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Mass Deacidification at the Swiss National Library

Abstract: Forty years ago anxious archivists and librarians coined the catchphrases 'paper decay' and 'acidic corrosion' and thus brought the preservation of archival and library holdings to public attention. The quantity of threatened cultural heritage prompted scientists and technicians to develop a wide variety of mass deacidification methods. Mass deacidification serves memory institutions as a means of preserving originals and also functions as a beacon which signals that conservation must be perceived as a core task and provided with the necessary resources. In Switzerland the Federal Archives and the National Library (NL) opted for the papersave® process in 1995 which was implemented in the papersave swiss facility and available to all interested parties in Switzerland until 2022. During the years 2000–2014 the NL treated all collections intended and suitable for deacidification. The quality assurance concept included long-term monitoring of the treated holdings; over the observation period of currently seven to twenty years, the deacidification treatment proved to be sustainable and stable in 97% of cases. Mass deacidification is an intervention in the original substance and cannot be reversed or repeated. The responsible selection of holdings and deacidification methods, for which international standards and sufficient experience are now available, is of decisive importance.

1 Initial Situation

Since the 1970s libraries and archives had increasingly noticed papers that were ageing rapidly and becoming brittle and the responsible librarians and archivists feared the worst and raised public alarm. Journalistic-effective catchphrases were coined such as 'acidic corrosion', 'paper decay' and 'paper crumbles to dust', which may be found in numerous press articles in North America and Canada in the early 1980s and in Europe in the 1990s.

Given the scale of the threat, the aim was to develop 'mass processes'. Scientists dreamed of inexpensive processes to neutralise acids in paper, combined with a stabilisation of the paper and even the fumigation of entire storage facilities; of the

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https://doi.org/10.1515/9783111386713-006

numerous processes that were developed only a few reached the practical stage and even fewer have proved successful in the long term.[1] From the outset the sponsors and users of mass deacidification were the large national archives and libraries.[2]

The problem also moved to the fore in Switzerland. At the beginning of the 1990s the Swiss National Library (NL) redefined the word 'conservation' to mean active and scientifically supported care of the original. As the name suggests, mass deacidification is a major conservation measure that requires a high level of financial and human resources, with its implementation requiring interest and personal commitment at both management and political level. The mass deacidification in the NL – as in many other national memory institutions – became a beacon signalling the way forward: our institution sees the preservation of originals as a core task. In retrospect, the predicted catastrophe of 'paper decay' turned out to be real but smaller in scope and more complex to manage than expected.

2 The Papersave Swiss Facility in Wimmis

The Bernese conservator Erwin Oberholzer has been working on mass deacidification at the Swiss Federal Archives since 1982. The 'mass deacidification' project was given the necessary political weight through cooperation between the Federal Archives and the NL; after a joint evaluation phase the decision was made in 1994 in favour of the papersave® process of Battelle Ingenieurtechnik GmbH which was subsequently developed into the papersave swiss process. This process is a non-aqueous liquid-phase process which uses hexamethyldisiloxane as a solvent and a magnesium-titanium ethylate complex as a deacidifying agent. The titanium component does not contribute to deacidification but optimises the solubility of the magnesium ethylate in the fluorine- and chlorine-free solvent.

In 2000, the papersave swiss facility commenced operations on the premises of Nitrochemie Wimmis AG (NCW) in Wimmis near Thun (Figures 1 and 2). The NL completely deacidified the designated holdings between 2000 and 2014 while the Federal Archives ended the deacidification process ahead of schedule in 2014, as digital transformation had become the primary goal in the meantime. The papersave swiss facility at the Wimmis site is already history; it was closed in mid-2022 as Swiss customers deacidified regularly but in quantities that were too small to continue operating the plant in the long term.

1 Baty et al. 2010.

2 Blüher and Vogelsanger 2001.

Fig. 1: The papersave swiss facility in Wimmis on the premises of the Nitrochemie Wimmis AG, in operation from 2000 to 2022. Interior of the papersave swiss facility. The treatment chambers. Photo: Nitrochemie Wimmis AG

Fig. 2: The reconditioning chambers. Photo: Nitrochemie Wimmis AG

3 Objectives and Priorities of Mass Deacidification

The aim of mass deacidification is to preserve the original substance in its original appearance and thus maintain usability. Chemically speaking, the acids in the paper are neutralised by the alkaline deacidifying agent, an excess of which is stored in the paper as an alkaline reserve. The acid-catalysed degradation of the cellulose, which is responsible for the loss of paper stability, is thus prevented altogether or else slowed down. The papersave swiss process has a proven slowdown of a factor 4 at least.[3]

Mass deacidification is a preventive measure and what it cannot do is improve paper stability as broken cellulose chains are not 'patched up'. To date there has been no effective and significant paper stabilisation by way of a non-aqueous bulk process and without drastic undesirable changes to the paper for bound cultural artefacts.

When it comes to setting priorities the approaches of individual institutions differ widely. If the manifest damage is decisive then the casualties shouting loudest are prioritised, namely extremely browned or already brittle papers. From a scientific point of view, however, mass deacidification reaches its limits with these heavily degraded papers for the following reasons:

– They are often not only affected by acid-catalysed degradation but have also become brittle due to oxidative degradation. As a result, they lack the necessary capacity to absorb the deacidification solution.
– They are filled with degradation products that are not removed during deacidification but are brought into an alkaline environment which can lead to browning and other unfavourable changes.
– Deacidification, combined with the incorporation of an alkaline reserve, has the effect of increasing the filler content which can be problematic with papers that have been mechanically severely weakened.

These restrictions apply to the papersave swiss process as well as to all non-aqueous liquid phase processes. Fine dust or particle processes are just as unsuitable for heavily degraded papers, even if the reasons here lie in the lack of mechanical resilience of the documents. Against this background, mass deacidification of such holdings is not the first priority but its justification must be examined and weighed up in each individual case.

3 Andres et al. 2008; Ramin et al. 2009.

4 The Priorities and Approach of the Swiss National Library

The aim of the NL was to treat its core holdings, i. e. all Helvetica in need of deacidification. To this end, a list of priorities was drawn up.[4] The long-term cooperation with the same deacidification company made it possible to plan and carry out systematically the deacidification according to priorities. The NL prioritised deacidification as described in Table 1:

Priority 0: No deacidification, which includes papers without browning or rag paper.

Priority 3: Preventive treatment, recommended in 10–20 years; the paper is beginning to show signs of browning.

Priority 2: Preventive treatment, recommended in 5–10 years; the paper shows slight signs of browning.

Priority 1: Preventive treatment, urgent; the paper shows clear signs of paper degradation.

Subcategory 1+: Treatment very urgent, bordering on the ‘too late’ category.

Very heavily browned, brittle paper is also not deacidified (‘too late’). For technical reasons holdings with extremely high preparation effort and complex individual selection were only deacidified at the end, regardless of their state of preservation.

4 In the period from November 2001 to April 2002, all of the NL’s holding units (excluding the Swiss Literary Archives and the Prints and Drawings Collection) were examined and a list of priorities was drawn up. This inspection did not constitute an actual survey or condition report, as no sample number was defined and the shelf marks of individual samples were not documented. The purpose of the inspection was to categorise the conservation priorities and estimate the amount of deacidification and the necessary preparation time for the individual holding units. The order of deacidification was determined based on this.

Tab. 1: Categories of priority for mass deacidification in the NL.

Paper browning	Usability	Priorities mass deacidification	SurveNIR condition category
none	unrestricted	**0** no mass deacidification	1 = good
head cut, edges: beginning; type area: none	unrestricted	**3** low (in 10–20 years)	2 = fair
head cut, edges: slightly; type area: barely to slightly	unrestricted	**2** recommended in 5–10 years	2 = fair
head cut, edges: clearly; type area: slightly to clearly	barely restricted	**1** urgent	3 = poor
head cut, edges: strong; type area: clearly to strong	slightly restricted	**1+** very urgent/borderline	3 = poor
head cut, edges: very strong; type area: strong	strongly restricted/ fragile	**X** too late	4 = critical

According to the initial planning mass deacidification was to be carried out generously, with minimal or no selection at all. As a measure of stabilising conservation, however, it is an irreversible intervention in the original substance; the principles of restoration conservation should not be suspended but adhered to as far as possible. This means no unnecessary deacidification of neutral or alkaline papers, no questionable deacidification of brittle papers and the minimisation of side effects by eliminating risk material.

In practice, this has led to a paradigm shift which has resulted in more and more resources being used in the selection process and fewer items being designated for treatment in the papersave swiss facility. The time required for the entire deacidification process was originally estimated to be 30 years but was actually reduced to 15 years.

Setting priorities and selection are easy to define in theory but not easy to implement in practice. Priorities can only be set at collection level, not at the level of individual documents; the list of priorities described above therefore refers to subcollections.[5] The NL has over 50 historically evolved subcollections which differ according to subject, format (octavo, quarto, folio, etc.), age, publication form (monograph, periodical, book, pamphlet), etc.

5 Called ‘shelf mark’ [Signaturen] in the NL.

During the 'selection' step those documents in the respective subcollection that were not to be deacidified in accordance with the above conservation principles were excluded as completely as possible. As there is no simple and easily accessible technical procedure for this the decision to 'deacidify' or 'not deacidify' always has a subjective dimension.[6] The exclusion of rag paper is clearly possible but the demarcation of the transition from acidic to neutral and alkaline paper production is more complex; the threshold is generally between 1980 and 1995[7] although lower-quality fibres such as recycled paper push the limit back, possibly to the year 2000. It is difficult if not impossible to recognise and exclude heavily degraded and brittle paper reliably without destructive testing; in addition to broken edges an important indication is heavy browning which, however, is not always present. Strong browning, i. e. an L* value below 80 in the CIELAB colour space, combined with a corresponding paper feel and a document age of at least 50 years, definitely indicates brittle paper. With this visual and haptic evaluation the majority of these papers can at least be recognised and excluded. If in a subcollection their proportion was too high (more than approximately 50%), the risk was too high despite sorting and the entire subcollection was not deacidified.

Even though the NL prefers to speak of 'paper deacidification' against the background of the targeted selection it has in fact carried out real mass deacidification; on average, a batch of 1,600 documents was deacidified per week. In total, the quantity of documents deacidified during the period 2000–2014 amounts to 1.18 million documents with a total weight of 483 tonnes. Figure 3 provides a graphic overview of the deacidified and non-deacidified documents as of 2014 at the end of mass deacidification out of total holdings of 3.8 million documents[8] in the General Collection at that time.

Some 31% of the documents of the total holdings were deacidified, 5% were removed as risk material and not deacidified and 2% were removed due to visible

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6 The SurveNIR device should be mentioned here, which was developed for this purpose, among others (Strlič et al. 2008; Rohde and Lichtblau 2013). It was only available in the NL since 2014, after a phase of further development. Its use is limited insofar as the time required for consistent measuring is too high (Kunze 2016).

7 Only papers with a surface pH below approx. 5.5 are categorised as requiring deacidification. According to some authors, deacidification is only really necessary at a pH value below 4.8. The classification with the Abbey pH pen indicates an excessive need for deacidification, as the colour change from violet ('alkaline') to yellow ('acidic') occurs on paper at a surface pH of 6.3 to 6.4 according to our own observations.

8 Excluding music, prints and drawings, photographs, other data carriers, digital collections. Source: Annual Report of the Swiss National Library 2014, Appendix.

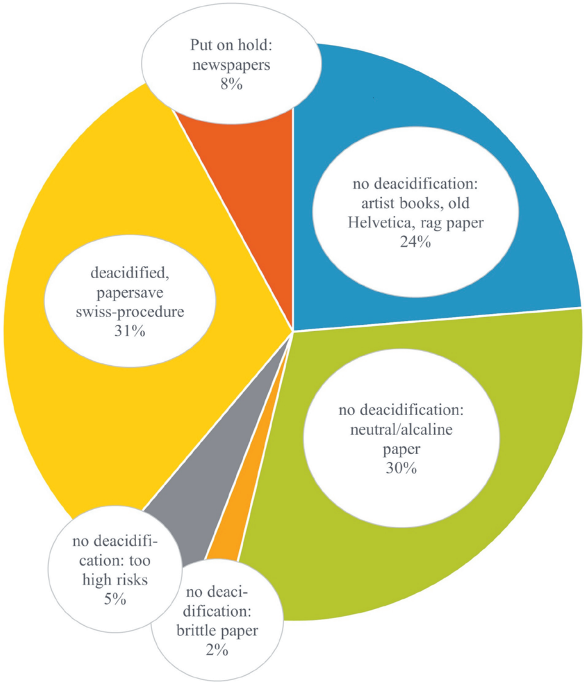

Fig. 3: Deacidified and not-deacidified holdings of the Swiss National Library in percent (General Collection, status 2014, without musical, prints and drawings, photographical and digital collections). Exact statistics were not kept for all categories of non-deacidified parts of the collection; in this case, the figures were estimated. Image: Swiss National Library

brittleness of the paper and not being deacidified. A total of 30% of the documents did not require deacidification as the paper was not acidic and 24% were deferred for technical reasons due to the material; the newspaper holdings of around 8% of the total holdings were also not deacidified. At the same time as mass deacidification, a large microfilming programme was launched for the newspapers in 1999 which was scaled back since 2014 in favour of digitisation and halted altogether in 2018. From a conservation point of view deacidification would be a sensible and necessary measure for some of the newspapers but for financial reasons this is not currently under discussion.

5 Quality Control

Quality control was an essential component of the selection and implementation of the papersave swiss process in the 1990s. The 'Quality Standards for the papersave swiss Process used for the Deacidification of the Collections of the Swiss Federal Archives and the Swiss Federal Office of Culture – Swiss National Library' of 2004 define physico-chemical and optical-haptic quality criteria and corresponding target or limit values[9] with details on the implementation found in the literature.[10] The integration of quality standards in the contract for carrying out deacidification is crucial. As the deacidification company is liable for compliance this has a preventive effect; the contractual partners carry out regular checks, inform each other of any problems that are expected or have arisen and share their experiences. On average, over the 15 years of deacidification, 98% of the physico-chemical target and limit values for the NL's holdings have been achieved.

Every mass deacidification process has its own particular and unavoidable side effects. With the papersave swiss process there are no deposits of the deacidifying substance on the paper, as the treatment solution is a true solution. It even penetrates thick books and archive boxes completely and can dissolve certain dyes in the process. The phenomenon of bleeding is therefore a consequence of the in-depth effectiveness of the process; it cannot always be prevented and its occurrence in mild form is tolerated in 1.5–2% of documents. The quality standards were rigorously applied so that in one case a subcollection from the post-war period was not deacidified because the percentage of documents affected by bleeding was too high.

6 Long-Term Monitoring

Mass deacidification is a measure with a long-term effect. The quality assurance of the NL is designed in such a way that the success of the treatment can also be monitored over the long term. Long-term monitoring basically serves several purposes:

1. Monitoring the condition of the deacidified holdings in the NL: knowledge of the condition and its progression is important for future decisions regarding conservation measures or restrictions on use.
2. Expansion of knowledge about the sustainability of mass deacidification depending on the initial state of the documents.

The long-term control is carried out on original documents as well as on three test papers. As the information value of the test papers is very limited compared with the many different original papers they are not included in the following analyses. The original documents examined as random samples were routinely returned to the stacks after deacidification and initial examination and they can easily be retrieved via their shelfmark. A total of 335 samples were measured which cor-

9 Swiss National Library 2004.

10 Andres et al. 2008; Blüher 2012.

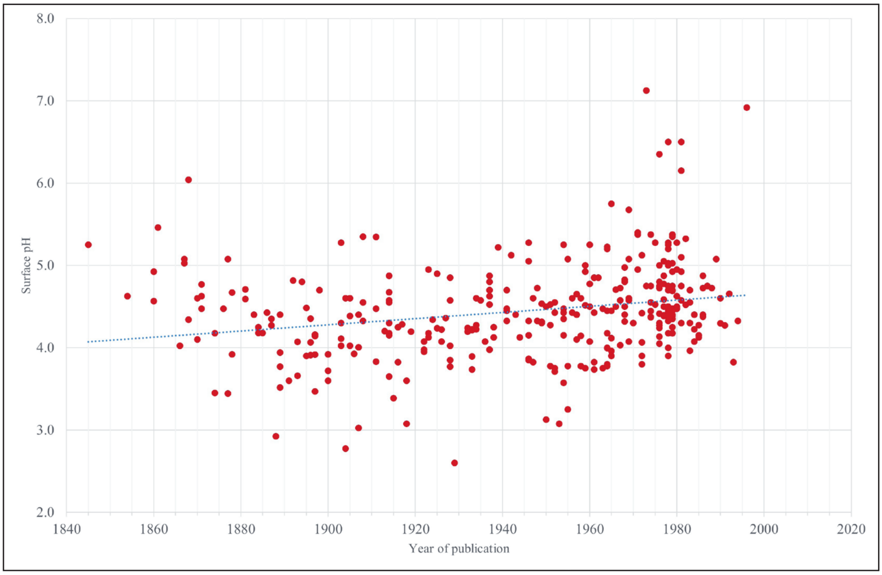

Fig. 4: Surface pH versus publication date of the 335 originals before deacidification. Image: Swiss National Library

responds to 0.03% of the deacidified documents; these were taken from the treatment years 2001–2014 with an average of 24 samples per year, a cross-section of all formats, treatment variants and materials selected at random. The remeasurement interval was five years and may in the future be extended to 10 years or longer.

Long-term monitoring of the NL includes remeasurements of the surface pH and the L*a*b* colour values, which can be carried out in a non-destructive way. The measured values are stored in the electronic archive and, if possible, in the Helveticat library catalogue, MARC field 583.[11] The deacidification record in Helveticat contains the item number, the treatment batch and the analysis values of the treatment intensity, the homogeneity, the L*a*b* colour measurement and the surface pH. The colour values and the surface pH are recorded for the remeasurement.

Figure 4 shows the surface pH of the 335 random samples before treatment versus the year of publication. The average value for the years 1845 to 1996 is pH 4.4. Four of the samples have an extremely low pH of 3 or less while ten samples (3%) have a pH above 5.5 and therefore would not have required deacidification.

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11 Proof of deacidification in Helveticat can only be added to documents that are catalogued individually and not as batches.

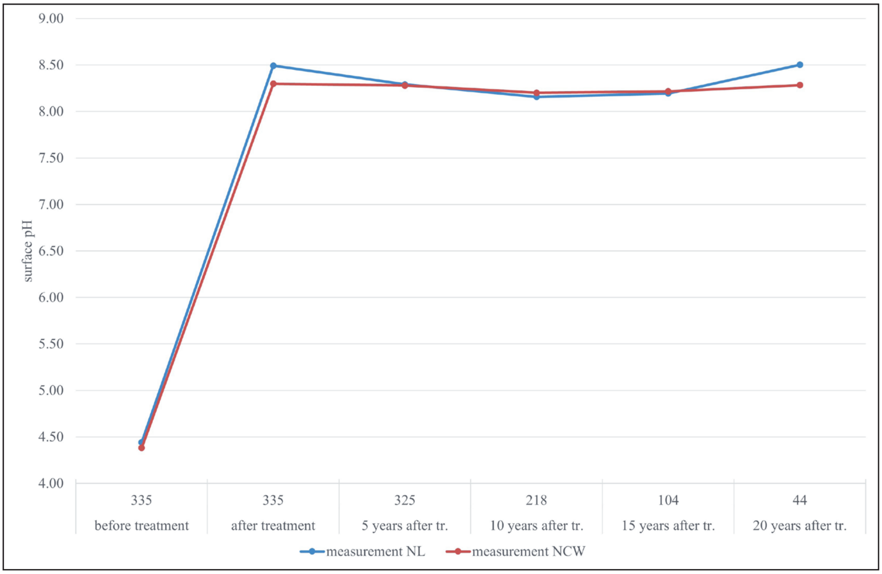

Fig. 5: Surface pH, average of the 335 random samples, before and after deacidification. 20 years after deacidification, a total of 44 samples was remeasured by 2021 (treatment in 2001) and 2022 (treatment in 2002). Image: Swiss National Library

Figure 5 shows the surface pH as the average value of all 335 random samples before treatment (pH 4.4), immediately after treatment (pH 8.4, average NL-NCW, 670 values) and after 5, 10, 15 and 20 years. The measurement of the surface pH is subject to large fluctuations, mainly due to the inhomogeneous composition of the aged paper surface; therefore, a large number of random samples and a long observation period are needed in order to make well-founded statements. The measurements were taken by the NL and by the Nitrochemie Wimmis AG (NCW) company in the same book, with two measuring points on each book page but in different places and on different book pages.

On the basis of several thousand data points it is possible to state with certainty that the surface pH is stable and that the minimum decrease after 20 years lies within the measurement accuracy of the method.

Figure 6 shows the colour values L*a*b* in the CIELAB colour space in the same way as the average values of all 335 random samples. The colour value is only measured by NCW; as it shows but minimal changes it will not be measured regularly in future.

Figure 7 shows examples of various subcollections where deacidification was more or less successful.

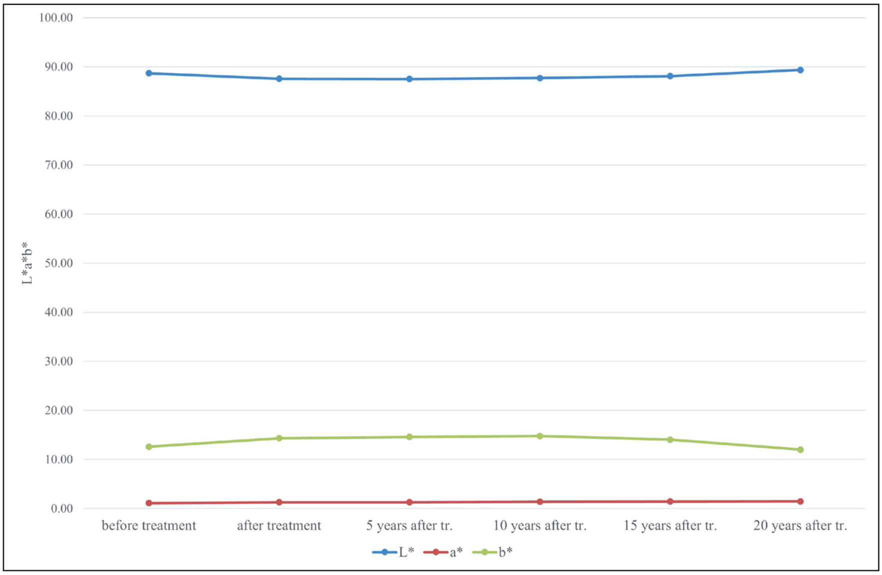

Fig. 6: Colour values in the chromatic field L*a*b*, average of the 335 samples, before and after deacidification. Image: Swiss National Library

The subcollection in Figure 7a with around 56,000 books from the years 1900–1930 was deacidified in 2004. The holdings contained strongly acidic and heavily browned papers that were not deselected at the time. The mean value of the surface pH of the 25 samples before deacidification was 4.1 while immediately after deacidification it was 8.0, decreasing markedly over time.

Two papers were previously extremely acidic and browned as well as heavily degraded by oxidation. Over time their surface pH dropped significantly to values below 5.5 which means that their alkaline reserve is already depleted as a result of post-acidification. As a consequence of this observation, such papers, as far as being visually recognisable, were later deselected.

In 2012, in collaboration with NCW, various attempts were made to improve the alkali absorption of such severely damaged papers: soaking the treatment material twice in the treatment solution, with or without interim drying, and increasing the treatment concentration. The trials did not produce the desired results and the effect of a later complete repetition of deacidification of such papers was not investigated.

The subcollection in Figure 7b with approximately 10,000 documents from the years 1890–1980 was deacidified in 2010. The subcollection also contained strongly acidic and heavily browned papers but these, as far as discernible, were deselected. The mean value of the surface pH of the 25 random samples before deacidification

Fig. 7: Deacidification of subcollections in different conditions. Image: Swiss National Library

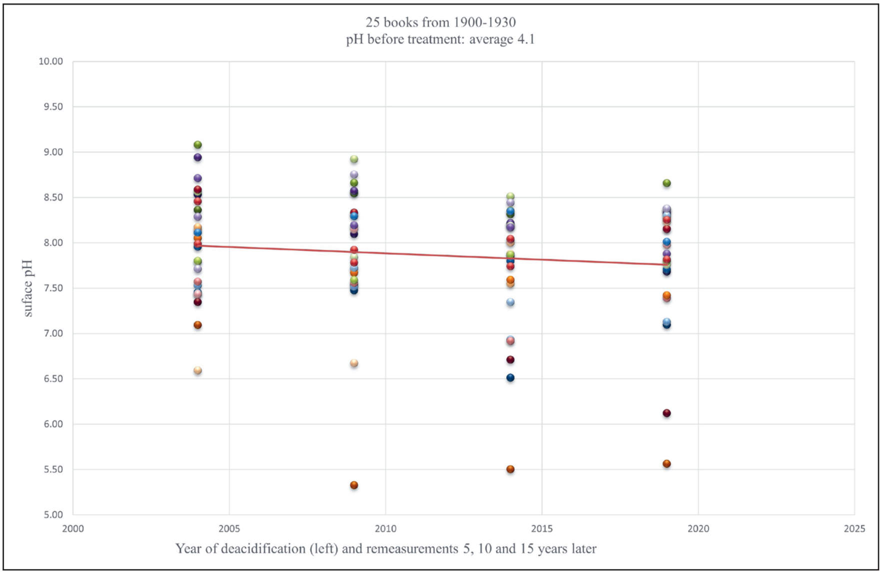

Fig. 7a: Condition 'poor', without deselection of damaged paper: limited sustainability

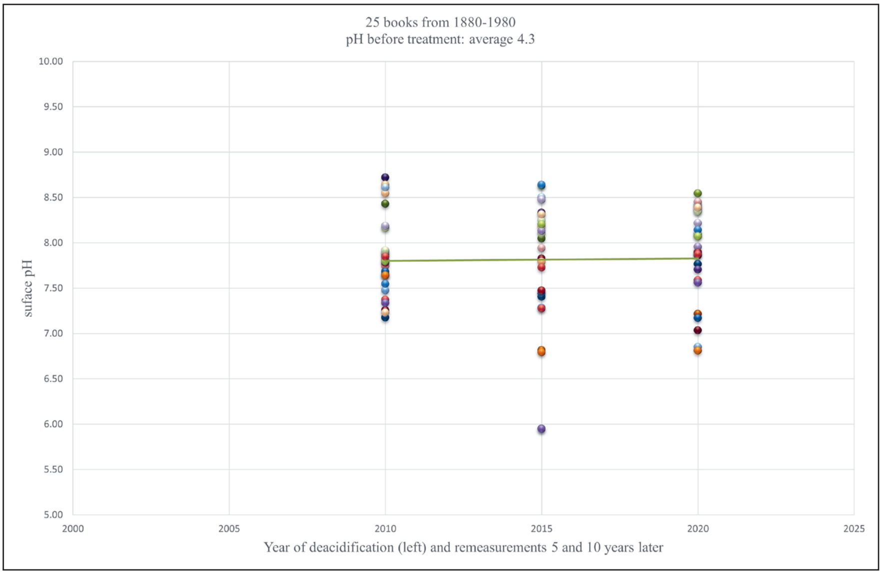

Fig. 7b: Condition 'poor', with deselection of damaged paper: fair sustainability

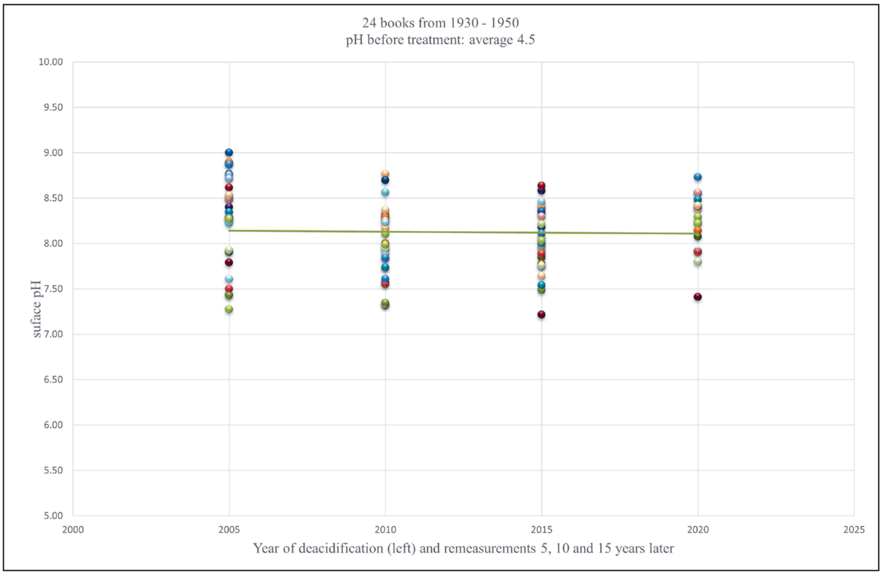

Fig. 7c: Condition 'fair', no deselection: high sustainability

was 4.3 while immediately after deacidification it was 7.8, i. e. at a relatively low but stable level.

Figure 7c shows subcollections with approximately 25,000 documents from the years 1930–1950 with papers in predominantly fair condition. The surface pH was previously 4.5 while immediately after deacidification in 2005 it was 8.3, also at a stable level. This places them in the area of optimal prevention.

A summary of the conclusions from the long-term control after 20 years shows that the surface pH is stable, indicating an intact alkaline reserve. Likewise, the L*a*b* colour values are stable. There are exceptions for around 3% of the documents based on the results of 218 random samples after 15 years. Affected are strongly acidic documents for which the sustainability of deacidification has not yet been proven. Overall, the condition of the deacidified holdings is stable and side effects such as the bleeding of red dyes are only noticeable in individual cases. Digitisation of deacidified documents is also possible without any problems, as there are no powdery deposits on the paper.

The determination of the surface pH is the only method that can be applied to originals on a large scale in a mostly non-destructive manner but it is subject to various uncertainties.[12] An examination of the strength and flexibility of the paper,

12 Ahn et al. 2011.

the alkaline reserve and the cellulose fibre at molecular level complete the picture. Available for this purpose is the ‘reference books’ data set, which was analysed and deacidified in 2009 and which consists of 18 book sets, of which one book – or one half of a book – is untreated in each case; these complex analyses are to be repeated at longer intervals. In addition, the papers and books are assessed from a restoration perspective with a view to their behaviour during restoration work.

7 Summary

The mass deacidification project is an important investment by the NL in the preservation of its collections. Founded in 1895, the NL is a relatively young institution; its collecting mission began in 1848, the year the federal state was founded. As a result, a large part of its collections falls into the critical period of ‘acidic’ paper production.[13] The NL carried out the mass deacidification project during the years 2000–2014, i. e. in half the time originally planned, as greater emphasis was placed on selection.

The NL continues mass deacidification, albeit on a smaller scale. This applies to new acquisitions published between 1840 and 1985 that through donations or individual purchases are integrated into collections that have already been deacidified.

As part of long-term monitoring, the NL observes and analyses its collections in order to anticipate the future requirements of the deacidified and non-deacidified parts of the collection. The data collected is a building block for later decisions regarding the preservation of the collections.

The mass deacidification processes were evaluated from the outset with the help of assumptions, in particular with the help of test papers that were analysed after deacidification and after artificially accelerated ageing. Several studies confirm the effectiveness of deacidification and the suitability of accelerated ageing in comparison with natural ageing but they are only based on a small database. With the larger database available in the NL it is possible to monitor comprehensively the sustainability of mass deacidification during natural ageing. In view of the amount of data, the rhythm and intensity of the control measurements must be optimised in order to obtain the critical information with minimal effort. It will be interesting to see to what extent the initial assumptions are confirmed or refuted.

13 Grossenbacher 2006.

8 Outlook

What is the future of mass deacidification? This question arises now that several large memory institutions have discontinued or reduced their deacidification activities, while other large institutions still do not carry out deacidification. This is due to a lack of resources as well as a lack of knowledge or interest. In many cases ethical considerations are decisive; mass deacidification changes the documents, even if no visible side effects are observed and the desired goal is achieved, namely a significant extension of the life span and usability. The legitimate concern about undesirable side effects which only later become disturbingly apparent may play a subliminal role. The alternative chosen is storage either at low temperatures or with a low oxygen level in order to avoid any risk. Against this background the control of deacidification processes in accordance with the applicable standards, transparent communication and, last but not least, transparent long-term monitoring take on a new importance. This is because the various processes of mass deacidification differ greatly in their area of application, their effectiveness and their side effects. Both advantages and disadvantages should be discussed more openly because secrecy is counterproductive to the preservation of our cultural heritage and the future of mass deacidification.

In the NL, at any rate, the beacon of mass deacidification still shines even if in the digital age it has gained quite a bit of competition.

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