COMPARATIVE ANALYSIS OF STAIN REMOVAL METHODS USED ON COTTON FABRICS IN SOME SELECTED HOSPITALS IN NIGERIA

By

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M.Sc./SCIE/11832/2010-2011

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN TEXTILE SCIENCE & TECHNOLOGY

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AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

APRIL, 2014

DECLARATION

I hereby declare that the work in this research entitled "Comparative Analysis of Stain Removal Methods used on Cotton Fabrics in some selected Hospitals in Nigeria" has been conducted solely by me under the supervision of Dr. A. Danladi and Dr. A. Kogo in the Department of Textile Science and Technology. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

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CERTIFICATION

This thesis, entitled "COMPARATIVE ANALYSIS OF STAIN REMOVAL METHODS USED ON COTTON FABRICS IN SOME SELECTED HOSPITALS IN NIGERIA" by Adekunle Bolarinwa AJAPONNA, meets the regulations governing the award of degree of Master of Science (M.Sc.) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research is dedicated foremost to God Almighty who gave me the strength, knowledge and inspiration regarding this work.

This research work is equally dedicated my dear mother late Mrs. L. L. Alabi Ajaponna and my father in-law late Mr. P. O. Ucherewe for their affectionate love when alive. May their gentle souls rest in perfect peace.

ACKNOWLEDGEMENT

I sincerely express my profound gratitude to God Almighty who gave me the privilege and ability to write this research.

My gratitude also goes to my supervisor Dr. A. Danladi who has inspired and gave me that push even when it appears difficult for me to take a step further. Thank you for your patience, guidance and assistance.

My warm and hearty appreciation goes to my darling wife, for her entire commitment and support (emotionally, spiritually, and financially) to enable me complete this course of study with gladness. I am deeply grateful for this since not much can be accomplished alone.

My special thanks goes to Mr. Omata and Mr. Okeji who have given their very best in guiding and assisting me in the course of my laboratory work.

I appreciate my H.O.D., Department of Laundry & Linen Services, A.B.U. Teaching Hospital, Alh. T.S. Abdullahi for his timeless support and patience all through this programme.

My thanks go to my siblings- Deji, Gbolani, Goke, Sanya & Kemi. Also my colleague in the office, Mr. Enoch Adukwu for his support and encouragement all the way.

My appreciation also goes to the Management of A.B.U. Teaching Hospital, Zaria for given me the approval to embark on this programme.

Finally, my deepest thanks goes to my classmates in the course of this programme, God bless you all.

ABSTRACT

Some effect of repeated laundering processes with different practical formulations of stain removal methods of blood and urine stains from 3 healthcare institutions (Ahmadu Bello University Teaching Hospital- Zaria, Aminu Kano Teaching Hospital- Kano and National Orthopedic Hospital- Kano) were carried out. Physical fabric properties such as breaking load, breaking extension, percentage shrinkage, moisture content and moisture regain as well as colour fastness were analyzed with the hospital white (bed-linen) and green theatre linen made from 100% woven cotton fabrics. Analyses of the sample after the 3rd, 6th and 9th washing cycles were investigated. The colour change in shades were evaluated from visual observation using the AATCC Evaluation Procedure 2 Gray Scale for Assessing Staining, which showed a yellowing effect on the white hospital linen (ABUTH) as a result of the continuous bleaching action on the repeated blood stained linen with a change in colour of 4 after the 9^{th} wash. The breaking load values increased after every washing for all samples analyzed with the ABUTH hospital linen showing the highest breaking load values up to the 9^{th} wash. The percentage shrinkage values also showed an increase in the shrinkage properties up to the 9^{th} wash for all sample analyzed with the least shrinkage properties from the blood treated samples of the ABUTH hospital linen. The moisture content and moisture regain showed the highest percentage values with the blood treated samples of the ABUTH up to the 9^{th} laundering. These attributes, specifically on the blood treated hospital linen from ABUTH amongst other samples analyzed showed an unequal property along the length and breadth of the fabric to a point of which the fabric stability and functionality becomes compromised thereby degrading the fabric. This study may help to improve the blood stain removal methods and fabric performances in hospital laundering.

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CHAPTER ONE

1.0 INTRODUCTION

Removal of stains from clothes is necessary for proper care of the clothes and to increase the lifespan of the fabric. Healthcare linen can be subjected to a huge range of staining, including food, blood, urine, sweat and other body excretions so the laundry's success in producing clean, stain-free linen is a testimony to the effectiveness of the applied washing regimes (Ian, 2010).

1.1 The Washing Process (Laundering Regime)

The washing or cleaning process in a typical detersive system usually consists of the following sequence of operations (Omole, 1994);

I. The soiled substrate (fabric) is immersed or otherwise introduced into a large excess of the bath liquor. Sufficient liquor is used to provide a thick layer over the whole surface of the substrate. During this stage, air is displaced from the soil and substrate i.e. they become wetted by the bath.

II. The system is subjected to mechanical agitation, for example, rubbing or shaking, this provides shearing action which aids in separating soils and other dirt's from the substrate and dispersing them in the bath.

III. The fouled bath, carrying the removed soil and dirt is drained, wiped, squeezed or otherwise removed from the substrate.

IV. The substrate is rinsed free of the remaining fouled bath. This rinsing step can be quite important in determining the final cleanliness of the substrate.

V. The clean substrate is dried or otherwise brought to the desired finished state.

1.2 Soil Removal from Fabrics

All soils on fabrics should be treated gently as hard rubbing or wrong application of cleaning fluid can ruin the cloth. If the cause of the soil and the type of fabric on which it has occurred are known, it is more likely to be able to remove the soil successfully without damaging the fabric (Peter, 1993).

There are four basic methods of soil removing from fabric:

i. Absorbing

ii. Washing in water

iii. Use of solvents

iv. Bleaching

1.2.1 Absorbing

This is used to deal with wet soils spilled on the fabric and also to get rid of greasy particles on fur and other fabrics that cannot be washed. Typical absorbents are salts (absorbs urine and fruit-juice soil from carpets etc.) and French chalk or talcum (absorb grit and dirt from fur etc.).

1.2.2 Washing in water

Soil must be removed immediately with cold water; hot water should be avoided (i.e. cause soil to be more strongly held onto the fabric). The whole fabric is soaked in soap solution for washing.

1.2.3 Solvents

Solvents are used to remove soils caused by grease or oil. Many solvents can be employed and the most common ones being used are trichloroethane (sold as spot remover under various trade names), carbon tetrachloride, (white spirit, Acetone, acetic

acid, white vinegar, oxalic acid, lemon juice or 50% solution of citric or tartaric acid, fat, margarine or butter) used to soften tar or oil.

1.2.4 Bleaching

Two types of bleaches are employed in dirt removal. They are oxidizing and reducing bleaches. Oxidizing bleaches are the ones which destroy dirt's by oxidation, while reducing of bleaches destroy dirt's by reduction. Examples of oxidizing bleaches are hydrogen peroxide and chlorine bleach (usually containing sodium hypochlorite). While example of reducing bleaches is sulphurdioxide; bleaches of this type are mainly used by laundries and dry-cleaners (Peter, 1993).

1.3 Factors affecting Soil Removal

Before considering practical washing systems (which are usually quite complex and difficult to resolve), it is helpful to outline the various factors which determine the degree of soil removal, and also to see how soil is removed in various simplified model washing system (Perdue, 1970). These factors are:

i. Temperature of operation.

ii. Duration of each step in the washing system.

iii. Type of degree of mechanical action used.

iv. Concentration of liquid bath detergents in the washing systems.

1.3.1 Temperature of Operation

Practical washing with materials shows that at high temperature of washing at long cycle's causes excessively hard wrinkles and reduces the crease shedding properties. Some experiments carried out showed that the effect of temperature on various types of fabrics at a particular concentration of soap and detergent was done keeping

concentration and time constant. E.g. Increase in temperature increases the degree of mobility of the soap particles thus increasing the chances of breaking up the dirt's or soils (Perdue,1970).

1.3.2 Duration of Each Step in the Washing Systems

This is the time taken for the soil to be released from the fabric at a particular concentration of soap and detergent solution, Keeping temperature and concentration constants.

1.3.3 Concentration of Liquid Bath Detergent in Washing Systems

This is the percentage of detergents used to remove soil on each of the soil fabrics by varying the concentration and keeping time of washing and temperature of washing constants. The importance of concentration determination or detergency is that, it helps to know the exact quantity of detergents to be used in washing processes, when the quantities of the fabrics are known (Perdue, 1970).

1.4 Detergents

A detergent is a cleansing agent which exerts cleansing action on a material by helping the water to soak into the material quickly to make washing easier. The dirt is divided into little particles by the detergent and this can be more easily washed out of the material. The detergent also keeps the dirt suspended in the water and prevents it from settling on the fabric again. Any material which exerts a cleansing action is referred to as a detergent; thus water alone or indeed a solvent such as perchloroethylene can be called a detergent. Soap is the product of the reaction between caustic soda and a fat by a process known as 'saponification' while synthetic detergents are manufactured from organic chemicals, most of which come from petroleum sources.

1.4.1 Types of Detergents

There are different groups in which detergents can be classified, namely anionic detergents, cationic detergents, non-ionic detergents, synthetic or soapless detergents. The most important thing is to be able to select a suitable detergent for a particular purpose because if the wrong detergent is used for a particular fabric, it could damage it, ruin the colours or not clean it efficiently.

1.4.1.1 *Anionic Detergents*

The most common detergent/surfactants are the alkyl sulphates and the aryl alkyl sulphates. Alkyl sulphate is one of the first soapless detergent. These compounds possess many desirable features. They are approximately neutral in aqueous solutions; they lather and clean in alkaline, neutral in acid solutions. Most importantly, these anionic surfactants do not form scum in hard water because calcium and magnesium alkyl sulphates are soluble in water. The alkyl sulphonates ionize in a manner similar to soap and to the alkyl sulphates (Mittal, 1978). The molecule ionizes thus:

$$\underset{\substack{Sodium\ alkyl \\ benzene\ sulphonate}}{RC_6H_5SO_3Na} \overset{ionisation}{\Longleftrightarrow} \underset{Anion\ /\ Cation}{RC_6H_5SO_3^- + Na^+}$$

Surfactants of this type are almost biodegradable (that is broken up by the bacteria present in rivers and in the sewage works treatment) and are known as ‘soft’ detergents; this is advantage because detergents that are for washing should be soft and at least 90% biodegradable (Mittal, 1978).

1.4.1.2 *Cationic Detergents*

These materials are cation active that is to say that they ionize or dissociate, they do not hydrolyze and can be used effectively in hard water.

Ionization of this type of compound takes place as follows:

$$R_4N-Cl(inH_2o) \overset{ionisation}{\Longleftrightarrow} R_4N^+ \quad + \quad Cl^-$$
$$Substituted \qquad\qquad Cation/Anion$$
$$Ammonium\ Chloride$$

They have disinfecting powers and are sometimes used, especially in hospital launderettes for disinfecting articles which cannot be subjected to high temperatures (Mittal, 1978). Due to this, they are added to the final rinse of the washing process.

Another possible application for cationic substances in the laundry is as textile softening agents. 'Softening' in this context refers to the effect of producing a more bulky fabric with a softer handle than one, which has not been so treated. When used as softening agent the cationic substances are again added to the final rinse of the washing process, but in this case there is no need of restriction on the type of detergent used in the washes (Mittal, 1978).

1.4.1.3 *Non Ionic Detergent*

As the name implies these material do not ionize and therefore are extremely stable under any condition likely to be encountered in laundry processing, making them good wetting and emulsifying agents for stain removal processes (Barry, 1998).

1.4.1.4 *Synthetic or Soap Less Detergents*

During the Second World War when there was a shortage of oils and fats in Great Britain a considerable amount of work was done on the production of synthetic detergent

compounds. It was at this time these new detergents came into use in package domestic washing powders and as a result the general public became aware of the word detergent (Barry, 1998).

Unfortunately, modern advertisement with its somewhat outrageous claim has resulted in the public believing that what package detergent provides is the magical answer to successful washing of all types of textile materials. This often produces disastrous result, which sometimes land in the hands of the professional launderer. Worse still, the launderer is expected to work this 'magic' on wholly suitable textile materials.

Soapless detergents do not react with minerals in hard water. They are formulated with such ingredients as surfactants, which suspend dirt particles with reduced suds, builders, which prevent scum formation.

1.4.1.5 *Surface Active Agent*

These are compounds which when dissolved in water; in a very small amount considerably reduce the surface tension of water with respect to air or other substances. They are sometimes called surfactants. They have an organic body made of long molecular chains, which confer, to its nature. At the end of the body is a hydrophilic head. It includes soluble detergent in liquid medium, dispersing agents, foaming agents in penetrating agent and emulsifying agent (Encyclopedia, 1990)

(a) Dispersing agents: increase the stability of the dispersion of one liquid in another.

(b) Emulsifying agent: increase the stability of dispersion of two immiscible liquid phases.

(c) Foaming agents: increase the stability of suspension of gas bubbles in a liquid medium.

(d) Penetrating agents: increase the penetration of liquid medium into porous materials.

(e) Wetting agents: increase the spreading of a liquid medium on the surface (Mittal, 1978).

1.5 Cotton (Natural Fibre)

Cotton is the most versatile and the most used textile fibres. It is the cheapest natural fibres used in clothing applications. Cotton is attached to the seed of certain plant of genius 'Gossypium'. Cellulose regardless of source has been shown to consist of carbon (44.4%), hydrogen (6.2%), and oxygen (49.4%) which corresponds to an empirical formular of $(C_6H_{12}O_5)n$ thus, classifying it as a carbohydrate (Peter, 1993). Investigations have shown that hydrolysis of cellulose gives high yield of the sugar D-glucose [1] the yield of glucose varying with the conditions of hydrolysis. The long linear chain of cellulose permits the (-OH) group on each hydro glucose to interact with the hydroxyl group of adjacent chains through hydrogen bonding and van der waal attractions. These strong intermolecular forces between chains, coupled with the high linearity of the molecule, account for the crystalline nature of cellulose fibre. All cellulosic fibre are hydrophilic (water attracting) in character, they crease badly when washed except when treated with crease resist finish (Peter, 1993)

1.5.1 Physical and Mechanical Properties of Cotton Fabrics- Physical Properties

1.5.1.1 *Fabric Thickness*

It might be expected that the thickness of a fabric is one of its basic properties giving information on its warmth heaviness or stiffness in use. In practice, thickness measurement is rarely used as they are very sensitive to pressure used in the

measurement. Instead fabric weight per unit area is used commercially as an indicator of thickness.

Besides fibres, a fabric encloses a large amount of air, which among other things, is responsible for its good thermal insulation properties. When a fabric is compressed, the space between the fibers is decreased until they eventually come into contact with one another. The stages in the deformation of a fabric have been identified (Matsudaira and Qin, 1995). Firstly, the individual fibers protruding from the surface are compressed. The resistance to compression in this region comes from the bending of the fibres. Secondly, contact is made with the surface of the yarn, at which point the inter-yarn and/or inter-fiber friction provides the resistance to compression until the fibres are all in contact with one another. In the third stage the resistance is provided by the lateral compression of fibers themselves.

1.5.1.2 *Fabric Shrinkage*

The product of textile manufacture, whether yarn or fabric, is stable only to moderate degree. The instability may manifest itself in shrinkage or in extensibility, and may assume such properties that garments become unsuitable for further use as soon as they are laundered or dry-cleaned, and sometimes even during wear.

$$Mathematically, shrinkage \ \frac{L_1 - L_2}{L_1} \times 100\%$$

$$Where \quad L_1 = Initial\ length\ of\ fabric$$

$$Where \quad L_2 = Final\ length\ of\ fabric$$

1.5.1.3 *Fabric Handle*

Fabric uses can be roughly divided into industrial, household and apparel. Fabric for industrial use can be chosen on straight forward performance characteristics such as tensile strength, extension and resistance to environmental attack. However, fabrics intended for clothing such as cotton fabrics have less emphasis placed on their technical specification and more on their appearance and handling characteristic such as luster, smoothness or roughness, stiffness and draping quality. 'Handle', the term given to properties assessed by touch or feel depends upon subjective assessment of a fabric by a person. Terms such as smooth, rough, stiff or limp depends strongly on the type of fabric being assessed, for instance the smoothness of a worsted suiting is different in nature from that of these properties. Attempt has been made over the years to devise the objective tests to measure some or all of the factors that make up handle. Fabric stiffness and drape were some of the earliest properties to be measured objectively (Pierce, 1980).

1.5.2 Mechanical Properties

1.5.2.1 *Breaking Strength*

This is the maximum tensile force extending a test piece to breaking point. The force at which a specimen breaks is directly proportional to its cross sectional area, therefore when comparing the strength of different fibres, yarns and fabrics, allowance has to be made for this (Morten and Hearle, 1993).

1.5.2.2 *Stress*

Stress is a way of expressing the force on a material in a way that allows for the effect of the cross sectional area of the specimen on the force needed to break it.

$$Stress = \frac{Force\ applied}{Cross\text{-}sectional\ area}$$

In the case of textile materials, the cross sectional area can only be easily measured in the case of fibres with circular cross section. The cross section of yarns and fabrics contain an unknown amount of space as well as fibres so that in these cases the cross sectional area is not clearly defined. Therefore stress is only used in limited number of application involving fibers.

1.5.2.3 *Specific (Mass) Stress*

Specific stress is a more useful measurement of stress in the case of yarns as their cross-sectional area is not known. The linear density of the yarns is used instead of the cross sectional area as a measure of yarn thickness. This allows the strength of yarns of different linear densities to be compared.

$$Specific\ stress\ = \frac{Force}{Linear\ density}\left(\frac{N}{Tex}\ or\ MN/Tex\right)$$

1.5.2.4 *Breaking Length*

Breaking length is an older measure of tenacity and is defined as theoretical length of a specimen of yarn whose weight would exert a force sufficient to break the specimen. It is usually measured in kilometers.

1.5.2.5 *Elongation*

Elongation is the increase in length of the specimen from its starting length expressed in units of length. The distance that a material will extend under a given force is proportional to its original length; therefore elongation is usually quoted as strain or percentage extension. The elongation at maximum force is the value some often quoted (Morten and Hearle, 1993), (McIntyre and Daniels, 1995).

1.5.2.6 *Strain*

The elongation that a specimen undergoes is proportional to its initial length. As a fraction of the original length.

$$Strain = \frac{Elongation}{Initial\ length}$$

1.5.2.7 *Extension Percentage*

This measure is the strain expressed as a percentage rather than a fraction.

$$Extension = \frac{Elongation}{Initial\ length} \times 100\%$$

Breaking fraction is the extension percentage at breaking point.

After care treatment such as laundering affects the breaking strength of cotton fabric in the fabrics are relaxed as a result of the mechanical application of laundering. Therefore, elongation at break or break elongation increase with increase in cotton fabric laundering.

1.5.3 Tear Test

A fabric tears when it is snagged by a sharp object and the immediate small puncture is converted into a long rip by what may be very small extra effort.

Measuring Tear Strength: The fabric property usually measured is the force required to propagate an existing tear and not the force required to initiate a tear as this usually requires a cutting of thread. As part of the preparation of the fabrics specimens, a cut is made in them and then the force required to extend the cut is measured. This is conveniently carried out by gripping the two halves of the cut in a standard tensile tester. The various tear test carried out in this manner differ mainly in geometry of the

specimen. The simplest is the rip test where a cut is made down the centre of a strip of fabric and the two tails pulled apart by a tensile tester.

1.5.4 Abrasion Resistance

Fabric abrasion has been defined as a simply rubbing action (Booth, 1968).It is an aspect of wear and rubbing away of the components fibres and yarns of the fabric.

Hamburger (1994) states that abrasion is a series of repeated stress application, usually caused by forces of a relatively low order of magnitude, which occur many times during the life span of the material. The ability of a material to absorb energy repeatedly by means of low load deformation and recovery is related to abrasion resistance.

1.5.4.1 *Factors Affecting Abrasions Resistance*

The evidence concerning the various factors that influence, the abrasion resistance of fabrics is contradictory. This is because experiment has been carried out under widely different conditions in particular using different modes of abrasion. The results are not comparable and often opposing results have been reported. The factors that have been found to affect abrasion include the following (Galbraith, 1975), (Birds, 1984).

- *Fiber Type*:

It is thought that the ability of a fiber to withstand repeated distortion is the key to its abrasion resistance. Therefore high elongation, elastic recovery and work of rapture are considered to be more important factors for a good degree of abrasion resistance in fibre. Nylon is generally considered to have the best abrasion resistance. Cotton has a moderate abrasion resistance.

- *Fiber properties*:

One of the results of abrasion is the gradual removal of fibres from the yarns. Therefore factors that affect the cohesion of yarns will influence their abrasion resistance. Longer fibres incorporated into a fabric confer better abrasion resistance than short fibers because they are harder to remove from the yarns. For the same reason filament yarns are more abrasion resistant than staple yarns from the same fibre.

- *Fabric Structure*:

The crimp of the yarn in the fabric affects whether the warp or the weft is abraded the most, Fabrics with crimp evenly distributed between warp and weft give the best wear because the damage is spread evenly between them. If one set of yarns is predominately on the surface then this will wear most; this effect can be used to protect the load-bearing yarns.

- *Yarn twist*:

There has been found to be an optimum amount of twist in a yarn to give the best abrasion resistance. At low-twist factors fibers can easily be removed from the yarn so that it is gradually reduced in diameter. At high twist level, fibres are held more tightly but the yarn is stiffer so it is unable to flatten or distort under pressure when being abraded. It is this ability to distort that enables the yarn to resist abrasion.

1.5.5 Fabric Drape

Drape is the term used to describe the way a fabric hangs under its own weight. It has an important bearing on how good a garment looks in use. The draping qualities required from a fabric will differ completely depending on its end use; therefore a given value for drape cannot be classified as either good or bad. Knitted fabrics are relatively

floppy and garment made from them will tend to follow the body contours. Woven fabrics are relatively stiff when compared with knitted fabrics so they are used in tailored clothing where the fabrics hang away from the body and disguise its contour. Measurement of fabric drape is meant to assess its ability to hang in graceful curves.

In drape test, the specimen deforms with multi-directional curvature and consequently the results are dependent to a certain amount upon the sheer properties of the fabric. The results are mainly dependent however, on the bending stiffness of the fabric (BS 5058). In crusick drape test, a circular specimen is held to its area.A value known as the drape coefficient, F, is determined by:

$$Drape\ of\ coefficient\ = \frac{Weight\ of\ shaded\ area\ (M_2)}{Weight\ of\ complete\ paper\ ring\ (M_1)} \times \quad 100\%$$

$$Drape\ of\ coefficient\ = \frac{M_2}{M_1} \quad \times 100\%$$

The higher the drape coefficient, the stiffer is the fabric.

1.6 Stains / Soils

1.6.1 Blood

Blood is the red fluid that oozes out of the body when sustained with a cut or deep injury. The composition of the blood is quite complex. Blood is composed of straw-coloured liquid called plasma which contains suspended cells. The different specialized cells found in blood are; Red blood cells, White blood cells and Platelets. Approximately 90% of plasma is water-blood`s solvent with the rest composed of dissolved substance, primary proteins (e.g albumin, globulin and fibrogen). Plasma typically accounts for 55% by volume of blood and of the remaining 45% the greatest contribution is from the red blood cells (Membranes, 2011).

1.6.2 Urine

Urine is composed mostly of water and organic wastes as well as some salt. The composition of urine can vary according to diet, time of the day, and diseases. In one measure the make-up of urine is 95% water and 5% solid. In terms of organic wastes (per 1,500 ml), urine containing 30g of urea, 1-2g each of ceratinine and ammonia, and 1g of uric acid. In terms of salt or ions, 25g per 1,500 ml of urine contain the positive ions of sodium, potassium, magnesium and calcium, as well as the negative ions of chlorine, sulphate and phosphate (Answer.com, 2011).

1.7 Statement of the Research Problem

"Removing stains can sometimes seem like a complex algebra problem". A Hospital's textile or linen will often become soiled with blood and other organic stains and the longer the blood stains are left; the more difficult it will be to remove them. Ordinarily, when someone gets blood on their clothing at home, they will usually sluice it or rinse off before it dries. In a hospital, blood soiled fabrics would rarely be sluiced immediately and the stain may not be treated until it reaches the laundry which may be several days later. By this time the blood would have dried onto and into the fabric and will no longer respond to normal wash. This means that launderers need to resort to more drastic measures if they are going to remove the blood successfully and return the item to the user in a stain free condition. Blood which is one of the prominent coloured stains on hospital linen is highly contagious and most proteins will set permanently if washed at high temperature at any stage as the higher temperature will "cook" the protein and make it difficult if not impossible to remove. Blood albumin and organic iron sometimes produce stain that are never completely removed, but only lightened.

Effect of urine in this case is predominantly on the bed linen. Urine discolours cotton white sheet and cotton blend fabrics. Urine stains are especially visible on white fabrics. Hot and warm water cause coagulation in the fibres of the material, making the stain more difficult to washout. Ammonia is also a common cleaning agent, which also happens to occur naturally in urine. However, when chlorine from bleach mixes with ammonia, it can create a noxious gas (mustard gas). This research work intends to study the cleaning processes of these organic stains and the effect of the methods on the properties of hospital textile linen.

1.8 Justification of the work

Procuring hospital textile linen by the hospital management may be capital intensive and uneconomical, if the linens are poorly managed. From this research study, assessing the characteristic changes in the performance of each fabric properties from the various stain removal methods may help to define the quality of the fabrics after some use. Hence, from the results obtained and where minimal effects occur on the fabric, a more sustainable method of upholding hospital spotted linen can be developed enabling a valuable fabric care handling with minimal damage.

1.9 Research Objectives

The aims and objectives of the research are;

1. To investigate the effect of laundering regime of three healthcares tertiary Hospitals with respect to their methods of organic stain removal for blood and urine.
2. To determine the effects of these procedures on the properties of cotton fabric.
3. To suggest improved method of stain removal with minimal degrading effects on the fabric properties.

1.10 Scope of Study

The mechanical and physical properties of the samples (theatre outfits and bed linen) used in this work were studied before and after laundering. The three tertiary healthcare institutions are;

- Ahmadu Bello University Teaching Hospital-Zaria.
- Aminu Kano Teaching Hospital-Kano, and
- The National Orthopedic Hospital-Kano.

This research was limited to the use of the fabric properties of each hospital, the available detergents and chemical components (reagents) used in each case, the laundering regime practiced in each hospital. This research also limits its study only on blood and urine amongst other organic stains. A standard drying method (Tumble drying) and drying time was considered for all washings.

CHAPTER TWO

2.0 LITERATURE RIVIEW

Some studies have demonstrated success on the effect of repeated laundering processes with two commercial (liquid detergent- Lira and Ariel) detergents with different formulations on structural characteristics such as weight per unit area, fabric thickness, course and wale density, stitch density and dimensional stability as well colour fastnesss of the single knitted fabrics made from 100% cotton of two different grades after some finishing process, first and fifth washing cycles were investigated of which the Lira showed more homogenous characteristics giving knitted fabrics with better dimensional stability than the Ariel (Emilija and Biljana, 2011). Another study on the effect of repeated laundering on some physical and mechanical properties of cotton fabric has been reported and the relationship between the number of laundering cycles and several key fabric performance parameters have been quantitatively investigated (Ogri, 2009).

During laundering, a fabric can be subjected to complex thermal, mechanical and physical actions in both wet and dry conditions and as a result the textile products must be able to withstand a reasonable number of laundering cycles. For shirts, the average life expectancy is approximately 30 to 40 laundering (Shurkian, et al 2002). Also for hygienic reasons garment need to be washed. Other studies on the effects of various home laundering practices on the dimensional stability, wrinkling, and other properties of plain woven cotton fabrics were carried out. The long-term objective of the investigation was to develop laundering equipment and regimes that reduce or delay the perceived negative effects of laundering (Higgins, et al 2003).

Today's hospital is not only aware of the style and comfort of the cotton fabrics, but also of their care and durability. With the rising demands for the cotton fabrics, demand in terms of dimensional instability, shrinkage and colour fading, in contrast to its excellent attributes, are the most critical quality problems after repeated laundering. Fabric performance is influenced by a number of variables that occur both in pre-consumer and post-consumer periods. Fibre quality, yarn formation, fabric construction, textile wet processes, and in this case hospital washing processes can all have influence on hospital fabric performances. Organic stains in the hospital – principally blood and urine – which are mostly protein can set permanently if the washing process exceeds 39^0C at any stage as the higher temperature will effectively "cook" the protein and make it very difficult – if not impossible to remove. In this case, it is necessary to monitor the re-wash and classify it according to the type of stain and treatment needed (Ian, 2010). Hospitals methods of stain removal process for blood and urine and the laundering regimes may alter a major role in the ability to retain hospital's bed linen and theatre outfit fabric performance.

From the review of published literatures, efforts to unearth evidences on stain removal methods and their effects on some properties of cotton fabric with respect to the laundering regime of some selected hospital laundries are yet to be published.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

Three samples each of white hospital linens and green theatre outfits respectively were obtained from three tertiary healthcare hospitals namely:

1. Ahmadu Bello University Teaching Hospital, Shika- Zaria. (A.B.U.T.H.).
2. Aminu Kano Teaching Hospital, Kano. (A.K.T.H.)
3. National Orthopedic Hospital, Kano. (N.O.H.)

The Samples were 100% woven cotton fabrics.

3.1.1 Chemicals

- Synthetic Powdered Detergent (Ariel)
- Cationic Powdered Detergent (Sigma-aldrich)
- Water
- Human blood
- Urine
- Hydrogen Peroxide 3.5% w/v (house-hold brand)
- Ammonia Solution 3.5% w/v (house-hold brand)
- Sodium Hypochlorite 3.5% w/v (house-hold brand)

3.1.2 Apparatus and Equipment

- Kelvinator washer/dryer combo 10.1kg (model number: MET1041ZAS2)
- Digital weighing balance
- Instron tensile tester (model 1025)
- Hotbox oven
- Gray Scale for assessing staining

3.2 Methods

Multiple squares shapes of 20 x 20cm of the linens were marked and labeled stained/treated and unstained/untreated. Samples of the human blood and urine were stained on the portions marked stained/treated of the linen and exposed for another 24hours. The marked portions of the blood and urine were categorically labeled for proper identification.

3.2.1 Laundering Regime 1

These samples were collected after 24 hours and laundered separately (according to similarity of stains) in the Kelvinator washer-extractor machine with a break-wash for 5-7 minutes by the action of 60g of synthetic detergent (Ariel) with 150ml of sodium hypochlorite bleach in a volume of 50 litres of water at cold wash. The samples were rinsed with sufficient water and prepared for regular wash. The regular wash was laundered with 120g of cationic detergent (Sigma-aldrich) in 50 litres volume of water at room temperature. This is laundered for 30 minutes and rinsed. A second rinse in water was carried out followed by the action of the hydro-extractor. The samples were then spread on the spotting tables for further treatment regarding stain removals.

3.2.2 Stain Removal Methods

AHMADU BELLO UNIVERSITY TEACHING HOSPITAL (ABUTH), ZARIA:

For the above hospital, the Fe^{2+} residual spotted areas of the blood stained white hospital linen indicated a deep brown colouration which were treated with hydrogen peroxide followed by the action of the ammonia solution; this gives rise to an effervescence reaction with a pungent odour. This was allowed to stay for another 5-7 minutes. The urine marked areas of the linen were not treated with any reagent since there were no residual stains on the linens after washing. The blood stained green theatre

linen was equally not treated with any reagent as the stains were completely washed off with no residual stains.

AMINU KANO TEACHING HOSPITAL (AKTH), KANO:

These samples were laundered as above but the blood stained linens were treated solely with sodium hypochlorite bleach and allowed to stay for 5-7 minutes.

NATIONAL ORTHOPEDIC HOSPITAL (NOH), KANO:

For this case, the blood stained linens were treated with hydrogen peroxide followed by sodium hypochlorite bleach and left for 5-7 minutes.

3.2.3 Laundering Regime 2

Further washings were carried out on the blood stained samples of each hospital after applying the reagents with 35g of synthetic detergent (Ariel) at cold wash and rinsed twice. The samples were dried in the Kelvinator dryer machine at 65-75^{o}C for 45 minutes. This procedure was carried out for all the nine laundering cycles, after which marked portions of the treated and untreated samples were removed after the 3rd, 6th and 9th wash respectively for analysis.

3.3 Determination of Fabric Properties

The BS EN 13934-1 method was used to determine the maximum force and elongation at maximum force for each sample using a strip method in equilibrium with the standard atmosphere for testing, and of test specimen in the wet state. By this principle, two sets of test specimen (quantity 5 per set): one in the warp direction and the other in the weft direction at a dimension of 10cm x 2.5cm, gauge length of 6.7cm and cross head speed of 50mm per minute were used with the Instron Tensile Tester (model 1025). The maximum load was 50kg for all tests and the rate of extension was 25%.The test specimen was fixed on the clamp and the upward button was pressed until the sample

break. The rapid downward movement button was pressed for a quick return for another sample to be clamped. Two readings were taken and recorded for each sample (in both warp and weft direction) for breaking load and breaking extension. The extension at break was calculated using the formular below:

$$Specimen\ elongation = \frac{Extension\ at\ break}{Original\ length} \times\ 100\ \%$$

3.4 Determination of Moisture Content and Moisture Regain (Physical Properties)

The samples of the treated and untreated fabrics were cut into 7cm × 7cm and weighed and dried in an oven temperature of 75^0C for 15 minutes, followed by cooling for 10 minutes and then weighed again. The steps were repeated until the weight remained constant. The moisture regain of the test specimen were expressed as percentage loss in weight of the final oven dry weight. (Booth, 1968)

3.5 Determination of Percentage Shrinkage (Physical Properties)

The initial length of the treated and untreated samples was measured before initial laundering. Final lengths of the samples were considered in warp and weft direction after the 3^{rd}, 6^{th}, and 9^{th} laundering cycles. The percentage shrinkage was then determined by finding the differences of the initial and final length using the formular below:

$$Percentage\ Shrinkage\ =\ \frac{Initial\ length - Final\ length}{Initial\ length} \times\ 100\ \%$$

3.6 Determination of Colour Fastness

The AATCC Evaluation Procedure 2: Gray Scale for Staining was determined. This evaluation method describes the use of a Gray Scale for evaluating staining of unstained textiles resulting from colourfastness tests. The original piece of all sample, untested and tested (treated) specimen side by side in the same plane and going in the same direction in the Colour Matching Cabinet so it can be viewed at a 45˚angle. The Gray Scales were placed along the edges of the two fabrics, tested and untested. These were then compared by visual differences between the two fabrics to the differences represented by the Gray Scale. The grades were determined by figuring out the grade that corresponds with the most appropriate change in colour. A grade of 5 is given only when there is no perceived difference in colour or contrast between the original and the tested specimen.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Effects of Washing Cycles on Breaking Strength- Hospital linen.

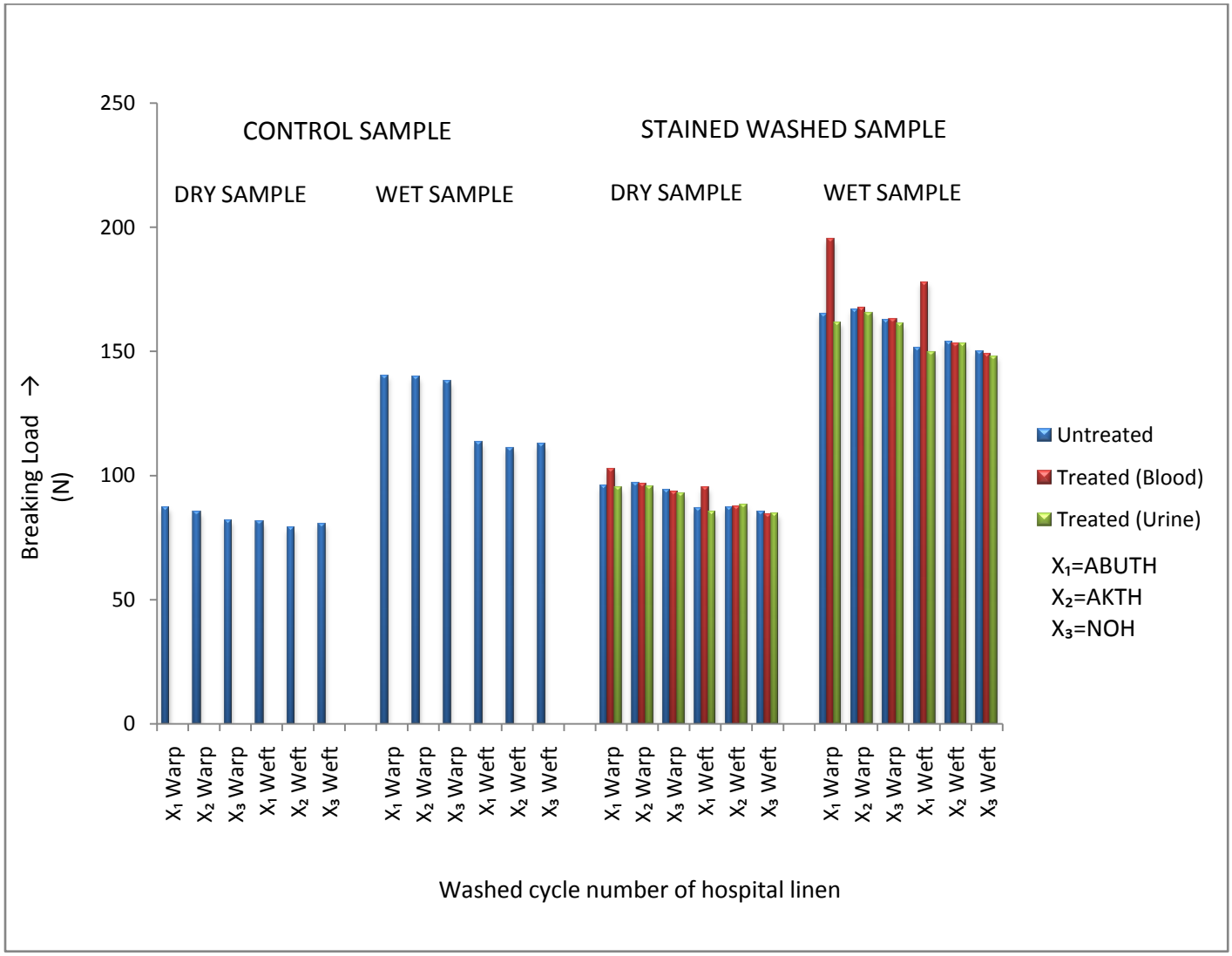


Fig. 3.3.1: Effect of third wash of hospital dry and wet linen on breaking load.

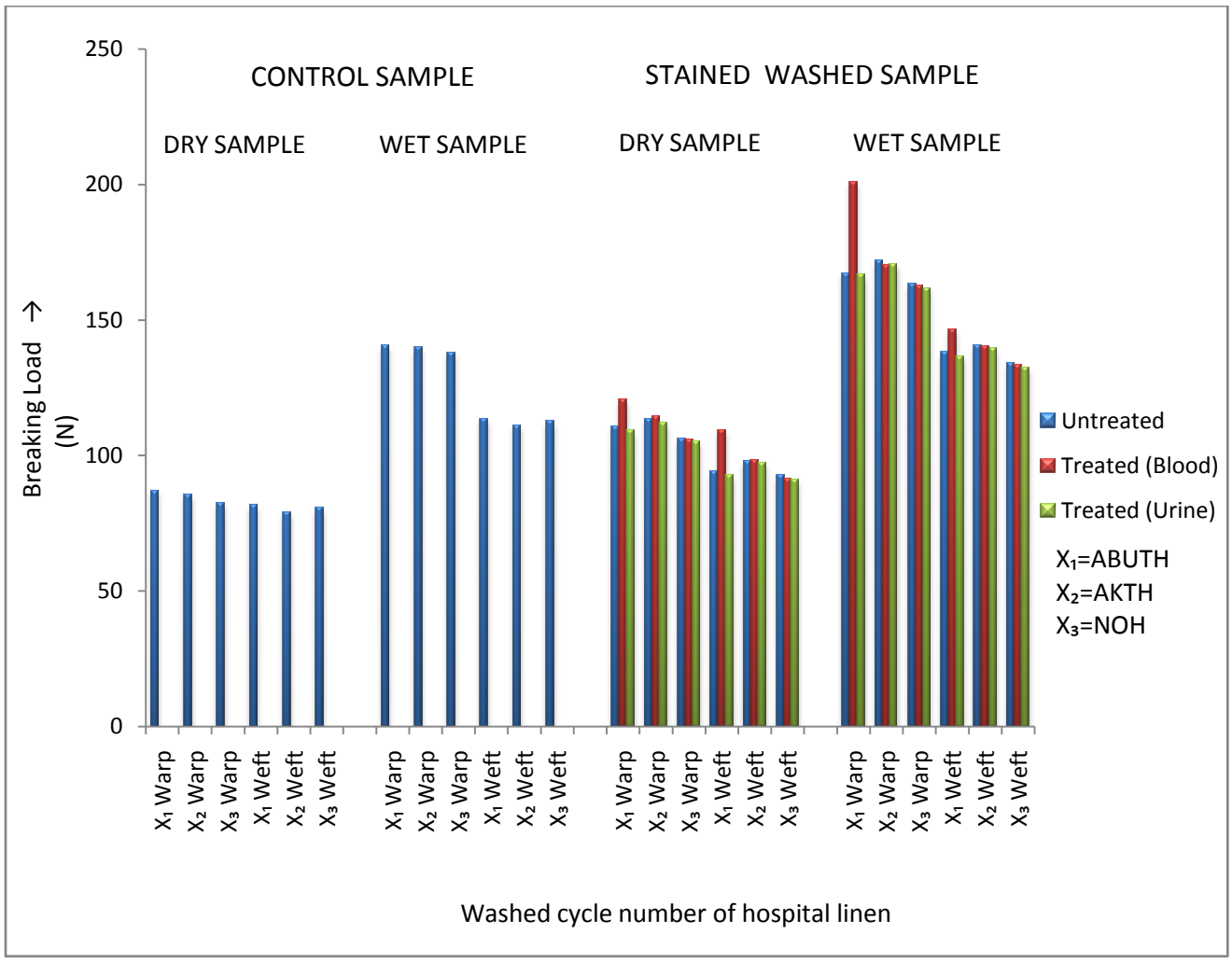


Fig.3.3.2: Effect of sixth wash of hospital dry and wet linen on breaking load.

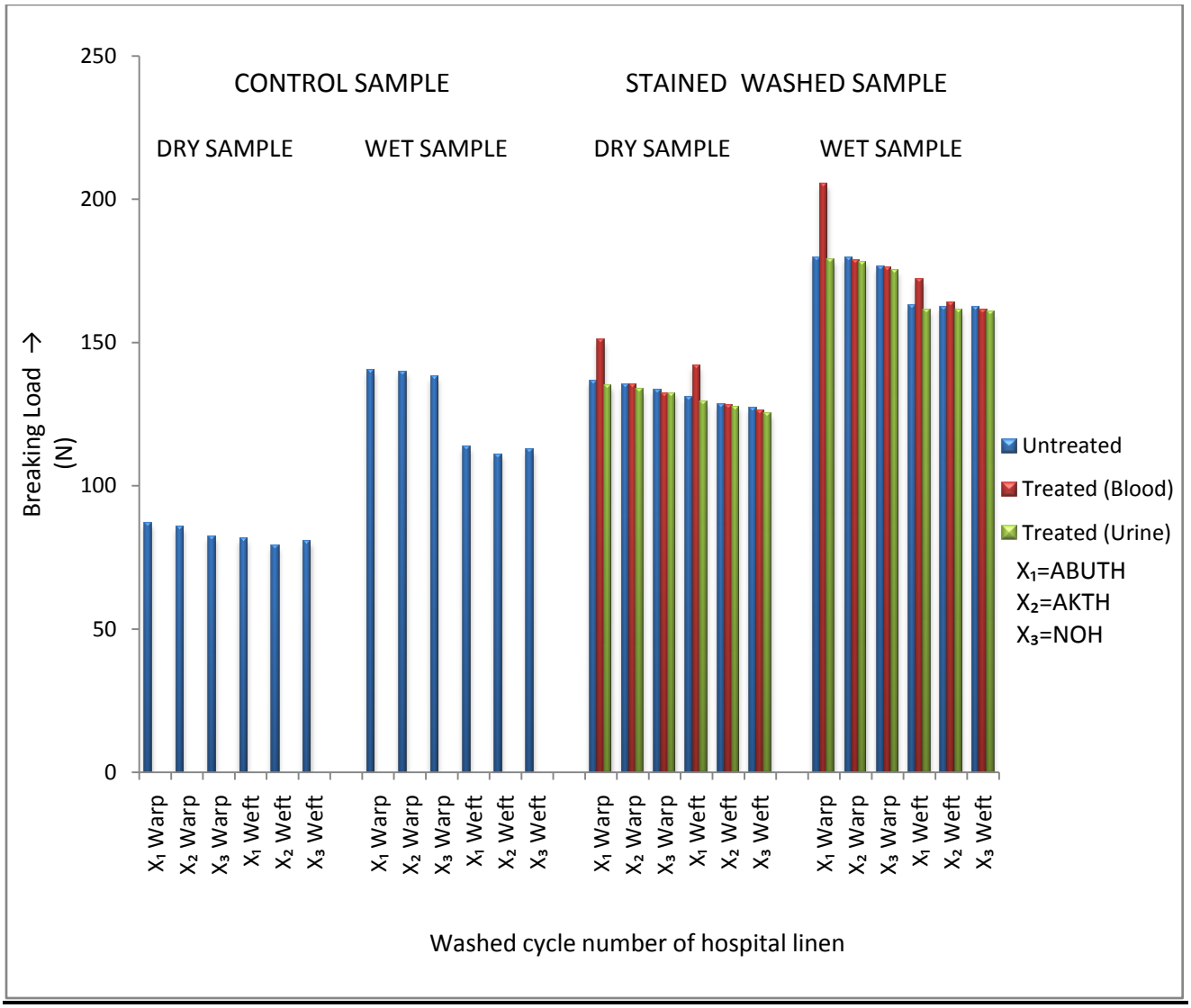


Fig. 3.3.3: Effect of ninth wash of hospital dry and wet linen on breaking load.

The control samples in the figures 3.3.1, 3.3.2 and 3.3.3 indicate higher breaking load values in the warp direction of the dry and wet samples than the weft direction of the dry and wet samples. Graphically, it also applies that as the washing cycle's increases from the 3rd, 6th and 9th the breaking load of the control sample (Untreated) also

increased. This could be as a result of the shrinkage property of the cotton fabric. This relaxation shrinkage could be caused by the tension applied to the yarns and fabrics during construction, as this tension is released when the fabric is washed causing it shrink to its natural size (Charles, 2010).

It is evident from the figures 3.3.1, 3.3.2 and 3.3.3 that there are higher breaking load properties in the blood treated samples from ABUTH. This could be as a result of the combination of the stain removal reagents by the action of the hydrogen peroxide and the liquid ammonia. The other hospital samples show about an equal breaking load values.

Also the figures show the effect of a graphical representation for the stained dry and wet linens of the 3^{rd}, 6^{th} and 9^{th} wash. This illustration shows that as the fabric undergo more cycles of laundering up to the ninth wash, the breaking load increases. This increase in strength may be as a result of the shrinkage of fabrics caused by relaxation during laundering. Shrinkage makes cotton fabric tighter, thicker and heavier. Thus, as the fabric laundering cycle increases, the strength of the fabric gradually increases up to the ninth wash. The assessment of the breaking load properties of textile materials is an important aspect of textile testing and indicates that strength is of great importance in fabric analysis for the end-use requirement (Booth, 1968).

The breaking load is often defined as the maximum load applied to a specimen in stretching it to rupture while the extension at this breaking load is referred to as the breaking extension (B.S. Handbook, 1974). The load-extension characteristics of a fabric are important in indicating the changes that occur when a fabric is subjected to a certain

load. Thus, the strength of yarn and other additional factors contributes to the breaking load of a fabric.

Breaking load alone, though of great importance is not a decisive factor in the performance of textile materials and no definite conclusions can be drawn from breaking load figures without reference to other equally important physical properties. As a result of the assessment of the wet-samples having a higher breaking load property than dry sample, this is due to the presence of moisture in the fabric from the hygroscopic nature of cotton fibre which causes them to swell when soaked in water during washing. This is due to the fact that those cellulose chains within cotton fibres are held in place by hydrogen bonding (Joseph, 1986). The presence of hydrogen bonding in the structure of the cellulose allows cotton to resist slippage during an applied force (tensile property) especially when wet. It is a good hydrophilic fibre because of the presence of hydroxyl group on the glucose rings. The presence of these groups, as well as its amorphous content enables cotton to bond well with water (Hatch, 1993). This swelling is accompanied by shrinkage in fibre length. There are non-uniform breaking load properties in the warp and weft direction of the blood stained samples compared with the untreated and urine stained samples of the various hospitals linens.

4.2 Effects of Washing Cycles on Breaking Extension- Hospital linen.

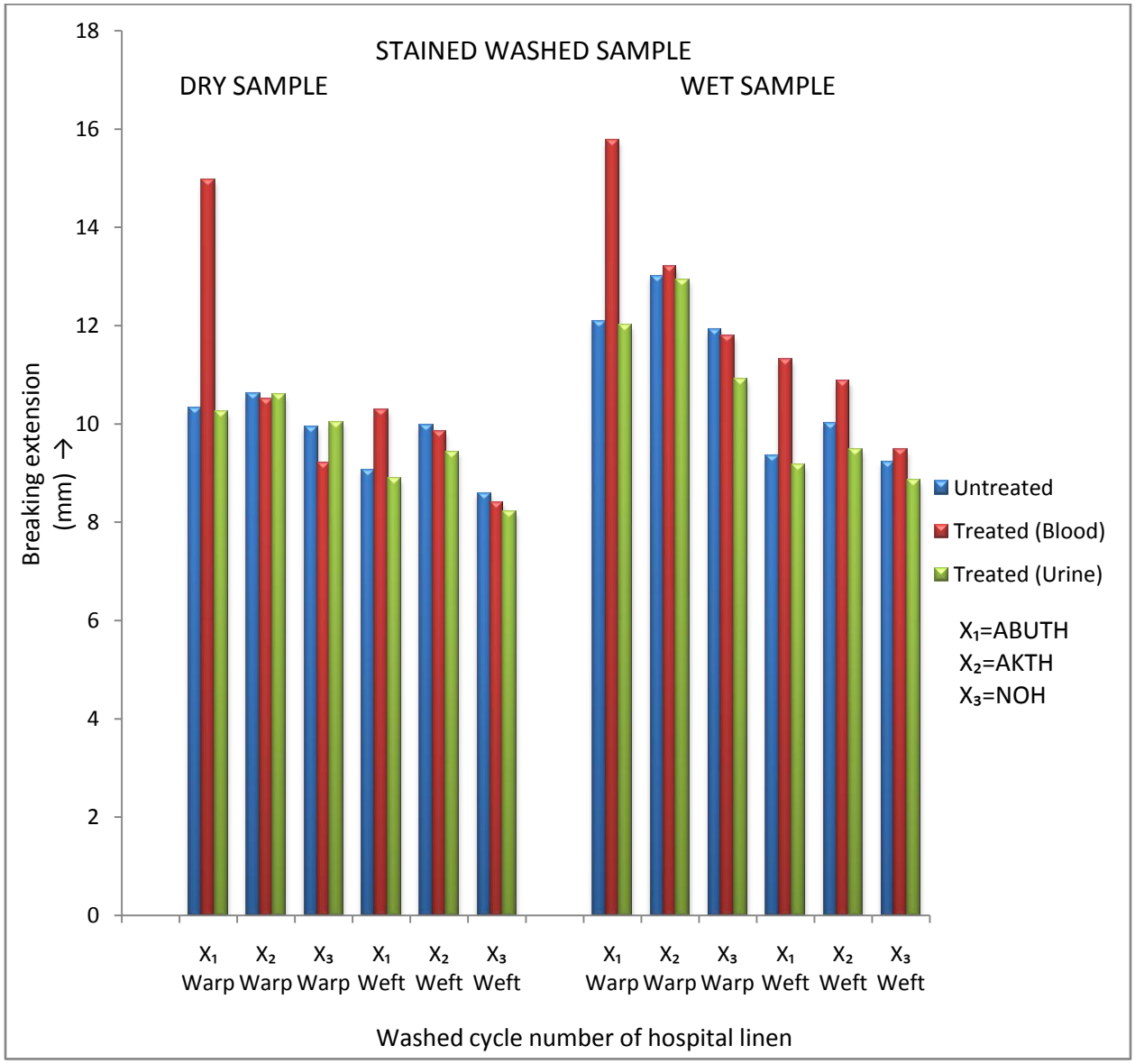


Fig. 3.3.4: Effect of third wash of hospital dry and wet linen on breaking extension.

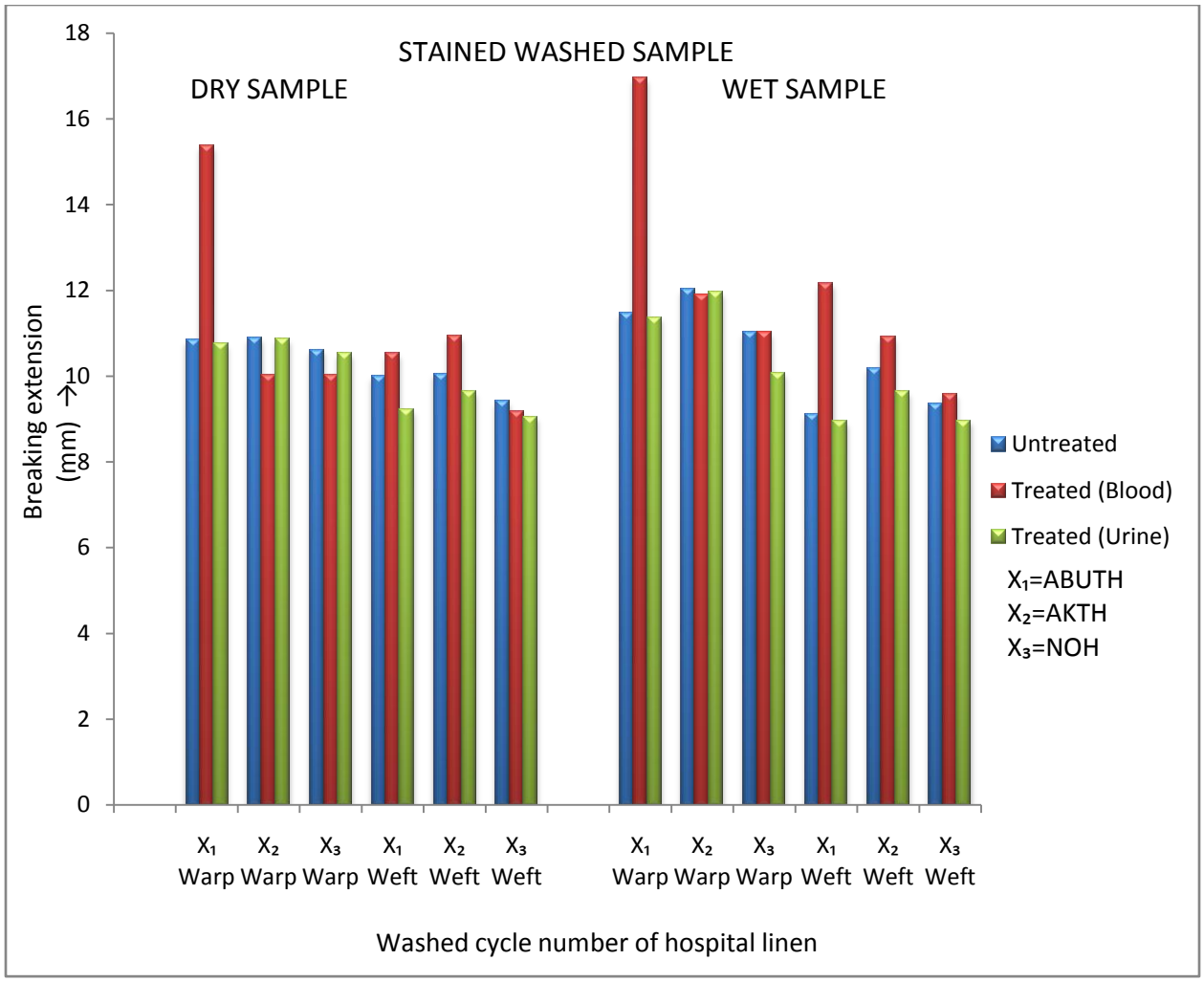


Fig. 3.3.5: Effect of sixth wash of hospital dry and wet linen on breaking extension.

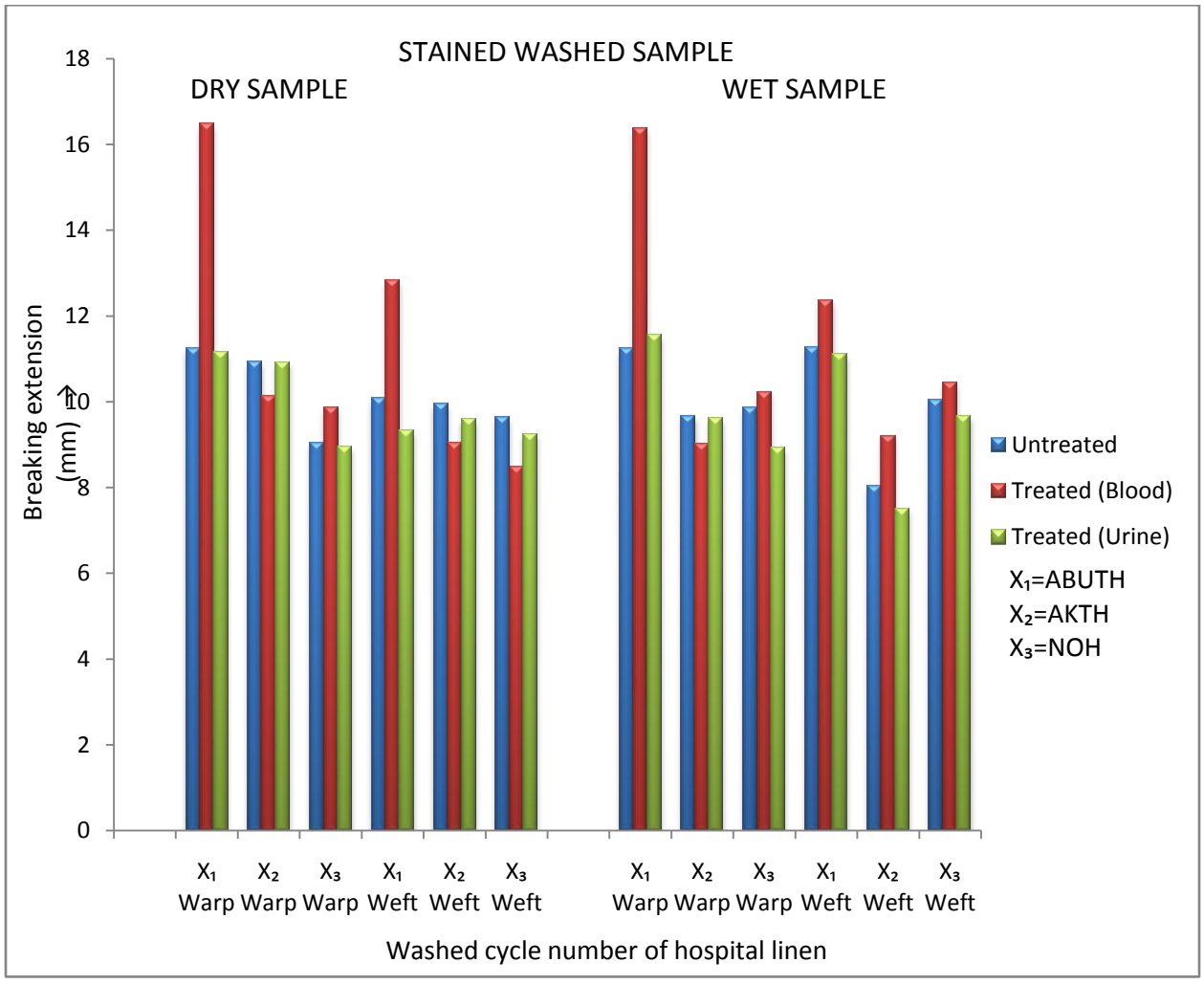


Fig. 3.3.6: Effect of ninth wash of hospital dry and wet linen on breaking extension.

For extension at break, blood treated samples from ABUTH has the highest extension at break in both warp and weft direction when compared with the untreated (control sample) and urine treated samples from figures 3.3.4, 3.3.5 and 3.3.6. The dry samples has the least extension at break in both warp and weft direction when compared

with the wet samples especially after the 3rd and 6th washings. Breaking extension is the percentage at which fabric stretch before breaking on application of force (Moji, 2000). Hence, the graph in figure 3.3.6 shows about the same breaking extension value after the 9th wash for the dry and wet blood stained samples of ABUTH both in the warp and weft direction; also a decrease in value for the breaking extension of the control, blood and urine samples for AKTH in the dry and wet condition of the warp and weft direction when compared with the breaking extension values of the 3rd and 6th washings. While all samples (control, blood and urine) for the NOH shows about the same breaking extension value for both dry and wet samples in the warp and weft direction for all washings.

From tables 1-14, it is evident that the strength in the warp direction is higher than the weft direction for almost all samples analyzed; this may be due to the fact that warp yarns carry a higher yarn linear density than the weft yarns.

4.3 Effects of Washing Cycles on Breaking Strength- Green theatre linen.

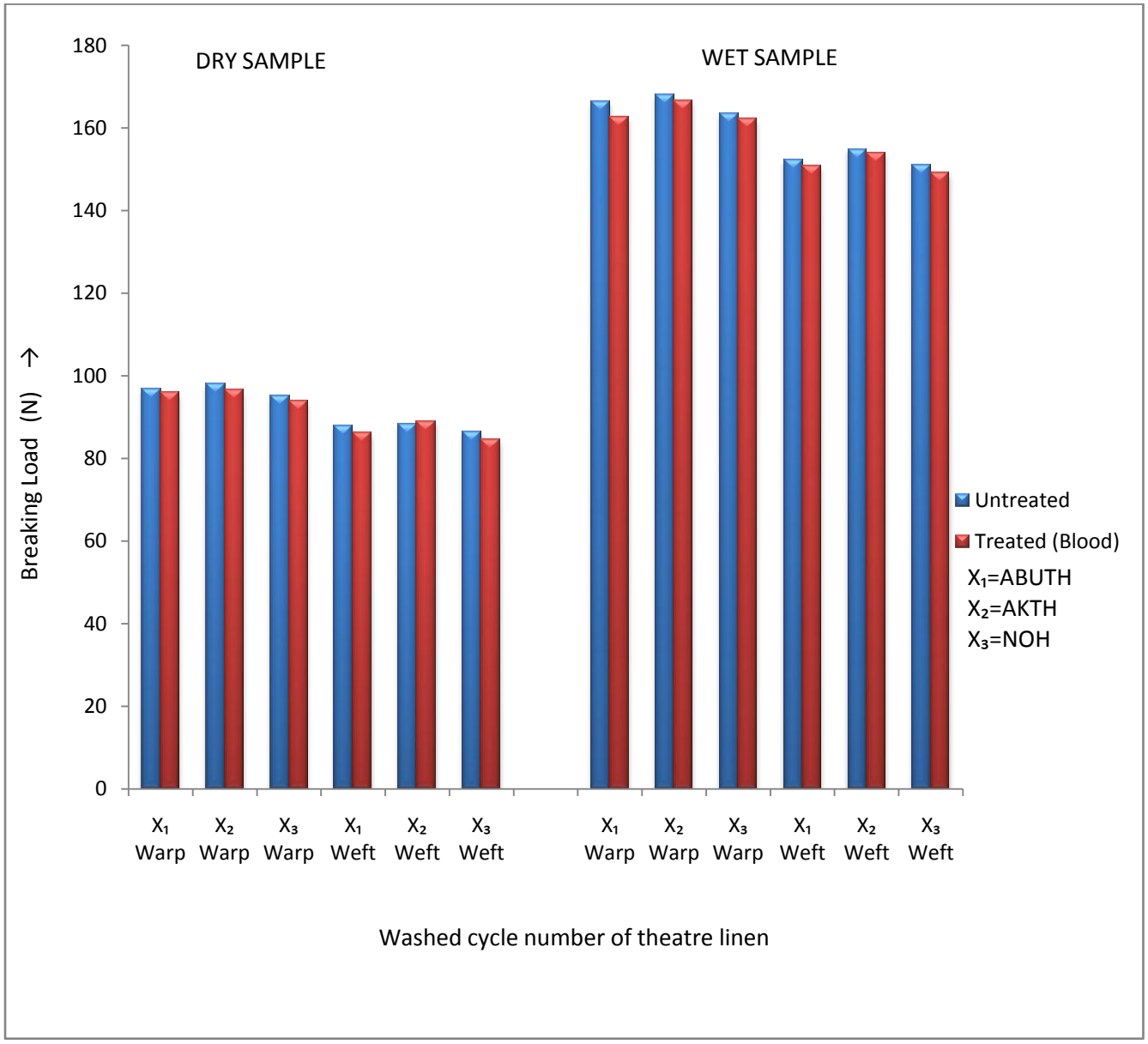


Fig. 3.3.7: Effect of third wash of theatre dry and wet linen on breaking load.

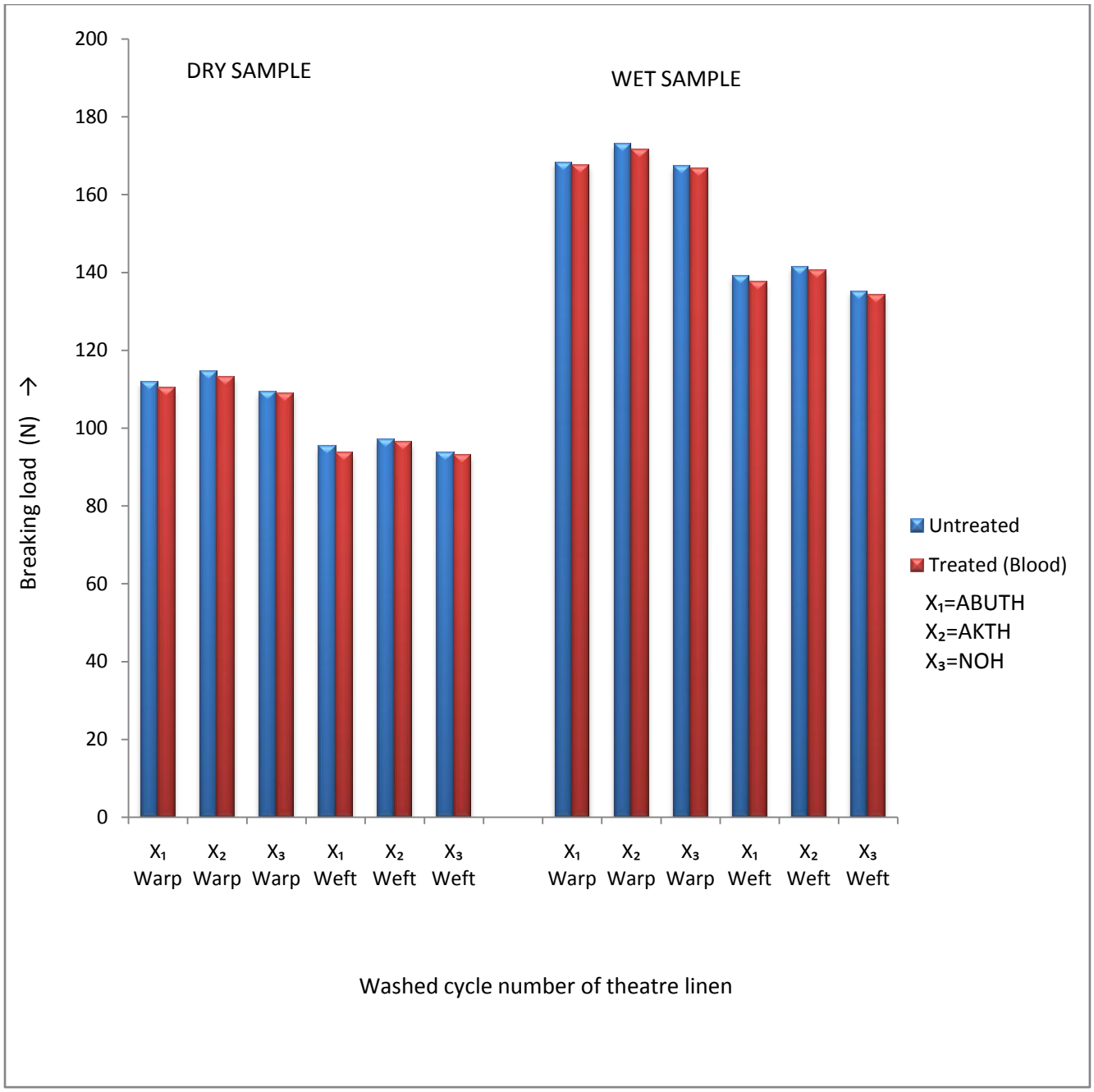


Fig. 3.3.8: Effect of sixth wash of theatre dry and wet linen on breaking load.

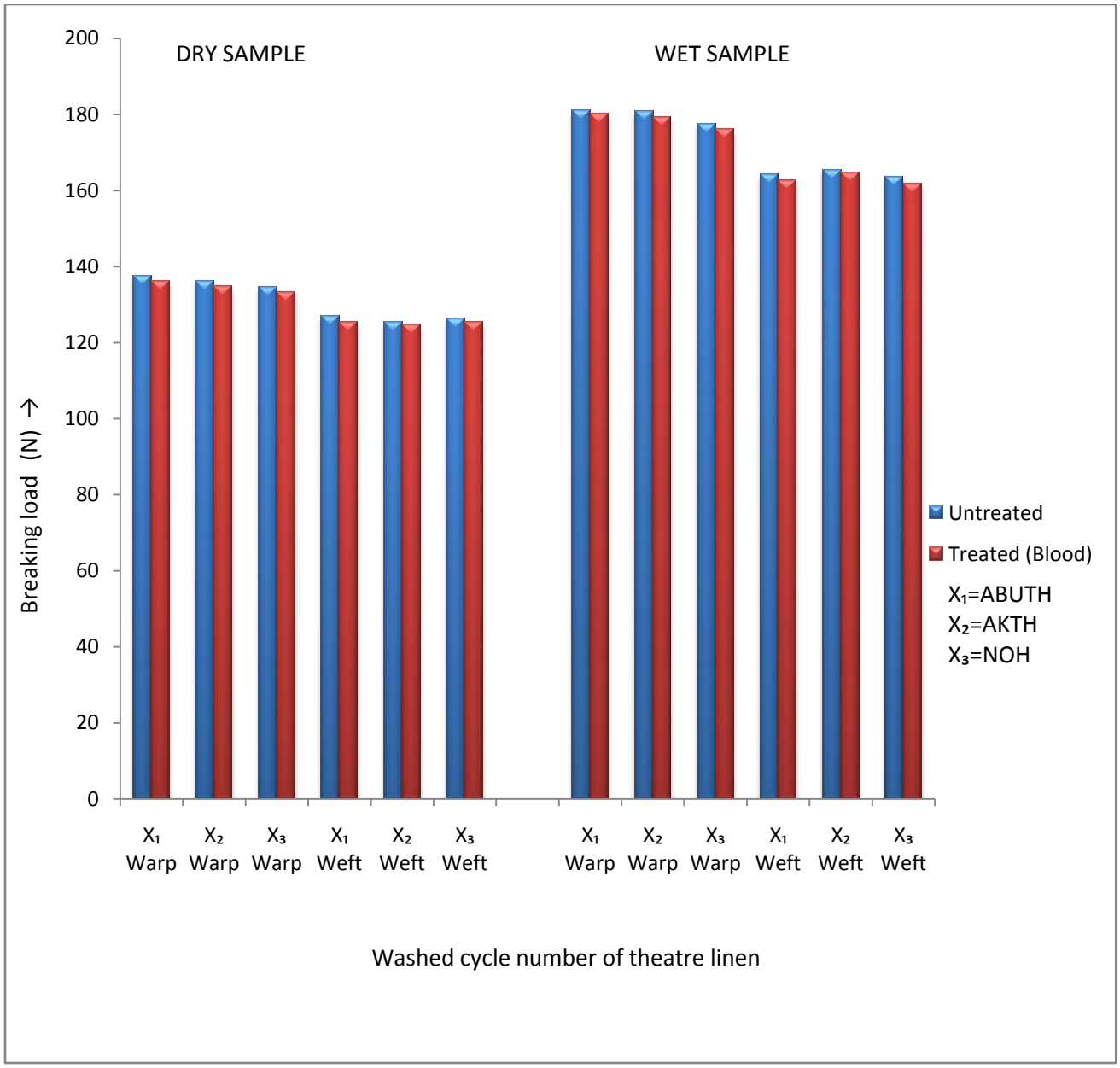


Fig. 3.3.9: Effect of ninth wash of theatre dry and wet linen on breaking load.

Figs. 3.3.7, 3.3.8 and 3.3.9 express the breaking load of the green theatre linen for control sample (untreated) and blood stained sample. The urine stained sample was not considered for the green theatre linen since practically there is no usual staining of the

green theatre linen with urine but rather with blood. The breaking load and extension at break are higher in the warp than the weft direction. It was observed that after the blood stains were laundered, there were no Iron residual stains on the green theatre linen as it is on the white hospital linen. Hence, the green theatre linen was not treated with any reagent after every washing cycle.

Figs. 3.3.7, 3.3.8 and 3.3.9 shows the graphical illustration of the increases in the breaking load of the warp and weft for the dry and wet samples after the 3^{rd}, 6^{th} and 9^{th} laundering cycles. This could be caused by the tension applied to the yarns and fabrics during construction, as this tension is released when the fabric is washed causing it shrink to its natural size (Charles, 2010).

4.4 Effects of Washing Cycles on Breaking Extension- Green theatre linen.

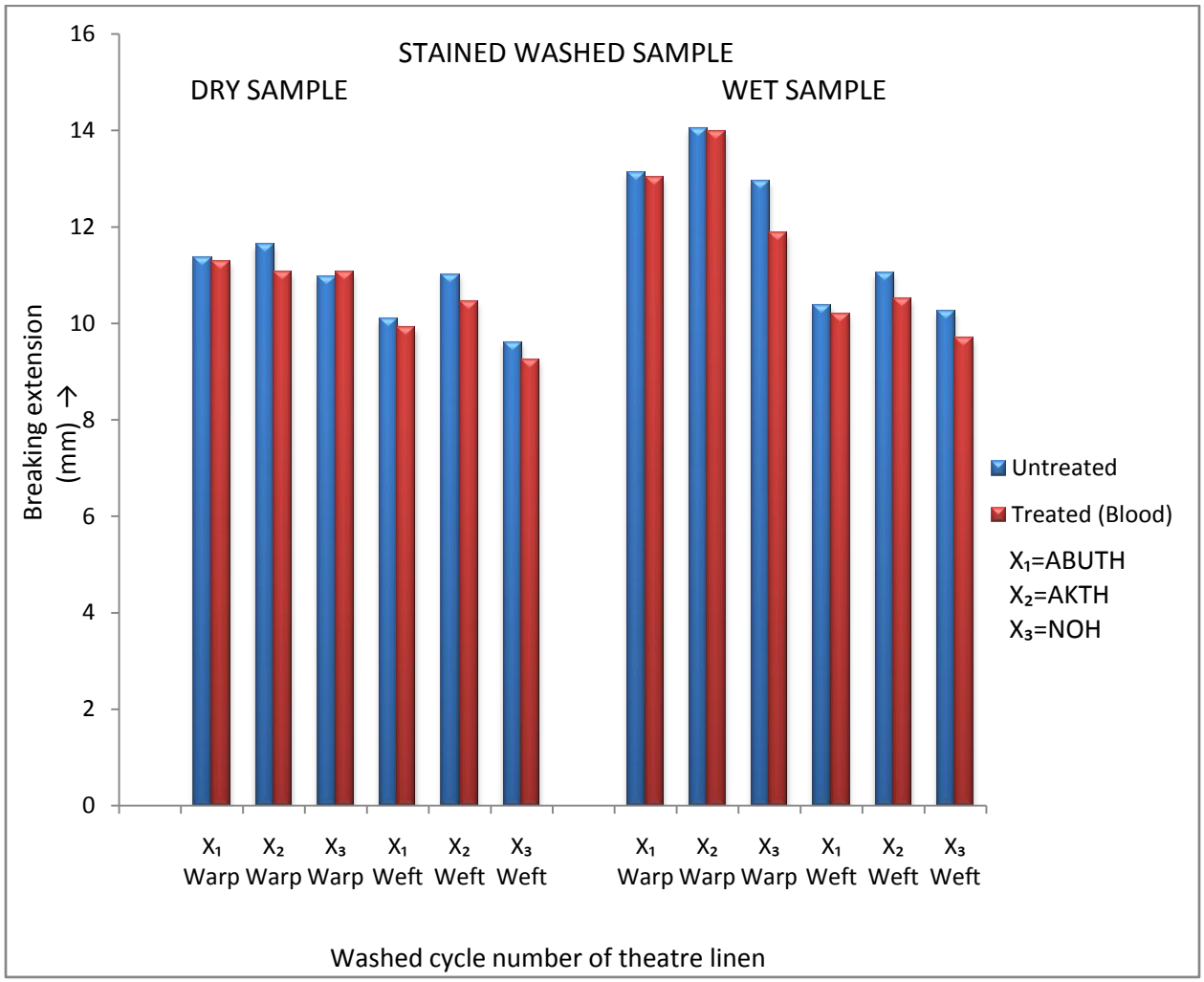


Fig. 3.3.10: Effect of third wash of green theatre dry and wet linen on breaking extension.

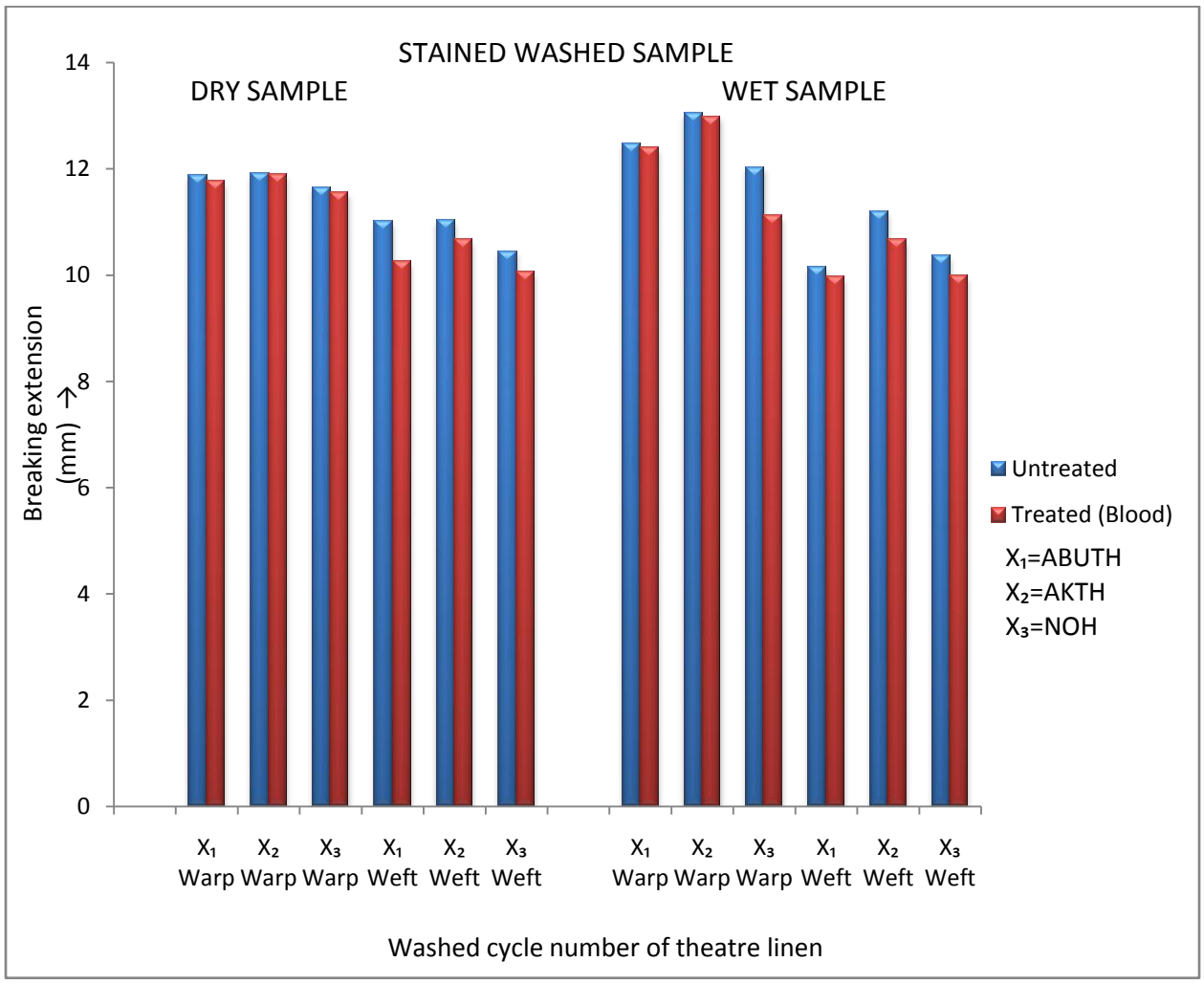


Fig. 3.3.11: Effect of sixth wash of green theatre dry and wet linen on breaking extension.

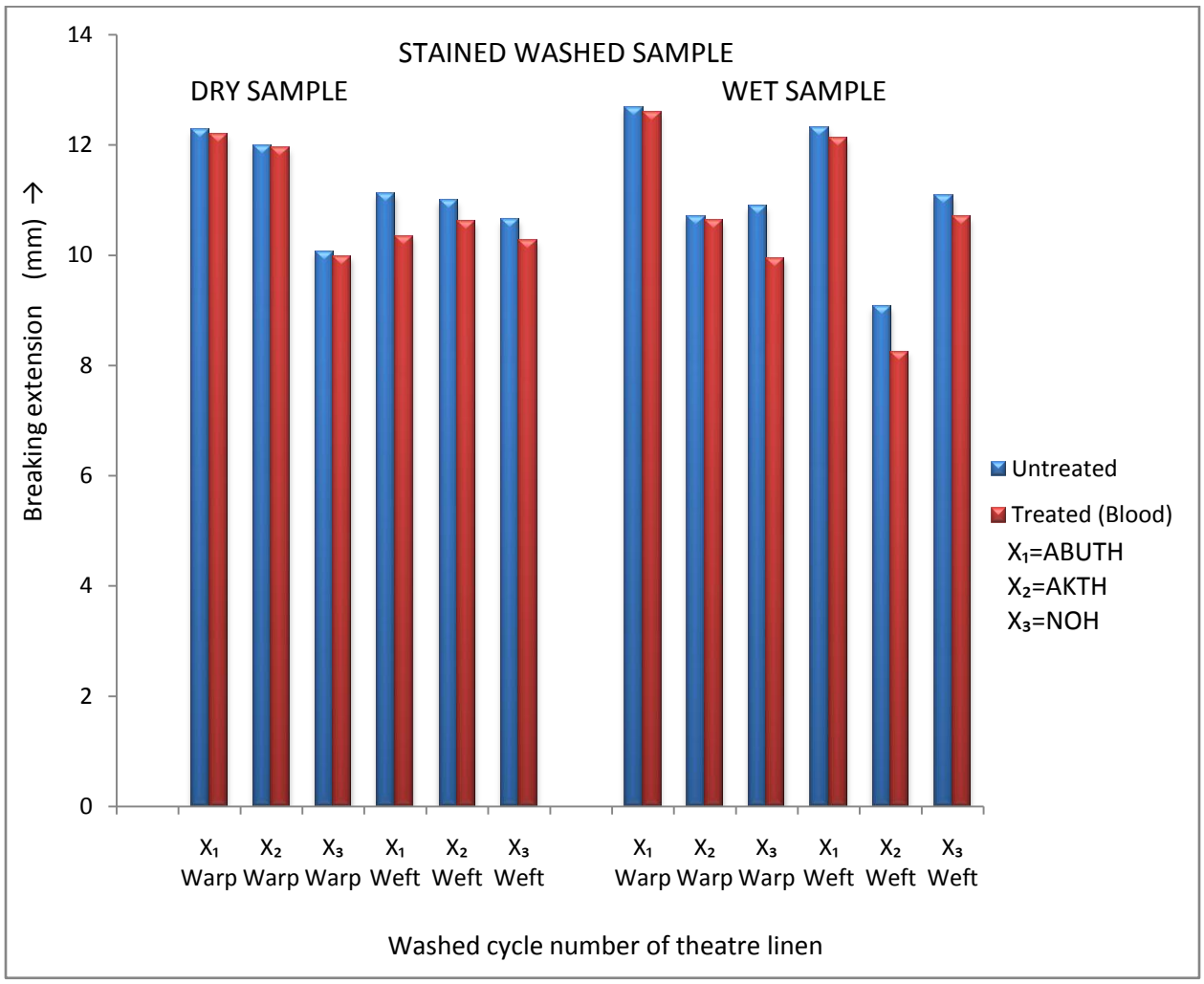


Fig. 3.3.12: Effect of ninth wash of green theatre dry and wet linen on breaking extension.

Figures 3.3.10, 3.3.11 and 3.3.12 express the breaking extension of the green theatre linen in the wet and dry samples and in the warp and weft direction of the fabric. It was observed that there were only little differences in value of the breaking extension for the control (untreated)

sample and the blood stained sample for all washings, irrespective of the hospital fabric. This could be as a result of the linens not treated with subsequent reagent after all washings done. There were also minimal differences in values of the breaking extension for all dry and wet samples after the 3rd and 6th washings. The breaking extension tends to decrease after the 6th and 9th washings for all samples in the dry and wet state of the fabric. This could also be as a result of the fabric shrinkage.

4.5 Effects of Moisture Content and Moisture Regain on Hospital Linen.

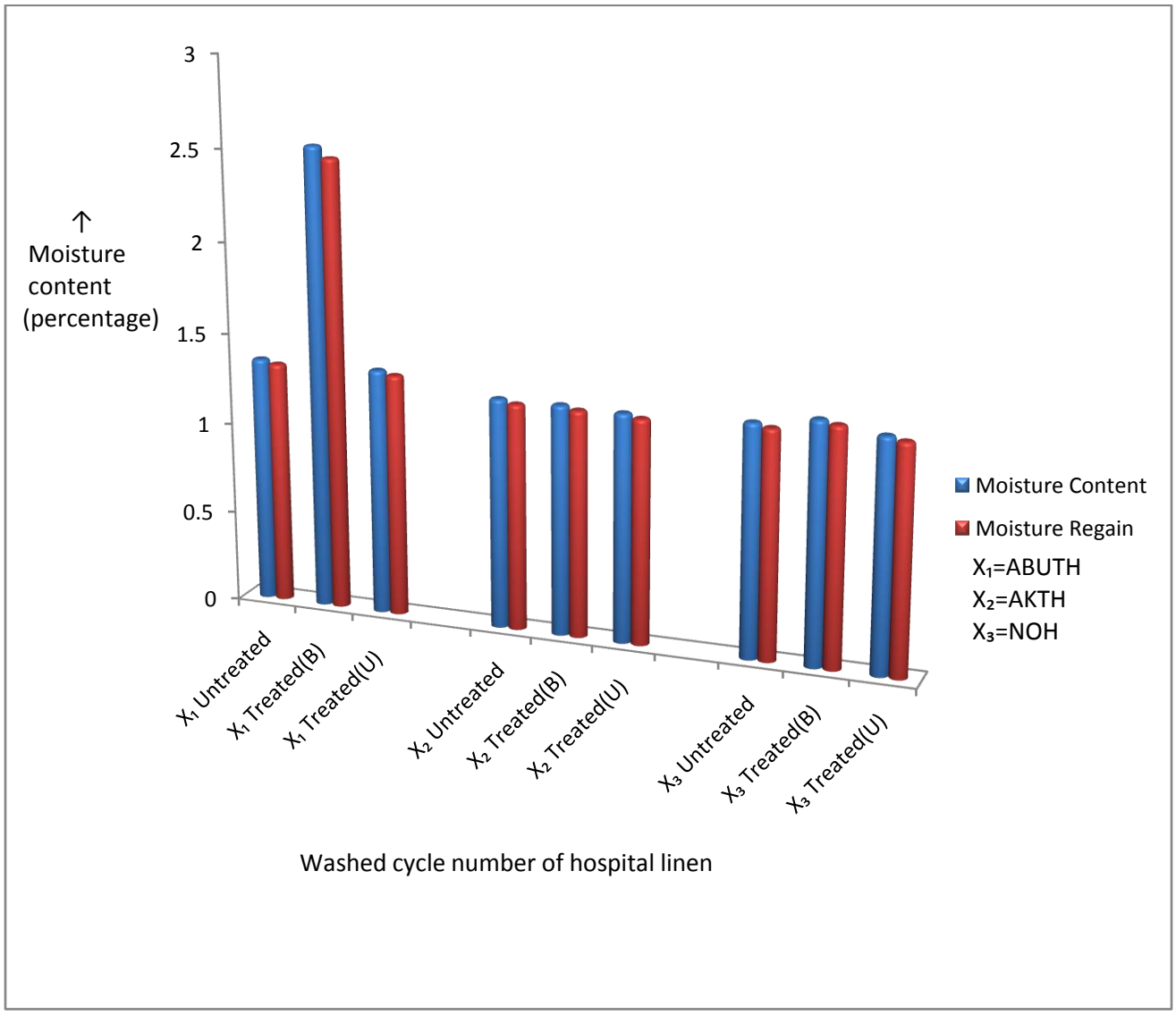


Fig. 3.4.1: Effect of Moisture Content and Moisture Regain for third wash of Hospital Linen on Percentage of Moisture.

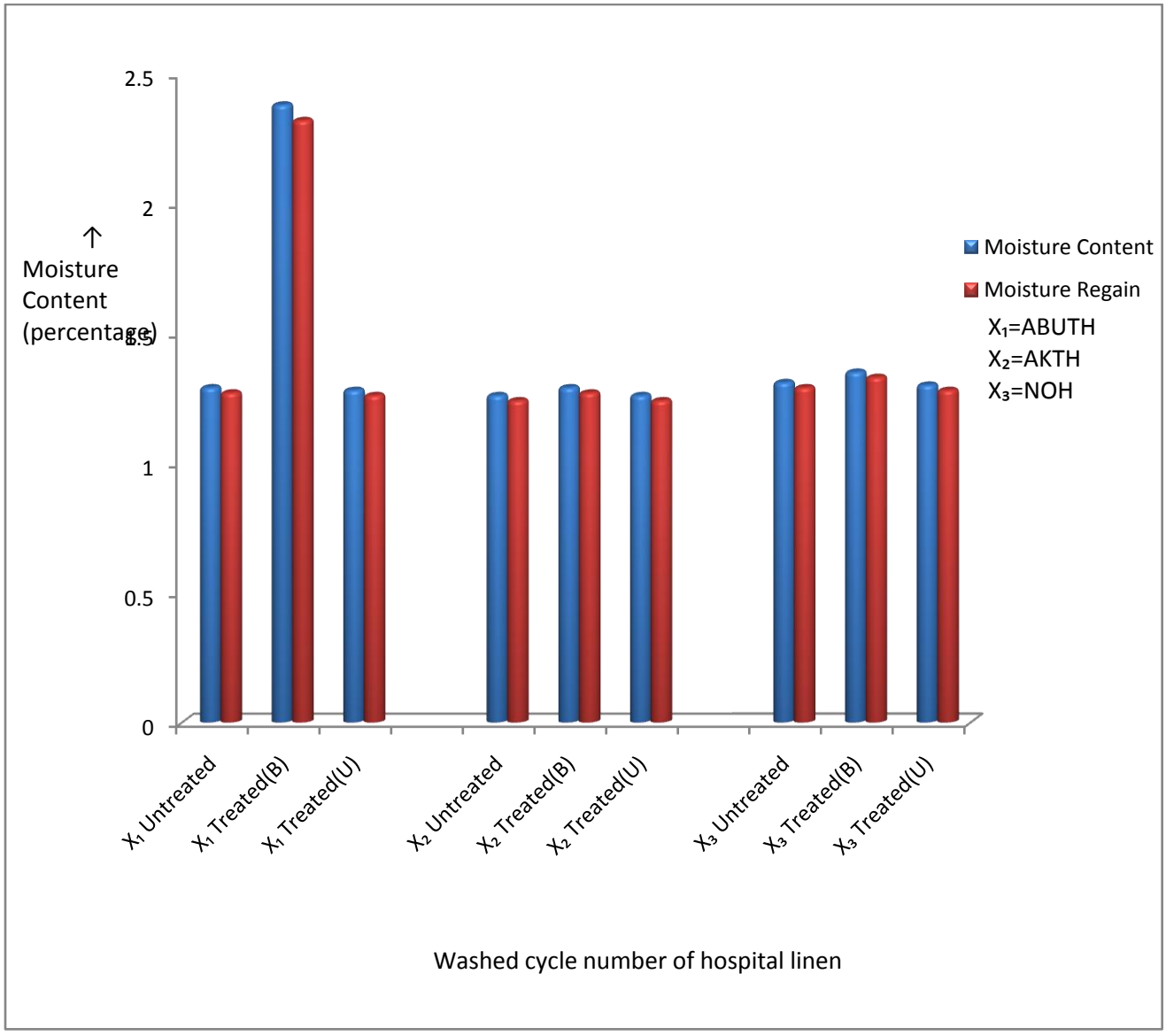


Fig. 3.4.2: Effect of Moisture Content and Moisture Regain for sixth wash of Hospital Linen on Percentage of Moisture.

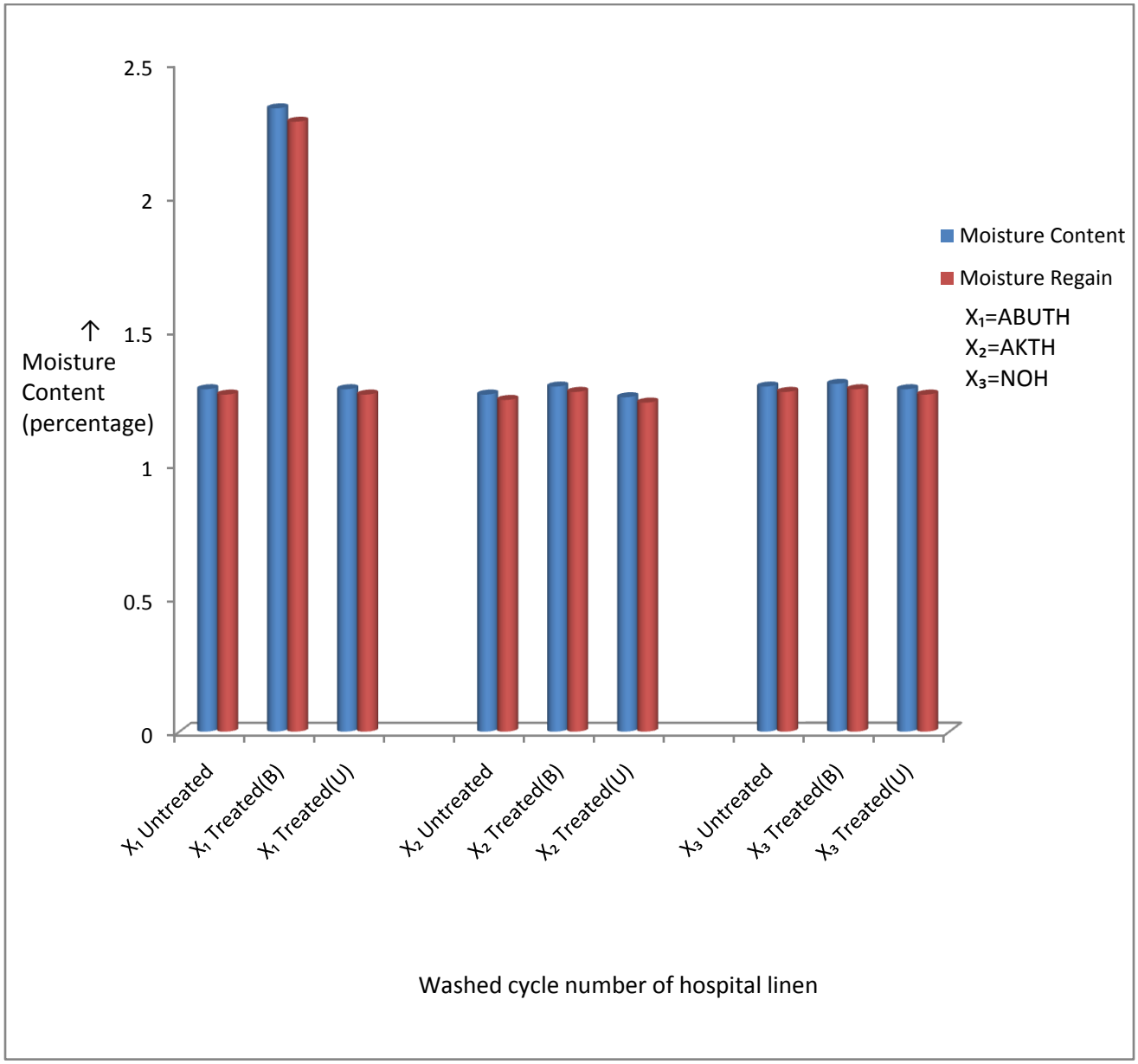


Fig. 3.4.3: Effect of Moisture Content and Moisture Regain for ninth wash Hospital Linen on Percentage of Moisture.

4.6 Effects of Moisture Content and Moisture Regain on Green Theatre Linen.

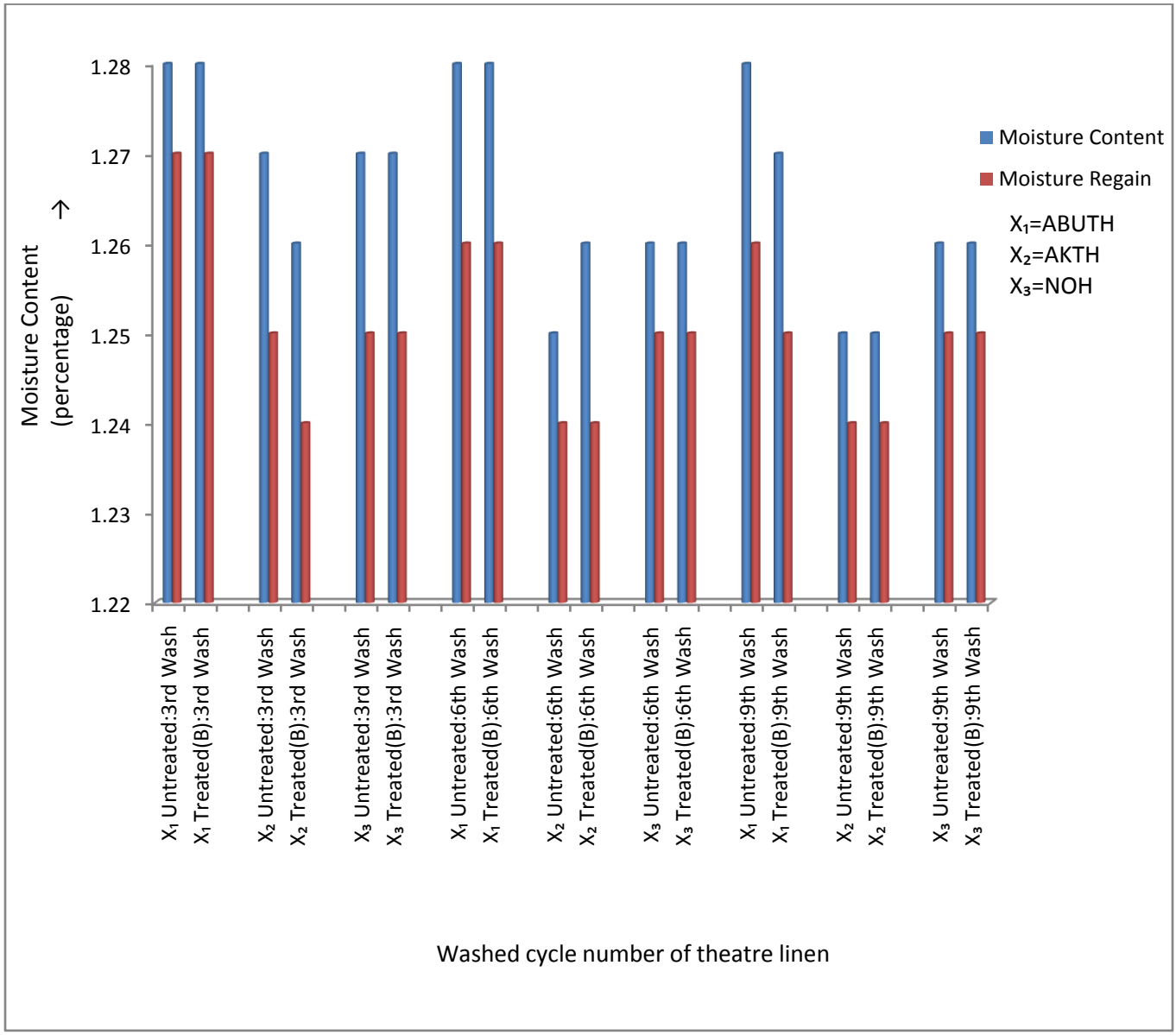


Fig. 3.4.4: Effect of Moisture Content and Moisture Regain of Green Theatre linen.

The moisture content is the weight of water expressed as percentage of total weight, while the moisture regain is the weight of water in a material expressed as percentage of oven dry weight. Moisture flow through textiles is an important parameter governing the comfort properties and how much water vapour can be absorbed by the clothing material from the skin (Brojeswari et al, 2009). The hygroscopic nature of cotton fibre causes them to swell when soaked in water during washing. Figures 3.4.1, 3.4.2, 3.4.3 and 3.4.4 express the moisture content and moisture regain both for the hospital linen and green theatre linen respectively. Figs. 3.4.1, 3.4.2 and 3.4.3 show blood stained samples from ABUTH for the 3^{rd}, 6^{th} and 9^{th} washing cycles to have the highest percentages of moisture content and moisture regain. This could be due to the presence of liquid ammonia which was one of the principal reagents used for treating Iron residual stains, this has a swelling effect on the fabric and the swelling treatment has also a positive effect on the crease recovery property (Barbara, 2008). The little differences in values of the other samples (Control and Urine stain) have relatively minimal differences in variation depending on the hospital samples as shown in figures 3.4.1, 3.4.2 and 3.4.3 shown above. The blood stained samples from ABUTH indicates the highest moisture content and moisture regain than the other sample as a result of the treatment of the sample with liquid ammonia. The other samples have relatively about uniform moisture content and moisture regained.

Fig. 3.4.4 shows the moisture content and moisture regain for the green theatre linen at the 3^{rd}, 6^{th} and 9^{th} washing cycles. The control and blood stained sample shows little differences in the moisture content and moisture regain with respect to the various

hospitals samples but the moisture content and moisture regain decreases in minimal value as the washing cycle increases from the 3rd to the 9th washing.

This correlates with the standard deviation (Table 3.4.2) remaining constant at the value of 0.01 during the washing cycles while the co-efficient of variation show only minimal changes in percentage differences. This could be as a result of the shrinkage of the sample.

Fig. 3.4.4 show the graphical illustration of the moisture content and moisture regain of the green samples, with the moisture content relatively higher in value when compared to the moisture regain, although, they all decrease in little percentages up to the 9th washing cycle.

One of the requirements of a textile fabric is to be able to maintain its dimensions throughout its use. When fabrics are subjected to aqueous treatment, there is change in dimensions due to swellings (Ibrahim, 1987), which causes the interlocking yarns to become more curved and thus produce area shrinkage. The hygroscopic nature of cotton fibre causes them to swell when soaked in water during washing. The swelling is accompanied by shrinkage in fibre length. During drying the reverse occurs, but the yarn cannot recover completely due to the frictional forces.

4.7 Effects of Percentage Shrinkage on Hospital Linen.

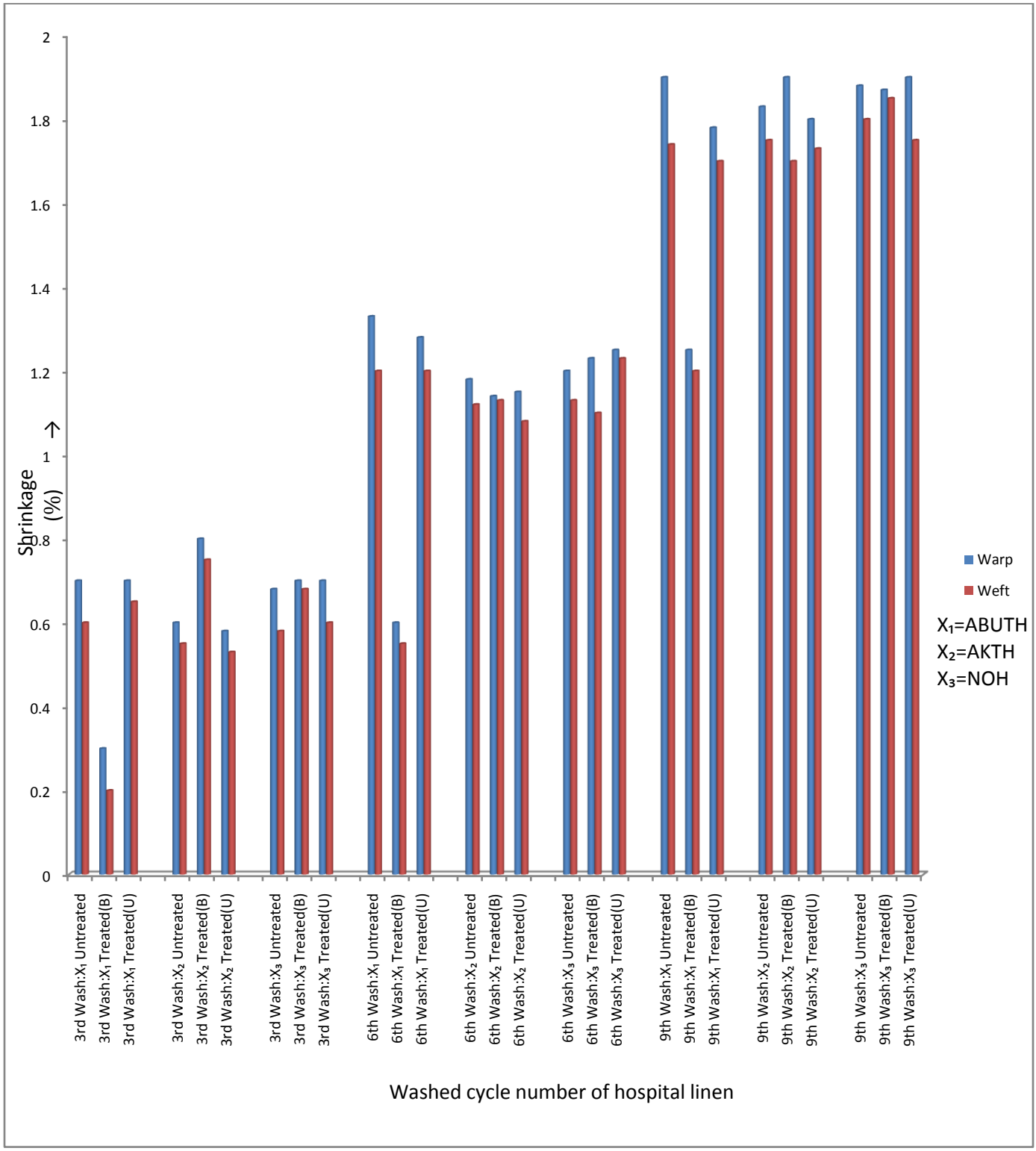


Fig. 3.5.1: Effect of Treated and Untreated Hospital Linen on Percentage Shrinkage.

4.8 Effects of Percentage Shrinkage on Green Theatre Linen.

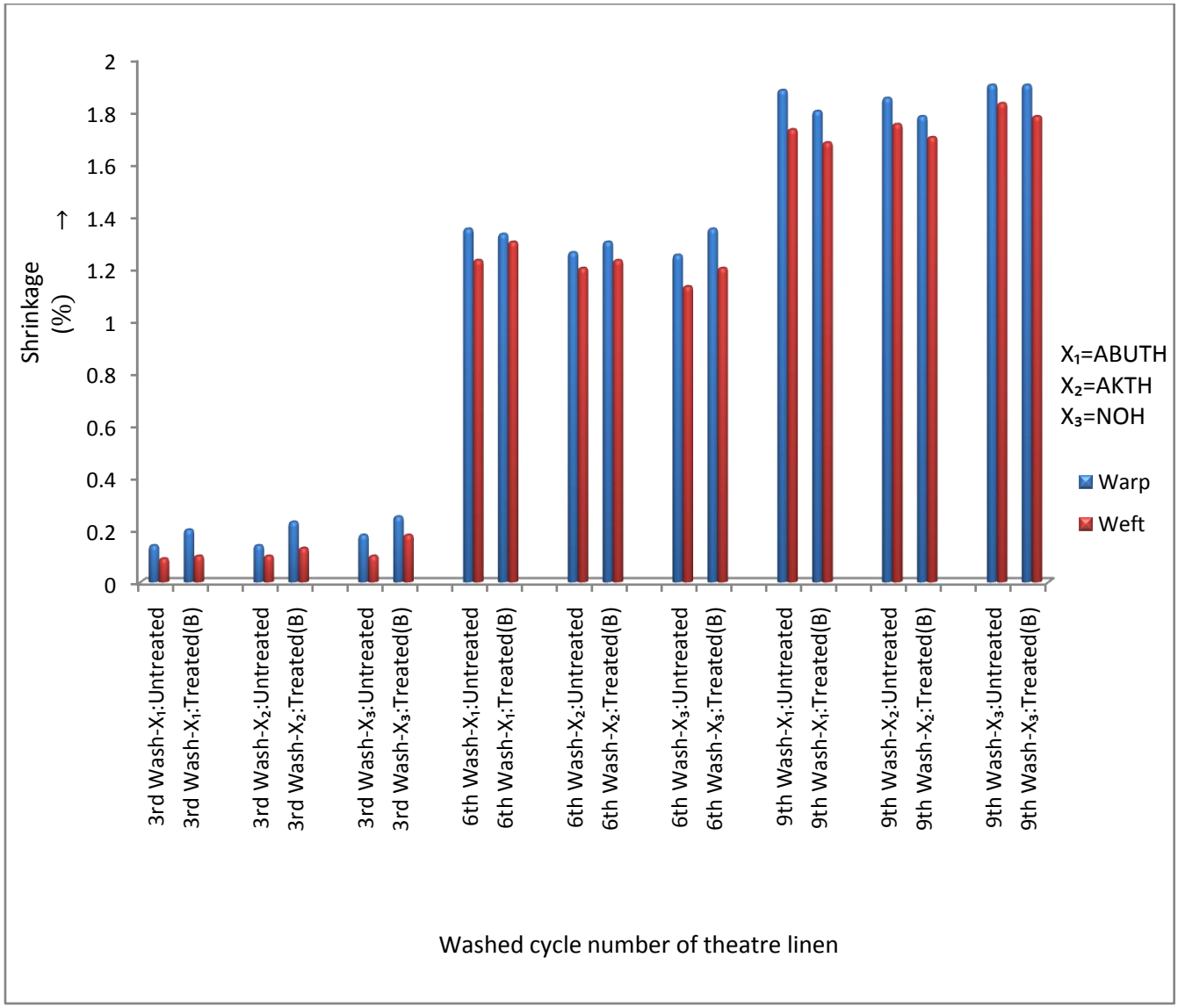


Fig. 3.5.2: Effect of Treated and Untreated Green Theatre Linen on Percentage Shrinkage.

From Figure 3.5.1, it can be seen that the percentage shrinkage is slightly greater along the warp direction compared to the weft direction. The blood stained samples from ABUTH shows the least shrinkage than any of the other samples after the 3rd, 6th and 9th

washings respectively. This could be due to the liquid ammonia treatment used for the removal of the residual Iron on the linen after every wash. Liquid ammonia has a swelling effect on the fabric and the swelling treatment has also a positive effect on the crease recovery property. Liquid ammonia strengthens the warp yarns. It also improves the dimensional stability (Barbara, 2008). The other samples show about uniform value up to the 9^{th} laundering cycle.

Figure 3.5.1 show a graphical illustration with evidence of the blood stained sample from ABUTH indicating the least shrinkage up to the 9^{th} washing cycle.

Fig. 3.5.2 show the percentage shrinkage of the green theatre linen with the shrinkage slightly greater along the warp direction compared to the weft. It also shows the fabric percentage shrinkage increasing up to the 9^{th} laundering cycles in both warp and weft direction. This theatre linen has good hydrophilic properties because of the presence hydroxyl group on the glucose rings. The presence of these groups, as well as its amorphous content enables cotton to bond well with water (Hatch, 1993). This swelling is accompanied by shrinkage in fibre length. This could also be caused by the tension applied to the yarns and fabrics during construction, as this tension is released when the fabric is washed causing it shrink to its natural size (Charles, 2010).

Table 3.6.1: Colour fastness result I.S.O. (1) for third wash

Sample- Hospital linen	Change in Colour
ABUTH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5

Table 3.6.1 (Contd.) - Colour fastness result I.S.O. (1) for sixth wash

Sample- Hospital linen	Change in Colour
ABUTH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	3 - 4
Treated (Urine)	4 - 5

Table 3.6.1: (Contd.) -Colour fastness result I.S.O. (1) for ninth wash

Sample- Hospital linen	Change in Colour
ABUTH:	
Untreated	4 - 5
Treated (Blood)	4
Treated (Urine)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	3
Treated (Urine)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	4
Treated (Urine)	4 - 5

Table 3.6.1: (Contd.) -Colour fastness result I.S.O. (1) for third wash

Sample- Green Theatre Linen	**Change in Colour**
ABUTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	4 - 5

Table 3.6.1: (Contd.) -Colour fastness result I.S.O. (1) for sixth wash

Sample- Green Theatre Linen	**Change in Colour**
ABUTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	4 - 5

Table 3.6.1: (Contd.) -Colour fastness result I.S.O. (1) for ninth wash

Sample- Green Theatre Linen	Change in Colour
ABUTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
AKTH:	
Untreated	4 - 5
Treated (Blood)	4 - 5
NOH:	
Untreated	4 - 5
Treated (Blood)	4 - 5

From Table 3.6.1, it was observed that as a result of the continuous bleaching action on the blood stained linen, a change in shade of a yellowing colour was established on the white linen under visual observation after the 3rd, 6th and 9th washings. The after yellowing effect became more obvious after every bleaching up to the 9th wash. Because the untreated and urine stained sample had no residual stain after every regular washings, no bleaching agent was necessary.

Therefore, the yellowing effect is evident on the blood stained sample changing in colour from 3 to 4 after the 3rd and 6th washing cycle. The blood stained sample after the 9th wash showed a deeper yellowing discolouration in the shade of 4 with ABUTH and NOH hospital linens compared with AKTH which showed a change in shade of 3.

However, the untreated and urine stained samples maintained a uniform slight change in shade of 4 to 5.

For the green theatre linen (Table 3.6.1); the visual observation of the green theatre linen samples showed that up to the 9^{th} washing, a uniform slight change in shade of 4 to 5 was maintained after the 3^{rd}, 6^{th} and 9^{th} washing cycles. This is attributed to the absence of any bleaching agent all through the washing cycle.

CHAPTER 5

5.0 CONCLUSION AND SUMMARY

In this research project, some mechanical and physical properties of the hospital cotton fabrics and green theatre linens were assessed to investigate the state of the fabric properties as a result of being subjected to different stain removal methods after repeated laundering. A total of 9 laundering cycles were carried out with assessment after the 3^{rd}, 6^{th} and 9^{th} washing cycles.

The hospital linen sample (blood stained samples) from ABUTH show an obvious increase in the breaking load properties up to the 9^{th} wash (which is opposite the norms) when compared the other samples (untreated and urine stained samples). This could be the result of the combining effect of the stain removal reagents by the action of liquid ammonia and hydrogen peroxide. From all samples assessed, generally there is an increasing breaking load up to the 9^{th} laundering cycles; this could be as a result of shrinkage in the fabrics caused by relaxation during laundering. Thus, as the fabric laundering cycles increases within the scope of this work, the strength of the fabrics gradually increases up to the 9^{th} washing cycles.

One of the noted effects of this study is that the higher breaking load properties observed from the selected treated portions of the hospital linen [blood stained samples from ABUTH] is applicable to only those portions of the fabric and as such the regular tension across the entire length and breadth of the fabric is disrupted to a point of which the fabric stability and functionality is compromised, there-by degrading the linen. Hence, during the physical and mechanical agitation of the washing processes over time

and the pulling action exerted on the fabrics when unloading the goods from the washing machine may generate a tear on the fabric.

The green theatre linen did not show any iron residual stains after the sample were stained with blood and washed. The breaking load of the green linen increased only minimally up to the 9th washings. This could be due to its fabric shrinkage properties.

The fabric moisture content and moisture regain of the hospital linen also increases up to the 9th laundering cycles. The blood stained samples ABUTH still showed the highest percentage of moisture content and moisture regain and this could be as a result of the ammonia reagent used for treating the iron residual stain on the white hospital linen after the usual staining and washings as this may have a swelling effect on the fabric which also have a positive effect on the crease recovery property of the hospital linen (Barbara, 2008). Other samples show very minimal differences in their variation after repeated laundering.

After the repeated laundering, the green theatre linen showed a little decrease in the moisture content and moisture regain caused by shrinkage during laundering. Fabric shrinkage occurs because of fabric relaxation and also irrecoverable shrinkage of cotton fibres during repeated wetting and drying.

The spotted fabric colour changes in shades (after every bleaching action) increases up to the 9th laundering cycles. It is evident under visual observation that the hospital linen exhibits an after yellowing colouring effect on the stained area of the sheets as a result of the repeated bleaching action on the blood stained samples. As a result, the deeper change in shade occurred with ABUTH and NOH hospital linen up to the 9th washing. The untreated and urine treated samples showed evident of a slight change in

colour on the bases of no bleaching agent after repeated washings. The green theatre linen equally showed a slight change in shade after all washings due to the absence of any bleaching agent.

The fabric shrinkage of the hospital linen increases after repeated laundering up to the ninth wash but the rate of this shrinkage is lower with the blood stained sample from ABUTH. This could also be as a result of the ammonia reagent used for removal of the iron residual stains on the white hospital linen since it has a positive effect on the crease recovery property and can as well improve the dimensional stability of the hospital linen (Barbara, 2008). The green theatre linen showed a minimal increase in its percentage shrinkage which was affected by repeated laundering up to the 9^{th} wash.

In summary, one can generally assume that the performance of the hospital linen is limited by the action of the reagents used as stain removal methods by the various hospitals. While the breaking load, moisture content and moisture regain and even shrinkage was enhanced from the applicable methods of ABUTH on its white hospital linen, it showed a high change in shade resulting in an obvious yellowing effect on the white fabric. Other untreated and urine stained sample were accompanied with lower tensile strength, moisture content and moisture regain properties when compared with the blood stained samples from ABUTH.

Blood stains on fabric can usually be removed without any application of reagent when washed immediately or soaked in water and washed subsequently without getting dried. But under some unavoidable circumstances in a large hospital setting and sometimes with poor water supply the reverse may be the case in practical terms. However, it is advised under best practice to advocate the linen users to minimally wet or

damp areas of the blood stained fabric with substantial amount of water when they cannot be soaked thereby making them damp and putting them in a size-able poly-laundry bag and tied so these goods can get to the laundry damp and not dried. When washed wet, these will eliminate the use of the costly reagents and its consequential effects on the fabrics. This is cost effective, saves time and improves the quality and use of these fabrics.

5.1 Recommendation

For further research purposes, it is recommended that other stain removal methods be performed for removing dried blood stained linen, for instance, the use of common iodized salts which are less cost effective and other non hazardous chemical reactive processes be considered and adopted. Additional testing of colourfastness, tear strength test and other physical parameters after laundering would be beneficial for a more in-depth study of the use of these types of fabrics for hospital applications.

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APPENDICES

Table 3.3.1: Breaking Load Test for third Wash (Dry Sample) - Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	95.79	86.75	10.34	9.07
Treated (Blood)	102.48	95.28	14.97	10.29
Treated (Urine)	95.01	85.24	10.25	8.89
AKTH				
Untreated	96.98	87.20	10.61	9,98
Treated (Blood)	96.40	87.35	10.50	9.85
Treated (Urine)	95.59	88.04	10.60	9.44
NOH				
Untreated	94.14	85.41	9.95	8.59
Treated (Blood)	93.55	84.24	9.20	8.40
Treated (Urine)	92.89	84.58	10.04	8.22

Table 3.3.2: Breaking Load Test for third Wash (Wet Sample) - Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	165.40	151.29	12.10	9.35
Treated (Blood)	195.20	177.80	15.77	11.32
Treated (Urine)	161.62	149.78	12.01	9.17
AKTH				
Untreated	166.92	153.84	13.01	10.02
Treated (Blood)	167.46	153.20	13.20	10.87
Treated (Urine)	165.53	153.00	12.94	9.48
NOH				
Untreated	162.65	150.04	11.92	9.23
Treated (Blood)	162.76	149.18	11.79	9.48
Treated (Urine)	161.14	148.21	10.92	8.86

Table 3.3.3: Breaking Load Test for Control Sample (Dry and Wet Sample) Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	165.40	151.29	12.10	9.35
Treated (Blood)	195.20	177.80	15.77	11.32
Treated (Urine)	161.62	149.78	12.01	9.17
AKTH				
Untreated	166.92	153.84	13.01	10.02
Treated (Blood)	167.46	153.20	13.20	10.87
Treated (Urine)	165.53	153.00	12.94	9.48
NOH				
Untreated	162.65	150.04	11.92	9.23
Treated (Blood)	162.76	149.18	11.79	9.48
Treated (Urine)	161.14	148.21	10.92	8.86

Table 3.3.4: Breaking Load Test for sixth Wash (Dry Sample) - Hospital Linen.

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	110.63	94.21	10.84	9.98
Treated (Blood)	120.59	109.35	15.37	10.52
Treated (Urine)	109.22	92.70	10.75	9.22
AKTH				
Untreated	113.46	97.86	10.89	10.06
Treated (Blood)	114.49	97.98	10.02	10.94
Treated (Urine)	112.07	97.20	10.87	9.64
NOH				
Untreated	106.16	92.64	10.62	9.42
Treated (Blood)	105.89	91.18	10.04	9.18
Treated (Urine)	104.91	90.81	10.53	9.05

Table 3.3.5: Breaking Load Test for sixth Wash (Wet Sample) - Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	167.20	138.08	11.46	9.12
Treated (Blood)	201.02	146.34	16.94	12.17
Treated (Urine)	166.42	136.57	11.37	8.94
AKTH				
Untreated	171.83	140.34	12.03	10.18
Treated (Blood)	170.27	140.12	11.89	10.92
Treated (Urine)	170.44	139.50	11.96	9.64
NOH				
Untreated	163.19	134.07	11.01	9.34
Treated (Blood)	162.44	133.22	10.64	9.59
Treated (Urine)	161.68	132.24	10.08	8.97

Table 3.3.6: Breaking Load Test for ninth Wash (Dry Sample) - Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	136.46	130.82	11.24	10.09
Treated (Blood)	150.88	141.91	16.48	12.83
Treated (Urine)	135.05	129.31	11.15	9.33
AKTH				
Untreated	135.18	128.24	10.94	9.95
Treated (Blood)	135.32	128.16	10.12	9.04
Treated (Urine)	133.79	127.58	10.92	9.58
NOH				
Untreated	133.63	127.14	9.04	9.62
Treated (Blood)	132.24	126.39	9.87	8.47
Treated (Urine)	132.38	125.31	8.95	9.25

Table 3.3.7: Breaking Load Test for ninth Wash (Wet Sample) - Hospital Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	179.80	163.20	11.24	11.28
Treated (Blood)	205.21	172.01	16.37	12.38
Treated (Urine)	179.02	161.69	11.55	11.10
AKTH				
Untreated	179.60	162.47	9.67	8.04
Treated (Blood)	178.72	163.94	9.01	9.20
Treated (Urine)	178.21	161.63	9.60	7.50
NOH				
Untreated	176.53	162.47	9.86	10.04
Treated (Blood)	176.07	161.22	10.23	10.44
Treated (Urine)	175.02	160.64	8.93	9.67

Table 3.3.8: Breaking Load Test for third Wash (Dry Sample) - Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	96.81	87.77	11.36	10.09
Treated (Blood)	96.03	86.26	11.27	9.91
AKTH				
Untreated	98.00	88.23	11.63	11.02
Treated (Blood)	96.61	89.06	11.06	10.46
NOH				
Untreated	95.16	86.43	10.97	9.61
Treated (Blood)	93.91	84.60	11.07	9.25

Table 3.3.9: Breaking Load Test for third Wash (Wet Sample) - Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	166.43	152.31	13.13	10.37
Treated (Blood)	162.65	150.81	13.03	10.19
AKTH				
Untreated	167.95	154.86	14.04	11.05
Treated (Blood)	166.55	154.03	13.97	10.51
NOH				
Untreated	163.67	151.07	12.95	10.25
Treated (Blood)	162.17	149.23	11.88	9.69

Table 3.3.10: Breaking Load Test for Control Sample (Dry and Wet Sample) Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
DRY:	**Warp**	**Weft**	**Warp**	**Weft**
ABUTH	106.03	82.59	11.07	9.15
AKTH	103.45	80.11	10.89	9.11
NOH	103.13	81.67	10.27	9.45
WET:				
ABUTH	163.43	114.57	11.55	10.39
AKTH	160.83	112.05	11.97	10.35
NOH	160.97	113.60	10.85	10.01

Table 3.3.11: Breaking Load Test for sixth Wash (Dry Sample) – Green Theatre Linen.

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	111.65	95.23	11.87	11.01
Treated (Blood)	110.25	93.72	11.77	10.25
AKTH				
Untreated	114.49	98.89	11.91	11.03
Treated (Blood)	113.09	98.23	11.89	10.67
NOH				
Untreated	107.19	93.67	11.65	10.45
Treated (Blood)	105.03	91.84	11.55	10.07

Table 3.3.12: Breaking Load Test for sixth Wash (Wet Sample) – Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	168.23	139.11	12.48	10.15
Treated (Blood)	167.45	137.59	12.39	9.97
AKTH				
Untreated	172.85	141.37	13.05	11.21
Treated (Blood)	171.47	140.52	12.99	10.67
NOH				
Untreated	164.21	135.09	12.03	10.37
Treated (Blood)	162.71	133.27	11.11	9.99

Table 3.3.13: Breaking Load Test for ninth Wash (Dry Sample) – Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	137.49	131.85	12.27	11.11
Treated (Blood)	136.07	130.33	12.19	10.35
AKTH				
Untreated	136.21	129.27	11.97	10.99
Treated (Blood)	134.81	128.61	11.95	10.61
NOH				
Untreated	134.65	128.17	10.07	10.65
Treated (Blood)	133.41	126.33	9.98	10.27

Table 3.3.14: Breaking Load Test for ninth Wash (Wet Sample) – Green Theatre Linen

Sample	**Breaking load (N)**		**Extension at break (mm)**	
ABUTH	**Warp**	**Weft**	**Warp**	**Weft**
Untreated	180.83	164.23	12.67	12.31
Treated (Blood)	180.05	162.71	12.59	12.12
AKTH				
Untreated	180.63	137.49	10.69	9.07
Treated (Blood)	179.23	136.65	10.63	8.25
NOH				
Untreated	177.55	163.49	10.89	11.07
Treated (Blood)	176.05	161.67	9.95	10.69

Table 3.4.1: Moisture Content and Regain for Hospital Linen, at different washing cycles

3rd Wash

Hospital linen	Moisture Content (%)	Moisture Regain (%)	Standard deviation	C.V (%)
ABUTH:				
Untreated	1.35	1.33	0.01	0.75
Treated(Blood)	2.53	2.47	0.03	1.21
Treated(Urine)	1.35	1.33	0.01	0.75
AKTH:				
Untreated	1.26	1.24	0.01	0.81
Treated(Blood)	1.26	1.24	0.01	0.81
Treated(Urine)	1.25	1.23	0.01	0.81
NOH:				
Untreated	1.27	1.25	0.01	0.80
Treated(Blood)	1.32	1.30	0.01	0.77
Treated(Urine)	1.27	1.25	0.01	0.80

Table 3.4.1: (Contd.)

6th Wash

Hospital linen	**Moisture Content (%)**	**Moisture Regain (%)**	**Standard deviation**	**C.V (%)**
ABUTH:				
Untreated	1.29	1.27	0.01	0.79
Treated(Blood)	2.38	2.32	0.03	1.29
Treated(Urine)	1.28	1.26	0.01	0.79
AKTH:				
Untreated	1.26	1.24	0.01	0.81
Treated(Blood)	1.29	1.27	0.01	0.79
Treated(Urine)	1.26	1.24	0.01	0.81
NOH:				
Untreated	1.31	1.29	0.01	0.78
Treated(Blood)	1.35	1.33	0.01	0.75
Treated(Urine)	1.30	1.28	0.01	0.78

Table 3.4.1: (Contd.)

9th Wash

Hospital linen	Moisture Content (%)	Moisture Regain (%)	Standard deviation	C.V (%)
ABUTH:				
Untreated	1.28	1.26	0.01	0.79
Treated(Blood)	2.33	2.28	0.03	1.31
Treated(Urine)	1.28	1.26	0.01	0.79
AKTH:				
Untreated	1.26	1.24	0.01	0.81
Treated(Blood)	1.29	1.27	0.01	0.79
Treated(Urine)	1.25	1.23	0.01	0.81
NOH:				
Untreated	1.29	1.27	0.01	0.79
Treated(Blood)	1.30	1.28	0.01	0.78
Treated(Urine)	1.28	1.26	0.01	0.79

Table 3.4.2: Moisture Content & Moisture Regain for the Green Theatre Linen at different washing cycles

3rd Wash

Green Theatre linen	Moisture Content (%)	Moisture Regain (%)	Standard deviation	C.V (%)
ABUTH:				
Untreated	1.36	1.34	0.01	0.75
Treated(Blood)	1.35	1.33	0.01	0.75
AKTH:				
Untreated	1.27	1.25	0.01	0.80
Treated(Blood)	1.27	1.25	0.01	0.81
NOH:				
Untreated	1.27	1.25	0.01	0.80
Treated(Blood)	1.27	1.25	0.01	0.80

Table 3.4.2: (Contd.)

6th Wash

Green Theatre linen	Moisture Content (%)	Moisture Regain (%)	Standard deviation	C.V (%)
ABUTH:				
Untreated	1.28	1.26	0.01	0.79
Treated(Blood)	1.28	1.26	0.01	0.79
AKTH:				
Untreated	1.25	1.23	0.01	0.81
Treated(Blood)	1.26	1.24	0.01	0.81
NOH:				
Untreated	1.26	1.24	0.01	0.81
Treated(Blood)	1.26	1.24	0.01	0.81

Table 3.4.2: (Contd.)

9th Wash

Green Theatre linen	Moisture Content (%)	Moisture Regain (%)	Standard deviation	C.V (%)
ABUTH:				
Untreated	1.28	1.26	0.01	0.79
Treated(Blood)	1.27	1.25	0.01	0.80
AKTH:				
Untreated	1.25	1.23	0.01	0.81
Treated(Blood)	1.25	1.23	0.01	0.81
NOH:				
Untreated	1.26	1.24	0.01	0.81
Treated(Blood)	1.26	1.24	0.01	0.81