NAVAL FACILITIES ENGINEERING SERVICE CENTER
Port Hueneme, CA 93043

NFESC
TECHNICAL REPORT
TR-2100-ENV

EVALUATION OF BIO-BASED INDUSTRIAL PRODUCTS FOR NAVY AND DOD USE

PHASE I
USA ABSORBENTS

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1.0 INTRODUCTION

Alternative Agricultural Research and Commercialization (AARC) Corporation is a wholly owned corporation of the U.S. Department of Agriculture (USDA). AARC is a venture capital firm that is authorized to make investments in companies to help commercialize bio-based industrial products (non-food, non-feed) from agricultural, forestry materials, and animal byproducts. As these bio-based products are made from agricultural materials, they tend to be environmentally friendly. In many instances, these products replace petroleum products and are comprised of recovered agricultural waste material.

Since the Federal government has an equity position in these companies, Section 729 of the 1996 Federal Agricultural Improvement and Reform Act (P.L.104-127, Title VII, Subtitle A, Chapter 2, Section 1657c) prompted an amendment of the AARC Corporation authorization. The authorization now allows other Federal agencies to establish procurement set-asides and encourages preferences for property that has been commercialized with assistance provided under Subtitle G of Title XVI of the Food, Agriculture, Conservation and Trade Act of 1990. To this end, the Federal Acquisition Regulations are in the process of being amended to encourage these preferences. In addition, both the Secretary of Defense and the Secretary of Agriculture have signed letters expressing their support of a partnership between Department of Defense (DOD) and USDA to increase DOD use of these bio-based products.

Under the sponsorship of AARC Corporation, Naval Facilities Engineering Service Center (NFESC) evaluated the potential use of a number of these bio-based products within the Navy and DOD. Representatives from both NFESC and AARC selected eleven bio-based products to undergo a two-phase evaluation process. This document provides the results from the first phase of the evaluation process.

2.0 EVALUATION METHODOLOGY

The evaluation methodology consists of a two phase approach. Details of the methodology are outlined in the following two subsections.

2.1 Phase I: Preliminary Product Evaluation

Each vendor's manufacturing site was visited to collect product data, discuss product usage, and to obtain information regarding the performance claims, savings, and environmental benefits. Existing third-party certifications and test results were also reviewed and current users of the product were contacted and interviewed. In addition, scientific and engineering literature was researched to establish the physical, chemical, or biological mechanisms employed by the product in achieving its claimed performance. Potential opportunities for using the product within the Navy were identified and a preliminary life cycle cost (LCC) analysis was performed using the Phase I product data. The evaluation process did not proceed to Phase II if the results of the Phase I product investigation clearly indicated that the product could not be cost-effectively employed within the Navy or that the product had no apparent cost-effective potential for Navy use. An implementation plan was developed for those products evaluated as having cost effective use within the Navy. Proceeding onward to Phase II product testing was recommended when the Phase I analysis suggested that the product had potential for cost-effective Navy use but lacked sufficient data to conclusively validate product performance and/or LCC.

2.2 Phase II: Product Testing

For those products proceeding onto Phase II of the evaluation process, a specific step-by-step test protocol is developed for each recommended product with the objective of providing sufficient data to verify product utility within the Navy. The protocol will be designed to evaluate life cycle performance of the product. Upon approval of the protocol by AARC, the product will be tested by a certified testing facility under controlled conditions. In addition, the life cycle performance of the product will be evaluated and the environmental, safety, and health benefits and trade-offs associated with the product will be estimated. A LCC analysis of the product will be performed using the proven costing techniques from the NAVFAC Economic Analysis Handbook P-442.

An implementation plan will be developed for each of the recommended products targeted for the potential user community within the Navy and DOD. During the development of the implementation plan, the requirements and needs of the Navy ship, aviation, and shore facilities will be considered. The resources of the Joint Group on Acquisition Pollution Prevention (JG-APP) will also be utilized to promote Army and Air Force implementation of the product. Product visibility may also be achieved through various publications distributed throughout DoD and other government agencies.

3.0 PRODUCTS EVALUATED

Table 3.1 lists the eleven products evaluated in Phase I for potential application within the DoD. Each product evaluation is presented in a separate report.

(Table 3.1 Omitted Due To Restricted Vendor Information)

4.0 AFFIRMATIVE PROCUREMENT

Section 6002 of Resource Conservation Recovery Act (RCRA) directs government agencies to promote recycling by increasing their purchases of products containing recovered materials. RCRA section 6002(e) requires the Environmental Protection Agency (EPA) to designate items that are or can be produced with recovered materials and prepare guidelines to assist procuring agencies in complying with their affirmative procurement responsibilities set forth in paragraphs (c), (d), and (i) of section 6002. Once EPA has designated items, section 6002 requires that any procuring agency spending more than $10,000 a year of Federal funds on an item must purchase the highest percentage of recovered materials practicable. Procuring agencies are Federal, state, and local agencies, and their contractors, which use appropriated Federal funds.

Executive Order 12873 reinforced RCRA's Federal buy recycled program by directing EPA to adopt modified procedures for designating items and providing procurement recommendations.
Under the order, EPA issued a regulation known as Comprehensive Procurement Guideline (CPG) which contains the item designations, and also prepared a guidance document known as a Recovered Materials Advisory Notice (RMAN). The RMAN contains EPA's recommendations to procuring agencies to assist them in purchasing the designated items and meeting their statutory obligations. The RMAN also provides general guidance for developing an affirmative procurement program. An affirmative procurement program is a procuring agency's strategy for maximizing its purchases of EPA-designated items, and must consist of the following:

- Recovered materials preference program
- An agency promotion program
- A program for requiring vendors to reasonably estimate, certify, and verify the recovered materials content of their products; and
- A program to monitor and annually review the effectiveness of the affirmative procurement program

On September 16, 1998 Executive Order 12873 was replaced by Executive Order 13101 which expanded the affirmative procurement program to include bio-based products on the EPA designated items list. A bio-based product list will be developed and published by USDA in the Federal Register no later than March 23, 1999. The list shall also be updated biannually after publication to include additional items. It is assumed that the bio-based product evaluated in this report will be included in the list.

In the spirit of section 6002 of the Resource Conservation and Recovery Act (RCRA) and Executive Order 13101, Federal procuring agencies and personnel should strongly consider implementing sustainable bio-based products when selecting items to meet the goals of the affirmative procurement program.

5.0 USA ABSORBENTS

5.1 Product Description

USA Absorbent manufactures a variety of absorbent products including mats, pads, pillows, socks, and boom. These absorbent products are made from wool or cotton gin motes, waste-grade, short-staple fibers with impurities, which fail to meet garment grade specifications. The gin motes are converted into sheets of wool or cotton absorbent using a patent pending needle-punch process. This process was developed by Hobbs Industries, formerly known as Western Textile Products, located in Waco, Texas. The patent-pending process is as follows. Wool or cotton gin motes are manually feed into a mechanical shredder where the fibers are separated into a homogeneous fluff. The fluff is then pulled into a long thin continuous sheet by a series of textured conveyor belts. The sheet is mechanically folded numerous times along the conveyor belt in long sections and fed through a press forming a lightweight (4 to 8 ounces per square yard) multi-layered mat. The mat is then punched by banks of needles which interweave the fibers together from the folded layers. Polyvinyl acrylic (PVA) resin is sprayed onto the needle-punched sheet which is then heat treated rendering the PVA resin less water soluble. This PVA treatment produces a strong lightweight mat that is very difficult to rip apart and allows the mat to be reused numerous times after wringing. Approximately 80,000 rolls of bonded needle-punched matting measuring 18” X 150’ are shipped per year from Hobbs Industries to USA Absorbents in San Antonio, Texas. At the San Antonio facility the large rolls of matting are cut, packaged, and marketed as various absorbent products. Booms, pillows, and socks are also stuffed at the San Antonio warehouse using stitched pads and rolls. Local industrial seamsters perform the necessary stitching required for assembly of these stuffed products. Table 5.1 in Section 5.2 lists and describes the various absorbent products available from USA Absorbents.

In addition to providing natural fiber absorbents from annually renewable resources, USA Absorbents also offers a closed-loop recycling program to selected users within the contiguous 48 states. These users have the option of returning their used absorbent to USA Absorbents for bioremediation as opposed to incinerating or landfilling the product as hazardous waste (HW) which can carry significant liability risks. USA Absorbents’ new bioremediation facility, located in San Antonio, Texas, is a one acre cement-lined compost staging area. An additional 30 acres, adjacent to the facility, is available for expansion as the bioremediation program grows. The facility currently accepts ten to fifteen 30-gallon barrels of used product per month. Used product is shipped in 30-gallon overpack containers, U.N. rated, via Roadway Package Service.

Participants in the program include government, military, and customers in the automotive and petroleum industries. Participants sign contracts agreeing to comply with terms such as acceptable and non-acceptable materials (i.e. chlorinated solvents). Bio-piles, each dedicated to one specific user, are monitored for total petroleum hydrocarbon concentrations (TPH) and, periodically, for organic and inorganic concentrations. With the exception of TPH, if analytical test results reveal presence of unacceptable materials or materials exceeding regulatory levels, the participant is financially responsible

for the hazardous waste disposal of the bio-pile. Before adding used absorbents to the biopiles, the used absorbent is passed through a hazardous materials detector capable of detecting undesirable compounds such as chlorinated solvents. Approximately three 30-gallon containers of used sorbent are tilled into 10 cubic yards of imported soil. Various types of animal fertilizer is also added to the biopiles to supply nutrients to the microorganisms that feed on the hydrocarbons. Using a fresh batch of imported soil for each biopile safeguards inorganic concentrations from exceeding regulatory levels. The biopiles are monitored daily to maintain temperatures within the range of 140 and 150 ^{0}F and tilled approximately every two weeks to promote the aerobic digestion of hydrocarbons. Once soil samples indicate that the total petroleum hydrocarbon concentration is below the State standard of 50 ppm, the remediation process is considered complete. The remediated soil is removed from the biopile facility and used as Class I compostable soil in commercial applications such as fill dirt for large construction projects (i.e. highways) or lawn and garden compost.

A copy of the contract to participate in the bioremediation/recycling program, is included in Appendix A.

Contact information:

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5.2 Vendor Claims

Table 5.1 lists the majority of absorbent products available from USA Absorbents and briefly describes each product's characteristics. The absorbency ratios presented in the table were converted from the gallons of oil absorbed per item, as listed in the vendor's catalogue, to grams of oil absorbed per gram of sorbent. This conversion assumed one gallon of oil weighs 7.2 pounds. Actual absorbency ratios will vary depending upon environmental conditions such as temperature and the type of oil absorbed.

Table 5.1: Absorbent Product List and Characteristics

Product Name	Product Characteristics
Woolzorb Pads And Rolls	Single bonded needle-punched wool Density: 6 to 8 oz / yd^2 11 grams of oil absorbed per gram of sorbent Suitable for heavy fuels
Wooly Mats	Double bonded needle-punched wool Density: 8 oz / yd^2 13.5 grams of oil absorbed per gram of sorbent Suitable for heavy fuels Designed for heavy industrial uses such as forklift traffic
Wooly Booms 6 Inch Diameter 8 Inch Diameter	Woolzorb sock, muslin inner liner, and cotton stuffing* Length: 10 ft 6.5 grams of oil absorbed per gram of sorbent 8.5 grams of oil absorbed per gram of sorbent For use in containing fuel and oil spills on streams, lakes, and seas Unique quick lock buckling system for fast deployment Optional reflective markings for easy recognition day or night
Cottonsoak Pads And Rolls	Single bonded needle-punched cotton 6 to 8 oz / yd^2 10 grams of oil absorbed per gram of sorbent Suitable for light fuels
Cottonsoak Pillows	Needle-punched cotton Cotton stuffing* 6 grams of oil absorbed per gram of sorbent Suitable for light fuels
Econo Pads (18” X 18”) Biorags (13” X 13”)	Single bonded needle-punched cotton 4 oz / yd^2 Suitable for shop rag use
Natural Fiber Sorbent Socks	Woven natural cotton outer cover Shorn wool stuffing* 3 grams of oil absorbed per gram of sorbent
Woolzorb Pillows	Woven natural wool outer cover Shorn wool stuffing* 6 grams of oil absorbed per gram of sorbent
Static Dissipative Blankets	Single bonded needle-punched cotton MIL Spec (MIL-B-81705C) EMI Static Shield Backing Density: 6 to 8 oz / yd^2 Suitable for aircraft and marine fueling operations

*All stuffing material is gin mote grade.

In addition to the product descriptions in the Table 5.1, USA Absorbents claims the following benefits in regards to their wool-based and cotton-based absorbents:

- All products are made from natural organic fibers and are biodegradable and friendly to the environment.
- All products are made from both recovered waste products and annually renewable resources.
- All products, excluding the static dissipative blanket, can be incinerated or landfilled in accordance with local regulations.
- Woolzorb and Cottonsoak products meet the National Fire Protection Association (NFPA) requirements as specified in the NFPA 99 test Section 2-6.3.8 (F)3B.
- All mats, pads, rolls, pillows, socks, and booms can be reused effectively at least 8-10 times if mechanically wrung out after each use.
- Wool saturated with oil has over 18,000 BTUs per pound for incineration.
- Wool-based products are designed to absorb water and oil.
- The all cotton absorbents (pillows, pads and rolls) are designed to absorb oil only.

5.3 Verification of Product Claims

The needle-punched wool and cotton absorbent products have been tested extensively by Millsaps Sorbent and Environmental Laboratory of Millsaps College located in Jackson, Mississippi. Bioremediation and HW characteristic testing was conducted by San Antonio Testing Laboratory (SATL), Inc. located in San Antonio, Texas. Anti-static testing was conducted by K & S Laboratories Incorporated located in Stoughton, Massachusetts.

5.3.1 Third Party Testing and Results

5.3.1.1 Millsaps Sorbent and Environmental Laboratory

Millsaps Sorbent and Environmental Laboratory, located at Millsaps College in Jackson, Mississippi has been engaged in oil spill technology evaluation and standardization since 1988. Extensive sorbency tests were conducted between May 19, 1993 and December 15, 1998 on Woolzorb pads, Wooly boom, Cottonsoak pads, and wool particulate (stuffing for Natural Fiber Sorbent pillows and socks). All tests were conducted under the protocol of the American Society for Testing and Materials (ASTM) standards on Hazardous Substances and Oil Spill Response, Section F 726 with modifications as noted.

Copies of all test dated presented in this Section are included in Appendix A.

5.3.1.1.1 Sorbency Tests on Wool Pads and Wool Particulate

Sorbency tests were conducted on prototype Woolzorb pads of various densities and wool particulate using test method ASTM F 726. Pad densities tested were 6, 8, and 12 ounces per square yard (oz/yd^2). These tests determined the maximum sorbency of the wool pads and wool particulate under an ideal controlled laboratory situation. The sorbency ratios presented in Table 5.2 are the average of three tests conducted each for light, medium, and heavy type oils. The results indicate that the wool pads and particulate consistently absorbed the heavy crude oil more

efficiently than the light crude oil and absorbed diesel #2 least efficiently. Pads that were 8 oz/yd^2 performed better than pads 12 oz/yd^2. Under these ideal test conditions, pads 8 oz/yd^2 absorbed heavy crude oil between 30 and nearly 50 times their own weight. The 8 oz/yd^2 pads also absorbed light crude and diesel #2 approximately 22 and 19 times their own weight, respectively. The wool particulate (shorn wool) absorbed heavy crude 35 times it own weight. Based on the results of these tests, the 8 oz/yd^2 was selected as the optimal density for the wool-based pads and mats.

Table 5.2: Sorbency Test Results For Wool Pads and Wool Particulate

Product Tested Report Date	Saturation and Drain Parameters	Sorbency Ratio (Grams of Oil Per Gram of Sorbent)		
		T-102 Light Crude	Diesel #2	T-201 Heavy Crude
6 Ounce Woolzorb 5-19-93	Full Saturation Plus 20% Saturation Time, 30 Second Drain	28.46	19.82	44.53
8 Ounce Woolzorb 5-19-93	Full Saturation Plus 20% Saturation Time, 30 Second Drain	22.29	17.11	35.32
8 Ounce Woolzorb 9/21/93	Full Saturation Plus 20% Saturation Time, 30 Second Drain	22.89	21.35	-
	Heavy Crude Has 15 Minute Saturation Time and 30 Second Drain	-	-	49.58
8 Ounces Woolzorb 1-12-94	Not Specified	17.39	16.53	-
	Complete Saturation 30 Second Drain	-	-	29.04
	15 Minute Saturation 180 Second Drain	-	-	20.72
12 Ounce Woolzorb 5-19-93	Full Saturation Plus 20% Saturation Time, 30 Second Drain	14.41	12.13	21.57
12 Ounce Woolzorb 9/21/93	Full Saturation Plus 20% Saturation Time, 30 Second Drain	21.32	19.46	-
	Heavy Crude Has 15 Minute Saturation Time and 30 Second Drain	-	-	44.01
12 Ounces Woolzorb 1-12-94	Not Specified	13.00	13.45	-
	Complete Saturation 30 Second Drain	-	-	19.42
	15 Minute Saturation 180 Second Drain	-	-	15.66
Wool Particulate 9-21-94	Not Specified	15.93	15.29	35.62

5.3.1.1.2 High Rate Exposure Tests On Wool Pads

A high rate exposure test was conducted on 6, 8, and 12 oz/yd^2 pads using test method ASTM-81 to determine the ratio of oil and water absorbed when the absorbent was exposed to a mixture of both fluids in a turbulent environment. A brief description of the test is as follows:

A wool sorbent sample is placed in a closed container with water. The container is agitated using a shaker table for five minutes. At the end of this period, 50 mL of light crude oil is added to the container and the table is again activated for five minutes. This procedure is repeated until complete saturation of the sorbent pad is achieved. Table 5.3 shows the high rate exposure test results. The 8 oz/yd^2 pad absorbed oil more efficiently than the other two pads. The 8 oz/yd^2 pad averaged 19 grams of light crude oil absorbed per gram of sorbent.

Table 5.3: High Rate Exposure Test Results On Wool Pads

Absorbent Description	Ratio of Oil to Water (Gram Per Gram)	Absorbency Ratio (Grams Oil Absorbed Per Gram of Sorbent)
6 Ounce Wool Pad*	4.29	15.06
8 Ounce Wool Pad*	3.80	13.86
8 Ounce Wool Pad**	4.48	18.77
8 Ounce Wool Pad**	7.67	24.76
12 Ounce Wool Pad*	3.44	10.46
12 Ounce Wool Pad**	2.64	13.68
12 Ounce Wool Pad**	6.22	14.77

* Data from report dated May 19, 1993.

** Data from undated report summary.

5.3.1.1.3 Hydrophobicity Tests On Wool Pads

Four hydrophobicity tests were conducted on various wool pads. The high rate water resistance tests and the long-term water sorbency tests were performed on 6 oz/yd^2 pads. The oil sorption tests and the high rate interval tests were performed on the 6, 8, and 12 oz/yd^2 pads. A brief description of each test and the test results are as follows:

<u>High Rate Water Resistance Test</u>

A sample is weighed and placed into a container of water only. The container is activated on a shaker table for 2 hours. The sample is removed and allowed to drain for 30 and 60 seconds and then reweighed. The test results showed that 4.92 and 3.59 grams of water were absorbed per gram of absorbent for the 30 and 60 second drain measurements, respectively.

Oil Sorption Test

The sorbent pads were saturated with water, squeezed through a roller to remove excess water, and then retested for oil sorbency using a light crude oil and a 30 seconds drain before reweighing. Test results, as shown in Table 5.4, averaged 19.49, 23.00, and 19.33 grams of oil absorbed per gram of absorbent for the 6, 8, and 12 oz/yd^2 pads respectively. Again, the 8 oz/yd^2 performed more efficiently than the other two pads absorbing 15% more oil under these test conditions.

Table 5.4: Oil Sorption Test Results For Wool Pads

Pad Density	Sorbency Ratios	Test 1	Test 2	Test 3	Average
6*	Grams Of Oil / Gram of Sorbent	19.09	19.89	-	19.49
6*	Grams Of Water / Gram of Sorbent	1.92	2.02	-	1.97
8**	Grams Of Oil / Gram of Sorbent	24.30	23.11	23.78	23.00
8**	Grams Of Water / Gram of Sorbent	2.18	2.19	2.24	2.20
12**	Grams Of Oil / Gram of Sorbent	18.98	19.68	19.35	19.33
12**	Grams Of Water / Gram of Sorbent	2.82	2.05	2.53	2.46

* Data from a report dated 5-19-93.
** Data from an undated report summary.

Long Term Water Sorbency Test

A sample is weighed and placed into a reservoir of water. The sample is allowed to float on the surface for 24 hours after which it is removed and allowed to drain 30 seconds before reweighing. Two test results showed that the samples absorbed 0.48 and 0.24 grams of water per gram of sorbent under these conditions.

High Rate Interval Test

A sample is placed into a closed container with water and oscillated in a high rate environment for intervals of 5, 10, 30, 60, 90, and 120 minutes. After each interval of oscillation, the pad is allowed to drain for 30 and 60 seconds before the sample is reweighed. The results are recorded as grams of water per gram of sorbent. Table 5.5 shows the results for the high rate intervals tests on 6, 8, and 12 oz/yd^2 pads. For the 120 minute oscillation period, the 6 oz/yd^2 pad and the 12 oz/yd^2 pad had retained the most and the least amount of water, respectively, for both the 30 and 60 second drain times.

Table 5.5: High Rate Interval Test Results For Wool Pads

Pad Density	Test Parameter	Water Absorbency Ratio (Grams Water Per Gram of Absorbent)					
		5 Minute Oscillation	10 Minute Oscillation	30 Minute Oscillation	60 Minute Oscillation	90 Minute Oscillation	120 Minute Oscillation
6-Ounce	30 Second Drain	6.02	6.75	6.75	7.45	-	8.31
6-Ounce	60 Second Drain	4.62	5.14	5.31	5.59	-	6.90
8-Ounce	30 Second Drain	-	6.76	6.10	7.51	6.62	6.87
8-Ounce	60 Second Drain	-	5.01	4.57	4.93	4.97	5.05
12-Ounce	30 Second Drain	-	6.76	7.08	7.79	5.89	5.62
12-Ounce	60 Second Drain	-	4.94	5.12	5.61	4.93	4.64

* Data from a report dated 5-19-93.
** Data from an undated report summary.

5.3.1.1.4 Hydrocarbon Release Test On Wool Pads

Three hydrocarbon release tests were conducted on wool sorbent pads. Samples were placed into a reservoir of light crude oil and allowed to saturate for a minimum of twelve hours. After saturation the pads were suspended above a scale and the weight of the oil released recorded at intervals of 0.5, 1, 5, 15, and 30 minutes. Table 5.6 shows the results of the three tests. The results determined that the rate of release was dependent upon the density of the wool pad. Increased density decreased the void space availability of the pad. Rates of release were greater in the denser pads and attributed to the oil being held on the surface and not in the interior void spaces of the pads.

Table 5.6: Hydrocarbon Release Test Results For Wool Pads

Test	Sample Weight (grams)	Sample Thickness (mm)	Drain Time (Minutes)	Weight of Retained Oil (grams)	Percentage of Retained Oil (%)
1	4.50	2.82	0.5	73.8	65.25
			1	66.2	58.53
			5	55.3	48.89
			15	52.3	46.24
			30	52.3	46.24
2	4.83	3.10	0.5	63.54	59.20
			1	55.44	51.65
			5	44.14	41.12
			15	42.04	39.17
			30	42.02	39.17
3	4.93	3.01	0.5	47.27	40.00
			1	36.27	30.69
			5	23.77	20.12
			15	22.27	18.85
			30	22.27	18.85

5.3.1.1.5 Sorbency Tests On Wooly Boom

Three sorbency tests were performed on Wooly Boom. Samples measured 3'3" long. Boom diameter was not specified. A brief description of each test and the test results are as follows:

Initial Absorption Test And Saturation Test

The initial absorption test determined how rapidly the boom absorbed oil. The dry weight of the boom was measured. The boom was placed by net, horizontally, into a tank of water with an oil layer of 1.5 inches for 2.5 minutes. The boom was removed with a suspended scale above the tank and allowed to drain exactly five seconds before the boom was reweighed. Three tests were conducted using diesel, light crude, and heavy crude oil.

The saturation test determined the quantity of oil a boom will absorb relative to its own weight, revealing the efficiency of each boom. After completing the initial adsorption test, the boom was lowered back into the tank and left there for 30 minutes. The boom was removed with a suspended scale and allowed to drain exactly five seconds before the boom was reweighed. Saturation is defined as total sorbent capacity at 30 minutes of exposure to excess oil. Test results are presented in Table 5.7. When comparing the amount of oil saturated after 2.5 minutes to the amount saturated after 30 minutes, the results indicate that the boom absorbed 85 % of light crude oil and 89 % of diesel #2 within the first 2.5 minutes. In addition, Wooly Boom absorbed diesel #2 and light crude oil more efficiently than heavy crude oil. These test results are contrary to the previously presented test results for the wool pads that indicate that wool absorbed heavy crude more efficiently. It should be noted that Wooly Boom is primarily a cotton-based product. The boom has an outer wool covering but is stuffed with cotton gin motes and, therefore, performs differently than USA Absorbents other wool-based products.

Table 5.7: Initial Absorption and Saturation Test Results For Wooly Boom

Absorbency Ratios	T-102 Light Crude	Diesel #2	T-201 Heavy Crude
Absorbency Ratio After 2.5 Minutes			
(Pounds of Oil / Pound of Boom)	7.27	9.19	0.89
(Gallons of Oil / Pound of Boom)	1.01	1.31	0.12
Absorbency Ratio After 30 Minutes			
(Pounds of Oil / Pound of Boom)	8.55	10.33	2.81
(Gallons of Oil / Pound of Boom)	1.19	1.47	0.38

Hydrocarbon Release Test

The boom, suspended from the scales in the "saturation" test, was allowed to remain draining over the test tank with weight readings taken every 5 minutes for 30 minutes. Test results, as shown in Table 5.8, are expressed as percentages of oil retained over time.
For the light crude, #2 diesel, and heavy crude oils, 47%, 29%, and 86 % of the oil remained in the boom after a 30 minute drain.

Table 5.8: Hydrocarbon Release Test Results For Wooly Boom

Oil Type	Drain Time (Minutes)	Weight of Retained Oil (Pounds)	Percentage of Retained Oil (%)
T-102 Light Crude	5	19.30	72
	10	15.90	61
	15	14.10	55
	20	13.00	52
	25	12.10	49
	30	11.50	47
Diesel #2	5	11.80	47
	10	9.00	38
	15	7.80	34
	20	7.00	32
	25	6.50	30
	30	6.10	29
T-201 Heavy Crude	5	6.50	89
	10	6.40	88
	15	6.40	88
	20	6.30	87
	25	6.30	87
	30	6.20	86

5.3.1.1.6 Sorbency Tests on Cotton Products

Sorbency tests were conducted on samples of Cottonsoak pads weighing 6 oz/yd^2. These tests determined the sorbency of the cotton-based pads under an ideal controlled laboratory situation. The sorbency ratios presented in Table 5.9 are the average of three tests conducted each for light, medium, and heavy type oils. Results indicate that the Cottonsoak pads absorbed approximately 18 grams of diesel #2 and light crude oil per gram of Cottonsoak and 13 grams of heavy crude oil per gram of Cottonsoak after a saturation and drain period of 15 minutes and 30 seconds respectively.

Table 5.9: Sorbency Ratios for Cottonsoak Pads

Saturation and Drain Parameters	Sorbency Ratio T-102 Light Crude	Sorbency Ratio Diesel #2	Sorbency Ratio T-201 Heavy Crude
	(Grams of Oil Per Gram of Sorbent)		
15 Minute Saturation 30 Second Drain	18.51	18.72	13.22

5.3.1.1.7 Calorimetric Analysis On Woolzorb

Three samples of unused Woolzorb were burned in a Parr 1241 calorimeter using ASTM procedure D 2015-66. The test results indicated that the average heat of combustion for the unused Woolzorb was determined at 9,206 BTU/lb. In addition, five samples of Woolzorb were saturated with a West Texas Sweet Crude oil, API gravity 32-36, and allowed to drain from a hanger for one hour. These samples were combusted using the same procedure described above. The average heat of combustion for the five samples of saturated Woolzorb was determined at 18,339 BTU/lb.

5.3.1.2 K & S Laboratories

The generation of static electricity in textiles can present a major hazard when responding to a flammable spill. The amount of charge on an item depends upon the rate of generation and the rate of dissipation of charge. A low charge and/or a slow rate of decay is less hazardous than a high charge and/or a quick rate of decay. After a tragic accident occurred at an Air Force Base involving absorbent pads and a flammable fuel spill, the Air Force adopted the anti-static standard stipulated in NFPA 99, originally used by hospitals. Section 2-6.3.8 (F)3A of the NFPA 99 states that, when using test method 4046 of Federal Test Method Standard (FTMS), after a specimen has received its maximum charge from the application of 5,000 volts, the time for the indicated specimen potential to drop to 500 volts shall not exceed 0.5 seconds. Section 2-6.3.8 (F)3B of the NFPA 99 states that, when using test method 76 of the American Association of Textile Chemists and Colorists (AATCC), an anti-static item shall have of a surface resistivity of less than 1.0×10^{11} ohms per square unit of material at an applied voltage of 102 volts per inch or 40 volts per centimeter of electrode spacing when preconditioned at 50% relative humidity. Wool fabrics exposed to low a relative humidity of 25% or less tend not to meet this requirement. In a memo, dated June of 1995, the Air Force states that the climatic conditions must be carefully evaluated before using anti-static absorbent pads in a fuel/vapor spill environment. It is the Incident Commander's responsibility to establish the appropriateness of their use under the existing climatic conditions since extreme temperatures and/or dry conditions significantly increase the potential for static discharge and ignition.

K & S Laboratories performed tests on Woolzorb, Cottonsoak, and USA Absorbents' Static Dissipative Blanket to determine the surface charge of these materials after preconditioning samples at 50% relative humidity at 23 ^{0}C for 25 hours or until equilibrium was reached. Table 5.10 shows the results of the static tests.

Table 5.10: Static Test Results

Sample	Surface Resistivity (Ohms / Square Unit of Material*)	Decay Time (Seconds)
Woolzorb	6×10^{10} to 9×10^{10}	0.16 to 0.37
Cottonsoak	9×10^{9}	0.03

* Per square inch if 102 volts is applied to the electrode spacing and per inch or 40 volts per square centimeter if 40 volts is applied to the electrode spacing.

All items tested showed a surface resistivity of less than 1.0×10^{11} ohms per square unit of material and a decay time less of than 0.5 seconds. In addition to Woolzorb and Cottonsoak pads, the Static Dissipative Blanket with EMI shielding was reported as having 20% less surface resistivity than the Woolzorb pads. All the tested items meet the anti-static criteria as specified by the NFPA 99. Copies of test results, dated February 3, 1999, the memo, and NFPA 99 Section 2-6.3.8(F)3 are included in Appendix A.

5.3.1.3 San Antonio Testing Laboratory

San Antonio Testing Laboratory (SATL), located in San Antonio, Texas, performed extensive analytical tests on Cottonsoak pads and on biopile soil samples. Since wool is an untreated, low-grade, natural fiber derived from animals, it was not considered necessary to test the wool-based pads for pesticides, herbicides, organic or inorganic compounds. SATL performed Toxicity Characteristic Leaching Procedure (TCLP) tests on Cottonsoak pads for inorganic, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and organochlorine pesticides. Additional testing was performed to determine concentrations of herbicide and orthophosphorus pesticide residues. TCLP tests were also performed on biopile samples for inorganics, VOCs, SVOCs, HW characteristics, and total petroleum hydrocarbons (TPH). Copies of test reports, dated September 4, 1996 through January 5, 1999, are included in Appendix A.

5.3.1.3.1 Cottonsoak Pads

The results in Tables 5.11, 5.12, and 5.13 show that Cottonsoak samples did not contain any target inorganics, VOCs, or SVOCs in concentrations that exceed the regulatory limits.

Table 5.11: TCLP Test Results For Inorganic Compounds In Cottonsoak

Inorganics	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Arsenic	<0.005	0.005	0.005
Barium	<0.50	0.5	0.50
Cadmium	<0.05	0.05	0.05
Chromium	<0.05	0.05	0.05
Lead	<0.10	0.10	0.10
Mercury	<0.0002	0.0002	0.0002
Selenium	<0.005	0.005	0.005
Silver	<0.05	0.05	0.05

Samples were analyzed using EPA test methods 1311, 206.2, 208.1, 213.1, 218.1, 239.1, 245.1, 270.2, 272.1.

Table 5.12: TCLP Test Results For VOCs In Cottonsoak

Volatile Organic Compounds	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Benzene	<0.20	0.20	0.5
2-Butanone	<0.20	0.20	200
Carbon Tetrachloride	<0.20	0.20	0.5
Chlorobenzene	<0.20	0.20	100
Chloroform	<0.20	0.20	6
1,1-Dichloroethene	<0.20	0.20	0.7
1,2-Dichloroethane	<0.20	0.20	0.5
1,4-Dichlorobenzene	<0.20	0.20	7.5
Tetrachloroethene	<0.20	0.20	0.7
Trichloroethene	<0.20	0.20	0.5
Vinyl Chloride	<0.20	0.20	0.2

Samples were analyzed using EPA test methods 8260 and 8151A.

Table 5.13: TCLP Test Results For SVOCs In Cottonsoak

Semi-Volatile Organic Compounds	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Pyridine	<0.01	0.01	5.0
2-Methylphenol	<0.01	0.01	200
3-Methyphenol	<0.01	0.01	200
4-Methyphenol	<0.01	0.01	200
Hexachloroethane	<0.01	0.01	3.0
Nitrobenzene	<0.01	0.01	2.0
Hexachlorobutadiene	<0.01	0.01	0.5
2,4-Dinitrotoluene	<0.01	0.01	0.13
Hexachlorobenzene	<0.01	0.01	0.13
Pentachlorophenol	<0.01	0.01	100
2,4,5-Trichloropheneol	<0.01	0.01	400
2,4,6-Trichloropheneol	<0.01	0.01	2.0

Samples were analyzed using EPA test methods 1311 and 8270B.

The organochlorine pesticides in Table 5.14 are listed as toxic organic compounds and regulated by the Clean Water Act. The test results indicate that the concentrations of organochlorine pesticides present in Cottonsoak pads were below the maximum allowable contaminant levels of 0.01 mg/L set forth by the EPA.

Table 5.14: TCLP Test Results For Organochlorine Pesticides In Cottonsoak

COMPOUND	Concentration (mg/L)	Method Detection Limit (mg/L)
Aldrin	<0.001	0.001
alpha-BHC	<0.001	0.001
beta-BHC	<0.001	0.001
delta-BHC	<0.001	0.001
gamma-BHC (Lindane)	<0.001	0.001
alpha-Chlordane	<0.001	0.001
gamma-Chlordane	<0.001	0.001
4, 4-DDD	<0.001	0.001
4, 4-DDE	<0.001	0.001
4, 4-DDT	<0.001	0.001
Dieldrin	<0.001	0.001
Endosulfan I	<0.001	0.001
Endosulfan II	<0.001	0.001
Endosulfan sulfate	<0.001	0.001
Endrin	<0.001	0.001
Endrin aldehyde	<0.001	0.001
Heptachlor	<0.001	0.001
Heptachlor epoxide	<0.001	0.001
Toxaphene	<0.01	<0.01

Samples were analyzed using EPA test methods 1311 and 8081A.

Table 5.15 lists the results of common orthophosphorus pesticide residues on a sample of Cotton soak. One major problem from the phosphates in water systems is algae bloom which can occur at levels as low as 2 mg/L. However, if the cotton absorbents are used as intended, the phosphate concentrations should not pose any algae bloom problem.

Table 5.15: Test Results For Organochlorine Pesticides In Cottonsoak

COMPOUND	Concentration (μg/Kg)	Method Detection Limit (μg/Kg)
Azinphos methyl	<250	250
Bolstar	<25	25
Chlorpyrifos	<25	25
Coumaphos	<250	250
Demeton-O	<25	25
Demeton-S	<25	25
Diazinon	<50	50
Dichlorvos	<25	25
Disulfoton	<25	25
Ethoprop	<25	25
Fensulfothion	<250	250
Fenthion	<25	25
Merphos	<25	25
Mevinphos	<25	25
Naled	<25	25
Parathion methyl	<5	5
Phorate	<25	25
Ronnel	<25	25
Stirophos	<250	250
Tokuthion	<50	50
Trichloronate	<25	25

Samples were analyzed using EPA test method 8140.

Table 5.16 lists the test results of common herbicide residues on a sample of Cotton soak. SATL analyzed a sample of Cottonsoak Pad for herbicides using EPA methods 1311 and 8151A. No herbicide residues were detected in concentrations at or above 2.0 µg/L.

Table 5.16: Test Results For TCLP Herbicides In Cottonsoak

COMPOUND	Concentration (µg/L)	Method Detection Limit (µg/L)
Acifluorfen	<2.0	2.0
Bentazon	<2.0	2.0
Chloramben	<2.0	2.0
2,4, DB	<2.0	2.0
Dalapon	<2.0	2.0
Dacthal	<2.0	2.0
Dicamba	<2.0	2.0
3, 5-Dichlorobenzioc acid	<2.0	2.0
Dichloroprop	<2.0	2.0
Dinoseb	<2.0	2.0
4-Nitrophenol	<2.0	2.0
Pentachlorophenol	<2.0	2.0
Picloram	<2.0	2.0
2,4,5-T	<2.0	2.0
2,4,5-TP	<2.0	2.0
MCPA	<2.0	2.0
MCPP	<2.0	2.0

5.3.1.3.2 Biodegredation Study

An initial bioremediation study was conducted in San Antonio, Texas at a private bioremediation facility owned by Mr. M. Beck to determine the feasibility of developing a closed-loop bioremediation/recycling system for used sorbents. On July 19, 1996 approximately 190 lbs of Woolzorb Pads contaminated with used oil, transmission oil, hydraulic fluid, gasoline, and grease were tilled into a 9 cubic yard biopile. A second 9 cubic yard biopile was started on September 19, 1996 using 274 pounds of Woolzorb Pads contaminated with jet fuel, antifreeze, bearing grease, and used oil.

SATL performed TCLP tests on soil samples collected from the biopiles. Samples were analyzed for target inorganics, volatile organic compounds, semi-volatile organic compounds, TPH, and HW characteristics.

The results in Table 5.17 show that the bio-pile samples contained concentrations of arsenic and barium that exceeded the regulatory levels of 0.005 and 0.5 mg/L, respectively. Since backgrounds levels of the soil were not established prior to the test, it is difficult to ascertain the

originating factor for the high arsenic and barium concentrations. Tables 5.18, and 5.19 show that bio-pile samples did not contain VOCs, or SVOCs in concentrations that exceed the regulatory limits.

Table 5.17: TCLP Test Results For Target Inorganic Compounds In Bio-Pile Samples

Inorganics	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Arsenic	0.01	0.005	0.005
Barium	1.37	0.5	0.5
Cadmium	<0.05	0.05	0.05
Chromium	<0.05	0.05	0.05
Lead	<0.1	0.1	0.1
Mercury	<0.0002	0.0002	0.0002
Selenium	<0.005	0.005	0.005
Silver	<0.05	0.05	0.05

Samples were analyzed using EPA test methods 1311, 206.2, 208.1, 213.1, 218.1, 239.1, 245.1, 270.2, and 272.1.

Table 5.18: TCLP Test Results For Target VOCs In Bio-Pile Samples

Volatile Organic Compounds	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Benzene	<0.005	0.005	0.5
2-Butanone	<0.005	0.005	200
Carbon Tetrachloride	<0.005	0.005	0.5
Chlorobenzene	<0.005	0.005	100
Chloroform	<0.005	0.005	6
1,1-Dichloroethene	<0.005	0.005	0.7
1,2-Dichloroethane	<0.005	0.005	0.5
1,4-Dichlorobenzene	<0.005	0.005	7.5
Tetrachloroethene	<0.005	0.005	0.7
Trichloroethene	<0.005	0.005	0.5
Vinyl Chloride	<0.005	0.005	0.2

Samples were analyzed using EPA test methods 1311 and 8260.

Table 5.19: TCLP Test Results For Target SVOCs In Bio-Pile Samples

Semi-Volatile Organic Compounds	Test Results (mg/L)	Method Detection Limit (mg/L)	Regulatory Level (mg/L)
Pyridine	<0.01	0.01	5.0
2-Methylphenol	<0.01	0.01	200
3-Methyphenol	<0.01	0.1	200
4-Methyphenol	<0.01	0.01	200
Hexachloroethane	<0.01	0.01	3.0
Nitrobenzene	<0.01	0.01	2.0
Hexachlorobutadiene	<0.01	0.01	0.5
2,4-Dinitrotoluene	<0.01	0.01	0.13
Hexachlorobenzene	<0.01	0.01	0.13
Pentachlorophenol	<0.01	0.01	100
2,4,5-Trichloropheneol	<0.01	0.01	400
2,4,6-Trichloropheneol	<0.01	0.01	2.0

Samples were analyzed using EPA test methods 1131 and 8270.

Both biopiles were monitored monthly for TPH concentrations for a period of 6 to eight months, the results of which are shown in Table 5.20. When comparing the first to the last soil samples collected, the results indicate a 73% and a 90% reduction in TPH for biopiles 1 and 2, respectively. Soils with TPH concentrations ranging between 150-200 ppm can be landfilled. USA Absorbents monitors biopiles until TPH concentrations are below the State standard of less than 50 ppm.

Table 5.20: Test Results For TPH From Biopile Samples

Date Sample Analyzed	TPH Concentration Pile 1 (ppm)	TPH Concentration Pile 2 (ppm)
8-29-96	671	-
9-25-96	347	-
10-21-96	812	1520
11-23-96	535	535
12-30-96	185	225
1-17-97	281	207
2-18-97	156	275
3-18-97	180	145

Samples were analyzed using EPA test method 418.1.

SATL determined the HW characteristics of a soil sample collected from biopile 1.
Table 5.21 shows the HW characterization test results including pH, ignitability, and reactivity of biopile soil samples. The samples were determined as not being an ignitable, corrosive, or reactive waste as defined by the Resource Recovery and Conservation Act.

Table 5.21: Test Results For Hazardous Waste Characteristics of Biopile Samples

Hazardous Waste Characteristic	Soil Sample From Bio-Pile	TEST METHOD
Ignitability	> 150 ^{0}F	1010
Corrosivity (pH)	8.44	9045
Reactivity-Sulfide	<108 mg/kg	7.3.4.2
Reactivity-Cyanide	<108 mg/kg	7.3.3.2

Samples were analyzed using EPA test method SW-846.

These results, coupled with the TCPL test results on soil samples in Tables 5.17, 5.18, 5.19, and 5.20, indicate that the remediated soil samples are not considered a HW.

5.3.2 Review Of Material Safety Data Sheets

Material Safety Data Sheets (MSDSs), compiled by USA Absorbents, were reviewed for the PVA resin, Woolzorb, and Cottonsoak absorbent pads. The Woolzorb pads are comprised of 82% needle punched wool and 18% PVA resin. The Cottonsoak pads are comprised of 90% needle punched cotton and 10% PVA resin. Both absorbent pads are incompatible with strong acids, strong alkalis, and oxidizing agents. Due to the presence of PVA resin, pads may release extremely minute traces of formaldehyde when burned or heated greater than 212 ^{0}F. Pads are considered non-toxic and usage requires no special personal protection equipment. Although the absorbent pads are considered combustible, their fire hazard rating is considered to be slight.

The MSDS for the PVA resin, compiled by National Starch and Chemical Company, was also reviewed. The resin contains less than 0.2% vinyl acetate and 0.01% formaldehyde. NFPA reactivity hazard class is rated as insignificant. The PVA resin is not considered toxic and not listed by OSHA, NTP, or IARC as a carcinogen.

Copies of the MSDSs for Woolzorb, Cottonsoak, and the PVA resin are included in Appendix A.

5.4 Current Users

USA Absorbents have been sold and used successfully by many companies for several years. Table 5.22 provides a partial list of current users.

Table 5.22: Partial Customer List of USA Absorbents

Customers	Customers
CALTRANS	Fort Huachuca
City of LaPorte Street Department	Kelly Airforce Base
City of Waco	Lindsey Oil Company
Davis-Monthan Air Force Base	Naval Air Station, Corpus Christi
Earth Friendly Products	Texas Department of Transportation
Fort Hood	Virginia Department of Transportation

A copy of the complete customer list of approximately 80 users is included in Appendix A.

5.5 Product Comparisons

(Section 5.5 Omitted Due To Restricted Vendor Information)

5.6 Preliminary Life Cycle Costs

(Section 5.6 Omitted Due To Restricted Vendor Information)

5.7 Potential Navy / DoD Users

All Joint Service activities with operations that involve petroleum, oil, and hydrocarbon products are potential users of USA Absorbent products.

5.8 Federal Supply Listings

National stock numbers (NSNs) are listed in the USA Absorbents product catalogue. A copy of the catalogue is included in Appendix A.

5.9 Conclusions

The following conclusions can be made regarding USA Absorbents:

- Although the vendor's catalogue claim that all products are of organic origin, the cotton products were not from an "organic" source. However, the cotton products have been tested extensively. TCLP analysis for pesticide and herbicide residues and for inorganic and organic compounds showed that the compounds were below the regulatory levels.
- Products are manufactured from a recovered industrial waste stream.
- Products are derived from a sustainable renewable resource and biodegradable.
- Used absorbent will require evaluation for disposal on a case by case basis given the necessary data submitted by the generator to allow proper waste classification.

- All products, excluding the static dissipative blanket, can be incinerated or landfilled in accordance with local regulations.
- Although Woolzorb, Cottonsoak, and the Static Dissipative Blanket meet the anti-static requirements as specified in the NFPA 99 test Section 2-6.3.8 (F)3 B, climatic conditions must be carefully evaluated before using anti-static absorbent pads in a fuel/vapor spill environment since extreme temperatures and/or dry conditions significantly increase the potential for static discharge and ignition.
- Absorbents can absorb 40 times their own weight in heavy crude oil.
- Unused Woolzorb and Woolzorb saturated with crude oil has approximately 9,000 and 18,000 BTUs per pound, respectively, for incineration.
- Wool-based products are intended to absorb oil only or water and oil.
- Cotton-based pillows, pads and rolls are intended to absorb oil only.
- Wool-based products absorb heavier hydrocarbons better than the light hydrocarbons.
- Sorbency tests on wool needle-punched absorbent have shown that the absorbent can absorb up to approximately 20 times its own weight in diesel #2 and light crude oil and nearly 50 times its own weight in heavy crude oil.
- Sorbency tests on cotton needle-punched absorbent have shown that the absorbent can absorb up to approximately 18 times its own weight in diesel #2 and light crude oil and 13 times its own weight in heavy crude oil.
- Wool generally has a reputation of being water-resistant. Test results indicate that there is a small attraction for water in the wool sorbent pads.

5.10 Recommendations

No additional testing on USA Absorbent mats, rolls, pillows, pads, socks, and boom is considered necessary.

5.11 Implementation

Section 6.0 contains detailed implementation methods and additional procurement contacts applicable to USA Absorbent products. It is also acknowledged that product visibility is crucial to product implementation. The following processes can assist the visibility of USA Absorbents within the military:

- The Defense Technical Information Center (DTIC) will receive a final copy of this report. Joint Service users can search for specific information using a “key words or phrases” search engine.

- USA Absorbent products will be logged into the Joint Service Pollution Prevention Technical Library. This library exists as a Web site and is accessed by the Joint Service for Pollution Prevention guidance.

- The findings of this evaluation will be submitted as publication articles for Navy-wide periodicals. For example, “Currents”, a full-color quarterly magazine, is published by NFESC and offers a wide variety of feature articles. “Indoor Air Monitor”, a monthly periodical in an electronic format, publishes articles related to Safety or OSHA issues.