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Subject: White Phosphorus Quenching by Water-Jel
Technical Report on IITRI Project No. C08066

IIT Research Institute has completed a brief exploratory investigation of the ability of Water-Jel dressings to quench burning phosphorus and to delay reignition. Tests were performed on an inert substrate as well as on the skin of anesthetized experimental animals, with results as described below.

SUMMARY OF RESULTS

In the laboratory, on the 1-2 gram scale, it was necessary to heat white phosphorus to ignite it, probably due to the sample size, but also to the air velocity across the work surface of the fume hood used to contain the experiments.

In the tests on a metal substrate, WP samples quenched with water soaked dressings reignited in 1-5 minutes, while those quenched with Water-Jel failed to ignite in periods up to 30 minutes, although ignition could sometimes be effected by touching the sample with a spatula. There appeared to be a thin coating covering the samples which prevented ignition, even after the sample appeared to have melted.

The results of the animal experiments were not quite as uniform. Some of the Water-Jel quenched samples reignited within 30 minutes, while some of the water-quenched samples also reignited in this time. However, it seems clear that the Water-Jel tends to keep the sample moist, especially if there is a wound where the gel is retained by the cavity. If the water - soaked dressing has an open mesh, or is too thin, air can reach the phosphorus through the dressing to continue burning.

EXPERIMENTAL

Preparation of white phosphorus samples.

All experimental work with white phosphorus was performed in a chemical fume hood. All handling of the phosphorus, was performed under water, and all phosphorus not in use was stored under water in sealed jars.

White phosphorus (WP), purchased from Aldrich Chemical Co., is supplied in cylindrical sticks, about 0.5 inch in diameter. After weighing a stick, it was cut with a knife into approximately sufficient 1-gram pieces for all planned tests. The samples were stored in a separate jar of water, and the stock container sealed and removed. In preparation for a test, the sample jar was brought to the hood and opened, a sample was transferred to a small beaker of water, and the jar sealed and removed.

Water-Jel dressings were supplied by Trilling Medical Technologies, Inc. Material used for the water - soaked dressings consisted of the gauze pads from Water-Jel dressings, from which all of the gelling agent has been removed by washing. In this way the size of the dressings for the two types of tests were kept the same.

Quenching on a Metal substrate.

Several tests were performed in which WP was ignited on a flat metal test plate, quenched, and observed for possible reignition. It proved more difficult to obtain ignition of the phosphorus than anticipated, possibly related to the airflow across the sample in the fume hood. In several experiments the phosphorus was initially ignited by a match flame. Similarly, reignition did not occur unless the sample was heated. Tests were performed with 0.5 gram and 2 gram samples. Since the 2 gram samples burned with a considerable amount of smoke and began to sputter vigorously, we determined that larger samples than this would be difficult to control in the animal tests. The amount of WP remaining after the quenching step appeared quite adequate to test reignition, since about two - thirds of the sample remained.

0.5 Gram Tests, M-1 to M4

A 150 watt reflector flood lamp was used to warm the samples for the reignition tests. In tests with 0.5 gram of WP, the samples quenched with water-soaked dressings reignited in 1 and 3 minutes after uncovering under the lamp. Two samples quenched with Water-Jel dressings did not reignite in 12 minutes under the light, but the second one ignited immediately when it was probed with a spatula.

2 Gram Tests, M-5 to M-9

On the supposition that ignition of a larger sample may be easier, a 2 gram sample was allowed to dry for 15 minutes at ambient temperature (27 deg C) on a test plate without igniting. Upon ignition by match, quenching with Water-Jel, and uncovering, it did not reignite in 20 minutes, nor did it ignite when probed with a spatula.

A "sand bath" (a pan of sand heated on a hot plate) was used to control the temperature of the test plates in the next experiments.

At 42 deg. C, WP samples did not ignite in 5 minutes, until they were touched with a spatula. After quenching with a water-soaked dressing, the first sample did not ignite for 22 minutes without the light, but ignited 3 minutes after the light was turned on. A sample quenched with a Water-Jel dressing did not ignite in 27 minutes with the light on, and appeared to be liquid with a thin "skin". When this covering was broken by touching it with a spatula, the sample ignited immediately.

At 55 deg C., 2 gram samples of WP ignited spontaneously in 1 and 3 minutes after placement. The sample quenched with a water-soaked dressing ignited in 1 minute when the dressing was removed under the light, but the water-jel quenched sample did not ignite in 30 minutes after uncovering under the light.

Animal Tests

In order to simulate burns inflicted on personnel under field conditions, anesthetized white rats were used in this series of experiments. At first, a small incision was made in the skin to expose about 1 square inch of flesh to serve as a test area. When it became apparent that liquid would accumulate in the incision and cover the phosphorus, the remainder of the tests were performed without incision. Instead, the haircoat was shaved to provide an exposed area for testing. The preparation of the animals is described in another section.

Tests were performed in shallow metal pans, which would contain the rat and any phosphorus which might melt and run off the animal. Upon completion of the test, the rat was asphyxiated using carbon dioxide.

Tests on Incision, R-1 to R-5

Test R-1 - 2 grams WP, quenched with water.

A 2 gram piece of WP was placed in the incision, ignited by match, and quickly covered with a 4"x4" water-saturated dressing. Smoking continued, and in 3 minutes, a tiny glowing spot appeared, where phosphorus vapor evidently was escaping through the mesh. It was extinguished with 1 mL of water, but appeared again after a few minutes. A second application of water extinguished it again, and it did not reappear, although moderate smoking continued. After one hour, the dressing was removed, and no ignition occurred in 30 minutes.

Test R-2 - 1 gram WP, quenched with water.

A test was performed in the same manner with 1 gram of WP, with identical results, except that the first glow appeared in 4 minutes.

Test R-3 - 2 grams WP, quenched with water.

After match ignition of a 2 gram piece of WP placed in the incision, it was quickly covered with a 4"x16" water-saturated dressing, doubled over. Moderate smoking continued, but no "breakthrough" was observed. Water was added at about 15 minute intervals to keep the dressing from drying out. After 1 hour, the dressing was removed, and much of the WP was found stuck to the gauze. No ignition occurred for 30 minutes. Upon lighting the lamp, smoking became stronger, and the sample ignited in 1 minute.

Test R-4 - 2 grams WP, quenched with Water Jel.

When a 2 gram sample was ignited and quenched with a 4"x4' Water Jel dressing, smoking stopped completely, and did not resume until the dressing was removed after 1 hour. The phosphorus remained in the incision, covered with a layer of liquid, which did not dry completely in 30 minutes, nor in an additional 11 minutes under the lamp. When the WP was exposed under the light by probing with a spatula, it ignited.

Test R-5 - 2 grams WP, quenched with Water Jel.

Quenching was immediate as in Test 5, and the phosphorus was also covered with liquid which had not dried completely when the lamp was turned on after 35 minutes. The WP did not ignite in 15 minutes under the lamp, or when it was exposed by probing with a spatula.

Tests on Shaved Haircoat, R-6 to R11

Test R-6 - 1 gram WP, quenched with Water Jel.

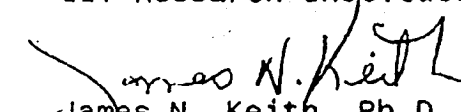
Quenching was complete, with no smoke. Slight smoking began upon uncovering after 1 hour, and continued until the WP ignited after 28 minutes, without the lamp.

Test R-7 - 1 gram WP, quenched with Water Jel.

Quenching was complete, with no smoke. Slight smoking began upon uncovering after 1 hour. No ignition occurred in 41 minutes, without the lamp.

The experimental work reported herein was performed in the Chicago Laboratories by Dr. James N. Keith and Dr. Brooks J. Harder. Please contact the undersigned for any clarification required.

Respectfully submitted,
IIT Research Institute


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Reviewed by:



A. Shefner
Associate Director of Research
Life Sciences Research

TABLE 1. SUMMARY OF TEST RESULTS

WHITE PHOSPHORUS QUENCHING TESTS ON A METAL SUBSTRATE

Test #	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8	M-9
WP, grams	0.5	0.5	0.5	0.5	2	2	2	2	2
Temperature	Ambient	Ambient	Ambient	Ambient	Ambient	42	42	55	55
					15 min, no ign.	5 min, touched	5 min, touched	3 min spontan.	1 min spontan.
Quench	Water 2"x2"	W-J 2"x2"	Water 2"x2"	W-J 2"x2"	W-J 4"x4"	Water 4"x4"	W-J 4"x4"	Water 4"x4"	W-J 4"x4"
Covered, min	10	10	60	60	10	10	10	10	10
Light on	Immediate	Immediate	Immediate	Immediate	NO	22 min	16 min	NO	NO
Reignition, min	Yes 3	No 12	Yes 1	No 15	NO 20	yes 3	no 27	Yes 1	No 30
Ignited on probe	-	No	-	Immediate	NO	-	Immediate	-	No

WHITE PHOSPHORUS QUENCHING TESTS ON WHITE RATS

Test #	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10	R-11
WP, grams	2	1	2	2	2	1	1	1	1	1	1
Placement	Incision	Incision	Incision	Incision	Incision	No Incision	No Incision	No Incision	No Incision	No Incision	No Incision
Quench	Water 4"x4"	Water 4"x4"	Water 4"x16"	W-J 4"x4"	W-J 4"x4"	W-J 4"x4"	W-J 4"x4"	W-J 4"x4"	Water 2-4"x4"	W-J 4"x4"	W-J 4"x4"
Comments	Glow, 3 min	Glow, 4 min	No Glow								
Covered, min	60 smoke	60 smoke	60 mod smoke	60 no smoke	60 no smoke	60 no smoke	60 no smoke	60 no smoke	60 no smoke	60 no smoke	60 no smoke
Light on	No	No	30 min	30 min	35 min	No	No	12 min	Immediate	Immediate	Immediate
Reignition, min	No	No	Yes 1	No 11	No 15	Yes 28	No 41	No 34	Yes 30	No 28	Yes 31
Ignited on probe	No	No	-	Yes	No	-	No	No	-	Yes	-



Inter-Office Memorandum
IIT Research Institute

Date: 5-25-90
To: J. Keith
From: A. Shefner, B. Harder ^{mt}
Subject: Animal Care and Use Committee Review

The document listed below has been reviewed by the
IITRI Animal Care and Use Committee:

Title: *White Phosphorus Quenching By Water-Jet*

RFP/PCR No.: 90-678 AC

ACUC Approval No.: 90-054

Please be informed that the committee has taken the
following action:

- 1. Approved - no modifications required
- 2. Approved - please modify as follows
- 3. Disapproved - reasons listed below

Animals:

Thirteen male C.D. rats were received from Charles River Laboratories, Portage, MI, on June 13, 1990. Their date of birth was listed as April 16, 1990. The animals all appeared healthy at the time of delivery. The animals were housed individually in polycarbonate cages each measuring 18.5" X 9" X 8". The animal room assigned was 1B2-5 located on the first floor of the Chemistry Research Building. The bedding material used in the cages was Sani-Chips (P.J. Murphy Forest Products Corp., Montville, NJ). The animals received a diet of Purina Rodent Chow #5001 fed ad libitum. Coarse filtered water from the City of Chicago was provided in standard water bottles. The animals were held on quarantine status until June 27, 1990 at which time they were officially released to be used for study purposes. The animals were rotated into clean cages a minimum of once weekly and were provided with fresh water bottles twice per week.

Anesthesia:

The anesthetic regimen used was a mixture of ketamine HCl (Ketaset, 10 mg/ml, Aveco Co., Inc., Fort Dodge, IA), xylazine (Rompun, 20 mg/ml, Mobay Corp, Shawnee, KS), and acepromazine maleate (PromAce, 10 mg/ml, Aveco Co., Inc., Fort Dodge, IA). The agents were premixed using the following ratio:

Ketaset	1.5 ml
Rompun	1.5 ml
PromAce	.5 ml

With the exception of the first three animals, the mixture was administered subcutaneously at the rate of 0.5 to 0.7 ml/kg of body weight. Prior to starting each animal on test, the animal's level of anesthesia was evaluated using the toe-pinch reflex. Animals whose level of anesthesia was determined to be inadequate were given additional doses of the anesthetic mixture at approximately one-half of the calculated dose. The initial three animals were given the anesthetic regimen by intraperitoneal injection. One animal died almost immediately leading to the decision to alter the route of administration. Animals were redosed during the conduct of the study if any evidence of movement was detected or if they responded to the toe-pinch test.

IITRI Project C08066
June 27, 1990

TEST PROCEDURE FOR WHITE PHOSPHORUS QUENCHING EXPERIMENTS.

WHITE PHOSPHORUS
P4
FLAMMABLE SOLID - PYROPHORIC

DANGER - This material ignites in air. Store and handle under water. Store primary glass container in metal can, cushioned from shock.

In an emergency, notify: James N. Keith at Tel. Extension 4318 or the EH&S office, x 4236.

Experimental Procedure: Quenching of Burning Phosphorus by Water-Jel

Purpose: To evaluate the capability of Water-Jel dressings to extinguish the burning of white phosphorus and to delay reignition.

Method: Small pellets of white phosphorus will be allowed to ignite on an incombustible substrate. Small squares of Water-Jel will be placed over the burning phosphorus, and later removed to estimate the time to reignition.

Facilities: An operating chemical fume hood

Equipment:

Screw-capped creme jars for storage and transfer of WP
Pan or dish of water for cutting phosphorus
Xacto knife or scalpel
Laboratory tongs
Tweezers
Dry chemical fire extinguisher
Can opener
Test plate - ceramic tile, sheet metal, etc.

Protective clothing:

Laboratory gloves
Laboratory apron
Face shield

Preparation of Samples:

1. Place pan of water in the hood, and fill a 1 pint creme jar about 2/3 with water. Add water to the sample jars.
2. Open the shipping container, and the inner cans, setting aside the packing material. Carefully open the inner can.
3. Open the jar and, with laboratory tongs, remove a stick of phosphorus, placing it in the pan of water. Transfer the remaining phosphorus to the storage jar. Check the container and remove all small pieces of WP.

4. Keeping the phosphorus completely under water, use Xacto knife or scalpel to cut off several small pieces, about 1 gram. Check weight by dropping a piece into a preweighed small beaker of water. Using tweezers, transfer the samples to a small creme jar of water.
5. Prepare several 2-gram and 5-gram pieces in the same way, storing in separate creme jars for each size.
6. Return unused phosphorus to storage jar.
7. Be sure that all storage and sample jars are labelled.
8. If samples are not to be used immediately, place jars in a metal can for storage. For permanent storage, pack the jar with vermiculite in a sealed metal secondary container with the same label.

Quenching Test:

1. All stocks of WP not in use should be removed from the hood during these experiments.
2. Appropriate protective clothing will be worn by anyone approaching the face of the hood - apron and goggles or face shield.
3. Place a pan of water, a test plate, and a beaker of water in the hood. Clear the hood of any combustible materials.
4. With tongs or tweezers, transfer a 1 - gram sample of WP to the pan of water. Seal the sample jar, and remove it from the hood.
5. Place the sample on the test plate and note the time.
6. Note the time of ignition. Let the sample burn to completion, and note the time.
7. Repeat this test, using a larger sample, if the WP burns too quickly.
8. After verifying the burning time of the WP samples, select a suitable sample size for the quenching test.
9. Place a sample of WP on the test plate, and allow it to ignite, noting the time.
10. After burning is established (probably about 30 sec.), cover the burning sample with a 2"x2" Water-Jel pad. If extinguishment is not immediate, note the time when extinguishment occurs.
11. Estimate (qualitatively) how much of the phosphorus remained.
12. After the pad has remained in place for 30 minutes, remove it, and record the time at which reignition occurs.
13. Repeat this test twice. If the 2" x 2" dressing is too small to adequately extinguish the burning, use a larger pad. Repeat until three successful tests have been completed.
14. Perform the same test, using water to extinguish the burning WP. Repeat twice.
15. If possible, recover all unburned phosphorus and transfer to a sealed jar of water. Hold for final disposal. Small amounts of phosphorus may be allowed to burn off in the hood.
16. After being sure no residual phosphorus remains, clean all equipment with an alkaline detergent, sodium carbonate or sodium hydroxide and wash down the laboratory sink.
17. Seal all storage containers of phosphorus.

Animal Experiment:

1. White phosphorus samples, 1 - 5 grams will have been prepared and stored under water in glass sample jars, as in the above procedure. A sample jar, a beaker of water, and a waste jar will be placed in the hood.
2. Life Sciences staff will prepare the animals, and restraints, as required. Each animal will be anesthetized before placing it in the fume hood, and preparations will be made to maintain the anesthesia for 90 - 120 minutes, as may be needed.
3. Make a small incision in the skin of the animal, to simulate a shrapnel wound, and to reduce the tendency of the phosphorus to fall off of the animal during the experiment.
4. Transfer a sample of WP to the beaker of water from the sample jar, seal the jar and set it aside.
5. Place the sample on the incision, and note the time.
6. Record the time of ignition.
7. After burning is established (about 30 seconds), cover the phosphorus with a 2" x 2" Water-Jel dressing and record the time.
8. Note the time of extinguishment, if not immediate.
9. Set the animal aside for 1 hour, placing it in the back of the hood, while other rats are treated.
10. After 1 hour, retrieve the animal, and remove the dressing. Do not disturb any gel that may coat the phosphorus. Check for phosphorus that may have been picked up by the dressing. Remove any WP with the tweezers, placing it in a waste jar. If phosphorus remains, immerse the dressing in water for later disposal.
11. Note the time of reignition of the phosphorus. If reignition does not occur in one hour, terminate the experiment.
12. Upon reignition, cover the phosphorus with another dressing. Remove the dressing, and debride all remaining phosphorus from the skin into a pan of water.
13. Sacrifice the animal by an appropriate method, check again for residual phosphorus, and set the animal aside for disposal.
14. Repeat the experiment with six rats.
15. Repeat the experiment with three rats, using only water to extinguish the burning phosphorus.
16. Collect all unburned phosphorus in a jar of water for disposal.

Emergency Procedures:

1. Fire. Phosphorus ignites in air. It may be extinguished by flooding with water, but this should not be used except for small fires, because of the risk of scattering the molten phosphorus. In all cases the phosphorus can be covered with wet sand. The mixture should be kept wet, and after it has had time to cool, should be scooped into a container, which is left uncovered in the hood overnight, then sealed for disposal. Small amounts may be simply spread out on a ceramic or steel surface in a hood or outside, and allowed to dry and burn off.
2. Spills. Spilled phosphorus which has not ignited should be covered with water or a cloth soaked in water to prevent ignition, then carefully scooped up and placed in a container of water in a fume hood.
3. Skin Contact. If phosphorus contacts the skin, immediately flood the skin or immerse in cold water. Remove particles under water and transfer to a container of water. Keep affected area under water until all phosphorus is removed, and wash with copious quantity of cool water. Get medical attention as soon as possible.
4. Eyes. Flush immediately with copious quantity of cool water, and, keeping the area wet, remove all particles from the eyes or surrounding skin. Continue irrigation of the affected eye at least 15 minutes. Get medical attention as soon as possible.