Restaurator, Vol. 32, p. 160–191

A New Mass Scale Surface Cleaning Technology for Collections of Historical Maps

by Ernst Becker, Manuela Reikow-Räuchle and Gerhard Banik

Dedicated to Roland Hartung on the occasion of his 75th birthday

Abstract: The Justus Perthes collection of historically valuable maps, dating from late 18th century to the 1960s, was acquired in 2003 by the State of Thuringa and given to the University and Research Library Erfurt/Gotha. The collection consists of more than 185,000 objects, of which 90 % have a format equal to or smaller than 96 by 135 cm. Only 10 % of the maps are much larger in format. The maps are etchings, drawings, lithographs and prints, many of them carrying valuable inscriptions in different media – pencil, crayon, chalk, water colour, gouache and writing ink of diverse composition. The whole collection suffered from contamination with dust particles with a particle size of ≤ 1µm that are harmful upon inhalation and therefore regarded as dangerous for users. To make the collections accessible, the dust contamination was to be diminished to values below the maximum threshold value. A new kind of equipment was engineered that automates the cleaning operation of maps. The cleaning operation could be performed with a speed of 80 items per hour based on a size of 1 m width and a 1.5 m length. Maps are hand fed into a machine, where surface soiling removal is realized by electrostatic foils that are brought in contact to both sides of the maps without any slippage, thus avoiding mechanical impact on the objects' surfaces. In the period from July 2008 to August 2010 about 177,000 individual items, that is 96 % of the collection, underwent successful surface cleaning and currently are made accessible to readers. The automated cleaning exceeded the expectations as far as treatment efficiency and treatment quality is concerned. The risk of mechanical damage that resulted from failures in the feeding and transport system was with less than 0.04 % extremely low. Even fragile and brittle objects passed the system without any observable mechanical damage. The technique can therefore be regarded as having a very gentle impact on delicate materials, and offers in selected cases an alternative to the conventional manual surface cleaning of paper-based objects.

Zusammenfassung/résumé at end of article

received: 20.06.2010 revised: 20.04.2011

1. Introduction

This paper describes a large-scale conservation treatment project focusing on the surface cleaning of a substantial collection of maps. It was realized with a collaborative team at the Universitäts- und Forschungsbibliothek Erfurt/Gotha (University and

DOI: 10.1515/rest.2011.009

Fig. 1: Typical example of a map from the collection with correction inscriptions in pencil.

Fig. 2: Well-preserved embossed stamp (arrow).

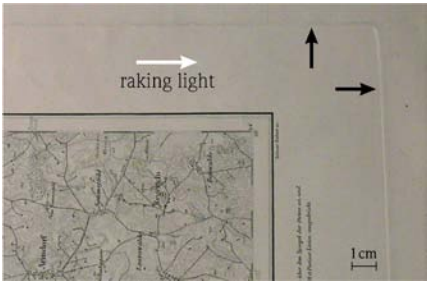


Fig. 3: Distinct plate-mark (arrow).

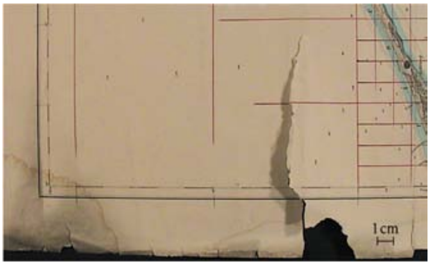


Fig. 4: Typical example of mechanical damages, tears, and losses in the map DR.72.

Research Library Erfurt/Gotha). The project was initiated when the State of Thuringa acquired the archives of the Perthes Geographischer Verlag (Perthes Geographical Press) located in Gotha for a considerable sum. The unique and historically valuable collection comprises in addition to books and archival materials an archive of historical maps totalling 185,000 sheets (Fig. 1), that uniquely document the development of cartography and the output of the Justus Perthes publishing house from the late 18th century up until the 1960s (Demhart 2006, Weigel 2011). The collection contains maps on highly diverse supports, including paper, tracing paper and textiles, templates for colouring the maps with watercolours and coloured pencils, as well as countless drafts or partial corrections of maps that were edited for republication at the publishing house, various inscriptions, marks and grid lines applied in graphite pencil as well as various coloured pencils, inks and watercolour washes. Embossed stamps often retain their legibility (Fig. 2) and thereby give indication about the date and the makers of the maps, as do well-preserved plate marks and other technical details about printing techniques (Fig. 3). Due to their cramped storage and their

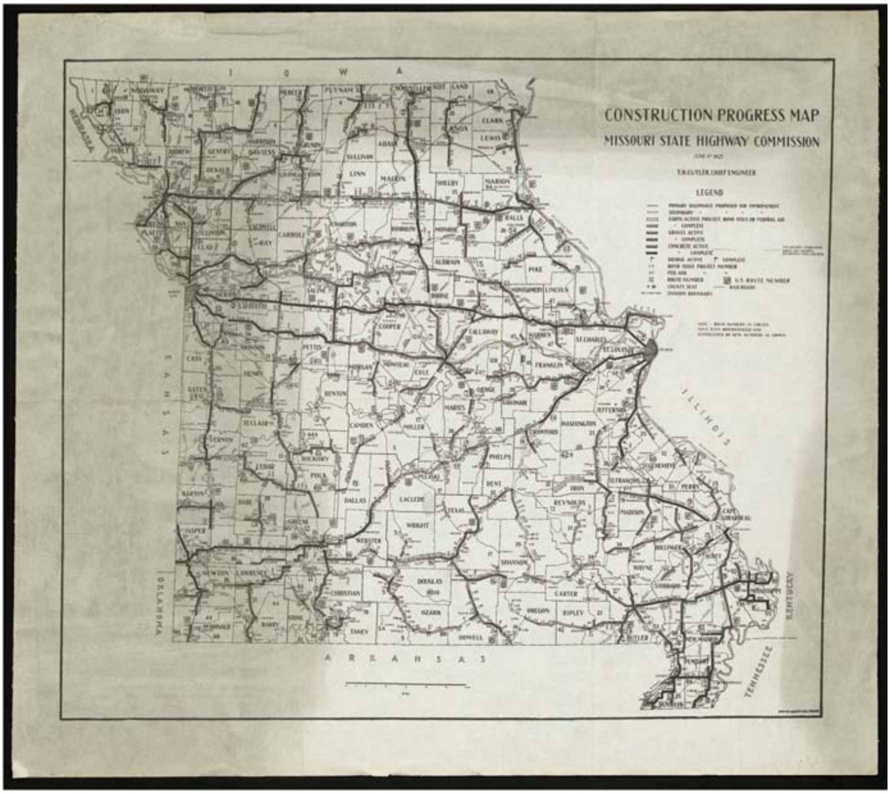


Fig. 5: "Construction Progress Map, Missouri State Highway Commission, June 1927" with multi-layered dust deposits.

having been in continuous use as working material for the cartographers, many of the maps are heavily damaged by cracks, holes, folds and tears (Fig. 4). Moreover, many of the sheets are partly soiled and their legibility is thus impaired (Fig. 5).

The archive was given to the University and Research Library Erfurt/Gotha, with the requirement that the collection be made accessible as quickly as possible for use as well as being preserved according to the current conservational standards (Reikow-Räuchle et al. 2007, Laube 2009). However, during preparatory investigations of the collection it became apparent that the maps were contaminated by ultra-fine respirable dust to such an extent that the health of the librarians, technicians and readers would be endangered just by handling the documents that would cause contamination of the surrounding air far beyond the current threshold limit value (TLV-TWA) [1].

It is strange enough that – in contrary to industry – where potentially hazardous dust and aerosol contaminations in the workplace air are subject to strict regulations in order to limit possible health risks for humans, this aspect has found only little attention in libraries, archives or art collections. Exceptions are two recent articles, entitled "*World Trade Center dust: Its potential to interact with artifacts & works of art*" (Ballard 2001) and *"Pay attention to books and deadly dust – relationship of lung-cancer and heart-attack to library books*" (Bolourchi 2003).

Analysis of the dust contamination revealed that the particles are mainly of inorganic composition consisting calcium aluminium and silicon. Most probably their deposition results from grinding lithographic stones in the workshop areas. It was further determined that the deposit consists of particles being significantly smaller than 1 µm in their majority [2]. Dust particles of such a small dimension are referred to in the literature as $PM_{1.0}$ and $PM_{0.1}$ [3] and represent a serious health risk to the humans as being inhalable. The collection therefore could not be made accessible to readers before removal of the dust contamination from the surfaces of the maps, in order to assure that the particle concentration that is released into the surrounding air through handling never would exceed the threshold limit value (TLV / MAK) that is currently set with 4 mg/m^3 under standard conditions (Blome and Barig 2002, Münzberger 2007).

In observance of the current regulations and in order to allow public access to the collection for scientific use, it was unavoidable to subject the complete map collection to surface cleaning that needed to be conducted in dry conditions. Considering the scale of the collection the responsible librarians engaged external experts to develop an innovative and automated solution for cleaning the maps, which is to say, reduce the contamination of surface soiling at least to an extent that would reach a level below the levels permissible for human exposure. The project was funded by the *Deutsche Bundesstiftung Umwelt* (DBU, Project 23000-4. Over a period of 26 months – from December 2005 to May 2008 – the authors developed an automated system for surface cleaning of the map collection.

2. Surface soiling of paper

Paper objects are often contaminated by surface soiling. The soiling originates mostly from airborne pollutants, i.e. inorganic and organic solids (dust) or liquids (aerosols) suspended in the air and further from solid accretions and residues of biological activity. Solid airborne particulate matter that usually is referred to as dust is transported to the objects by gravitational, electrical and thermal gradient fields or by condensation of liquid aerosols. The term dust includes a mixture of mostly in-organic but also some organic matter that is deposited on the surfaces of paper-based objects in libraries, archives and graphic art collections. Dust particles settle upon paper surfaces and are forced into closer contact with the surfaces of the cellulose based objects by physical interaction forces. Adhesion of dust particles to the surface of the objects occurs through several mechanisms, such as physical absorption, diffusion, electrostatic forces, Van-der-Waals-forces, capillary forces, hydrogen bonding, and mechanical interlocking of particles in surface pores. The latter is strongly influenced by the surface morphology of the object where soft-texture papers feature a high sensitivity.

Surface soiling may impact the object in several ways. It may interfere with the readability of the information or is aesthetically disturbing. It may cause abrasion of the objects' surfaces, it may be hygroscopic, acid or alkaline, may enhance the corrosion of paper through its specific catalytic activity, thus initiating or accelerating the chemical degradation of the object under suitable conditions.

Surface soiling may also constitute a serious risk for the health of librarians, archivists, and readers if it contains toxic agents or is inhalable due to small dimensions of the settled particles.

The intensity of adhesion forces that cause dust particles to adhere to surfaces of paper depends on the material composition of the respective dust particles that determines their capability to build up an electrostatic charge, their dimension and shape. However, the main player in dust deposition is the type and material composition of the surface on which dust deposition takes place, e.g. paper. It determines the mechanisms of the adhesion process that is strongly influenced by the physical and chemical characteristics of paper i.e. its density, its surface shape, texture, roughness, its mechanical properties, the presence of coatings, fibre composition and additives, e.g. sizes, fillers etc. Further, dust adhesion depends on the external environment conditions, i.e. humidity and temperature (Wolbers 2000, Wiesner et. al. 2010). Once deposited, dust particles may get more firmly bonded to a paper's surface by mechanical action, e.g. by handling that involves rubbing or pressing and by storage situations that put weight on the objects' surfaces. The strong adhesion and the small size of the deposited particles counteract the traditional mechanical procedures to separate and remove them from the surface.

3. Surface cleaning options

3.1 Conventional surface cleaning treatments

Surface cleaning, a term that is synonymously referred to as "dry cleaning", per definition refers to "*a mechanical technique to reduce superficial soil, dust and other deposits on the surface of a paper based object*" (AIC Paper Conservation Catalog

1992). Surface cleaning operations on paper are done by treating the objects' surfaces with an erasing medium. The common tools are erasers. Other cleaning tools for the treatment of paper artefacts are different types of cleaning sponges, soft brushes, blower brushes, cheese cloth or vacuum cleaners, often used in combination with erasers and with a separate brushing action.

Erasers that find application in paper conservation consist of a number of natural and synthetic components. Regarding natural products, latex, vulcanized rubber and factice – a sulphur vulcanized vegetable oil – find wide distribution. Among the synthetic materials, polyvinylchloride, styrene butadiene co-polymer, and polyurethane ester are the most important species (AIC Paper Conservation Catalog 1992, Roelofs et al. 1999, van Keulen et al. 2009) The action of erasers invariably aims at dislodging and removing dirt particles by either lifting them off the contaminated surfaces through contact with rubber based sticky erasers – so-called kneaded erasers, or by gently rubbing over surfaces with block erasers, ground eraser crumbs or cleaning sponges by which soiling gets mechanically separated and incorporated into the eraser particles or into the sponge surface and can be transported off the paper surface (Hakney et al. 1990, Phenix et al. 1990, Cowan et al. 2001, Noehles 2002). Vinyl-based erasers contain considerable amounts of plasticizers based on phthalate esters that may affect treatment results by being transferred to the object's surface or even deeper into the paper matrix. In addition many erasers contain abrasive materials, such as calcium carbonate, magnesium silicate, and kaolinite particles. Therefore their application on paper and other materials is not without abrasive damage to the objects' surfaces (Pearlstein et al. 1982, van Keulen et al. 2008). They may irreversibly alter the morphology of the paper surface. The unavoidable mechanical impact to the objects carries the risk of causing undesired side effects, such as distortion or compression of the paper, changes in its texture and gloss and abrasion and roughening its surface. Further, fine eraser particles may be rubbed into the paper's surface and get permanently trapped. Cleaning results may be inhomogeneous es-pecially in the case when large formats are subjected to overall surface cleaning. Objects that feature friable media cannot be treated with erasers if not distinct work-around areas have bee defined prior to treatment.

A serious disadvantage of all conventional surface cleaning methods is the fact that it requires an individualistic approach for making treatment decisions. In other words cleaning tools must be selected according to the physical properties that determine their effectiveness, and objects need to be carefully examined to estimate risks involved in the cleaning operation (AIC Paper Conservation Catalog 1992). For large collections conventional surface cleaning techniques therefore must be regarded as financially prohibitive.

3.2 Electrostatic surface cleaning

A promising alternative to traditional surface cleaning techniques makes use of static electricity. Non-conductive materials, such as paper, wood and synthetic materials may develop an electrostatic charge due to the fact that their electrons cannot move freely to maintain the material's electronic balance. By rubbing non-conductive materials or by creating intimate contact between them, a negative electrostatic charge is built up on either surface while the contacting opposite surface becomes positively charged. Static electricity is defined as a non-flowing electrical charge or in other words, as "standing" electricity. Paper is an example of a material that features static electricity. The intensity depends on its composition and surface characteristics. In particular coated paper, such as light-weighted, large-format gloss-coated papers may accumulate a considerable electrostatic charge. This electrostatic charge is capable to attract and fix particles that feature an opposite electrostatic charge.

In current technology electrostatics finds wide application, among others in air purification systems (Allemann et al. 1965), to fight dust deposition on the surfaces of equipment used for aerospace exploration missions (Calle et al. 2008), for improvement of paper production printing technology and industrial book production, to enable non-contact lifting of deposited dust particles from sensitive surfaces (Eltex n.y.) and as efficient cleaning tools for housekeeping. Among the numerous technological solutions the following three are mentioned as promising options to be technically adapted and transferred to conservation practice:

- Remoistening of paper after sheet formation through the charged aqueous aerosols in an electric field (Wegele 1980);
- "smart" electrostatic textiles or fibres for dust removal in the household e.g. Swiffer Duster™ [4];
- electrostatic lifting techniques that have found application in forensic science to document and save dust shoe prints for evidence (Wiesner et al. 2011).

Electrostatic dust removal or dust lifting follows complete different mechanisms than conventional surface cleaning techniques. The technique requires charging a non-conducting and flexible material that in many technical applications is brought in close contact to a dust carrying surface. As many inorganic dust particles carry a positive electrical charge, they get attracted and transferred from the original surface to an applied film or textile if these carry a negative electrostatic charge. The latter must exceed the competing electrostatic force that holds particles in place. The technique finds its limitation in the distance of the contacting material because due to Coulomb's Law [5] the force of attraction is strongly reduced with the distance of the material that features the opposite charges. In order to overcome this limitation, which is especially, influenced by surface roughness and texture effects an electrostatic film or textile often is applied with help of suction and soft brushing onto the contaminated surfaces with only little mechanical impact.

4. Technical solution

Given the scale of the collection and the overall highly fragile condition of many maps that featured, losses, extensive tears, old repairs, presence of adhesive tapes etc., any conventional surface cleaning method would have caused considerable mechanical impact to the objects. Further, the presence of sensitive media in many maps prohibited dust removal over the total area.

To clean the 185,000 maps in a reasonable time, with a technique being economically affordable, an automated system must effectively remove the dust contamination from both sides of the maps. The system had to be applicable safely for the treatment of a wide range of objects, the majority of them being composites of different materials, including paper, boards, textiles, repair tapes and media.

The solution was found in the application of an electrostatic film that is brought into intimate contact with the surfaces of the originals. The film can lift small particles and their agglomerates off the surface. Contacting of the two surfaces is technically realized without any sharing force friction and only little mechanical pressure. After subsequent separation of the foil from the originals, the dust particles are bound to the electrostatic film, due to an electrostatic charge that is higher than that holding it on of the papers' surface. The intention of electrostatic cleaning is not to remove soils embedded into the paper matrix, but only to lift harmful dust particle deposits off the surface. As the electrostatic attraction force is limited, the electrostatic film can only carry particles of dimensions of smaller than approximately 25 µm in diameter. This diameter mainly depends on density, conductivity and the morphology of the surface.

4.1 System requirements

The automated solution had to fulfil the following requirements:

- The proof that the maximal workplace concentration (TLV) of the respirable ultra fine dust released into the air when using a map is reduced to values below the TLV limit of 4 mg/m^3 under standard conditions;

- avoidance of any abrasive treatment techniques that would cause a lasting alteration of the surface of the objects;
- no reduction in legibility;
- complete preservation of the printing inks, inscriptions and other media;
- avoidance of any mechanical damage to the support;
- no increase of already existent mechanical damage on the maps.

During preliminary assessment, the collection was divided into five groups according to the delicacy of the support materials colouring matters and media of inscriptions:

- **Group 1:** minor or limited mechanical damage, no platemarks or embossed stamps, no hand-written annotations;
- **Group 2:** maps with platemarks and embossed stamps, minor or limited mechanical damage, no hand-written annotations;
- **Group 3:** maps with hand-written annotations, minor or limited mechanical damage;
- **Group 4:** creased and folded maps;
- **Group 5:** maps with moderate or heavy mechanical damage, handwritten annotations, platemarks or embossed stamps, creases and folds.

Preliminary tests allowed the manual simulation of the cleaning cycle (later to be automated) using duplicates from the collection. Doing so, the findings gained allowed a list of requirements for cleaning the maps to be drawn up as well as the following parameters for the construction of the machine:

The cleaning process must be done without use of abrasive media and

- must use dry-cleaning techniques;
- the maps should be able to be automatically fed through the machine without any laborious preparation. The securing and stabilizing of rips, holes, protruding bits of paper, and brittle paper cannot take place beforehand;
- neither material loss nor further damage should be caused by the automated treatment in the machine;
- lifting of any kind of colouring matters present on the maps' surfaces as inscriptions or colourations must be excluded or at least be minimized to a negligible extent;
- the legibility of embossed stamps and platemarks must not be affected;
- depending on the kind of damage the settings of the machine must be adjustable, e.g. the speed of the conveyor belt, and the under-pressure of the suction units.

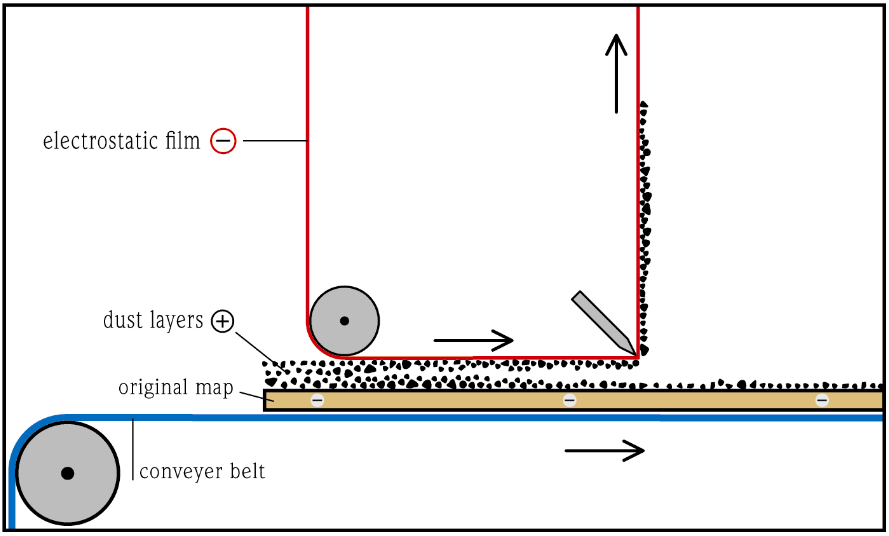


Fig. 6: Basic principle of the removal of dust particles using a negatively charged electrostatic film.

4.2 Operation mode of the cleaning equipment

The new equipment cleans the objects on both sides by means of two identically designed and identically operating cleaning modules that are connected in a series. The principle behind the cleaning procedure is a gentle removal of the fine dust using an electrostatically charged film that is applied to the original without any slippage, i.e. no friction occurs between original and electrostatically charged film and after contact is removed at a sharp angle as well without any friction. The strong negative charge of the film allows the positively charged dust particles to be pulled off from the paper's surface – which is likewise negatively polarized – and affixed to the film, thus allowing them to be safely removed. Removal of the surface soiling deposit occurs in layers, chiefly in mono-layers of particles (Fig. 6). Heavy dirt accumulation – for example multiple layers of dust – is lifted off by passing the original through the equipment several times.

The map-cleaning equipment consists chiefly of the following components (Figs 7 and 8a–c):

- Conveyer belts for moving the maps through (Fig.7, no. 1, 5 & 8);
- suction devices to fix the maps to the belt and keep them lying flat (Fig.7, no. 7) (cleaning module II), suction device of cleaning module I not shown;

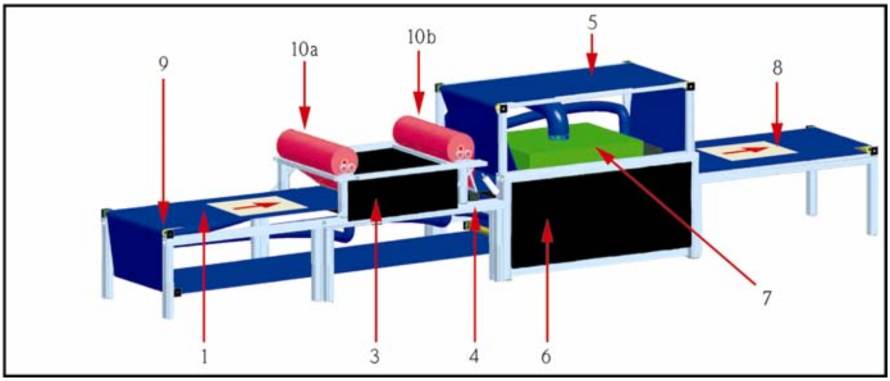


Fig. 7: Construction elements of the electrostatic map cleaning system *Gothana*: 1 conveyer belt (loading end and cleaning module I), 3 cleaning module I, 4 spent electrostatic film removal unit, 5 conveyer belt (cleaning module II), 6 cleaning module II, 7 suction device II, 8 conveyer belt (discharge end), 9 synchronized drive unit, 10a electrostatic film infeed (cleaning module I), 10b winder for spent electrostatic film (cleaning module I).

- drive unit with coordinated and feed rollers that operate synchronously (Fig. 7 and Fig. 8a, no. 9);
- film infeed unit (Fig. 7, no. 10a and Fig. 8b, no. 10c);
- cleaning modules accordingly outfitted with a film, with which the surface soiling particles can be removed from the object surface without any mechanical stress to the object: (Fig. 7, no. 3 & 6);
- spent electrostatic film removal unit (Fig. 4, no. 4);
- exhaust unit: (Fig. 8a–c, no. 11).
- to run the equipment risk-free, it features open belt sections of 2 m length that allows full access to the object (Fig. 7, no. 1 and 8) both before and after the cleaning modules (see also Fig. 8 c).

4.3 Technical data

• Usable width of the band: (maximum width of the maps to be treated)	1 m
• variable speed control of conveyor: (this corresponds to a cleaning capacity of between 12 and 240 maps per hour with a maximum size of 1 x 1.5 m)	0.2 to 4 m/min

Fig. 8a: Electrostatic cleaning system *Gothana*: 1 conveyer belt (loading end / cleaning module I), 2 suction device I, 3 cleaning module I, 5 conveyer belt (cleaning module II), 9 synchronized drive unit, 10a electrostatic film infeed (cleaning module I), 11 exhaust unit.

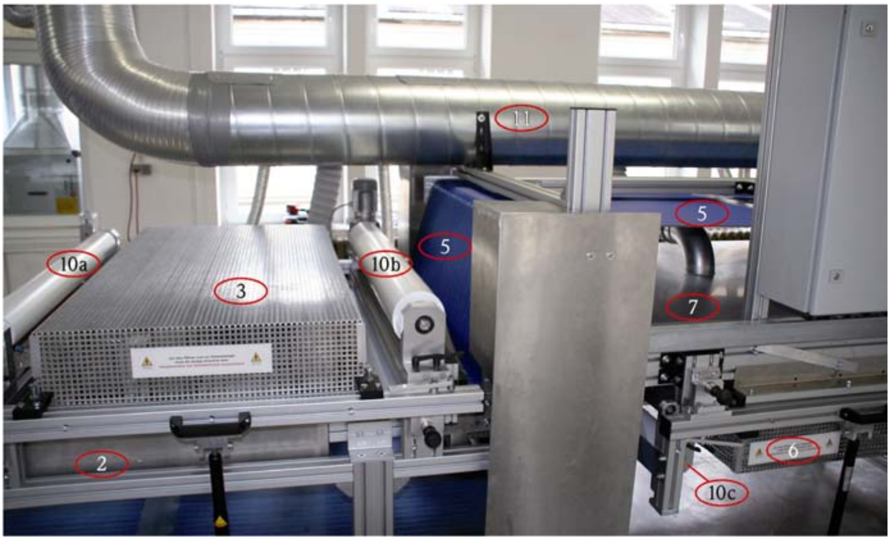


Fig. 8b: Electrostatic cleaning system *Gothana,* dust removal unit: 2 suction device I, 3 cleaning module I, 5 conveyer belt (cleaning module II), 6 cleaning module II, 7 suction device II, 10a electrostatic film infeed (cleaning module I) 10b winder for spent electrostatic film (cleaning module I), 10c electrostatic film infeed (cleaning module II), 11 exhaust unit.

Fig. 8c: Electrostatic cleaning system *Gothana*: 1 conveyer belt (loading end / cleaning module I), 2 suction device I, 3 cleaning module I, 5 conveyer belt (cleaning module II), 8 conveyer belt (discharge end), 9 synchronized drive unit, 10a electrostatic film infeed (cleaning module I), 11 exhaust unit.

• operating height:	0.9 m
• advance and follow-up stretch:	2 m each
• length of the entire apparatus:	8 m
• width of the apparatus: (without exhaust fan)	1.5 m
• height of the apparatus:	1.75 m

4.4 Key equipment parts

- The speeds of the three conveyer belts are perfectly synchronized, to assure that there is no dislocation of the original and the film, when passing from one belt to the other;
- pivoting cleaning modules: maps can be removed from the apparatus without risk of damage in the case of malfunction;
- suction devices to fix the maps securely to the belt and hold them flat until they can be removed from the equipment without risk of damage;
- emergency button that allows immediate and complete stop of the machine;

- automatically operating modules of the machine for safe operation; e.g. all modules can be lifted automatically in the case of a jam; the original can be removed easily and safe.

5. Quality management

5.1 Residual contamination

To ensure the quality of the treatment, every 200th map is to be tested after it had passed through the machine and checked for the remaining level of dust contamination. The particle retention of the maps is analyzed in a test chamber developed specifically for this quality-control, which simulates the movement of a map during normal library use. The dust particles thereby are released into the chamber air and are quantitatively determined with an instrument suited to determine the level dust contamination in the chamber space.

The concentration of the particles in the chamber air is measured by a light-optical measurement system, which measures the diameter and the number of particles by light scattering.

5.2 Media stability

To test the stability of media on the map surfaces towards the electrostatic cleaning, test sheets were developed in cooperation with the company Stabilo International GmbH in Heroldsberg (Figs 9 and 10). A wide variety of writing materials – from pencil to pastel crayon – with a defined intensity were applied to the surface of various types of paper by machine. The writing materials were selected to match those on the original maps as closely as possible.

Due to the standardized attrition susceptibility of the test sheets, the removal rates could be reproduced when the sheets were passed through the equipment. The results could be interpreted in relation to the original media on the maps, thus accurately assessing the risks posed by the treatment. Using these test sheets, it could be ascertained that even the pastel crayon application (CarbOthello Stabilo) only suffered a minimal loss of material in that the top-most layer of the media application was removed (see Fig. 6). And even this reduction on the most sensitive test sheets was so minimal that it was not perceptible to the human observer when the sheet was passed through the equipment only once. Furthermore, because the object on the conveyer belt and the electrostatic film are contacted without any slippage, smearing of media is also avoided. The test sheets were used in the machine during opera-

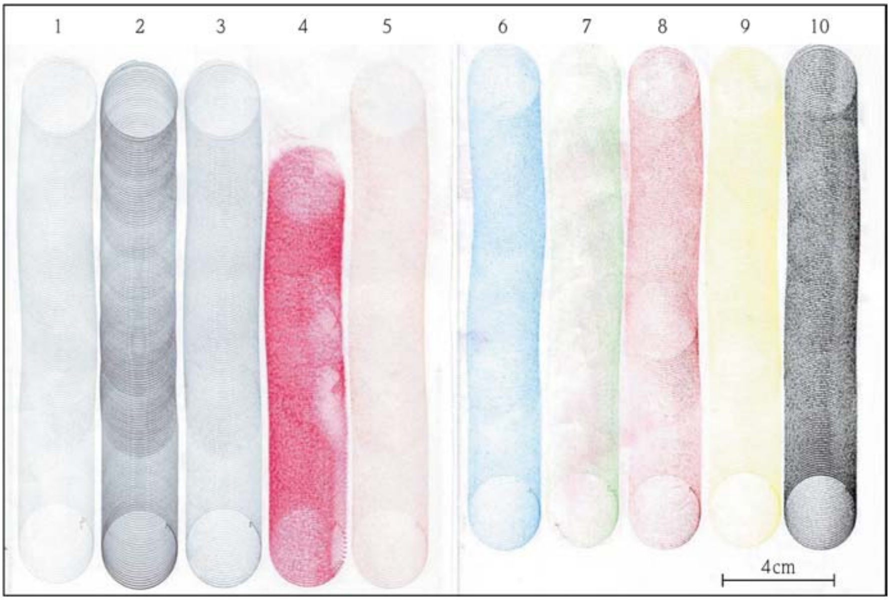


Fig. 9: Test sheet, developed with the company Stabilo International, Heroldsberg. Colour application from right to left: pencils of the type H, HB and B (Stabilo brand); red CarbOthello pastel pencil (Stabilo brand); FA5 coloured pencils (blue, green, red, yellow and black) (Stabilo brand).

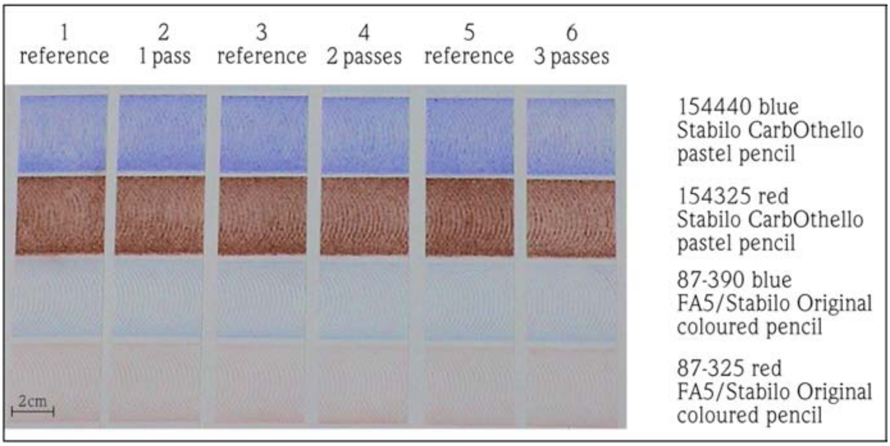


Fig. 10: Test sheet with red and blue CarbOthello pastel pencils samples. The sheet was cut into strips and fed through the machine three times. Between the strips 1/2 (1 pass through the machine), 1/4 (2 passes) and 1/6 (3 passes) is one reference strip for comparison. The test strips clearly show that even after the second pass, no visible changes to the colour can be seen. Only after the third pass is a significant change noticed.

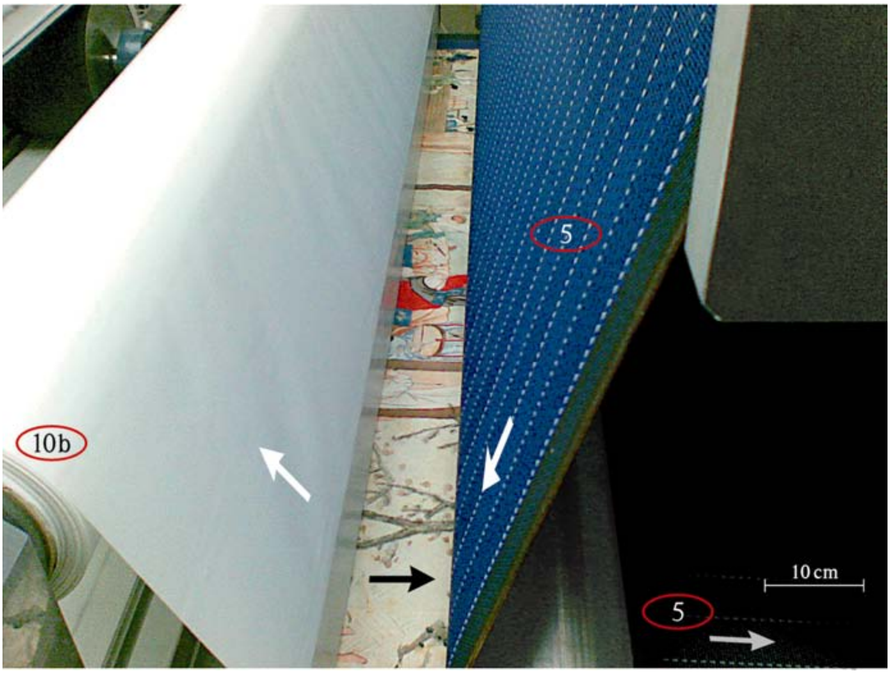


Fig. 11: Fragment of a Chinese wallpaper from late 18th century after having passed cleaning module I; on the left hand side the spent white electrostatic film is separated from object and winded up (10b); no traces of pigments removed from the painted areas are visible on the film surface. On the right hand the object is being transferred to the conveyor belt of cleaning module II (no. 5 in Fig. 8c) to undergo subsequent cleaning operation on its reverse side.

tion to determine the suitable cleaning parameters for the original maps as well as for continuous quality control testing of the system. The positive results gained with the test sheets could be verified by subjecting fragments of a 18th century Chinese wallpaper to the treatment that passed through without visible transfer of pigments from painted areas to the electrostatic film (Fig. 11)

6. Operating results

The first real-life testing of the system with the test sheets described above and with secondary copies from the map collection showed that all the original technical requirements were fully met by the equipment. The surface cleaning equipment can remove respirable dust particles with sizes ranging from >10 µm to far smaller than 0.1 µm. The cleaning system is suited to clean the surfaces of delicate objects, since

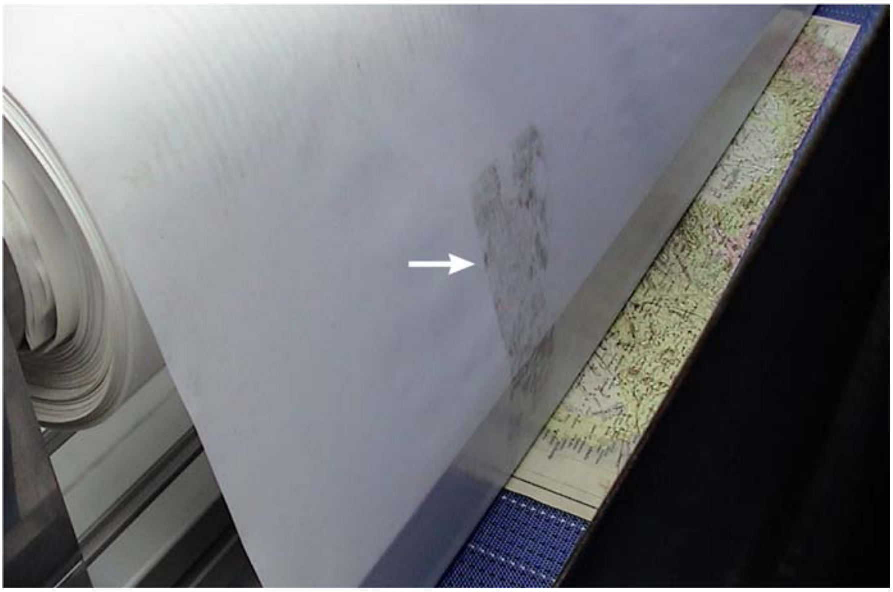


Fig. 12: View of the film with the dirt removed from the surface (arrow).

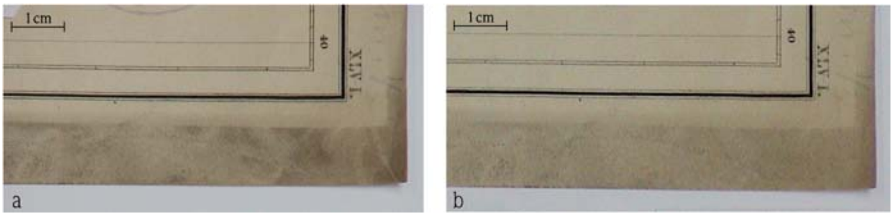


Fig. 13: Surface staining on the border of map no. 547$111339782 before (a) and after (b) cleaning; the treatment was done at a feed rate of 1m/min.

it neither puts mechanical stress on the surface, nor abrasive media are involved. Using electrostatic films, even heavy, multi-layered dirt deposits can be removed (Figs 12 and 13) heavily soiled objects can be cleaned by passing them through the machine several times.

Analysis of the film and the lifted particles using a scanning electron microscope (SEM) after treatment shows that, if the particles are very small, some layers of the dust deposit have been lifted off in the form of agglomerations (Fig. 14). According to x-ray microanalysis (EDX) the particles mainly consist of aluminium and silicon; the presence of titanium was also revealed by EDX spectrum since the film is enhanced with titanium oxide to make it opaque for its normal technical use (Fig. 15).

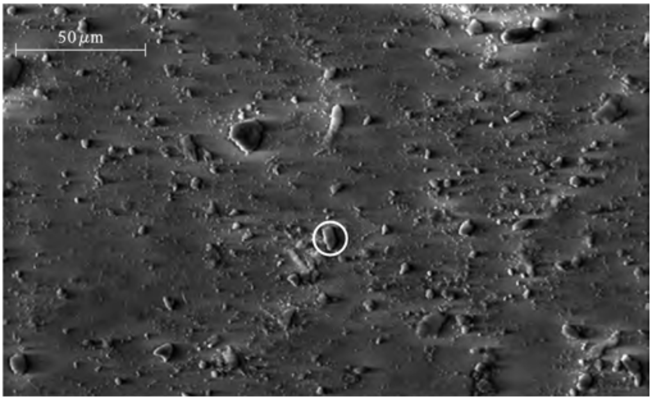


Fig. 14: SEM image of the particles clinging to the film after one cleaning operation. The particle marked with the white circle was analyzed (Fig. 14).

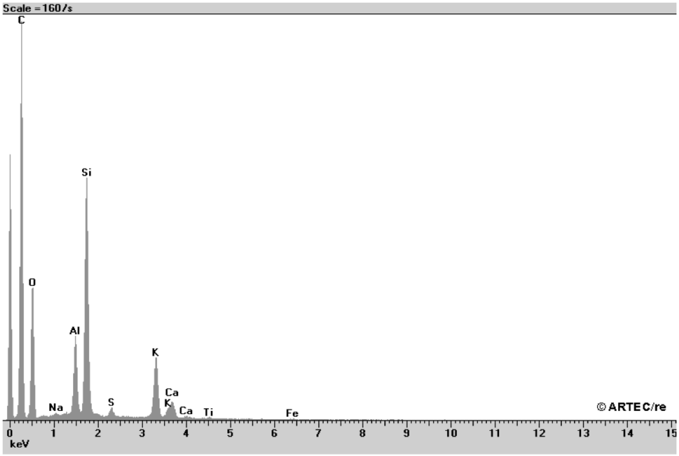
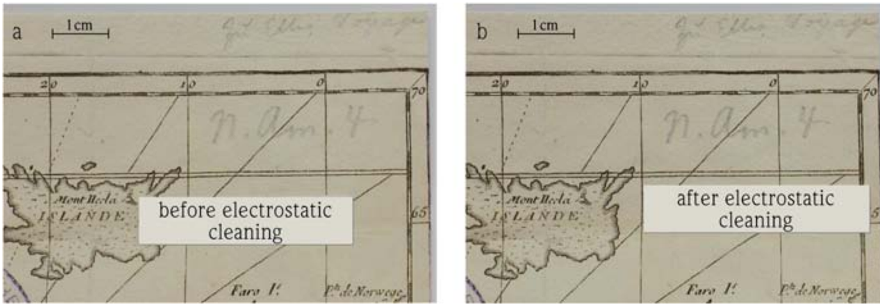


Fig. 15: EDX spectrum of the particle marked in Figure 13. The main elements are aluminium, silicon, potassium and calcium.

When implementing the prototype of the equipment, it was observed that the process altered neither platemark (Fig. 16) nor embossing (Fig. 17) on the surface. Media applications were not affected by the cleaning and – depending on their sensitivity – could be fed through the cleaning apparatus at least twice – or, in some cases, more often (Fig. 16). Only for those objects with chalky media layers the cleaning operation was limited to one pass through the machine to avoid media loss. The legibility of individual media lines or their appearance, i.e. intensity, was not affected by the cleaning process. The legibility of the annotations was fully preserved



Fig, 16: Platemark from the map no. 547$111339596 before (a) and after (b) cleaning. The platemark was retained without any changes; the hand-written annotations are visibly unchanged after electrostatic cleaning (8b).

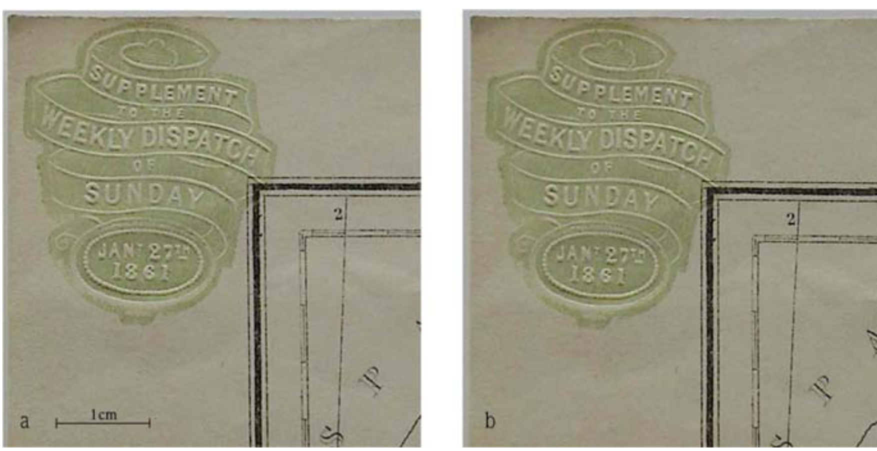


Fig. 17: Embossed stamp from the map no. 547$11133960X before (a) and after (b) being passed through the cleaning machine.

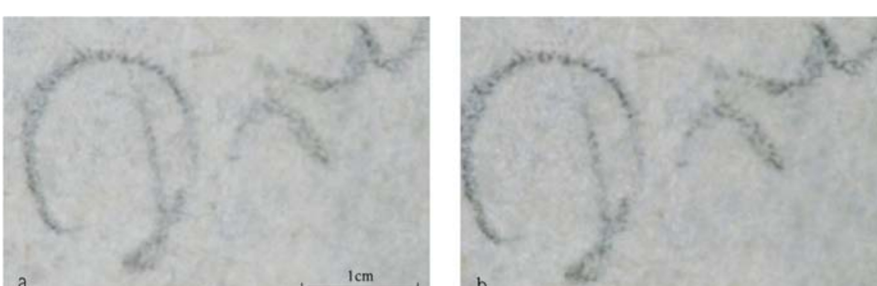


Fig. 18: Hand-written annotation in pencil from the map no. 547$111339561 before (a) and after (b) being passed through the cleaning machine.

Fig. 19: Test unit to determine the particle contamination in the range of 0.3 to 10 µm. 1 support rail for the maps, 2 grating, 3 funnel, 4 superfine filter for air intake, 5 isokinetic sampling probe, 6 light-optical particle measuring device.

(Fig. 18). Papers with physical damage could be treated by the equipment without any problems. No further damage occurred during routine operation. Old repairs that had been made using tapes that were barely adhering due to their aged condition also were not affected.

6.1 Evaluating the efficacy of electrostatic dust removal

A measurement chamber equipped with a special light-optical micro-particle measuring device by light scattering (Fig. 20) and constructed specifically for proof of the effectiveness of the cleaning performance (Fig. 19) verified the reduction of the respirable particles to a level below the legal definition (TLV / MAK). Determination

Fig. 20: Light-optical particle measuring device – Klotz Ama LDS 0.3/10.

of particle contamination involved affixing the map securely to a rail (1) (Fig. 19) and manoeuvring it inside the closed chamber in a way that simulated normal use. In so doing, particles fell from the surface of the original and were floating in the atmosphere surrounding the original object. They were floating on the air current and then settled towards the bottom of the chamber. The isokinetic sampling probe (5) of the measuring device (6) was located at the bottom of the measuring chamber, at the end of a funnel (3) covered by a grating (2). By means of a ventilator creating a vacuum, the air inside the measuring chamber was suctioned from the top to the bottom of the chamber, the air intake from outside being cleaned with a micro filter (4). The air stream containing particles and leaving the chamber was channelled through the light-optical particle measuring device (6), where the quantity and the diameter of particles were continuously measured. As the map was manoeuvred, the measurement lasted for one minute, in which the air cycled through the measuring chamber several times, ensuring that all the particles were captured. Particles from 0.1 to 100 µm in diameter could be determined. The resolution of the measurement range was > 0.3 and < 10 µm. Results of a typical measurement of the particle concentration in the ambient air of a cleaned map were 0.08 mg/m^3 under standard conditions. The measurements of the fine dust on the maps consistently yielded values that were far below the permissible maximum threshold limit value (TLV / MAK) of 4 mg/m^3 under standard conditions. Thus the maps could be released for further use.

7. Conclusions

An automated electrostatic method for surface cleaning large paper objects on mass scale could be developed and successfully implemented to routine application. The historical maps that were the first items to be treated with this method were mechanically fragile and carried delicate media. Using the traditional methods for cleaning surfaces by hand, it would not have been possible to treat the 177,200 maps within a period of 24 months. The new automated cleaning system was the prerequisite for both the indexing and scholarly usage of the collection, as well as for ongoing preservation measures.

The efficiency of the applied electrostatic equipment is much higher than to manual cleaning methods. On average, 80 maps per hour can be effectively cleaned on both sides. This number is based on a format of 1.5 by 1.0 m and one pass per item through the system. Two people operate the machine during this pro-cedure. By comparison, when cleaning by hand, two people can only clean on average between two and a maximum of forty maps (ARK-Ausschuss “Restaurierung” 2002). Moreover, the cleaning rate by hand depends on the condition of the maps. Fragile objects will take a correspondingly longer amount of time, perhaps requiring more than one hour per map. Furthermore, when manually removing surface soiling, the effectiveness and uniformity of the cleaning treatment can be verified only visually a procedure that is quite unreliable if large scale collections are to be treated.

The basis for both, the successful development of the equipment and its implementation to daily conservation in the library was facilitated by the fact that every individual step of the procedure was clearly defined, from lifting the maps from their storage cabinets to stacking them back in the cabinets. The preservation plan had to be comprehensive so that the markers of authenticity that make the original maps important would be considered beyond the process of surface cleaning. Handling the materials in a low-risk fashion must be a priority before and especially after treatment as well, for example during indexing, digitalizing and conserving the collection. For the Perthes map collection, the mechanical cleaning was the most important first step, but not the only one, as it was the precondition for the indexing and other preservation measures that followed. The project required an interdisciplinary approach of librarians, conservators and engineers that were involved in developing an operation chart as a working tool for the process to make the collection assessable.

However, it is crucial for this kind of project that conservators have not only been involved in the development of the treatment technique and process, but that they assume leadership for all conservation activities relating to the physical maintenance of the collection, because collection care is a comprehensive task affecting many branches within an institution. Conservators are familiar with the materials involved, the treatment methods and the risks associated with them. They are capable to train and supervise conservation assistants carrying out treatments. This way, they are best equipped to coordinate the activities surrounding mass treatment that require a high level of labour division. By this approach the risk of mechanical damage to the maps even during routine operations, such as transport, handling, packaging, could be almost completely eliminated already in the planning phase. The quality management, involving the examination of every 200th map, was also set in an interdisciplinary cooperation. The continuous examination of selected maps before and after treatment was integrated in the work flow. The gained results are documented in the database of the library.

The operating results of the surface cleaning equipment inaugurated in June 2008 have by far exceeded the original expectations. According to the final project report submitted in 2011 by the University and Research Library Erfurt/Gotha 177,200 maps underwent successful cleaning by the end of August 2010 and then were released for documentation and scientific work. The electrostatic cleaning system exceeded the project targets as it can process an average of approximately 1,000 maps in a typical 8 hours working day with very low risk. Damages to the original materials caused by operation failure or technical malfunction of the equipment ranged below 0.04 %, i.e. in total 64 maps that were affected mostly by creases and tears. None of the maps was mechanically damaged to an extent that it had to be regarded as total loss. Damages were caused by a mechanical failure of the slipping clutch of the electrostatically charged film. The failure was eliminated on short term and after the first 3 months of operation there was no further occurrence of damage. Other potential damages, such as changes in paper texture, abrasion or losses of friable media or inscriptions have not at all been observed [6]. Electrostatic cleaning therefore seems to be a promising and gentle alternative especially treat delicate or friable paper based objects in comparison to conventional manual surface cleaning techniques.

There are various applications for this technique for cleaning surfaces in conservation besides paper objects, in particular for removing surface soiling from large textiles, or for cleaning materials contaminated from biological infestation. Unique is its efficacy in the removal of particles from fragile surfaces, which cannot be treated with abrasive mediums or by compression. The automated equipment also avoids inhomogeneous cleaning results. In the near future further development of this process could possibly result in a significantly smaller, semi-automated apparatus, suitable for a cost-efficient treatment of smaller collections. Currently, investigations are underway to determine whether the equipment can be further developed into a semi-automated cleaning apparatus the size of a tabletop in the context of another DBU project. In addition to the removal of regular surface soiling, investigations in collaboration with research bodies and potential users are taking place to determine whether it can also be used to eliminate mould spores effectively. The inducible electrostatic charge in the case of mould spores is negative and can only be removed by a positive charged electrostatic film. The existing machine was operated with a negative charged film. Current efforts are taking place to develop a special positive charged film.

Notes

[1]: Definition of TLV:
"The threshold limit value (TLV) is a term for airborne concentration of a hazardous substance in workplace air below which all workers are believed to be protected while exposed to it day after day for 8-hour periods. The value is set by competent national authorities and enforced by legislation to protect occupational safety and health.
For gases and vapours, TLV is stated as parts per million (ppm) of surrounding air, and for fumes, mists, and dusts as milligrams per cubic meter (mg/m^3) of surrounding air; TLV –TWA is the respective value set as: time weighted average concentration for a normal 8-hour workday or 40-hour workweek".
(http://www.businessdictionary.com/definition/threshold-limit-value-TLV.html accessed 05.01.2011)
In Germany TLV is termed MAK (Maximale Arbeitsplatz Konzentration); data are compiled by the Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area of the Deutsche Forschungsgemeinschaft (DFG), revisions are published annually.
(http://www.dfg.de/dfg_profil/gremien/senat/gesundheitsschaedliche_arbeitsstoffe/index.html, accessed 01.04.2011)

[2] Agrar Umweltanalytik GmbH, Jena, Prüfbericht Nr. AUA 7882/1.1-04, 22.10.2004

[3] PM stands for particulate matter suspended in air. PM followed by a number refers to a fraction of PM, i.e. all particles with a certain maximum size that termed as their aerodynamic diameter. All smaller particles are included to the respective fraction.
$\mathbf{PM_{10}}$ defines a fraction of particles with an aerodynamic diameter of 10 µm or less**,**
$\mathbf{PM_{0.1}}$ stands for a fraction of particulate matter with an aerodynamic diameter 0.1 µm less, in the literature this fraction is referred to as the ultra fine particle fraction (UFP).
(http://www.greenfacts.org/glossary/pqrs/PM10-PM2.5-PM0.1.htm,
accessed 01.04.2011)

Health problems of humans that result from inhaling particulate matter have been studied extensively since the 1970s. Small sized particles featuring an aerodynamic diameter of 10 µm (PM_{10})are hazardous; they get tra nsported deeply in to the lung where they irreversibly settle , particles smaller than 2.5 µm ($PM_{2.5}$) tend to penetrate into the ga s exchange regions of the lung, a nd ultra fine particles (**$PM_{0.1}$**), i.e. 100 nm and smaller may pass through the lungs to affect other organs.
(http://en.wikipedia.org/wiki/Particulates, accessed 01.04.2011)

[4] Swiffer Duster™ is a trade-marked product line of Procter and Gamble. Very efficient lifting of dust from surfaces is possible trough "sm art" synthetic fibres offering large surfaces that attract dust by electrostatic charge and traps particles due to their specific surface characteristics.
(http://www.test.de/themen/haus-garten/test/Swiffer-Co-Die-besten-Abstauber-1538688-1545245/, accessed 01.14.2011)

[5] The electrostatic force between electrical charged particles (point charges) is described by the Coulomb's law, named after the French physicist Charles Augustin de Coulomb. He stated in 1783: "The m agnitude of the electrostatic force of interaction between two point charges is directly proportional to the scalar multiplication of the ma gnitudes of charges and inversely proportional to the square of the d istances between them."

$$F_{12}=k \times \frac{Q_1 \times Q_2}{r^2} = \frac{Q_1 \times Q_2}{4 + \pi + \varepsilon + r^2}$$

F_{12} is the force between 2 charges Q_1 and Q_2, r is the dista nce between the c harges, k is a proportionality factor and ε is the dielectric coefficient. In the practical application of the Coulomb e ffect there a re no real existing point charges. The effective electrostatic forces between particles and electrostatically charged film are additional depending on size o f particles, density of the material and the morphology of the surfaces.
(http://en.wikipedia.org/wiki/Coulomb%27s_law, accessed 01.04.2011)

[6] Details of the practical experience made during the electrostatic cleaning of the Perthes map collection will be provided in the f inal report of the proj ect and published by the Research and University Library Erfurt/Gotha in June 2012.

Acknowledgements

This project was generously funded by the Deutsche Bundesstiftung Umwelt (DBU), Project Nr. 23000-45. We would like to especially thank Lutz Töpfer the project responsible at DBU for his advice and continuous support.

The authors would like to thank Christiane Schmiedeknecht, Rupert Schaab, Kathrin Paasch, Petra Weigel, Evelyn Ernst and Christian Kreienbrink from the Research and University Library Erfurt/Gotha, who initiated the project, for the constructive cooperation during the development phase of the map cleaning system.

Further, we are indebted to the members of the advisory board Ulrike Hähner, Barbara Kunze and Monika Kahl for providing valuable ideas and support during the development phase.

Special thanks we owe Karl-Peter Kämpf from Stabilo International GmbH in Heroldsberg for providing information to select suitable materials for the preparation of test sheets.

We would also like to thank Rudolf Erlach, Institut für Kunst und Technologie at the Universität für angewandte Kunst in Vienna for carrying out the SEM/EDX analysis.

Appendix

After completing the cleaning operation of the Justus Perthes collection in late August 2010, the equipment was given to the Department of Records, Book and Art on Paper at the University of Applied Science Holzminden/Hildesheim/Göttingen, to enable further technical development of the system. The installation is available for interested institutions for testing and eventual cooperation. Interested parties may contact:

Prof. Dipl.-Rest. Ulrike Hähner
University of applied sciences and arts HAWK
Faculty Preservation of cultural heritage
Department of Records, Book and Art Design
Tappenstraße 55
D-31134 Hildesheim
Germany
Mail: Haehner@hawk-hhg.de

References

Allemann R.T., Moore, R.L., Upson, U.L: *Electrostatic apparatus for removal of dust particles from a gas stream.* US Patent 3,218,781, issued: 23.11.1965.

Archivreferentenkonferenz (ARK), ARK-Ausschuss Restaurierung: *Restaurierung und Konservierung in den staatlichen Archivverwaltungen – Maßnah men und Aufwand.* August 2002,
http://www.landesarchiv-bw.de/sixcms/media.php/120/47168/ife_publ_restaurierung.pdf (accessed 12.09.10).

Ballard, M.: *World Trade Center dust: Its potential to interact with artifacts & works of art.* (2001).
http://www.si.edu/mci/downloads/articles/wtc_dust.pdf (accessed 03.04.2011).

Blome, H., Barig, A.: *Der neue Staubgrenzwert (A/E-Staub) – Erläuterung des Beschlusses des Ausschusses für Gefahrenstoffe.* BIA/BG Symposium Allgemeiner Staubgrenzwert, Bad Hennef, 2002.
http://www.dguv.de/ifa/de/vera/2002/staub/beitraege/blome.pdf (accessed 01.04.2011).

Bolourchi, H.: *Pay attention to books and deadly dust – relationship of lung-cancer and heart-attack to library books dust.* Poster Abstract, 6th Conference: Indoor Air Quality in Archives and Museums, Padova, 2004.
http://www.isac.cnr.it/iaq2004/pdfabstract/bolourchi_abstract.pdf (accessed 01.04.2011).

Calle C.I., McFall, J.L. Snyder, S.J., Arens, E.E., Chen, A., Ritz, M.L., Clements, J.S, Fortier, C.R. Trigwell, S.: *Dust particle removal by electrostatic and dielectrophoretic force with applications to NASA exploration missions.* In: Proceedings of the Electrostatics Society of America Annual Meeting, Minneapolis, June 17–19, 2008, Paper O1.

Cowan, J., Guild, S.: *Dry methods for surface cleaning of paper.* Paper Technical Bulletin No. 11, 2nd edition, Ottawa: Canadian Conservation Institute (CCI), 2001.

Demhardt, I. J.: *Der Erde ein Gesicht geben. Petermanns Geographische Mitteilungen und die Anfänge der modernen Geographie in Deutschland*, Gotha, 2006.

Duhl, S., Nitzberg, N. (Compilers): *Surface cleaning*. Paper Conservation Catalog, Chapter 14, Washington D.C.: American Institute for Conservation, 1992.

Eltex-Elektrostatic-GmbH: *Electrostatic systems: The sourcebook*. Weil am Rhein: No year.
http://www.eltex.de/fileadmin/pdf/elt_Sourcebook.pdf (accessed 05.01.2011).

Hackney, S., Townsend, J., Eastlaugh, N. (eds): *Dirt and pictures separated*. Preprints to the Conference Organized jointly by United Kingdom Institute for Conservation of Historic and Artistic Works (UKIC) and The Tate Gallery, London: UKIC, 1990.

Hahn, H.-U., Käfferlein , H.U, Brüning, T.: *Bewertung der gesundheitlichen Wirkung von Tonerstäuben für Menschen am Arbeitsplatz*. Final Report, Bochum: Berufsgenossenschaftliches Forschungsinstitut für Arbeitsmedizin, 2006.
http://www.ipa.ruhr-uni-bochum.de/pdf/VBGToner07.pdf (accessed 01.04.2011).

van Keulen, H., Groot, S., Groot Wassink, M., Joosten, I., Daudin, M.: *Dry cleaning products analysed and tested at the Netherlands Institute of Cultural Heritage*. October 2009.
http://www.scribd.com/doc/28005037/Painting-Dry-Cleaning-Table
(accessed 01. 04. 2011).

Laube, S.: *Eine Metropole der Untergrundstudien – Das Gothaer Forschungszentrum zur historischen Kulturwissenschaft*. Frankfurter Allgemeine Zeitung, 30.09. 2009, Nr. 227, S. N 5.

Münzberger, E.: *Modularer Lehrbrief „Einführung in die Arbeitsmedizin“ Abschnitt: Exposition gegenüber nichttoxischen Stäuben*.
http://arbmed.med.uni-rostock.de/lehrbrief/staub.htm (accessed 06. 01.2011).

Noehles, M.: *Die Kunst des Radierens – Radiermittel im Überblick*. PapierRestaurierung 3 (2002): 22–28.

Pearlstein, E.J., Cabelli, D., King, A., Indictor, N.: *Effects of Eraser Treatment on Paper*. JAIC 22 (1982): 1–12.

Phenix, A., Burnstock, A.: *The deposition of dirt: A review of the literature, with scanning electronmicroscope studies of dirt on selected paintings*. In: Dirt and pictures separated, S. Hackney, J. Townsend, N. Eastlaugh (eds), London: UKIC, 1990: 11–18.

Reikow-Räuchle, M., Banik, G., Becker, E., Ernst, E., Kreienbrink, Ch.: *Entstaubung planliegender Papierobjekte: Eine neue automatisierte Methode. Dust removal from flat paper items: A new automated method.* Poster Abstract, in: Summaries of the Contributions of the 11th IADA-Congress, Birgit Reißland, Anna Bühlow and Andrea Pataki (eds), Göttingen: IADA, 2007: 72.

Roelofs, W., Th., de Groot, S., Hofenk de Graaff, J.H.: *Die Auswirkung von Radierpulvern, Knetgummi und Radiergummi auf Papier.* In: Preprints to the 9th IADA-Congress, Copenhagen, Mogens S. Koch (ed.), Copenhagen: The Royal Academy, School of Conservation (1999): 131–135.

Wegele, G.: *Vorrichtung zum elektrostatischen Besprühen von fortlaufend transportierten Bahnen.* Deutsches Patent 25 046 025, issued: 20.11.1980.

Wiesner, S., Tsach, T., Belser, C., Shor, Y.: *A comparative research of two lifting methods: Electrostatic lifter and gelatin lifter.* J. Forensic Science 56 (2011): S58– S62.
Available online:
http://onlinelibrary.wiley.com/doi/10.1111/j.1556-4029.2010.01617.x/pdf.

Weigel, P.: *Forschungsbibliothek Gotha: Die Sammlung Perthes Gotha.* In: Reihe Patrimonia der Kulturstiftung der Länder, Band 254, Erfurt: Universität Erfurt, 2011.
Information on the Perthes collection:
http://www.uni-erfurt.de/sammlung-perthes/

Wobers, R.: *Cleaning painted surfaces.* London: Archetype Publications (2000): 2–4.

Zusammenfassung

Eine neue Technologie zur Oberflächenreinigung großer Bestände historischer Karten

Der Kartenbestand Justus Perthes besteht aus ca. 185.000 Kartenblättern, deren Formate zu 90 % Maße von 96 x 135 cm aufweisen oder kleiner sind. Durch die thematische Vielfalt und die Vollständigkeit der Sammlung handelt es sich um einen weltweit einzigartigen Quellenbestand, der sich aus Radierungen, Handzeichnungen, Lithographien und Drucken zusammensetzt. Zusätzlich finden sich auf vielen Objekten handschriftliche Vermerke und Kolorierungen, die mit den unterschiedlichsten Beschreibstoffen aufgebracht sind. Die historische Bedeutung der Eintragungen ist hoch, sodass die Abnahme von Fein- und Feinststaub von den Kartenoberflächen eine besondere technische Anforderung stellte. Da der aufliegende Staub Partikelgrößen von ≤ 1 µm und damit als gesundheitsgefährdent eingestuft ist, musste der Gesamtbestand gereinigt werden, um die Sammlung der Öffentlichkeit zugänglich zu machen. Das hierfür neu entwickelte System erlaubt eine Bearbeitungsgröße von 1,0 x 1,50 m bei einer Reinigungsleistung von 80 Karten dieses Formats pro Stunde. Die Staubaufnahme erfolgt ohne mechanische Belastung der Oberflächen mit elektrostatisch aufgeladenen Folien. Die Technik gestattet die weitgehende Entfernung der Staubkontamination bei vollständigem Erhalt der Eintragungen und Kolorierungen. Im Zeitraum von 24 Monaten – von Juli 2008 bis August 2010 – konnten mit der Kartenreinigungsanlage 96 % des Gesamtbestands „Justus Perthes“ an der Universitäts- und Forschungsbibliothek Erfurt/Gotha, das sind ca. 177.000 Objekte vollständig mit hoher Qualität gereinigt werden. Die Ergebnisse der Reinigung übertrafen die Erwartungen in Bezug auf Effektivität und Behandlungsqualität. Die Schadensquote für mechanische Beschädigung durch Einzug oder Transport in der Maschine von 0,04 % war extrem niedrig. Auch empfindliche und brüchige Objekte konnten in der Anlage behandelt werden, ohne dass zusätzliche mechanische Beschädigungen auftraten. Die Technologie kann daher als ein Verfahren betrachtet werden, das ein sehr geringe Belastung für empfindliche Objekte darstellt. In bestimmten Fällen ist das Verfahren eine Alternative für die manuelle Oberflächenreinigung von historischen Papierobjekten.

Résumé

Une nouvelle technologie visant à éliminer la poussière recouvrant les cartes historiques appliquée à la collection Justus Perthes de la Bibliothèque de l'Université et de la Recherche de Erfurt/Gotha

Le nombre des cartes contenues dans la collection Justus Perthes s'élève à environ 185.000, dont 90 % sont d'un format allant jusqu'à 96 x 135 cm. Par la variété thématique et l'immense richesse de la collection il s'agit d'une source scientifique unique d'importance internationale qui se compose de gravures à l'eau forte, de dessins, de lithographies et d'estampes. Beaucoup de ces cartes sont revêtues d'annotations écrites à la main avec des moyens graphiques et des coloris différents, tels que le crayon, le fusain, la craie, l'aquarelle, la gouache et les encres. Les annotations sont d'une importance historique capitale, ce qui signifie qu'aucune opération technique visant à nettoyer la surface ne doit les altérer ou les effacer. Les cartes sont contaminées par des particules de poussière de taille ≤ 1 µm qui sont potentiellement dommageables pour les humains qui les inhalent. Comme toute la collection doit être rendue accessible au public il faut la décontaminer de la poussière ou tout au moins réduire considérablement le seuil de contamination au-dessous duquel elle ne présente plus de danger pour les usagers. Le nouveau système qui a été développé dans ce but permet de nettoyer la surface de 80 cartes d'un format de 1 x 1,50 m par heure de travail. L'élimination de la poussière se réalise sans impact mécanique à l'aide de lamelles chargées électrostatiquement. Cette technique permet de dépoussiérer au maximum les objets tout en conservant complètement les annotations écrites et les coloris. En l'espace de 24 mois, l'équipement

“Gothana” de nettoyage de cartes a permis de traiter 96 % de la collection Justus Perthes de la Bibliothèque de Recherche de l’Université d’Erfurt/Gotha, soit un total de 177.000 pièces intégralement nettoyées avec la plus grande qualité.

En termes d’efficacité et de qualité du traitement, les résultats du nettoyage ont dépassé les attentes. Le taux de dégâts dûs aux opérations mécaniques de retrait ou d’insertion dans la machine a été de 0,04 %, ce qui est extrêmement faible. Même des objets délicats et fragiles ont pu être traités sans dégâts mécaniques visibles. Cette technologie peut ainsi être qualifiée de procédé assurant une sollicitation réduite des objets particulièrement délicats. Dans certains cas, c’est une bonne alternative au nettoyage manuel de surfaces d’objets historiques en papier.

Authors and contact

Ernst Becker attained his Diplom Engineer (Dipl.-Ing.) degree in the field of Chemical and Process Engineering at the University of Stuttgart. Following his university education, he was active as an Entrepreneur in the field of developing technologies, plant engineering and construction, measurement technologies as well as preservation and conservation. He is currently CEO and managing partner of Becker Systems GmbH, involved in renewable energies as well as the development and manufacture of conservation technologies.

Becker Systems GmbH
G.-F.-Haendel-Str. 15
D-73663 Berglen
Mail: EBecker@Becker-Systems.net

Manuela Reikow-Räuchle is the proprietor of a private conservation practice in Remshalden near Stuttgart since 2006. Since 2008, she is the research conservator in the project “The preservation of pressure-sensitive adhesive tapes – a general problem and the specific case of the Ernst Jünger Estate at the German Literature Archive Marbach.” She studied at the Studiengang Konservierung und Restaurierung von Graphik, Archiv- und Bibliotheksgut, Staatliche Akademie der Bildenden Künste Stuttgart from 1995 to1999 and received her diploma in 1999.

Ina-Seidel-Strasse 26
D-73630 Remshalden-Geradstetten
Mail: mreikow-raeuchle@online.de

Gerhard Banik holds a PhD in chemistry of the Vienna University of Technology. From 1990 until 2008 he was Professor and Director of the Studiengang Konservierung und Restaurierung von Graphik, Archiv- und Bibliotheksgut at the Staatliche Akademie der Bildenden Künste in Stuttgart. He is currently adjunct research scientist at the Department of Chemistry of the University of Natural Resources and Life Sciences in Vienna (BOKU) in Vienna and Guest Professor at the University of Applied Arts Vienna. He is co-editor and main author of the textbook "Paper and water: A guide for conservators".

Institut für Kunst und Technologie
Universität für angewandte Kunst Wien
Salzgries 14/1
A-1013 Wien
Austria
Mail: gbanik@web.de