



Wound Care – Antimicrobial Treated Fabrics as Protective and Therapeutic Materials

W. Curtis White, ÆGIS Environmental Management, Inc

Robert A. Monticello, PhD, ÆGIS Environmental Management, Inc.

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ABSTRACT

Skin, the largest organ of the human body, is a complex mixture of functional and protective cells. When the skin is compromised by intentional, physiological, or traumatic means, a wound is created.

Wound protection must include protections against physical, chemical, and microbiological stresses. Combinations of external and systemic therapies and barrier coverings/coatings have been used for centuries.

This paper presents a review of the physiological problems and available solutions for all types of wounds. Specific examples of fabrics treated with antimicrobial treatments and their protective and therapeutic benefits will be presented. Risks and benefits of various antimicrobial technologies will be discussed.

INTRODUCTION

Skin is the largest organ of the human body. Skin is a complex tissue that gives form to the body and functions to protect the inner parts of the body from invasive chemicals, particulates, and biologicals. Skin changes according to hereditary and environmental factors as one ages and bestows on each individual their own unique exterior.

When the skin is compromised by traumatic (cuts, burns, punctures, scrapes, etc.) or disease (nervous, genetic, microbial, dietary,

immunological, etc.) conditions, dermal penetration occurs and a wound is formed.

Wound care requires protections against physical, chemical, and microbiological stresses. Such care must be done in a way that minimizes primary and secondary infectious microorganisms and provides for an optimized healing environment. Antimicrobial treatments and treated fabrics are critical as protective and therapeutic devices for proper wound care.

Having the proper chemical and physical properties for such devices enhances the healing process.

Antimicrobials are used to protect a variety of treated goods from microbiological deterioration, staining, and odors or are part of a class of chemicals called antibiotics. These chemicals are also used in sanitizers and disinfectants as well as preservatives of paints, adhesives, wood, and other materials or, in the case of antibiotics, used to treat systemic infections. When considering the use of these materials for therapeutic and protective reasons and they will be in contact with the skin it is critical to consider the full range of risk factors associated with such use.

Proper wound care requires the integration of knowledge about the cause of the wound, the skin, the healing process, available therapies, and the affected individual's genetics and health.

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THE SKIN

The skin is made up of the general class of cells called epithelial cells. These are arrayed in a loose complex that supports the fatty tissue below. Besides the skin epithelial cells, this class of cells are also the basis of the mucus membranes of the naso-pharyngeal passages, the gastrointestinal tissues, and reproductive organs.

The skin functions:

- 1) As an almost perfect water proof barrier that holds in the necessary 60-70% water needs of the body and also minimizes the intrusion of water from the external environment.
- 2) As the ultimate barrier to external injury and microbial invasion. Like all epithelial tissues, the skin is the master of repair. Whether scrapes, cuts, or third degree burns, the skin through reproduction and scarring makes it right.
- 3) As the place of exchange for heat, both heat in and heat out. Skin is the ultimate air conditioner for the body. Our sense of hot and cold and the body's first line of defense for temperature extremes are all found in the skin.
- 4) As the receptor site for nerve endings and critical blood and lymph interfaces that allow for protective immunological responses. Pressure and temperature reception - touch, warmth, cold, and pain.
- 5) As part of the waste control system of the body. Sweat carries with it small amounts of the wastes that the body must deal with each day.
- 6) As part of the respiratory system that balances some of the body's flow of gasses. This is an often-overlooked function of skin but people that do body painting are well aware of the risk of suffocation.
- 7) As a storage place for water, fats, glucose, and some salts.

Never exceeding three-sixteenths of an inch in thickness, the skin is an extremely complex set of layers and functions. **The epidermis** - is composed of generally two but sometimes as many as four layers. The upper of these layers is generally dead and composed of non-living

proteinacious material called keratin. **The dermis** - the inner layer of the skin - has two layers. The upper layers are near dead to dead scaly cells constantly being replaced by new cells from the *stratum germinativum*. This *stratum germinativum* is also the layer that contains the pigment melanin that, depending on level, determines the color of one's skin. Melanocytes are also found in the hair and iris of the eye. At the basal layer of the skin, you find the subcutaneous fascia, a webbing of fibrous tissue, nerve endings, blood vessels, roots of hairs, sweat glands, sebaceous glands.

Besides the cellular nature of the skin, part of its "health" is predicated on the normal mix of microorganisms that live on the and in the layers and component structures of the skin. These organisms are usually a mix of aerobic Gram – and Gram + organisms that align themselves with the hair follicles and the sebaceous and sweat glands. Their balance is predicated on the genetics, health, and diet of the person, and external influences such as skin care products, soaps, and environmental conditions.

Besides all these functions of the skin, skin by its nature of being the body's interface with the environment, can be a transporter of microorganisms from the body to others or to environmental surfaces. This potential for transport and cross-infection is of serious concern to food preparers, pharmaceutical workers, micro-electronic workers, other cleanroom personnel, and to medical personnel such that hygiene protocols are very stringent. Microorganisms, their metabolic products, reproductive structures, and body parts, contribute chemicals, particulates, and infective microbiological agents into the environment and into contact with occupants and work processes and products.

No matter how you view the skin, the proper balance of microorganisms is essential. Under normal healthy conditions the skin can be a transporter and amplification site for microorganisms. When a person is ill or stressed their skin changes and so do the microbial flora – sometimes good and sometimes bad. When the skin is broken "bad" microorganisms can cause skin or systemic problems affecting both morbidity and mortality.

WOUNDS

Wounds to the skin can be characterized as traumatic (cuts, scrapes, abrasions, penetrations, burns, etc.) or disease mediated (sun-mediated skin cancer, other cancers, bacterial infection, fungal/yeast infections, viral infections, immunomediated disease, endocrine based disease, and other diet or health related) compromises to the skin.

With respect to microorganisms, there are primary and secondary infections that cause wounds or are manifested at wound sites. A maze of environmentally and human sourced bacteria, fungi, yeast, and viruses are ready to compromise a wound site and complicate the healing process in both acute and chronic situations.

Traumatic Wounds

The most common way of thinking about traumatic wounds is to consider the broad list of accidental or on-purpose punctures, cuts, scrapes, tears, abrasions, and burns that break the skin. From shots, surgical incisions, "strawberries" from that slide into home base, paper cuts, knife cuts, razor nicks, to burns, we all experience wounds on almost a daily basis. These wounds can be further characterized by their size from a pin prick to massive burns.

Disease Mediated Wounds

Disease of all types: nervous endocrine, allergenic/immunological, or infective, compromise or break the skin and facilitate or cause wounds. Skin cancer, aplastic anemia, atopic eczema, psoriasis, chemical (e.g. diaper rash) and /or physical irritation, sensitizations, diabetes, etc, all set up wound conditions that are acute or chronic and where either primary or secondary infections can be established.

Infectious disease wounds include a range of bacterial (aerobic and anaerobic), fungal, yeast, and viral causative agents. These are serious conditions that range from small cuts with Staphylococcal or Pseudomonal infections, burns with Pseudomonal or Clostridial infection, *Streptococcus pyogenes* (flesh eating bacteria) infection, herpes, athlete's foot (bacterial and/or fungal), to acne. Wounds with infectious disease need to be cared for by reducing the contamination and the re-contamination of the site

A Common Thread:

What these wounds all have in common is that they are open to the environment and susceptible to further trauma and contamination from "dirt particulates" and microorganisms. The microbial contaminants can come from the affected person, the environment, or other people.

The skin, at the wound site, has some microbial fighting assistance from blood and lymph but also provides a nutrient rich site where a series of successional microbial attacks are facilitated. The first colonizers are usually "dirt" or skin sourced fast growing aerobic bacteria (*Staphylococcus spp.*, *Streptococcus spp.*, Dipteroids, *Klebsiella spp.*, *Serratia sp.*, *Enterobacter sp.*, *Acinetobacter sp.*, or *Pseudomonas spp.*). As the body begins the healing process, the populations of these contaminants increases and dominant species begin to take over. As tissue necrosis develops, anaerobic bacteria can become established.

This only begins to define the broad array of conditions that allow for specific primary and secondary infections of wounds.

For healing to take place, the wound should be cleaned, kept clean, and protected from microbial contamination and proliferation. This is not always a simple task and proper wound care requires knowledge of the body, the wound cause, and the materials useful in assisting the healing process.

WOUND HEALING

With all of the complexity of the skin complex and the versatility of the epithelial cells the most amazing system operation that occurs is the healing process. When the dermis is penetrated, blood vessels are ruptured. This is done in an environment that is contaminated with various bacteria, particulates, oils, and other chemicals. The rupture causes the movement of blood and all of its components most importantly fibroblasts, red, and white blood cells. Blood moves to the surface and mixes with the torn skin cells where fibrin mediated by Vitamin K forms a net-like structure that becomes a clot and then drying into a scab. Underneath this activity, the dermis begins to reproduce in a battle where the white blood cells fight any bacteria and clean up the left over torn

cellular material. In 2-3 days the new epidermal cells have formed a "bridge" across the cut. Below this cellular layer the fibroblasts build supportive connective tissue. In a healthy person this healing process takes about 6-7 days when the scab falls off and the new skin is in place. Maintaining the health of the skin and reducing abnormal levels of bacteria, fungi, or yeast during this time is very important to the health of the skin and the person.

WOUND CARE THERAPIES:

Therapies for wound care are established in order to reduce healing time, scarring, length of hospital stay, pain, and cost. Treatment practices must consider each of these factors when creating an environment ideal for wound repair. The basic tenants of clean, treat, and protect provide guidance for wound care product design and utility.

The Body:

Whether the wound is acute or chronic, the same environmental conditions that regulate the healing effects must be considered. Wound repair and protection is best done in an environment that promotes cellular proliferation and a focused immunological response. This "healthy" environment can be created using several creative techniques. Stimulation of cellular proliferation and immunological responses can be done through Laser Therapy, Hyperbaric Oxygen Therapy, Sub Atmospheric Pressure Therapy, Gene Therapy and through the application of topical antibiotics and/or vitamins. These techniques and treatments are intended to reduce the field of anaerobic and aerobic bacteria contamination that cause infection while stimulating the host defense system, our own "home-land security" response team. Choice of treatments is also driven by the nature of the wound. In a triage situation a different wound care product would be used when compared to the healing/protection situation.

Direct Treatments:

Direct treatments of the site of infection are only one part of the needed system. The above therapies create an environment that is ideal for our body to promote healing. The stimulation of our own bodies host defense system is critical for rapid healing. However, the protection of this system is just as important. Wound dressings, gauze, bandages, and wraps, protect the wound site from physical, chemical, and microbiological environmental stresses. The protective coverings can be viewed as a synthetic epidermal layer of skin.

As indicated above, the epidermal layer is composed of two to four layers of dead cells and proteinacious material. These layers of skin act as both a physical barrier to the outside world and also act directly on the outside biological contaminants. Disease fighting chemicals released by the body at the epidermis act directly on bacteria, yeast, and fungi to reduce the numbers and control wound contamination as part of the healthy natural defense system. Any artificial protective barriers employed during wound repair, whether they are composed of woven and non-woven textiles or foams, should mimic and complement the body's natural antimicrobial activity.

These artificial barriers should provide an environment that protects from physical abrasions and also from biological attack. (Fig.1)

Leaching Antimicrobials

Wound care products containing antibiotics and other leaching type chemicals are used

commonly in the market today. These types of

antimicrobial agents act as a reservoir of active defensive system, constantly attacking both the bacteria in the wound dressing and leaching into the wound site itself, assisting the host defense system.

The leaching type agents include Chlorhexidine, Iodine Proflavine,

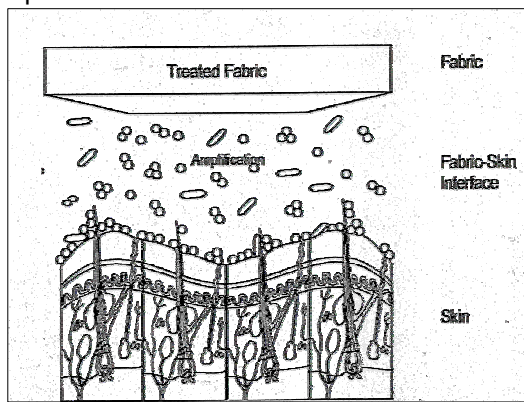


Fig. 1. Fabric-Skin Interface.

polyhexamethylene biguanide (PHMB), Silver and Honey. These agents all can be formulated or embedded into wound care products and function by the sustained release of low concentrations of active ingredient over time.

This leaching activity of the agent has been shown to reduce the overall bacterial bioburden at the wound site in addition to lowering or eliminating the potential bacterial contamination from the wound care product itself or the caregiver. The benefits seen in the patient with these leaching type antimicrobial agents are balanced against the future threat of inadequate control of wound infections due to the generation of resistant organisms or to any possible cytotoxic response. The continued loss and/or consumption of the antimicrobial agent over time has been shown to promote the development of microorganisms resistant to multiple antibiotics and antiseptics.

The literature has a number of good papers on these technologies. A typical paper on the PHMB technology cites use of a PHMB gauze showing excellent activity against 10^6 bacteria on the gauze and very low levels of pass-through to the skin. This was done under clinical conditions on human volunteers with and without the presence of protein.¹ In a similar way, laboratory experiments with silver-based technology were run. Conclusions were: "The results show that the silver-containing dressing makes silver available at a dressing-agar interface at a concentration that is effective against a broad range of aerobic, anaerobic, and antibiotic-resistant microorganisms."²

Non-Leaching Antimicrobials

Non-leaching antimicrobial agents can be used as a passive defense system in wound

care products. These agents do not leach from the treatment site, which greatly reduces the chance of generating resistant organisms or for any cytotoxicity concerns. Examples of this type of antimicrobial agent include trimethoxysilylpropyldimethyloctadecyl ammonium chloride (SiQuat, AEGIS Microbe Shield™). Non-leaching antimicrobial agents will reduce or eliminate the bacterial contamination in the wound care product only by direct contact and do not need to rely on the leaching of the active ingredient. Such technology has been utilized with a variety of woven and non-woven fabrics and foams in health-care/wound care products. The broad spectrum antimicrobial, contact kill capabilities, lack of leaching and risks of cytotoxicity and adaptation make this a useful technology on wound care products.

Tables I-III show data useful for determining antimicrobial utility for wound dressings and illustrate the performance benefits of the SiQuat technology. Table I shows contact kill performance against a range of bacteria and a yeast in a static test. Table II shows dynamic testing against a series of clinical isolates. Table III shows the effectiveness against a model bacterium in a static test in the presence of various fluids including serum.³ Additional work was done with this technology on silk fabrics (Alpretec – Venice, Italy) in a clinical study of atopic dermatitis (AD) in children. Using the SCORAD index, a significant decrease in AD severity was noted with the treated dressings (mean SCORAD decrease from 43 to 30: $P = 0.003$). This allowed for the conclusion that such treated clothes (dressings) should be useful in the management of AD in children.⁴



TABLE I
Results
AATCC Method 100, Antimicrobials on Fabrics¹
AEM 5700 Antimicrobial Agent Treated Nonwovens

<u>Microorganisms</u>	<u>Sample</u>	<u>Percent Reduction</u>
<i>Staphylococcus aureus</i> Gram (+) Bacteria	Control	16
	Treated ²	100
<i>Escherichia coli</i> Gram (-) Bacteria	Control	0
	Treated	99.6
<i>Klebsiella pneumoniae</i> Gram (-) Bacteria	Control	0
	Treated	100
<i>Saccharomyces cerevisiae</i> Yeast	Control	0
	Treated	99.9

¹ DuPont FC-170 surfactant used, substituted for Rohm and Haas Triton X-100

² Fabric was Kaycel

Table II
Results
Clinical Isolate Control²
AEM 5700 Antimicrobial Agent Treated Nonwovens

<u>Microorganisms</u>	<u>Sample</u>	<u>Percent Reduction</u>
<i>Citrobacter diversus</i> Wound Isolate	Untreated ¹	14.3
	Treated ¹	93.6
	Inoculum	0
<i>Pseudomonas aeruginosa</i> Urine Isolate	Untreated	28.3
	Treated	99.9
	Inoculum	0
<i>Staphylococcus aureus</i> Wound Isolate	Untreated	0
	Treated	99.7
	Inoculum	0
<i>Escherichia coli</i> Urine Isolate	Untreated	11.6
	Treated	98.6
	Inoculum	0
<i>Proteus mirabilis</i> Wound Isolate	Untreated	0
	Treated	99.5
	Inoculum	0

¹ Sontara Fabric

² ASTM E-2149-01



**Table III
Results
Fluid Compatibility Tests
AEM 5700 Antimicrobial Agent Treated ISO-BAC Fabric**

<u>Sample</u>	Percent Reduction ¹ with 15 min. Contact		
	<u>Buffered Phosphate</u>	<u>Saline</u>	<u>Serum</u>
Untreated Linen	8	0	0
Untreated Sontara Nonwoven	0	0	0
Treated Sontara	99+	90+	90+

¹ Modified AATCC method 100 using test fluids *Klebsiella pneumoniae* statistically significant at the 95% confidence level.

These performance properties are complemented by a series of safety tests on the SiQuat that provide for a high degree of confidence on the safety and performance of the treatment:

1. Safety to the Skin System – Irritation and Sensitization Tests⁵ No irritation or sensitizations were shown in tests of the raw treatment and the treatment on a treated surface.
2. Lack of Skin Penetration – Percutaneous Adsorption⁶ No transport of the raw treatment across the skin and into the body was found in this very rigorous test.
3. Safety to Normal Skin Organisms – Effects on Normal Skin Flora⁷ No negative effects were seen in the normal microbial flora.
4. Performance of ÆGIS Microbe Shield Treatment Silk Baby Clothing – Control of Atopic Dermatitis⁴ In a clinical trial the ÆGIS Microbe Shield Treatment Silk Baby Clothing provided for better healing and no negative effects on the skin than traditional therapies.

SUMMARY

For wound care product developers, it is useful to set design criteria around the nature of the wound, the holistic view of the patient, the use environment, and the technologies being used. The antimicrobial technology of choice needs to provide the broad-spectrum activity, safety, and compatibility with people and the dressing fabric appropriate for the end-use.

Antimicrobial treated fabrics provide useful and protective therapeutic materials for acute and chronic wound care. Combining antimicrobial and fabric technologies that are safe and effective for the broad spectrum of organisms and diverse wound conditions clearly provides benefits for protecting wound sites and enhances the healing process.

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AEGIS Environments

2205 Ridgewood Drive

Midland, MI 48642

800.241.9186

www.aegismicrobeshield.com

