Development of Deacidification Methods in Paper Preservation: Systematic Review

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Abstract. Systematic review is a method for research synthesis to summarize the results of primary research based on comprehensive and balanced facts. The development of the deacidification method is an interesting and important theme to be reviewed with a systematic review. So that new knowledge is obtained and in order to consider the right method to be used in information institutions in paper preservation. This study aims to investigate the development of deacidification including the substance used, the method applied, its novelty, its measurement and testing as well as assessment in determining the success of the process.

Keywords: Deacidification · Novelty · Paper · Systematic Review · Preservation

1 Introduction

One medium for disseminating information is paper. The spread of information to the wider community results in the spread of knowledge, science, and technology. Another effect of the spread of information and knowledge through paper is the advancement of civilization because of the development of this knowledge. Paper was first discovered in China in 105 AD and is a very rare material [1].

Paper is the largest collection owned by information institutions such as libraries, archives, and a small part in the museum. Because of the historical value and importance of the information contained in it, making paper preservation the main concern for conservators and researchers. The basic material for making paper is cellulose from wood. Cellulose polymer is a polysaccharide compound $(C6H12O6)_n$ which can be broken down into glucose monomer (C6H12O6) which consists of carbon, hydrogen and oxygen [2]. Intermolecular and intramolecular hydrogen bonds are responsible for the supramolecular structure of cellulose.

Cellulose can experience fragility or be degraded due to the breakdown or weakening of the strength of cellulose bonds which results in a decrease in the mechanical properties of the paper. Factors that influence the decrease in the mechanical properties of paper due to internal factors in the form of acid content on paper that comes from the manufacturing process, the metal content in ink which results in corrosion, the aging process naturally

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and external factors such as temperature, humidity, light intensity and pollutant gases that can trigger the occurrence of hydrolysis, oxidation and further damage due to the interaction of oxidation compounds with the acid content of the inside and outside the paper.

Acidic problems on paper are important issues that need to be addressed to prevent long-term fragility and paper damage. According to Baty, et al. [3] deacidification is the treatment of paper-based objects to neutralize the acid content, with the aim of extending the useful life of the object. There are three types of deacidification, namely aqueous deacidification, non-aqueous deacidification, and gas deacidification [4].

1.1 Background

Based on the writings of Blüher and Vogelsanger [5] the deformation of paper began in the 1930s, the process at that time was to neutralize one sheet of paper with a solution of calcium bicarbonate in water. Since then, the process of cleaning and removing acidity on paper has become a subject of much research. Of course, with the passage of time, deacidification research has experienced many developments both from the substances used, the methods applied and modifications to these substances.

Baty, et al. [3] reviewed the deacidification process for paper-based preservation and conservation. Hubbe et al. [6] wrote a review that focused on the completeness of the reaction in the deacidification process of books and acid paper by means of non-aqueous dispersions of Alkali Particles.

Some of the criteria for evaluating and evaluating the success of the deacidification process according to Baty et al. [3] are no harm to the sample, effective neutralization, sufficient basic reserves, homogeneous distribution, low cost, safety for collection users as well as deacidification officers, proving effectiveness through accelerating aging, physical testing in the form of paper folding test and tensile strength test, flexibility test, measurement of cellulose polymerization level, changes in paper appearance, odor and monomer release when accelerating aging.

The lack of writing about the process of developing paper deacidification with a systematic review is an interesting breakthrough. According to Burgers et al. [7] systematic literature review is a type of research synthesis that can be used to make an overview of research on a particular topic. According to Siswanto [8] systematic review is a research method that summarizes the results of primary research to present more comprehensive and balanced facts.

The purpose of this research is to investigate the development of the paper deacidification process, starting from the substance used, the method carried out, the novelty, how to measure and evaluate its success.

2 Methodology

Review of relevant research journals using systematic review methods. The reviews included planning, implementation, and reporting. Planning includes determining the topics and research questions. The implementation includes search strategies, determining search terms, determining search databases, selecting types of research, and extracting data. The form of the report is a synthesis of data in the table and the results of the discussion.

2.1 Research Question

Based on the existing problems regarding deacidification research, the questions raised are:

1. What substances are used in deacidification studies?
2. What type of deacidification method is used?
3. What the novelty in the deacidification method?
4. What measurements and tests are carried out in the deacidification process?
5. How to determine the success of the deacidification method?

2.2 Search Strategy

Search strategy by determining the database, the right terms, using a Boolean AND combination, determining the type of article, relevant journal title, year of article publication and determining inclusion and exclusion criteria, then assessing the quality of the filtered article.

2.3 Search Database Used

The database used is Science Direct with the last five years (2014–2019), the journal title used is a type of research article and can be accessed in full.

2.4 Term Used

The term used is deacidification, deacidification archives, deacidification paper. Full text criteria and research journals.

2.5 Inclusion and Exclusion Criteria

See Table 1.

Table 1. Table of Inclusion and Exclusion Criteria

No	Inclusion	Exclusion
1	Year of publication of articles 2014–2019	Articles published before 2014
2	The focus of the research is deacidification	The focus of the research is not deacidification, the theme of deacidification as an additional benefit
3	articles in the form of laboratory research	Not related to laboratory research such as surveys

2.6 Quality *Assessment of Research*

Every filtered research can answer the questions that have been set at the beginning. So, the articles obtained can be extracted.

2.7 Findings

The author determines the terms deacidification archives and deacidification AND paper, obtained by the number of searches that are not the same. Search results in the second term result in a higher number of searches of 648 articles, so that this term is used further. The selection of the title of the Journal of Cultural Heritage Journal was chosen because other journals were not related to conservation and preservation such as related to food, oil and others. The number of articles obtained is 25 articles. Then the articles published from 2014–2019 are set in view of the rapid development of research in the exact field. The number of articles obtained is 15 which are then evaluated according to the research objectives and quality. The results of the assessment produced 7 articles to be extracted and discussed (Table 2 and Fig. 1).

3 Results

Qinglian Li, et al. [9] present a new method of reducing acid on paper with plasma technology, which can be applied to room temperature and atmospheric pressure. Cold plasma systems are used with deacidification reagents which consist of saturated $Ca(OH)_2$ solutions to fill alkali groups into paper fibers and to modify the fiber surface. Calcium compounds, chosen because of better performance than other usual reagents such as sodium and magnesium compounds which are considered significant in the yellowing of processed paper. The ability of free calcium ions in cellulose fibers that bind to the carboxyl group can slow the rate of cellulose degradation, and on the surface of the sample can be calcium carbonate which can protect in the next process. The plasma system is chosen because it takes place in a dry, clean process and does not cause environmental problems. Some of the tests carried out were pH measurements, measurement

Table 2. Table of Selection Stages

Selection process	Number of Articles
Deacidification	1507
deacidification AND Paper	648
Research Article	391
Journal of Cultural Heritage	25
Five years back	15
Removing journals that are not directly related to desidification, for example: coatings, disinfection, etc.	8
Exclude a journal in the form of a survey	7

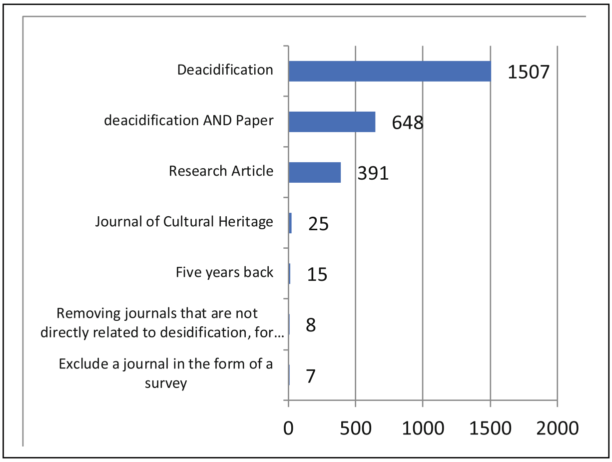

Fig. 1. Graph of the number of articles found based on search criteria

of paper tensile strength before and after deacidification, before and after artificial aging, colorimetric measurement on samples, colored paper before and after deacidification, electron microscopy scanning and X-ray energy dispersion spectroscopy.

The results of the above study after treatment of deacidification by plasma, paper-made and hand-made paper samples experienced an increase in pH and increased tensile strength. The effect of artificial aging on the tensile strength of the sample also showed an increase in mechanical properties compared to those not treated with plasma technology. The results of the discoloration of the display showed that the administration of plasma $Ca(OH)_2$ did not provide a significant color change. The color change on colored paper shows no change except for the red giver, this is because the red color giver like eosin is easily oxidized to the artificial aging process. Comparison of plasma technology deacidification treatments in the traditional way is done by repeated measurements after 45 days treatment, the result of deacidification treatment with plasma technology is more durable. Experiments were also applied to relic (ancient) paper, the result was a plasma deacidification method that only reduced the degree of acidification and did not affect the appearance of paper or pigments and writing on it. The advantage of this method is that it does not cause wrinkles because it is carried out in a dry environment, a short duration, and is more durable.

Bicchieri and Sodo's [10] study shows a comparison of simple deacidification methods by combining simultaneous reduction-deacidification methods in laboratory, paper samples that are artificially aged and then measured again after 10 and 15 years of natural aging. The purpose of this study was to look at the effectiveness of non-water deacidification and reduction simultaneously on paper with natural and artificial aging. The substances used in the study are Calcium propionate in ethanol as a deacidator and tert-butylamine boran [$(CH_3)_3CNH_2BH_3$, TBAB] complex as reducing agents. Deoxidation treatment is carried out by a non-aqueous (non-water) process that is safe for water-soluble ink dyes and restoration actions without the release of book binding. Some measurements and tests were carried out such as pH measurement, carbonyl content in the sample, degree of polymerization, Raman spectroscopic techniques and optical methods.

The results of this study are alkaline pH stability after deacidification is on samples with simultaneous deacidification and reduction treatment. Based on the degree of viscos metric polymerization, sample with treatment deacidification and combination of reduction offers a very large protection against hydrolytic degradation which causes a decrease in the strength of the paper. The presence of carbonyl groups is tested and shows the reduction method provides benefits in maintaining the carbonyl group thus encouraging paper stabilization in oxidative processes that continue to occur throughout the life of the paper. The results of the Raman spectroscopic test showed no oxidative process, which confirmed the long-term effectiveness of the reducing treatment. The combination method provides a greater stability than the simple deacidification method. The reducing agent (TBAB) converts groups potentially harmful (carbonyl) into harmless (hydroxyl) and is very effective in inhibiting the formation of oxidized groups. Some of the advantages of this study are the use of non-water solvents (ethanol) so that it is safe for paper containing ink or dyes that are not waterproof, this combination treatment saves on the amount of treatment to be provided on paper (efficient), application can be done by soaking, spraying and dispersion in the form of a gel.

Writing Poggi, et al. [11] based on paper problems which were degraded due to the presence of acid catalysts and metal ions, in this study iron ions contained in ink. The Archive of Crown of Aragon laboratory strengthens the manuscript with gelatin and Japanese tissue. Based on this, it is necessary to test the combined method of deacidification using Ca(OH)2 nano particle form and reinforcement with Japanese tissue. This new method, applied to paper in hydro alcohol media, is intended to slow down cellulose degradation, and, at the same time, improve the mechanical properties of the original paper. Media alcohol (ethanol or n-propanol) was chosen to avoid using water that can damage paper or interact with ink. Tests carried out include determination of pH and viscosity of the cellulose polymerization level in the artificial aging process for the success of deacidification, penetration of nanoparticles in cellulose fibers by scanning electron microscopy with X-ray energy dispersion spectroscopy (SEM EDX). The treatments were tested on mockups containing Iron Gall ink and original 16th and 18th century manuscripts that suffered severe corrosion damage.

The results confirm that treatment using gelatin and nanoparticles can limit cellulose depolymerization during long-term aging of manuscripts and books in archives, museums, and private collections. The nanoparticle in ethanol and n-propanol, is effective in inhibiting cellulose depolymerization, as indicated by the level of cellulose polymerization. The treated mockup can maintain a fixed pH value of 9 even after an accelerated aging process for 48 h, indicating that this action is effective in stabilizing the pH of the paper during natural aging in the long run. The SEM-EDX scan shows that the deacidification agent is distributed homogeneously over the treated surface and the presence of Japanese tissue, which is used on paper laminates, does not inhibit the spread of particles. The superiority of this combined method can overcome the limitations of traditional methods, increase life span and strengthen the text.

In the study Poggi, et al. [12] alluded to the limited method of safe acid removal in the preservation of paper-based contemporary artwork. So, the purpose of this study is to develop a pH stabilization method on a medium of contemporary art paper containing ink from ballpoints, paper that is folded, wrinkled, or burned. This deacidification research methods are uses calcium hydroxide nanoparticles with cyclohexane solvents. Tests carried out include determining the pH of the sample, measuring the viscosity of the cellulose polymerization level with artificial aging, color colorometry, and testing the reflectance transformation imaging (RTI).

The result is the determination of pH, the sample was successfully increased from a pH value of 4, 6 to 7, 5. Samples that are deactivated more resistant to aging are shown by lower depolymerization values and fewer color changes. Based on DTG measurements, it shows that dehydrated cellulose has thermal degradation resistance. The results of the RTI analysis showed no change in paper topography in the samples before and after treatment. This new period is a promising application for acid removal in contemporary paper-based artwork.

The next study was the use of modified MgO nanoparticles with oleic acid with non-polar solvents [13]. The use of oleic acid serves to modify the surface of nanoparticles to be evenly dispersed or not to clump in non-polar solvents. Non-polar cyclohexane solvents are used to prevent discoloration of inks, dyes and pigments. MgO substances are chosen because of their basic properties, high reaction activity, small and economical side effects. Testing using FTIR to investigate the chemical interactions between MgO and oleic acid, sedimentation test to see the dispersion of oleic acid modified MgO nanoparticles. The success of modified MgO substances was tested through artificial aging tests, and measurements of pH, tensile strength of paper and colorimetric samples. Paper morphology was scanned by SEM and the surface properties of the paper were tested through water contact angles.

The results of FTIR testing revealed a new band at 1574 cm^{-1} which was in the spectrum of oleic acid modified MgO nanoparticles. And this new band is related to the vibration of carboxylic stretching, which states that the carboxyl group of pure oleic acid reacts with the hydroxyl group on the surface of pure MgO nanoparticles and the product is carboxylic (C (= O) OMg). Thus, chemical reactions can occur through the esterification process.

$$MgO(OH)_n + yHOOCC_{17}H_{33} \rightarrow MgO(OH)_{n-y}[OOCC_{17}H_{33}]_y + yH_2O$$

The result of the TGA analysis also shows that there is an effective chemical bond between MgO nanoparticles and oleic acid. There was no difference in X-ray diffraction patterns between pure MgO nanoparticles and modified MgO with oleic acid indicating modification only occurred on the surface of MgO nanoparticles. The sedimentation test results showed that pure MgO nanoparticles were deposited within 30 s in a cyclohexane solvent, while stable oleic acid modified MgO particles were suspended for 6 h in cyclohexane. This stability indicates that the hydrophilic nature of MgO changes to lipophilic thereby increasing the dispersibility of nanoparticles in non-polar solvents.

Post-deacidification showed an increase in pH which was significant with optimal pH 8. All sample, both treated with nanoparticles and did not show a decrease after the artificial aging process. However, the biggest decrease occurred in samples not given nanoparticles. The properties of paper tensile strength in samples not given nanoparticles were reduced by 80%, while samples given by nanoparticles after aging still retained their tensile strength. In conclusion, modified MgO nanoparticles of oleic acid improve pH stability and mechanical properties of paper. SEM scanning results after aging showed that cellulose fibers did not experience structural damage, indicating that MgO nanoparticles modified by oleic acid slow down the aging of paper and inhibit damage to cellulose fibers.

The results of chromatography showed no change in color display due to the administration of modified nanoparticles, for samples of original paintings from the Qing dynasty even showing no change in color in ink and pigment on paper. Samples that were not given nanoparticles and deacidified samples were examined for the contact angle of the water. The result is a sample that is not deacidified has a decrease in the contact angle of water indicating that water penetrates the paper fiber while in the sample carried out the value of the contact angle of the water is fixed. This means that modified nanoparticles increase paper hydrophobicity due to the presence of long carbon chains of oleic acid. The advantage of this method is that changes or modifications only occur on the surface of the nanoparticles, the appearance of ink colors and pigments in the sample does not appear to change.

Jiajia Weng, et al. [14] study focused on deacidification using $Ca(OH)_2$ nanoparticles with fluorohydrocarbon, 1,1,1,2-tetrafluoroethane (R134a) supercritical solvents. $Ca(OH)_2$ was chosen based on its characteristics better than Magnesium, the stability of the interaction of Ca and cellulose. Supercritical solvents are used as non-water solvents that are safe, non-corrosive, colorless, do not form liquid droplets. This study compared the ability to remove acid nanoparticles $Ca(OH)_2$ with atmospheric pressure (SPRA) with nanoparticles $Ca(OH)_2$ in subcritical solvents (Sub-R134a). Paper test resistance is through accelerated aging methods. FTIR analysis for paper sample testing and SEM was carried out to look at paper morphology. The tensile strength of the paper was tested with a testing paper machine, the color of the sample was tested through colorimetric measurement. Determination of the acidity of the sample (pH) was measured by means of a pH meter by measuring the cold extract method.

The results of the deacidification treatment at SPRA and in Sub-R134a after deacidification, both treatments increased the pH of all paper samples, and the increase in pH with the treatment of Sub-R134a was higher than that of treatment with SPRA. Increasing the pH value is directly proportional to the increasing concentration of $Ca(OH)_2$. The $Ca(OH)_2$ substance on the surface of the particles will react with carbon dioxide in the atmosphere to form calcium carbonate. Calcium carbonates formed and unreacted calcium hydroxide alkaline deposits that neutralize acidic species in the future. The alkali reserve content of the paper treated in Sub-R134a is higher than that in SPRA.

Based on morphological analysis with SEM, the Sub-R134a has a significant impact on cleaning paper samples. Nanoparticles in Sub-R134a have a wider distribution of alkali reserves and deeper penetration in the fiber structure, which can explain why internal pH and alkali reserves are relatively high in paper samples given by Sub-R134a.

From colorimetric measurements showed that all treated specimens showed color changes that were not detected before and after deacidification. Based on the measurement of paper tensile strength, it shows that the tensile strength of paper samples increases with increasing pressure and the concentration of Ca(OH)2. Changes in the tensile strength index with pressure are clearer than the concentration.

Based on the paper endurance test after the artificial aging process, the presence of nanostructures contained in cellulose fibers due to deacidification can overcome paper degradation due to aging. The results of pH measurements, samples given sub-R134a had a lower decrease in internal pH before and after aging compared with samples treated with the SPRA system. Samples not given nanoparticles show darkening and bleaching that are more severe than samples treated after the artificial aging process. The advantage of this method besides removing acidity is cleaning paper samples.

The next study was conducted by Nemoykina, et al. [15] using nanocoloid Mg through laser ablation. The choice of deacidification method using water (aqueous) based on the type of sample with permanent ink content that you want to neutralize does not have a problem with water solvents. $Mg(OH)_2$ in the form of nanoparticles has been shown to show many advantages, such as the ease and convenience of paper maintenance procedures (spraying, brushing, dyeing), cheapness, and eco-friendly. The pH value of Mg colloid is also a consideration because it is not too high, so it does not trigger a hydrolysis reaction on cellulose fibers. Through pulsating laser ablation method (PLAL) produces a stable nanocoloid without additional substances such as stabilizers or surfactants. The characteristics of nano use the Transmission electron microscope (TEM) and X-ray diffraction to see the crystal structure and composition of nanoparticles. The pH test and the tensile strength of the paper were carried out.

Through the deacidification process using nanocoloid magnesium oxyhydroxy there is an increase in pH value. Through the artificial aging process, the paper degradation test after deacidification is examined. Paper that is not given a nanocoloid has a decrease in pH greater than the sample given dehydration, indicating that the nanocoloid Mg provides protection to the sample. Paper whitening after aging is increased in samples given nanocoloid magnesium oxyhydroxide, this can occur because of the formation of oxides from oxyhydroside.

The tensile strength test of the paper gave the results of the sample which was deacidified with nanocoloid Mg having increased tensile strength by 7–26%, while the sample rinsed with water decreased by 30%, and samples with Magnesium carbonate decreased 25%. The effect of artificial aging decreases the tensile strength of all samples but only the nanocoloid sample has the smallest decrease. Nanocoloid Mg provides increased mechanical properties of paper and is more stable after artificial aging. The advantages of this method aside from increasing pH value and paper mechanics also increase the whiteness of the paper (Table 3).

4 Discussion

4.1 Substances Used in Deacidification Studies

Based on seven studies, it was seen two studies using Mg^{2+} metal ions and five other studies using Ca^{2+} ions. Both are alkaline earth elements. The application of alkali metals, especially calcium ions due to their superiority, can interact with the carboxyl group of cellulose, thus protecting cellulose from degradation. Some literature shows that the activeness of calcium ions is better than magnesium, and the ability of calcium ions to be calcium carbonate on the surface of cellulose increases pH stability thereby extending cellulose resistance.

Table 3. Table details answer question

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
1	Deacidification of paper relics by plasma technology	Qinglian Li	2014	$Ca(OH)_2$	Aqueous deacidification	Plasma technology	pH measurement	Increased pH value after deacidification
		Sancai Xi						Increased or stable pH after accelerating aging
		Xiwen Zhang						PH stability by plasma treatment is more resistant than traditional methods (nonplasma).
							Measurement of paper tensile strength	Increased or stable mechanical properties
							Color measurement (colorimetric)	Does not change color
								Post-aging does not change color significantly, indicating that plasma decreases the speed of cellulose degradation
							Scanning electron microscopy	High-energy plasma does not damage the fiber but modifies the surface of the fiber.
							X-ray energy dispersion spectroscopy	Plasma affects the chemical structure of fiber surfaces
							Acceleration of aging	

(*continued*)

Table 3. (*continued*)

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
2	Alcoholic deacidification and simultaneous deacidification-reduction of paper evaluated after artificial and natural aging	M. Bicchieri	2016	Calcium propionate $Ca(CH_3CH_2COO)_2$ as a deasidifier	Non-aqueous deacidification	Deasidfication-reduction combination reaction	PH measurement	PH stability, best stability in combination deasidification-reduction
		A. Sodo					Measurement of carbonyl content	The number of carbonyl groups
								Post-treatment carbonyl content Deasidification has the same value as the sample without aging even when it is 15 years old naturally.
							Degree of polymerization	The DP value of the sample treated with deasidification and deacidification has a value comparable to a sample that is not accelerated by aging (not treated)
								Stability of degree of polymerization
				Ethanol as solvent			Raman Spectroscopy Technique	the spectrum does not show a band of around 1577 cm^{-1}, indicating no oxidative process.
				$[(CH_3)_3CNH_2.BH_3$ as reductor			Optical Method	Cellulose chromophore at around 260 nm shows the formation of carbonyl and carboxyl
							Perform testing for artificial and natural aging	

(*continued*)

Table 3. (*continued*)

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
3	Calcium hydroxide nanoparticles in hydroalcoholic gelatin solutions (GeolNan) for the deacidification and strengthening of papers containing iron gall ink	Giovanna Poggi	2016	$Ca(OH)_2$ nanoparticles	Non-aqueous deacidification	Deacidification of nanoparticles and strengthening with Japanese gelatin and tissue	PH measurement	Increased pH after deacidification
		Maria Carmen Sistach		Hidroalkohol solvent				PH stability after acceleration of aging
		Eva Marinc					Degree of polymerization	Stability of the degree of polymerization after artificial aging
		Jose Francisco Garcia					Acceleration of aging (artificial)	
		Rodorico Giorgia					Scanning electron microscopy	Ca nanoparticles were distributed homogeneously to the sample
		Piero Baglionia						Iron is not evenly distributed in inked samples
4	A stabilizer-free non-polar dispersion for the deacidification of contemporary art on paper	Giovanna Poggi	2017	$Ca(OH)_2$ nanoparticles	Non-aqueous deacidification	Nanoparticles with alcohol solvents through solvothermal reactions	PH measurement	Increased pH after deacidification
		Rodorico Giorgia		cycohexane solvent		in the absence of stabilizers	Degree of polymerization	Low decrease in value Degree of polymerization
		Antonio Mirabile				Deacidification for contemporary artwork	Color measurement (colorimetric)	no or slightly discolored
		Huiping Xing					Thermogravimetri	Resistance to thermal degradation
		Piero Baglionia					Image reflectance transformation	There is no change in paper topography
							Acceleration of aging	

(*continued*)

Table 3. (*continued*)

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
5	Conservation of acidic papers using a dispersion of oleic acid-modified MgO nanoparticles in a non-polar solvent	Jie Huang	2018	MgO nanoparticles	Non-aqueous deacidification	MgO nanoparticles are modified with oleic acid with non-polar solvents	PH measurement	Increased pH after deasidification
		Guozhou Liang		Oleic Acid			Acceleration of aging	Low pH decrease (pH is more resistant)
		Gang Lu		Cyclohexane (solvent)			Measurement of paper tensile strength	Stability The tensile strength of post-identification and post-aging paper
		Jinping Zhang					FTIR Analysis	Chemical interactions of oleic acid with MgO nanoparticles
							Sedimentation test	Stability (homogeneous)
							Color measurement (colorimetric)	No change in color
							Scanning electron microscopy	No structural damage
							Water contact angle test	Does not decrease the contact angle of water
6	Deacidification of aged papers using dispersion of $Ca(OH)_2$ nanoparticles in subcritical 1,1,1,2-tetrafluoroethane (R134a)	Jiajia Weng	2019	nanoparticles $Ca(OH)_2$	Non-aqueous deacidification	$Ca(OH)_2$ nanoparticles are dissolved in a supercritical solvent	Acceleration of aging	Samples with nanoparticles are more resistance to degradable
		Xiaogang Zhang		fluorohydrocarbon, 1, 1, 1, 2- tetrafluoro etana (R134a) (supercritical solvent)			PH measurement	Increased pH after deasidification

(*continued*)

Table 3. (*continued*)

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
		Minghao Jia						A lower decrease pH after aging is compared to the normal $Ca(OH)_2$deasidification process
		Jie Zhang					Measurement of paper tensile strength	Increased post-deacidification tensile strength in samples given by nanoparticles
							Sedimentation test	Modified $Ca(OH)_2$ with titanate has the best dispersion stability with isopropanol
							FTIR Analysis	Shows the bond between cellulose fibers and nanoparticles to modify the mechanical properties of paper.
							Alkali reserve measurement	The deasidification treatment with subcritical solvents produces the most alkaline reserves
							Scanning electron microscopy	Ca is distributed more into cellulose
							Color measurement (colorimetric)	There are no color changes

(*continued*)

Table 3. (*continued*)

No	Title	Authors	Year	substance used	Deasidification Method	Novelty	Measurement and Testing	Assessment of success
7	Restoration and conservation of old low-quality book paper using aqueous colloids of magnesium oxyhydroxide obtained by pulsed laser ablation	Anna L. Nemoykina	2019	Nanocoloid $Mg(OH)_2$	Aqueous deacidification	nanocoloid Mg $(OH)_2$ with laser ablation transmission	PH measurement	Increased pH after deasidification
		Anastasiia V. Shabalina					Acceleration of aging	The lowest decrease in pH in the nanocoloiddeasidification sample
		Valery A. Svetlichnyi						The lowest decrease in tensile strength in samples with nanocoloid deacidification
							Measurement of paper tensile strength	Increased tensile strength after deacidification
							Study of optical properties	Samples with nanocoloid MgO deacidification after aging increase the whiteness of the paper
							Nano Characteristic Test with TEM	Proof of nanoparticle characters
							crystal test with X-ray diffraction	For observations of crystal composition and structure.

Table 4. Strengths and Weaknesses of Each Study

No	Deasidification Article	strengths	weaknesses
1	Research (1)	- The plasma system ensures deacidification procedures in dry conditions - Does not cause wrinkles - Short duration - Durable - pH is stable - Compare the plasma method with ordinary solutions - Comparing the effect of plasma treatment on colored paper and pigmented paper	Did not make cellulose polymerization degree measurements
2	Research (2)	- Inhibiting the growth of oxidized groups - Increase stability / reduce the oxidation process - Safe for paper containing dyes or water-soluble inks - Efficient	- Do not analyze changes in paper appearance. - Do not do physical testing such as the tensile strength of paper
3	Research (3)	- The correct deacidification method for paper containing iron gall ink. - There is a strengthening function using gelatin and Japanese tissue. - Increases the usefulness of ink-corroded manuscripts.	- Do not do physical testing such as the tensile strength of paper. - Do not analyze changes in paper appearance.
4	Research (4)	- Deacidification method in contemporary art. - Dispersed particles without additives. - Does not change the shape or topography of the paper used as a medium of contemporary art. - Has thermal degradation resistance - No paper topography changes	- Does not measure pH stability - Does not measure the tensile strength of paper

(*continued*)

Table 4. (*continued*)

No	Deasidification Article	strengths	weaknesses
5	Research (5)	- Oleic acid modification Forms suspension stability for 6 h. - Increases pH stability and mechanical properties of paper. - Inhibits damage to cellulose fibers. - The surface of the paper sample with treatment provides hydrophobic properties.	Did not make cellulose polymerization degree measurements
6	Research (6)	- Has additional functions in cleaning paper - Contains high alkali reserves (functions in stabilizing pH and inhibiting paper damage) - Inhibits paper damage due to aging. - Does not change the color of the sample significantly	Did not make cellulose polymerization degree measurements
7	Research (7)	- Stabilize the suspension without additives - Improved mechanical properties of paper. - Reducing the decrease in tensile strength due to aging - Increase paper whiteness.	Did not make cellulose polymerization degree measurements

4.2 The Type of Deacidification Method Applied

Of all the studies reviewed, the majority were 71% non-aqueous deacidification methods. Consideration of the non-aqueous deacidification method is more widely applied because it avoids further damage to the sample. Several studies carried out deacidification of samples containing iron metal ink which resulted ink corrosion, of course the use of water medium was avoided. Collection of contemporary art with ink from ballpoint pen, of course markers cannot use water solvents. In addition to easy and short application, non-aqueous deacidification measures do not need to release binding if the sample is a bound book.

4.3 Novelty in the Deacidification Method

All the above studies show the novelty of each. Although there were four studies that used substances Ca(OH)2 but there were clear differences. Research (1) calcium hydroxide particles are converted into plasma so that the process remains dry even though it starts from solution. The study (3) used nanoparticles calcium hydroxide which was accompanied by a strengthening process in the sample by giving gelatin and Japanese tissue which acted as a laminate. The study (4) used $Ca(OH)_2$ nanoparticles with non-polar cyclohexane solvents in the absence of stabilizers in contemporary art. Research (6) calcium hydroxide nanoparticles were dissolved with supercritical 1, 1, 1, 2-tetrafluoro ethane solvents, these solvents were liquid at low pressure while at atmospheric pressure they immediately turned into gases which did not cause wet samples.

Research (2) uses Calcium propionate in ethanol. The novelty is a deacidification reaction combined with a reduction reaction using a tert-butylamine boran complex. The function of the reducing agent is to maintain the carbonyl group in preventing further oxidative reactions during the storage period. Research (5) used modified magnesium oxide nanoparticles with oleic acid in n-hexane (non-polar) solvents. The function of oleic acid is to increase the solubility of MgO so that it is distributed evenly in non-polar solvents. Research (7) Using Mg(OH)2 in the form of colloidal nano with laser ablation. The advantage of nano colloid is the formation of a stable dispersion system in the absence of additives as stabilizers.

4.4 Measurement and Testing Carried Out in the Deacidification Process

There are similarities in the seven studies above in terms of measuring and testing the deacidification process. Of course, pH measurements and artificial aging tests were carried out by all the studies above to prove their new method is effective in increasing the acidity (pH) and paper resistance to the aging process. In measuring the mechanical properties of paper such as the tensile strength of paper only carried out by three articles, observation of color differences was only carried out 4 articles.

4.5 Assessment Determines the Success of the Deacidification Method

Based on information from Baty et al. [3] there are 14 criteria for determining a successful deacidification process, which are not harmful to the sample, effective neutralization, have sufficient base reserves, are homogeneously distributed, low cost, safety for collection users as well as deacidification actors, prove effectiveness through accelerating aging, physical testing in the form of paper folding test and tensile strength test, flexibility test, measurement of cellulose polymerization level, changes in paper appearance, odor and monomer release when accelerating aging. None of the above studies provided a complete success criteria. Although there are several criteria that might be eliminated because they do not affect the durability or durability of the paper, such as odor and costs are eliminated, but there are still shortcomings.

5 Conclusion

The use of alkaline particles in this case an alkaline earth group dominated by calcium ions based on several things such as having a stronger alkalinity, can interact with the carboxyl group oxidized in cellulose so that it inhibits the rate of degeneration in cellulose.

The application of nanoparticles in acidity removal is based on the small particle size thereby increasing the extent of the touch field of the reacting substance and the ability to reach the deepest cracks in cellulose fibers so that they are effective in neutralizing. $Ca(OH)_2$ solution with plasma form makes acid reduction in a dry atmosphere. The combination of deacidification and reduction simultaneously serves to increase pH and prevent oxidative reactions or degradation of cellulose during the storage period. The modification of cellulose surface with oleic acid and nano colloidal systems functions in the homogenization of deacidification reagents (Table 4).

All studies measured pH and accelerated aging to measure increase, pH stability and test the resistance of cellulose polymers. Several studies were made specifically according to the research objectives, so that the tests carried out were adjusted.

The systematic method of review is one method that makes it easy to draw conclusions so as to produce an overview of primary research based on the facts that exist.

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