ANOLYTE AS AN ALTERNATIVE BLEACH FOR STAINED COTTON FABRICS

Kgalalelo Seiphetlheng*, Hester JH Steyn & Robert Schall

ABSTRACT

Anolyte has been successful in the food industry and in disinfecting textiles, extensive research has not been done to determine the bleaching effect on textiles. If it can bleach textiles, it can be considered alternative bleach. If it does not bleach textiles, it can be useful as a disinfectant without the bleaching damage as result of it.

The aim of this study was to determine if Anolyte could be used as an alternative stain remover. The commonly used sodium hypochlorite and distilled water were used as a control. The study was an experimental research where bleaching of samples was done according to AATCC Test Method 61- 2009 carried out in the Launder-O-Meter. Data for the four types of stains, namely blood, juice, soot and tea were analysed separately. The dependent variable, colour change, was analysed through an analysis of variance (ANOVA) fitting the three design factors bleach (Anolyte, distilled water and hypochlorite), bleach temperature (30°C, 40°C and 60°C) and bleach time (9, 18 and 45 minutes), as well as the two- and three-factor interactions. The results from the study indicated that Anolyte was less effective than sodium hypochlorite as a stain remover for blood, tea, soot/mineral oil and blackcurrant juice. It was noted that the temperature of bleach liquids had an influence on the removal of stains by both bleach liquids.

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INTRODUCTION

The textile industry is one of the largest and most basic industries worldwide, which covers the needs of consumers in sectors such as apparel, household textiles, medical textiles, hotel and hospitality, as well as military sectors. Cotton fibres are the purest of cellulose and the world's most important textile material, because of its good qualities like good absorbency and good abrasion resistance, to mention a few. Therefore, chemical modification on the cotton fibre has been studied as a means of improving its wettability, dye ability, chemical affinity and to improve the competiveness of the textile products made of blends of cotton with chemical fibres (Shahidi *et al.,* 2013:34). Important factors for improving textile wet processing include lower processing costs, a reduction in the environmental impact and an improvement in quality (Tavčer, 2012:20). Textile finishing does not end at the manufacturing process. Bleaching of textiles forms part of the maintenance and care procedure of many cotton textile products like towels and dishcloths at home, as well as in the hospitality industry. The efficiency of bleaching effects by various chemicals and conditions is continuously investigated by researchers in order to improve the quality and useful life of the products made from cotton fibres. These new technologies do have pros and cons that may affect the environment as well as the quality of the final product itself.

LITERATURE REVIEW

Cotton is a natural fibre that is high in demand worldwide. The textile industry faces a challenge, as new technologies arise in order to meet the high demand and in order not to compromise on the quality of the products during processing. New technologies are developed to speed up production, use less water and electricity and to avoid endangering the environment as much as possible. However, in some instances the processes used in the textile industry pose a danger to the environment, to people working in the factories, to the quality of the finished products and to the economy of many countries. Chemicals like sodium hypochlorite, sodium hydroxide and various dyes are commonly used in the processing and specifically in the bleaching of cotton.

Anolyte and Catholyte solutions are the two distinct by-products of the Electro-Chemical Activation (ECA) technology process, where the Anolyte solution is a disinfectant and the Catholyte is a detergent. The ECA process concept involves the passage of a high-voltage current through a brine solution with a membrane interposed between the anode and cathode, which produces a substantial electrical potential difference, leading to two types of water, namely Anolyte and Catholyte (Idris & Saed, 2002:139). Huang *et al.* (2008: define electrolysed oxidising (EO) water, also known as strongly acidic electrolysed water (SAEW) or electrolysed strong acid aqueous solution (ESAAS), as a novel antimicrobial agent that has been used in Japan and many other countries worldwide for several years. These two solutions are used extensively in different applications, ranging from disinfection to cleaning in both an economical and an environmentally friendly manner. Electrochemically activated water (EO) is formed by electrolysing a diluted salt (NaCl) solution, which is further separated into a basic fraction (Catholyte) and an acidic fraction (Anolyte) (Kim, Hung & Russell, 2005:. Marais and Williams (2001:238) explain that Catholyte is reputed to having a strong cleaning or detergent effect, while Anolyte is antimicrobial.

Steponavičius and co-workers (2012:193) explain in their research that studies on electro-chemically activated water (Anolyte) demonstrate its bactericidal, antiviral and partially fungicidal properties. The authors add that extensive studies on the use of electro-chemically treated water for the reduction of mycobiotic contamination during the harvest processing have been widely performed in Japan, the United States, China and Russia. Cloete and co-workers (2009:379) add that Anolyte possesses antimicrobial activity against a variety of micro-organisms as a disinfectant used in agriculture, dentistry, medicine and the food industry.

Anolyte (the product of the high anode) has a high oxidation potential of around +1000 mV, whereas Catholyte (the product of the cathode chamber) has a high reduction potential of around -800mV. The Anode has a low pH (2.3 – 2.7), high dissolved oxygen and contains free chlorine. This is why one expects the bleaching to take place (Huang *et al.,* 2008:332). Because of the potential EO possesses, it has been described by Ghebemichael and co-workers (2011:210) as another form of chlorine solution.

Anolyte has an antimicrobial effect and causes no harm to human beings. It is also used to control microbial growth in various fields such as hospitals and agriculture (Cloete *et al.,* 2009:379). Another advantage of using Anolyte, as stated by Huang and co-workers (2008:332), is that it is cheap to produce, as it is produced from tap water, with naturally organic matter, and with no added chemicals except NaCl (Kim *et al.,* 2001:92). The production of Anolyte does not require the use of expensive and toxic chlorine and it is produced at room temperature; hence, cutting on production costs (Takasu, Masaki & Matsuda, 1986:304). Anolyte is effective as a disinfectant for textiles (Vermaas, 2011), but its qualities as a bleach have not been reported before.

Each year, large amounts of hypochlorite bleaches are released into the environment through washing processes. These bleaches harm the environment as they affect the ozone layer (Q-water 2012:1). Additionally, the use of chlorine as a micro-biocide and water disinfectant is declining because of its negative safety, environmental and community impact.

Bechtold (2005:121) further warns that although sodium hypochlorite offers a wide range of bleaching effects, is easy to use and inexpensive, producing the bleach is affected by a lack of stability pertaining to storage, especially under warm conditions, making the bleach not user-friendly; hence, caution must be taken during use.

Khan and co-workers (2012:30) add that sodium chlorite and hypochlorite have been widely used to bleach cotton in the textile industry, but it has a harmful effect on the environment due to chlorine liberation during bleaching. Therefore, these substances cannot be used with wool and acrylics, as they damage the fibre and cause them to become yellow. It is advantageous to use hypochlorite bleach at room temperature, but slight heating accelerates the bleaching rate and reduces the amount of hypochlorite required (Perkins, 1996:64). It must be noted that sodium hypochlorite is not part of detergent formulas, but is a separate product added during laundering. Alternatively, it can be used directly for cleaning surfaces. It is considered advantageous to use sodium hypochlorite bleach, compared to others, as it requires less energy, labour, water and time. During manufacturing, temperature and storage affect the stability of hypochlorite solutions. At high temperatures, this will increase the decomposition rate and if kept at low temperatures where it is stable, freezing should be avoided. The quality of sodium hypochlorite solutions may be affected by traces of metals such as copper, nickel and cobalt as they cause bleach to catalyse and form oxygen gas, thus lowering bleach strength.

Sodium chlorite is a light-yellow, alkaline liquid that is stable at ambient temperature. When broken down by acids, it forms chloride dioxide ClO_2, a green gas that is water soluble (Moissan, 2012:1). It must be rinsed out of the textile completely to avoid further chemical reaction, as it reacts with phenolic compounds found in the dye. This means that colour can be removed or altered. Moreover, chlorine in the bleach reacts with protein by breaking down protein molecules, which results in weakening silk, wool or any hair fibres. The longer the protein fibres are exposed to chlorine the more damage it causes in these fibres. Sodium chlorite is effective bleach for natural and synthetic fibres like nylon and polyester, which are difficult to bleach with hydrogen peroxide (Perkins, 1996:64), but to avoid any damage to the fibres, cotton can be bleached at pH 4.0 – 5.0 and synthetic fibres at pH 2.0 – 4.0.

Wieprecht and co-workers (2007:326) explain in their research that in laundry the bleach is mainly directed at destroying unwanted stains in order to achieve the intended cleaning effect as well as at destroying dyestuff in solution in order to prevent discoloration of acceptor fabrics. Chlorine is frequently used as a disinfectant for textiles in the home and in the hospitality industry, but it has a negative impact on the environment (Lehtola *et al.,* 1999). Anolyte is effective for replacing the sodium hypochlorite as a disinfectant (Vermaas *et al.*, 2015). Ghebremicael and co-workers (2011: describe Anolyte as “another form of chlorine solution”. Huang and co-workers (2008:) expect Anolyte to have a bleaching effect.

METHODOLOGY

Four different stained cotton fabrics from the Center for Test Materials BV, Netherlands were used. The stained fabrics are described as follows: cotton stained with tea (code W 10 J); cotton stained with blackcurrant juice (code W 10 JB); cotton stained with blood IEC 60456 (code W 10 PBU); and cotton stained with soot/ mineral oil IEC (code W 10 RM). The AATCC test method 61-2010, procedure 5A (AATCC technical manual 2009:87) was followed but adjusted to suit the experimental needs. Bleaching procedures were carried out on the stained cotton. Anolyte and sodium hypochlorite was used as bleach and distilled water were used as control. Bleaching took place in the Launder-O-Meter (Atlas Electric Devices Co.) machine, which was preheated to the correct temperature before any bleaching procedure. Using a Launder-O-meter provides accelerated results in a short time, as 45 minutes of laundering in a Launder-O-meter is equal to five washes in a domestic washing machine. Procedure 7.3.3 in the AATCC test method 61-2010 was followed in the bleaching process. The procedure specifies that a total of 150 ml of bleaching liquid be added to each canister with 50 stainless steel balls and a specimen (test fabric). For sodium hypochlorite, 2 ml was measured and distilled water added to the beaker to make a volume of 150 ml. This solution in each beaker was then dispensed into each canister with 50 balls of stainless steel.

Anolyte solution and distilled water were prepared an hour before any test was carried out whereby 150 ml bleaching solution was measured into each canister with 50 balls of stainless steel. After bleaching was carried out, the canisters were emptied and each sample rinsed in distilled water placed in a water bath at 40 °C, and then removed and allowed to dry at room temperature in a room without any fluorescent lights. The bleaching temperatures were 30 °C, 40 °C and 60 °C, respectively, whereas bleaching times ranged from 9 minutes to 18 minutes and 45 minutes.

AATCC test method 135-1985 for instructional colour measurement of textiles was used in determining the bleaching effect of Anolyte, sodium hypochlorite and distilled water on the specimens. Before any testing the test samples were preconditioned by bringing them to the appropriate in moisture equilibrium the standard atmosphere as directed in Practice D1776, which suggests that test samples should be conditioned at 21±1 °C and 65z ±2% relative humidity for 24 hours.

The Konica Minolta Spectrophotometer CN - 2300d was calibrated before any readings were taken. Five measurements were taken on each specimen before bleaching and after bleaching in order to determine the colour difference. The five measurements were averaged to get the mean and statistically analysed to determine the extent in colour change. ΔE indicates the colour difference between two objects. ΔE= the square root of $\Delta a^2 + \Delta b^2 + \Delta L^2$ where a represents the difference in redness-greenness between the two, b represents the difference in yellowness-blueness and L the difference in lightness between the two objects.

Statistical analysis of the data obtained from the replicate observations per sample of the variable (stained, bleached, unbleached and dyed cotton) was averaged and analysed through an analysis of variance (ANOVA) fitting the three design factors bleach (Anolyte, distilled water and sodium hypochlorite), bleach temperatures, bleach time and bleach cycles. F-tests and P-values for the effects in the model were obtained from the ANOVA. Furthermore, estimates of the differences between least squares means associated 95% confidence intervals and P-values were reported as well. The program used for the data analysis was SAS version 9.22, procedure GLM.

RESULTS AND DISCUSSION

The objective of the research was to determine if Anolyte could be used as an alternative stain remover to the commonly used sodium hypochlorite and distilled water was used as a control. The stains that were bleached included blood, tea, black currant juice and soot/mineral oil at temperatures of 30 °C, 40 °C and 60 °C, respectively and the duration of exposure was 9 minutes, 18 minutes and 45 minutes.

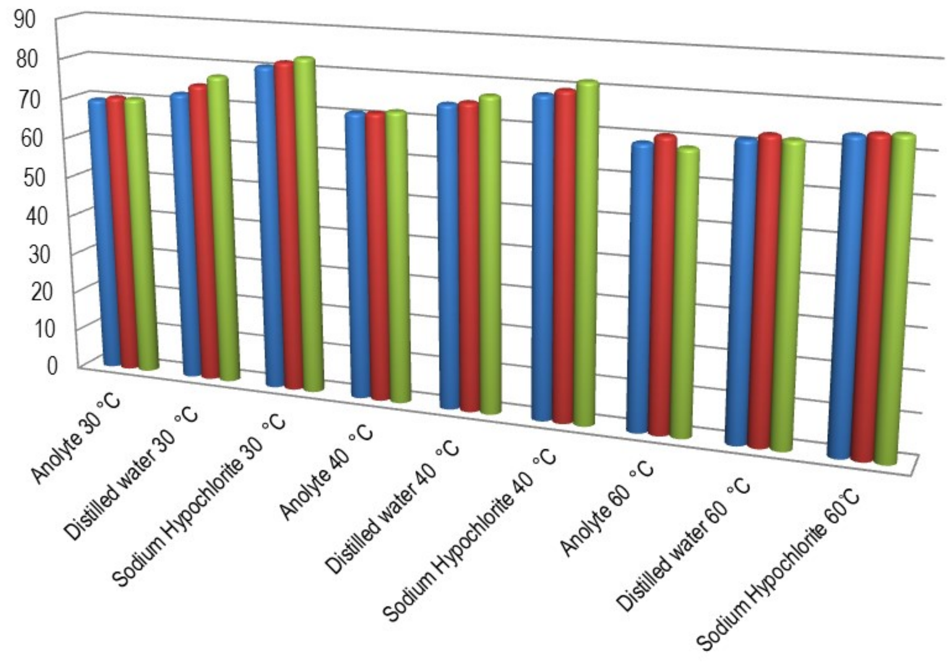
Effects of anolyte, sodium hypochlorite and distilled water on the removal of blood stain on cotton

As indicated in Figure 1, bloodstains were removed best by sodium hypochlorite at temperatures 30 °C, 40 °C and 60 °C. The longer the stain was bleached, the better the removal of the stain. Even distilled water removed the stain better than Anolyte solutions at 9, 18 and 45 minutes, as the ΔE for all the bleach times were higher than that of Anolyte. The pH of Anolyte ranged between 2.06 and 3.05, which were acidic and the pH of distilled water was 8. There is no literature that explains why distilled water removes bloodstains better than Anolyte. Although the bleaches removed the stain at 60 °C, it was observed that bloodstains were removed best when bleaching took place at 30 °C for sodium hypochlorite, and 40 °C when bleached with Anolyte and distilled water. According to Pušić *et al.* (2007:407), sodium hypochlorite bleaches are dominant bleaches in stain removal, especially in a cold bath. The hypochlorite bleaching agents oxidize the double bonds in the chromophore of the colour stain, destroy the colour and produce a colourless compound (Anon n.d.), thus improving the whiteness of the fabric, whereas Anolyte lacks this capacity. The low pH of the Anolyte may explain this; low pH is rather associated with colour fixing than with bleaching. The best removal of bloodstains was obtained when bleached with sodium hypochlorite at 30 °C for 45 minutes with a colour change of 83.2 ΔE. Collier and co-workers (2009:487) explain that if the stain is fresh, soaking in cold water will give better wash results, but these stains were not fresh. Stone (2009:1) concurs with Collier and co-workers that bloodstains should be soaked in cold water to dislodge the stain within the fibres. It is generally accepted that blood should be treated while the stain is fresh and in a cold solution, as heat will rather set the stain. Table 1 below indicates that there was a statistically significant difference in colour change between all the bleaches (Anolyte, distilled water and sodium hypochlorite) and bleach times (9, 18 and 45 minutes). However, there was no statistically significant difference in bleach temperatures between 30 °C and 40°C, but there was a significant difference between 30 °C and 60 °C. It seems that both the temperature and pH of the wash liquid influence the removal of bloodstain up to 40 °C. At 60 °C, the stain is already set by heat and even the hypochlorite was less effective. This result is in agreement with the advice that a bloodstain should be treated with a cold detergent solution (PV22. 2014).

Simpson (1983) makes the observation that effective bleaching can take place at a lower pH of 8,5 but it takes up to 16 hours. Hypochlorite bleaching is usually not done at a pH as low as 2,0-5,0, as result of the danger of generating chlorine gas (Vigo.1994:20), preventing the researchers in this project the advantage of comparable bleaching results.

Effects of anolyte, sodium hypochlorite and distilled water on the removal of blackcurrant juice stain on cotton

The blackcurrant juice stain was removed by all bleach liquids at all temperatures. The stain was removed at different intensities as indicated by Figure 2. Anolyte removed blackcurrant juice s best at 30 °C when bleaching took place for 45 minutes, while sodium hypochlorite and distilled removed the stain best at 60 °C when bleaching took place for 45 minutes. Sodium hypochlorite removed the stains better than other bleach liquids, with the highest colour difference reaching 90.7 ΔE. Anolyte removed the juice stain better than distilled water did at all bleach times. Distilled water removed the juice stain the least, with colour difference reaching 73.8 ΔE. The pH range of Anolyte was between 2.65 and 3.06, which is acidic; that could be the reason



	Anolyte 30 °C	Distilled water 30 °C	Sodium Hypochlorite 30 °C	Anolyte 40 °C	Distilled water 40 °C	Sodium Hypochlorite 40 °C	Anolyte 60 °C	Distilled water 60 °C	Sodium Hypochlorite 60°C
9 minutes	69.6	72.5	80.6	70.9	74.5	78.2	68.7	71.2	73.8
18 minutes	70.5	74.9	81.9	71.2	75.2	79.5	70.7	72.6	74.4
45 minutes	70.4	77.4	83.2	71.9	77.1	81.8	68.3	71.8	74.7

FIGURE 1: COTTON STAINED WITH BLOOD: EFFECTS OF ANOLYTE, SODIUM HYPOCHLORITE AND DISTILLED WATER AT 30 °C, 40 °C AND 60 °C ON COLOUR CHANGE (MEAN VALUES)

TABLE 1: COTTON STAINED WITH BLOOD: MAIN EFFECTS OF BLEACH, TEMPERATURE AND TIME ON COLOUR CHANGE

COTTON STAINED WITH BLOOD		COLOUR DIFFERENCE MEAN (ΔE)	MEAN DIFFER-ENCE	95% CONFIDENCE INTERVAL FOR MEAN DIFFER-ENCE	P-VALUE
			(Relative to Anolyte)		
BLEACHES	Anolyte Distilled water Sodium hypochlorite	70.240870 74.127615 78.642291	 -3.886745 -8.401422	 -4.192253 -3.581238 -8.706929 -8.095914	 <.0001 <.0001
			(Relative to 30 ° C)		
TEMPERATURE	30 °C 40 °C 60 °C	75.642350 75.588866 71.779561	 -0.53484 -3.862790	 -0.358992 0.252023 -4.168297 -3.557282	 0.7293 <.0001
			(Relative to 9 minutes)		
TIME	9 minutes 18 minutes 45 minutes	73.327379 74.535203 75.148195	 1.207824 1.820816	 0.902316 1.513331 1.515309 2.126324	 <.0001 <.0001

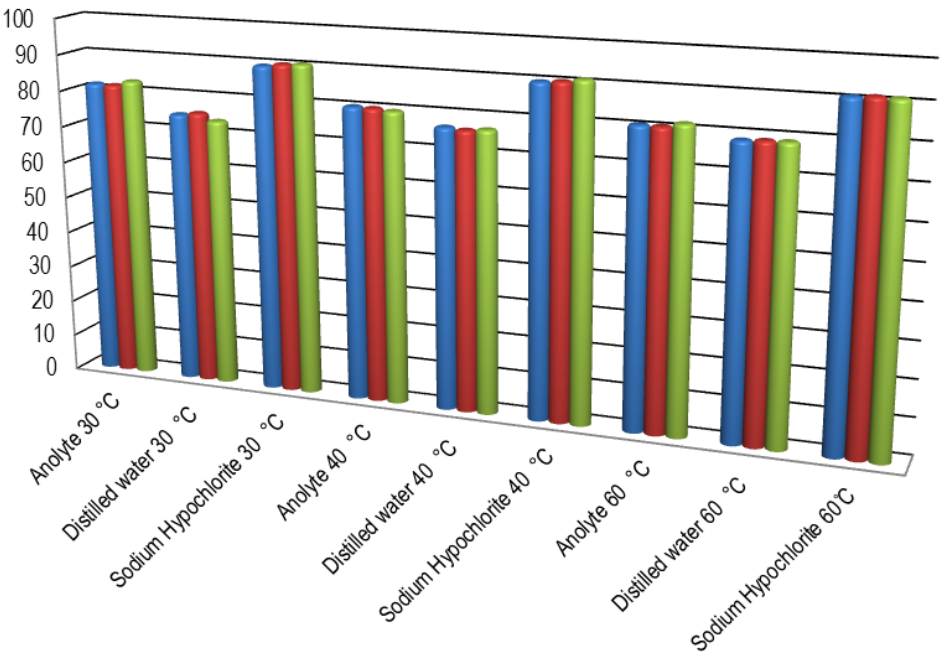
why Anolyte could not remove the stains better than sodium hypochlorite, as the blackcurrant juice stain is also acidic, according to Bechtold and co-workers (2007:2590) blackcurrant juice is better extracted in an acid environment. Sodium hypochlorite's pH ranged between 9.65 and 9.70, which are alkaline and it removed the stain best in all the temperature ranges. Bechtold and co-workers (2007:2587) explain that blackcurrants are known to have a characteristic strong smell and high contents of anthocyanin and ascorbic acid. The alkalinity of sodium hypochlorite could have had a great influence in removing the stain best, along with oxidation of the double bond of the chromophore. It was observed that distilled water deepened the stain into the cotton fabric the longer it was laundered, compared to other bleach liquids. The combination of temperature and time of exposure might cause the stain to set and the longer exposure and higher temperature are the reasons for the deepened colour of the blackcurrant juice stain.

The difference in colour change observed between the reactions of the black currant juice stain compared to the blood stain is prominent. It can be explained by the difference in nature of the stain, with black currant juice a fruit stain with anthocyanin and ascorbic acid (Bechtold *et al.*, 2007:2587) reacting with the cellulose in the fibre. Black currant juice is effective as a natural dye for cotton.

Table 2 below shows that there was a statistically significant change in colour difference between the Anolyte and distilled water as well as between Anolyte and sodium hypochlorite. It was also noted that there was a statistically significant difference between bleach temperatures regarding the removal of the blackcurrant juice stain. However, there was no statistical difference between temperatures 30 ° C and 40 °C. The table also indicates that there was no statistical difference in bleach times between 9 and 18 minutes.

Effects of anolyte, sodium hypochlorite and distilled water on the removal of soot/mineral oil stain on cotton

According to Figure 3 below, soot/mineral oil stain was best removed when bleached by sodium hypochlorite at 60 °C for 45 minutes as the whiteness reached 69.5 ΔE. The stain was best removed in all wash temperatures when bleaching took longer (45 minutes), compared to 9 and 18 minutes. Anolyte removed the soot/ mineral oil stain, but there was not much difference in the ΔE. The figure indicates that all bleach liquids removed the soot/mineral oil as time increased; however, at different levels of whiteness. Soot/mineral oil was best removed when the temperature was at 60 °C. Collier and et al. (2009:489) explain that soot/mineral oil stains can be laundered using the hottest water safe for fabric.



	Anolyte 30 °C	Distilled water 30 °C	Sodium Hypochlorite 30 °C	Anolyte 40 °C	Distilled water 40 °C	Sodium Hypochlorite 40 °C	Anolyte 60 °C	Distilled water 60 °C	Sodium Hypochlorite 60°C
9 minutes	81.8	74.9	89.7	80.4	76.7	90.1	80.9	78.8	91.2
18 minutes	81.7	75.6	90.4	80.3	76.3	90.5	80.8	79.1	91.5
45 minutes	83.1	73.8	90.7	79.9	76.8	91.3	81.9	79.2	91.4

FIGURE 2: COTTON STAINED WITH BLACKCURRANT JUICE: EFFECTS OF ANOLYTE, SODIUM HYPOCHLORITE AND DISTILLED WATER AT 30 °C, 40 °C AND 60 °C ON COLOUR CHANGE (MEAN VALUES)

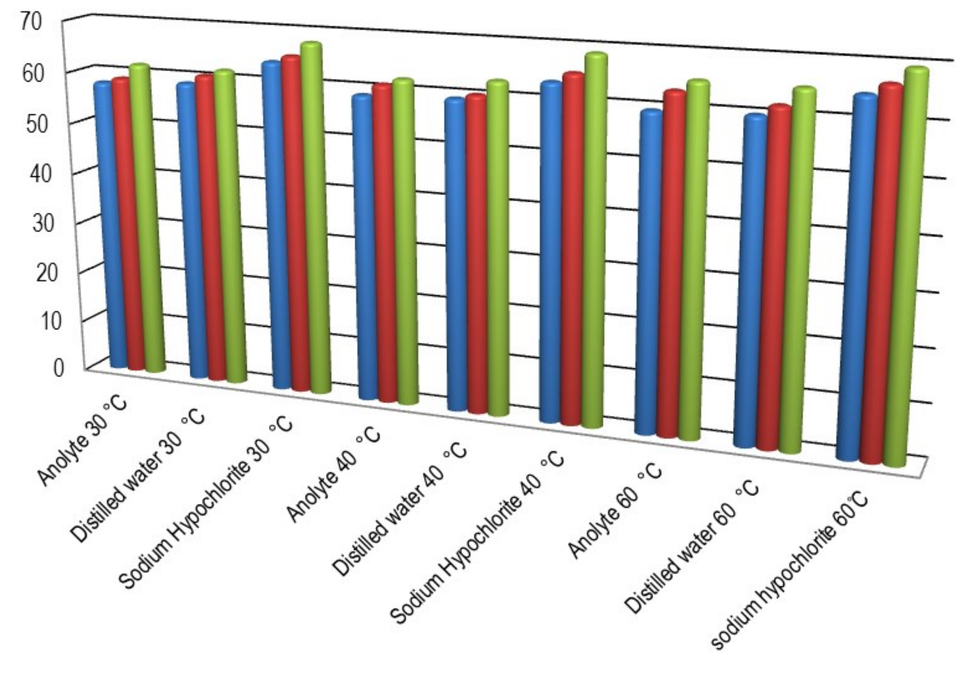
TABLE 2: COTTON STAINED WITH BLACKCURRANT JUICE: MAIN EFFECTS OF BLEACH, TEMPERATURE AND TIME ON COLOUR CHANGE

COTTON STAINED WITH BLACKCURRANT JUICE		COLOUR DIFFERENCE MEAN (ΔE)	MEAN DIF-FERENCE	95% CONFIDENCE INTERVAL FOR MEAN DIFFERENCE	P- VALUE
			(Relative to Anolyte)		
BLEACHES	Anolyte Distilled water Sodium hypochlorite	81.224469 76.799570 90.777529	 4.424899 -9.553060	 4.204234 4.645564 -9.773725 -9. 332395	 <.0001 <.0001
			(Relative to 30 °C)		
TEMPERATURE	30 °C 40 °C 60 °C	82.422853 82.485166 83.893548	 0.062313 1.470695	 -0.158351 0.282978 1.250030 1.691360	 0.5768 <.0001
			(Relative to 9 minutes)		
TIME	9 minutes 18 minutes 45 minutes	82.741116 82.923011 83.137440	 0.181895 0.396323	 -0.038770 0.402559 0.175658 0.616988	 0.1025 0.0006

An analysis of variance of colour change of soot/ mineral oil stain indicated in Table 3, shows that there were statistically significant differences ($p<0.05$) in colour change between all the bleaches, temperatures, time, bleach and temperature and lastly temperature and time. However, there was no statistically significant difference in colour change between factors bleaches and time, or between bleach, temperature and time. The analysis further indicates a statistically significant difference ($p<0.05$) in efficiency between Anolyte and sodium hypochlorite, between temperatures 30 °C, 40 °C and 60 °C and lastly between bleach times of 9 minutes and 18 minutes as well as 9 minutes and 45 minutes. However, there was no statistically significant difference in colour change of soot/mineral oil stain between Anolyte and distilled water as the p-value was 0.42. Soot is the carbon residue of a burning process; apart from the carbon, it also contains other chemical compounds. Soot and oil need hot water to dislodge carbon from the fibres (Collier *et al.,* 2007:). The soot gets absorbed into and absorbed onto the fabric along with the oil and although it causes the stain, no reaction takes place between the stain and the fibre. As the temperature of the wash liquid rises and the time of exposure increases, the energy breaks down the oil and dislodges the soot particles. The process improved as the pH became higher.

Effects of anolyte, sodium hypochlorite and distilled water on the removal of tea stain on cotton

Leverette (2013:1) describes a tea stain as a tannin stain, a plant component that shows up as a colour on the fabric. He further claims that these stains can easily be removed by laundering with detergent in hot water. Older stains need bleach to be removed. Other authors describe it differently, explaining that the group stains from tea, wine, tomatoes and berries are very difficult to remove, as

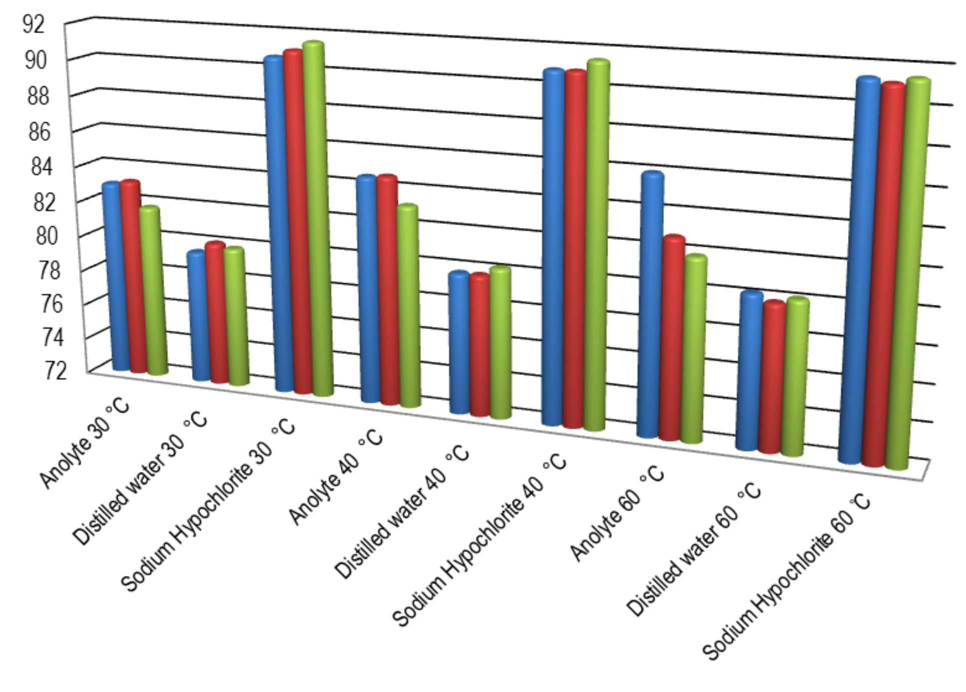


	Anolyte 30 °C	Distilled water 30 °C	Sodium Hypochlorite 30 °C	Anolyte 40 °C	Distilled water 40 °C	Sodium Hypochlorite 40 °C	Anolyte 60 °C	Distilled water 60 °C	sodium hypochlorite 60°C
9 minutes	57.9	58.8	63.9	58.8	59.3	63.4	59.5	59.9	64.6
18 minutes	58.9	60.5	65.2	61	60.2	65.2	63.2	61.8	66.6
45 minutes	61.8	61.7	67.9	62.2	63	68.9	65.2	65.1	69.5

FIGURE 3: COTTON STAINED WITH SOOT/MINERAL OIL: EFFECTS OF ANOLYTE, SODIUM HYPOCHLORITE AND DISTILLED WATER AT 30 °C, 40 °C AND 60 °C ON COLOUR CHANGE (MEAN VALUES)

TABLE 3: COTTON STAINED WITH SOOT/MINERAL OIL: MAIN EFFECTS OF BLEACH, TEMPERATURE AND TIME ON COLOUR CHANGE

COTTON STAINED WITH SOOT/ MINERAL OIL		COLOUR DIFFERENCE MEAN (ΔE)	MEAN DIFFERENCE	95% CONFIDENCE INTERVAL FOR MEAN DIFFERENCE	P-VALUE
			(Relative to Anolyte)		
BLEACHES	Anolyte Distilled water Sodium hypochlorite	60.986777 61.161808 66.124911	 -0.175031 -5.138134	 -0.605151 0.255089 -5.568254 -4.708014	 0.4217 <.0001
			(Relative to 30 °C)		
TEMPERATURE	30 °C 40 °C 60 °C	61.846269 62.499620 63.927606	 0.653351 2.081337	 0.223231 1.083470 1.651217 2.511457	 0.0032 <.0001
			(Relative to 9 minutes)		
TIME	9 minutes 18 minutes 45 minutes	60.671050 62.514811 65.087634	 1.843761 4.416584	 1.413641 2.273881 3.986464 4.846703	 <.0001 <.0001



	Anolyte 30 °C	Distilled water 30 °C	Sodium Hypochlorite 30 °C	Anolyte 40 °C	Distilled water 40 °C	Sodium Hypochlorite 40 °C	Anolyte 60 °C	Distilled water 60 °C	Sodium Hypochlorite 60 °C
9 minutes	83	79.5	90.7	84.6	79.8	90.9	86	80.3	91.4
18 minutes	83.2	80.1	91.1	84.7	79.8	90.9	82.8	79.9	91.2
45 minutes	81.8	79.9	91.6	83.2	80.3	91.5	81.9	80.2	91.5

FIGURE 4: COTTON STAINED WITH TEA: EFFECTS OF ANOLYTE, SODIUM HYPOCHLORITE AND DISTILLED WATER AT 30 °C, 40 °C AND 60 °C ON COLOUR CHANGE (MEAN VALUES)

chromophores are present, inhibiting the removal of the stain (Johansson & Somaundaran, 2007:65). Mere washing with detergent does not remove those kinds of stains; bleaching might be required. The authors state that bleach present in the wash water degrades the chromophores, leading to the discolouration of the stain. Even when the stain may not be completely removed it is generally no longer visually detectable.

As illustrated in Figure 4, tea stains were removed by Anolyte and sodium hypochlorite bleach, but darkened more than the untreated stains at all the bleach times when bleached with distilled water, as the temperature aids to set the stain. The best results were obtained when cotton stained with tea was bleached with sodium hypochlorite at 30 °C for 45 minutes, whereby the whiteness of the bleached stain reached 91.6 ΔE. In all the bleach times where sodium hypochlorite bleach was used, there was a steady increase in the whiteness of the bleached stain as time increased. Tea stains bleached with Anolyte were best removed when bleaching took the shortest time, 9 minutes, as the whiteness reached a maximum of 86 ΔE when temperature was at 60 °C. It was observed that the effectivity of Anolyte diminishes with an increase in exposure time in all the bleach temperatures. According to Collier *et al.* (2009:487), tea stains should be soaked in cold water, pre-treated with stain remover, liquid laundry detergent or paste of granular laundry product and water. Further laundering using chlorine bleach or oxygen bleach could be used to improve the whiteness. Stone (2009:1) explains that fresh tannin stains usually can be removed by laundering the fabric using detergent (not soap) in hot water (if safe for the fabric), without any special treatment. Bleaching tea stains at a high temperature of 60 °C removed the stain at a similar rate as when bleached at 30 °C and 40 °C.

Table 4 below, which presents the p-values of effects of bleach, time and temperature, clearly shows that there was a statistically significant difference in colour change in all the removals of tea stains. Distilled water, however, did not remove the stain at any given temperature and time but rather darkened it.

SUMMARY

The efficiency of Anolyte as an alternative bleach to stained cotton was compared to sodium hypochlorite and distilled water was used as control. Cotton test materials were stained with blood, tea, blackcurrant juice and soot/mineral oil. Bleaching ranged between temperatures of 30 °C, 40 °C and 60 °C and various times of 9, 18 and 45 minutes to determine the effect of temperature on stain removal and bleaching. The influence of the bleaches, temperature, cycles and time on the textile fabrics was evaluated in terms of colour change. The results of the study therefore suggest that sodium hypochlorite removed the stains more effectively than Anolyte at all the given temperatures. Bleach temperature and time had an effect on the whiteness of stains as,

TABLE 4: COTTON STAINED WITH TEA: MAIN EFFECTS OF BLEACH, TEMPERATURE AND TIME ON COLOUR CHANGE

COTTON STAINED WITH TEA		COLOUR DIFFERENCE MEAN (ΔE)	MEAN DIFFERENCE	95% CONFIDENCE INTERVAL FOR MEAN DIFFERENCE		P-VALUE
			(Relative to Anolyte)			
BLEACHES	Anolyte	83.489646				
	Distilled water	79.967701	3.521945	3.270465	3.773425	<.0001
	Sodium hypochlorite	91.186857	-7.697211	-7.948691	-7.445732	<.0001
			(Relative to 30 °C)			
TEMPERATURE	30 °C	84.536055				
	40 °C	85.084818	0.548763	0.297284	0.800243	<.0001
	60 °C	85.023330	0.487275	0.235795	0.738755	0.0002
			(Relative to 9 minutes)			
TIME	9 minutes	85.130148				
	18 minutes	84.858425	-0.271723	-0.523202	-0.020243	0.0345
	45 minutes	84.655630	-0.474518	-0.725997	-0.223038	0.0003

the higher the temperature and longer the bleaching process, the better the stain was removed. It was also observed that in all the stains, except the tea stain, distilled water removed the stains less effectively than Anolyte and sodium hypochlorite bleaches. It can therefore be concluded that Anolyte will not reasonably be alternative bleach for stained cotton.

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