks and varnishes; vapour re-crystallisation and yellowing of paper), this substance is no longer used. Residues of previous thymol treatments will have gradually evaporated.

Arsenic compounds - Arsenic compounds (arsenic trichloride, diarsenic trioxide, rat poison) were used in previous centuries to treat insect infestations. It was used in particular in the preparation of stuffed animals (taxidermy). These substances are no longer authorised but can still be found on old objects. Sometimes they are visible as a fine, white powder. Arsenic compounds are very poiso-

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nous to humans. They are taken up by ingestion, inhalation and skin contact. Handle suspicious objects only when wearing (nitrile) gloves, a lab coat and respirator. Seal the objects carefully in a plastic bag to avoid the spreading of powder and poisonous dust.

Eulan - The textile industry uses substances to protect textiles against insect attack. There were different types of Eulan™ on the market produced by the Bayer Company (CN Extra, NK, WA and BLN). The most commonly used was Eulan™ U33 (Endolan U), a chlorophenylether with a chloromethanesulphonamide group, applied in a watery solution. Much like dyeing it was added to the fibres during the manufacture process in order to make textiles indigestible for clothes moths and carpet beetles ('moth proofing'). The substances were also used in after-treatments. Eulan™ U33 was used in natural history collections to replace the arsenic compounds. The old Eulan™ was banned due to high toxicity to the environment. The present formulation is based on the currently approved pyrethroid insecticides.

2 Recommendations for handling 'old' pesticides

Contact with old pesticides must be avoided to keep health risks as low as possible. To that end, the objects with old pesticides must be avoided altogether or the powder or crystal residues must be removed. Since the former is usually not an option, the residues must be safely removed. Buildings present a slightly different situation. Should the crystals be in a place where normally no one ever comes (e.g., the back of a roofing board) then they may be safely left alone. Always seek advice from the Health and Safety officer who can also supervise such activities[1].

Discussions between the ICN and the Dutch Health and Safety Inspection led to the following recommendations:

1 - So long as there are no crystals or white bloom on objects or the wood of the building, the chance of contact is very small and there is no direct danger for staff or visitors.

2 - Care must be taken whenever a white bloom or crystal growth on a surface is observed. Provide a clear notice for suspicious objects, for example by applying red labels. Identify the residue. It will not always be an insecticide and can also be mould or salt efflorescence.

3 - Avoid contact so long as the composition of the residue is unknown. Take measures for personal protection if an object must be handled or people have to work in the area. Wear gloves, a dust coat, cap, dust mask and safety glasses (see point 4). Move objects in a box or plastic bag to prevent the spreading of crystals or powder. Pay attention to personal hygiene: do not smoke, eat, or drink in the area. Remove protective clothing and wash hands before doing something else.

4 - If indeed residues of old control substances are present then these must be removed. At the time of writing (2001) the most suitable method is under saction with a vacuum cleaner with a micro-filter or a HEPA filter[2]. Pesticide particles are 0.7-11 micrometers in size and a micro-filter or HEPA filter retains 99.99% of them. Bear in mind that the dust bag and filter must be disposed of as chemical waste. The town council can provide chemical waste containers. If there is a great deal to be vacuumed, exchange the filter and dust bag regularly, before they are saturated. The vacuum cleaner cannot be used for usual cleaning during the period that it is used for this particular task, unless supplied with a clean filter and new dust bag.
Also provide correct personal protection. Wear gloves (nitrile) and a cap and dispose of them after use. Wear a dust coat and wash it after use. Disposable overalls are also available. Wear a dust mask for nose and mouth (FFP3) to be disposed of afterwards and safety glasses. A full-face mask can also be used instead of safety glasses and dust mask. Do not wear the protective clothing outside the areas where the pesticides are.

5 - Once everything is finally clean, there is no guarantee that crystals will not reappear with time. Stay alert. Provide the labels of the cleaned objects with a clear sign that shows that they have been cleaned and must be monitored. Put a warning on cleaned wood in buildings to say that it has been cleaned and when. So long as no new deposit appears, the chance of contact with the pesticide is small and there is no immediate health danger.

6 - It is important to set up a protocol of procedures so that it is clear for all staff and users of the collection what must and must not be done.

Footnotes:
1. For Health and Safety services in your area, contact the appropriate local government department.
2. A good vacuum cleaner has a HEPA (high efficiency particulate) filter but the rest of the machine must also be 'leak proof'. It is of little use to have a HEPA filter while the contaminated air blows from the side of the casing.

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APPENDIX 8 Personal protection

Working with infested collections poses health risks. Insect problems are sometimes related to mould problems of which some species can cause diseases. Some insects can sting, bite or suck blood. Their airborne excretions, scales and hairs can cause allergic reactions.

The basic equipment for safe work consists of the following:

Dust coat or lab coat

A white dust coat is most suitable because all adhered dirt is visible. In addition, a white coat invites regular washing. A dust coat should contain a high percentage of cotton. Cotton absorbs and holds moisture whereas nylon or polyester allows moisture to pass through to the clothing and skin underneath.

Gloves

Latex surgical gloves are suitable for handling infected or infested objects. As they are inexpensive, they can be disposed of after use. People with a latex allergy should use nitrile gloves. Only nitrile is suitable for handling objects contaminated with old pesticides. Neoprene or rubber gloves are best worn when using disinfectants.

Face masks or respirators

Masks are divided into dust masks and gas or vapour masks (half and full-face masks that can filter out chemicals as well as dust). A P2 filter (fine dust) is sufficient for working with dust and affected collections; filter quality P3 (finest dust) is required for insect remains, working with moulds and old pesticides. Dispose of masks after use.

APPENDIX 9 Cleaning & disinfestation of the area

The procedure described here was developed for archives but is very appropriate for other collection areas. Starting points were adopted from the following: NEN norms 2075 (Netherlands Standards Institute, 2001), *In schone staat bewaren* (*Keep in a clean condition*) (Dalhuizen and Van der Most, 1994) and Brokerhof, A.W., van Zanen, B. and den Teuling, A.J.M. (2007) *Fluffy stuff: integrated control of mould in archives*, Netherlands Institute for Cultural Heritage (ICN) and IADA, Amsterdam.

1 Why clean?

- The storage conditions of the collection must be as unattractive as possible for insect pests and micro-organisms.
- Dirt and dust are good sources of nutrition for insects and moulds.
- Dust can absorb moisture: accumulated moisture encourages the development of moulds.

2 Basic storage room procedures

- Provide personal protection. Always wear a dust coat and also a dust mask (with insects at least P2 and for old pesticides P3) for infestations or infections.
- Keep the general area and storage room as clean as possible. Vacuum floors rather than sweep because that only moves dust about. Otherwise clean using anti-static or micro-fibre cloths. Wax-saturated paper towels can be used on waxed linoleum.
- Prevent dampness occurring in the storage room. Should moisture be necessary for disinfecting floors, protect boxes on the lower racks from becoming wet.
- Shelves are best cleaned with anti-static or micro-fibre cloths that hold onto dirt and dust. They should be washable.
- Do not use chemically treated cloths or cloths that must be treated chemically.
- Do not use feather dusters as they only move dust around.
- With insect infestations, always use a vacuum cleaner with a HEPA filter (high efficiency particulate filter).

- Soak crusted or adhered dirt with a mild soap to loosen (be careful with water).
- Shelves must be absolutely dry after wet cleaning before objects are put back.
- Cleaning is the most efficient when carried out in teams of two with a wagon, cloths and vacuum cleaner.
- Work from above to below.
- Work per shelf. Lay the objects on the wagon against a high sloping rim. Clean the shelf.
- Clean every object with cloth or vacuum cleaner.
- After cleaning the entire shelf, replace the objects.

3 Evaluation methods

The quality evaluation system of the professional association of cleaning research (VSR-KMS) is used to guarantee cleaning quality. The evaluation system is based on the NEN standard 2075 that forms the norm for the Netherlands professional cleaning services.

Standards and practice
As 'soiled' and 'dirty' are subjective concepts which are interpreted differently in different situations, the cleaners' association (VSR) collaborated with TNO (Dutch Organisation for applied science) to develop the quality evaluation system (VSR-KMS). This system defines the quality of cleaning procedures according to objective technical cleaning criteria.
Since buildings holding collections are not included in this quality evaluation system, comparable situations were chosen and their 'Acceptable Quality Levels' (AQL) adopted. The definition of the terms given below can be found in the VSR-KMS and NEN 2075 (Netherlands Standards Institute, 2001).

Storage area
Floors category: traffic area
Acceptable Quality Level (AQL): 7%
Storage racks category: office space
Acceptable Quality Level (AQL): 7%

Collection workshops
Category: office space
Acceptable Quality Level (AQL): 7%
Quarantine area
Category: ranges from sanitary area to hospital space
Acceptable Quality Level (AQL): 4% to 3%

Washbasins in workshops
Category: sanitary area
Acceptable Quality Level (AQL): 4%

4 Cleaning practices

Certain cleaning frequencies have been chosen. A few cleaning specifications are presented below. 'Building level' concerns the cleaning of the building and inventory in the case of passive dirt. This cleaning also includes places that are normally not or barely accessible. 'Staff level' concerns the cleaning of workrooms/offices, machines and equipment that are soiled through use (by the staff). These recommendations should become normal working practice.

Cleaning specifications (building level)
Storage area – normal
4 x per year tidy and vacuum.
- Vacuum with HEPA filter.
- Work from above to below and towards the door.
- From the top shelves of racks to the bottom, then walls and plinths and finally the floor around and under the racks.

Storage area – with microbiological infection
Wet cleaning with disinfectant (for example Sumabac™).
See also Brokerhof, A.W., van Zanen, B. and den Teuling, A.J.M. (2007)
- Air ducts and outside vents
- Electrical fittings
- Top shelves
- Empty shelves
- Ledges
- Floors

Collection workshop
- Daily removal of coarse dirt.
- Weekly cleaning according to the collection workshop standard (see above).

Quarantine area

- After use clean according to the quarantine area standard (see above), category: sanitary area.
- After use for mouldy objects clean according to the quarantine area standard (see above), category: hospital space.

Washbasins

- Daily clean according to washbasin standard (see above).

Cleaning specifications (staff level)

General

- Work from top to bottom and towards the door.
- When using disinfectants, do not forget personal protection.
- Keep a small supply of packaging material in the work area with the bulk supply elsewhere.

Whenever mouldy objects are treated, always clean the work area (table, rack, floor) with a disinfectant. No other objects may be present at that time.

Daily

- Clean the table at the completion of every project (dust cloth[1]).
- Clean the table at the end of the work day (dust cloth[1]).
- Wipe the floor around the table at the end of the work day (wiper[2])

Weekly (Friday afternoon)

- Vacuum the table (filter vacuum cleaner[3]).
- Vacuum the floor around the work table (filter vacuum cleaner[3]).

Monthly

- Vacuum all tables thoroughly and systematically with a slow action (filter vacuum cleaner[3]).
- Vacuum the floor thoroughly, put all objects outside the room and dust them before replacing (filter vacuum cleaner[3]).
- Mop the floor after having removed all objects from it: no objects should be present.

Half yearly (July & December)

- Vacuum all tables thoroughly and systematically with a slow action (filter vacuum cleaner[3]).
- Wipe the tables with a disinfectant[4].
- Remove everything from the floor and vacuum it thoroughly (filter vacuum cleaner[3]).
- Then mop the floor with a disinfectant[4].

Footnotes:
1. anti-static, washable cloth or micro-fibre cloth
2. wiper mop with wax-paper (on linoleum wax) or micro-fibre cloths
3. powerful vacuum cleaner with absolute filter or HEPA filter
4. quaternary ammonium in tap water (e.g., Sumabac™)

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APPENDIX 10 Cleaning & disinfestation of paper collections

Cleaning routines are one of the regular activities taking place in the storage area. Infected archive material must certainly be cleaned after treatment. Avoiding damage to the occasional fragile binding or type of paper during the process is important. Every person carrying out the cleaning or the supervisor must have the ability to estimate whether using the methods to hand would be responsible and whether the treatment could cause damage.
The organisation of a cleaning project depends on the condition of the archive material or books, the number of objects to be treated, the origin and degree of dirt, infestation or infection. The type of object and its values also play a role in this consideration. When in doubt, always ask an expert for advice.

During the cleaning of soiled collections, always look out for any mould infection or insect infestation. Mould fluff is often found in places with much accumulated dust.
Look out for living or dead adult insects and be alert to signs of larvae, cocoons and pupae. Look out for colour changes on objects in the presence of moulds and insects.

Basic procedure for cleaning an object

- Carry out cleaning in a room with good ventilation, preferably with air extraction or even in a fume cupboard.
- Provide personal protection. Always wear a dust coat and a face mask for an infestation or infection (for insects, at least P2; for mould and old pesticides, P3).
- For cleaning infected and treated books use a HEPA vacuum cleaner fitted with a soft brush or in combination with a handheld brush.
- For very fragile or damaged objects, use a HEPA vacuum cleaner with adjustable suction power set on low with a piece of gauze fixed over the mouth piece to prevent fragments being sucked up.
- Use a handheld soft brush for the removal of fixed soil. Brush away from yourself towards the vacuum mouthpiece.
- The upper side of an object is usually the most soiled and should be cleaned before the rest of the object.
- Clean the book hinges on the outside first and then on the inside. Dirt and dust collect in these hollows which are also where the first signs of mould infection or insect attack are to be seen.
- Bound objects are to be brushed or vacuumed from the spine towards the fore edge. Avoid the deposit of or rubbing in of dirt in the spine gap or between the pages.
- Never use commercial products for book cleaning (leather, parchment, linen or paper) without first seeking advice from a paper or book conservator.
- Remove all superfluous elements from the book (book marks, strips of (acidic) paper, paper clips and any other sorts of binders in order to prevent acidification, colour changes, rust, or deterioration.

See also Appendix 8: *Personal protection.*
See also: *References and literature*

Appendix 10

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