Red Phosphorus for Use in Screening Smoke Compositions

Authors: N. Davies; ROYAL MILITARY COLL OF SCIENCE SHRIVENHAM (UNITED KINGDOM)

It has been known for many years that red phosphorus reacts with moist air to produce phosphorus oxide because of the present and likely future importance of red phosphorus as the major constituent of compositions for visual and ... understood. This report comments on the pyrotechnic problems of using red phosphorus, and surveys the literature (largely patents) ... work to clarify the reaction mechanisms, for collaboration between red phosphorus and pyrotechnics manufacturers work to improve the ingredients supply and processing of red phosphorus pyrotechnic compositions for the development of non-...
amount of new raw materials needed for the manufacture of L8A3 ... L8A3 grenades. Significant cost avoidance was realized through successful reclamation and reuse of the L8A1 mix in the L8A3 grenade manufacturing program. Recycling, L8A3, Talc, Reuse, Red phosphorus, Silica, L8A1, Butyl Rubber, Agglomeration.

**NOSC - RED PHOSPHORUS STUDY. PART I. SMOKE.**
Dec 3, 1968

Authors: William T. Biggs; NAVAL AMMUNITION DEPOT CRANE IND

A study of red phosphorus compositions was performed using a chemical and mathematical models as a means of formulation. Fluorine, chlorine, and oxygen oxidizers were studied, and the advantages and disadvantages of each are given. The mixing of the composition was performed in solution using a precipitation and prepolymer technique. This type of mixing was used to overcome the hazard factor involved with red phosphorus compositions. (Author)

**Pollution Abatement: Reclamation of Red Phosphorus Smoke Composition.**
Apr 1, 1974

Authors: Duane M. Johnson; Clarence W. Gilliam; NAVAL AMMUNITION DEPOT CRANE IND

Investigations leading to safe, ecologically-permissible disposal of red phosphorus smoke compositions have been completed and have resulted in a laboratory demonstration of methods for disposing of and reclaiming the pyrotechnic ingredients used in signals containing red phosphorus compositions. Laboratory test data are provided which demonstrate that pyrolusite, one of the ingredients in the waste composition, is not manganese dioxide as commonly thought in the pyrotechnic field. It is recommended that the nitric acid ...

**A 1/10 Scale Pilot Plant for the Ecological Demilitarization of Mk 25 Marine Location Markers/Red Phosphorus Composition.**
Nov 11, 1977

Authors: Frank E. Montgomery; James E. Short Jr; NAVAL WEAPONS SUPPORT CENTER CRANE IND

... The typical pyrotechnic formulation for the Mk 25 and Mk 58 Marine Location Markers plus the Mk 6 Aircraft Smoke and Illumination Signal is 53 percent red phosphorus, 34 percent manganese dioxide, 7 percent magnesium, 3 percent zinc oxide and 3 percent linseed oil. The process includes breakdown equipment to extract the red phosphorus composition from the markers and an incineration complex to convert the composition to phosphoric acid suitable for fertilizer application. Processing the composition from the Mk 58 Marine Location ...

**Mammalian Toxicologic Evaluation of Hexachloroethane Smoke Mixture and Red Phosphorus.**
Sep 1981

Authors: Mary C. Henry; Jesse J. Barkey Jr.; C. David Rowlett; LITTON BIONETICS INC KENSINGTON MD

Four red phosphorus samples, three containing oil, were chemically analyzed for conformation to specifications. A hexachloroethane smoke mixture was burned in a laboratory apparatus to confirm that organic combustion products were present. The acute toxicity of one oiled red phosphorus sample was determined. This sample did not produce irritation in rabbits’ eyes at a dose of 100 mg. It was also nonirritating to intact or abraded skin of rabbits when applied at doses of 0.5 g per application site under a patch for 24 hours. Dermal application to guinea pigs did not produce skin ...

**Phosphine Evolution Control in Red Phosphorus Munitions.**
Jan 1989

Authors: Pascal A. Tarantino; William L. Brown; CHEMICAL RESEARCH DEVELOPMENT AND ENGINEERING CENTER ABERDEEN PROVING GROUND MD

Several desiccants and sorbents were investigated for reducing or eliminating corrosion in red phosphorus munitions. It was shown that corrosion will not occur in the absence of moisture. Moist air and phosphine from oxoacids corrode the electrical components ... of desiccant and sorbent in a perfectly sealed munition round or carrying case will provide a non-corrosive environment. Phosphine, Oxyacids, Red phosphorus, Desiccant, Smoke munitions, Sorbent, Gas chromatography, Activated carbon, Phosphine capacity, Reaction chamber, Dessicant capacity. (jes ...) 

**Environmental Fate of White Phosphorus/Felt and Red Phosphorus/Butyl Rubber Military Screening.**
Apr 1985

Authors: Ronald J. Spanggard; Robert Rewick; Tsong-Wen Chou; Robert Wilson; R. T. Podoll; SRI INTERNATIONAL MENLO PARK CA

Investigations were conducted to identify those processes that control the loss and movement of White phosphorus/felt, Red phosphorus/butyl rubber, and their combustion products in air, soil, and aquatic environments. The fate of RP/BR will be controlled by oxidative transformation. In air, half-lives of 1.8 years were found while in aerated water, the half-life approach 3 years and was found to be dependent on both particle size and oxygen concentration. In soil, the transformation was limited by oxygen diffusion and ...

**Research and Development on Inhalation Toxicologic Evaluation of Red Phosphorus/Butyl Rubber Combustion Products.**
Aug 1983

Authors: C. Aranyi; IIT RESEARCH INST CHICAGO IL LIFE SCIENCES RESEARCH DIV

... controlled conditioned filtered air supply and appropriate chamber exhaust through a coalescent filter system were built with five 1-m3 exposure chambers. Red phosphorus/butyl rubber combustion generators provided by the Government were installed for each aerosol chamber. A separate room and air handling ... optically, particle size by a quartz crystal microbalance-based cascade impactor and analysis of percentage phosphorus acid spectro-photometrically. Preliminary experiments were conducted testing generator performance and various RP/BR ...
Research and Development on Inhalation Toxicologic Evaluation of Red Phosphorus/Butyl Rubber Combustion Products, Phase 4
Authors: Catherine Aranyi; IIT RESEARCH INST CHICAGO IL LIFE SCIENCES RESEARCH DIV

Full Text

The no-measurable effect level of inhaled smoke of red phosphorus/butyl rubber (RP/BR) combustion products in male Sprague Dawley rats was evaluated in two subchronic studies. The rats were exposed for 13 weeks to filtered air to RP/BR aerosol in the second study. Biological endpoints examined within 24 hr of the last exposure and for selected exposure groups following an 8-week recovery period included clinical signs, body weights, pulmonary bactericidal activity and histopathology of the lungs for both studies, with pulmonary cellular ...

Behavioral-Physiological Effects of Red Phosphorus Smoke Inhalation on Two Wildlife Species
Authors: S. A. Shumake; R. T. Sterner; B. E. Johns; R. D. Thompson; ANIMAL AND PLANT HEALTH INSPECTION SERVICE DENVER WILDLIFE RESEARCH CENTER

Full Text

Effects of red phosphorus/butyl rubber (RP/BR) smoke on 2 wildlife species, prairie dogs and rock doves, were evaluated in laboratory range-finding experiments. Prairie dog groups showed no mortality within 30 days post exposure to 0.0, 2.0, 4.0 and 6.0 mg/l target concentrations of the smoke over 1 to 4, 80-min sessions. Rock doves exposed in groups to 0.0, 3.0, or 6.0 mg/l target concentrations over 1 to 4 sessions, however, showed 26 percent mortality within 8 days post exposure. Male rock doves were much more vulnerable to RP/BR smoke effects with 42 percent mortality in lost ...

Chemical Characterization and Toxicologic Evaluation of Airborne Mixtures: The Chemical and Physical Characterization of XM819 Red Phosphorus Formulation and the Aerosol Produced by Its Combustion
Authors: R. S. Ramsey; J. H. Moneyhun; R. W. Holmberg; OAK RIDGE NATIONAL LAB TN

Full Text

... samples for various analysis were taken. Generation and collection conditions were similar to those used for two other phosphorous obscurant sources, red phosphorus-butyl rubber (RPBR) and white phosphorus-felt (WPF), to allow direct comparisons between the aerosols. The RPNO3 material was also analyzed for composition and impurities. The formulation was found to be uniform in density, reactivity, and composition of phosphorus, extractable, sodium, nitrate, and silica. An epoxy containing no unreacted resin detectable by infrared spectroscopy. Elemental impurities were determined ...

New Potentials in Red Phosphorus Compositions
Authors: III. Webster Henry A.; Duane M. Johnson; NAVAL WEAPONS SUPPORT CENTER CRANE IN

Full Text

New phosphorus compositions have been demonstrated which meet the current burning rate and smoke volume requirements but do not contain pyrolusite and/or magnesium. Phosphorus composition which used chlorotrifluoroethylene as an oxidizer-binder combination and magnesium as a fuel had reciprocal burning rates of 42-73 s/in. Phosphorus compositions which used calcium sulfate as the oxidizer and boron as the fuel had reciprocal burning rates of 80-130 s/in. These compositions have the advantages ...

ENGINEERING AND LABORATORY EVALUATION TO IMPROVE TEST PROCEDURES IN MILITARY SPECIFICATION JAN-P-670, STABILIZED RED PHOSPHORUS
Authors: George Norwitz; Joseph Cohen; Martin E Everett; FRANKFORD ARSENAL PHILADELPHIA PA

Full Text

... are added. It is recommended that the aluminum be determined by the 8- hydroxyquinoline procedure used by the National Bureau of Standards. The use of the classical magnesium ammonium phosphate method is recommended for the determination of total phosphorus. The oxida lion test has been improved by use of an automatic recorder to measure the pressure and by use of a definite amount of water (0.5 ml) in the bomb. The methods previously proposed for yellow phosphorus and granulation are satisfactory.

Behavioral-Physiological Effects of Red Phosphorus Smoke Inhalation on Two Wildlife Species
Authors: R. T. Sterner; S. A. Shumake; R. D. Thompson; B. E. Johns; ANIMAL AND PLANT HEALTH INSPECTION SERVICE DENVER WILDLIFE RESEARCH CENTER

Full Text

This report summarizes a 3-year Project Order (85PP6847) to determine lethal and sub-lethal symptomatological, behavioral and physiological effects of red phosphorus/butyl rubber (RP/BR) smoke exposure(s) upon black-tailed prairie dogs (Cynomys ludovicianus) and rock doves (Columba livia). Use of this mammalian and avian model extended the Army's comparative database of RP/BR- smoke effects. All research involved whole-body, inhalation chamber studies designed to assess immediate, acute or sub-acute effects. Research comprising the project was divided into 3 tasks. Task 1 involved: (1) setup ...

Behavioral-Physiological Effects of Red Phosphorus Smoke Inhalation on Two Wildlife Species, Task 3, (RP/BR Aerosol Effects upon the Spontaneous Activity, Startle Response, Pulmonary Function and Blood Chemistry/Hematology of Black-Tailed Prairie Dogs (Cy)
Authors: R. T. Sterner; S. A. Shumake; R. D. Thompson; B. E. Johns; ANIMAL AND PLANT HEALTH INSPECTION SERVICE DENVER WILDLIFE RESEARCH CENTER

Full Text

This Task 3 Report describes research conducted to evaluate selected behavioral-physiological effects of multiple exposures to a red phosphorus-butyl rubber (RP/BR) military smoke product in 2 wildlife species -- black-tailed prairie dog (Cynomys ludovicianus) and rock doves (Columba livia). Results expand the Army's comparative database of sub-lethal consequences of RP/BR-smoke exposure. Eight separate inhalation-
chamber studies were conducted. Each study evaluated the effects of 4 or 2 successive 80-min RP/BR-aerosol exposures in prairie dogs and rock doves, respectively; and, each study...

### Behavioral-Physiological Effects of Red Phosphorus Smoke Inhalation on Two Wildlife Species

**Authors:** R. T. Sterner, S. A. Shumake, R. D. Thompson; B. E. Johns

**FISH AND WILDLIFE SERVICE DENVER CO DENVER WILDLIFE RESEARCH CENTER**

This report summarizes a 3-year Project Order (85PP5847) to determine lethal and sub-lethal symptomatological, behavioral and physiological effects of red phosphorous/butyl rubber (RP/BR) smoke exposure(s) upon black-tailed prairie dogs (Cynomys ludovicianus) and rock doves (Columba livia). Use of this mammalian and avian model extended the Army's comparative database of RP/BR smoke effects. All research involved whole-body, inhalation chamber studies designed to assess immediate, acute or sub-acute effects. Research comprising the project was divided into 3 tasks. Task 1 involved: (1) setup...

### Chemical Characterization of the Pyrotechnically Disseminated KM03 Red Phosphorus Floating Smoke Pot

**Authors:** J. S. Anthony, Emily A. Davis, Mark V. Hale, David A. McCaskey, Robert L. Kristovich, Charles L. Crouse, Kathy L. Matson, Steven D. Turley, Dennis T. Burton

**EDGEWOOD CHEMICAL BIOLOGICAL CENTER ABERDEEN PROVING GROUND MD**

The United States Marine Corps Floating Smoke Pot (FSP) MK 7 MOD 0 Program was established to redesign the previously fielded M4A2 Hexachloroethane (HC) Smoke Pot. Although the HC pots were extremely effective as an obscurant, there were safety concerns from manufacturing and operational perspectives. Red phosphorous (RP) has been widely used in screening applications and was chosen as a replacement for the smoke payload. The smoke payload contained within the FSP MK 7 (KM03 pot) is a specific formulation that has been developed by Diehl BGT Defence GmbH and Co., KG (Uberlingen, Germany). ...

### Characterization of Phosphine Production During Extended Storage of the KM03 Red Phosphorus Floating Smoke Pot

**Authors:** Robert L Kristovich, Kathy L Crouse, David A McCaskey, Charles L Crouse

**ARMY EDGEWOOD CHEMICAL BIOLOGICAL CENTER ABERDEEN PROVING GROUND MD**

The U.S. Marine Corps (USMC) Floating Smoke Pot (FSP) MK 7 MOD 0 Program was established to redesign the previously fielded M4A2 Hexachloroethane (HC) FSP. Although the HC pots were extremely effective as an obscurant, there were safety concerns from manufacturing and operational perspectives. Red phosphorous (RP) has been widely used in screening applications and was chosen as a replacement for the smoke payload. The smoke payload (approximately 8 kg) contained within the FSP MK 7 (KM03 pot) is a specific formulation developed by Diehl BGT Defence (Uberlingen, Germany). One compound of...

### EFFECT OF METALS ON THE OXIDATION RATE OF RED PHOSPHORUS

**Authors:** Khizar Wasti, K. J. R. Abaidoo, Jon E. Villaume

**FRANKLIN INST RESEARCH LABS ROCKVILLE MD SCIENCE INFORMATION SERVICES DEPT**

... information on toxicological aspects and health hazards of red phosphorus, white phosphorus, butyl rubber/... phosphorous, and epoxy white phosphorus. The subjects covered in this review are chemical and physical properties, ... not been studied very well. While phosphorus has been found to be highly toxic ... animals and humans. Occupational exposure to
white phosphorus vapors has produced necrosis of the jaw ... reported cases of carcinogenicity in humans after white phosphorus intoxication. Tests for mutagenicity and teratogenicity ...

**Chemical Characterization and Toxicological Evaluation of Airborne Mixtures. The Chemical and Physical Characterization of Phosphorus Smokes for Inhalation Exposure and Toxicology Studies**

Authors: R. S. Brazell-Ramsey; J. H. Moneyhun; R. W. Holberg

Abstract: The chemical and physical properties of the aerosols produced from the combustion of red phosphorus containing butyl rubber (RPBR) and white phosphorus impregnated in felt (WPF) have been examined. The aerosols were produced at a uniform concentration by extruding softened raw material and burning the emerging filament or by igniting fragments of the formulations in a convective air flow. Aerosol particle sizes were found to be within the respirable range, varying from 0.4 to 1.0 ...


Authors: R. L. Yon; R. S. Wentzel; J. M. Bane

Abstract: Phosphorus type smoke/obscurants have been used extensively in the past and will continue to be used widely in the future. Their prime function is to obstruct the visual spectrum and conceal the movement of friendly troops in the battlefield. The environmental impacts associated with the use of these compounds for testing and training purposes have been reviewed and compiled in this report. Based on the toxicological data gathered and the regulatory aspects associated with the use of these smoke/obscurants it was concluded that this portion of the smoke program will not significantly affect ...

**Acute Toxicity of Smoke Screen Materials to Aquatic Organisms. White Phosphorus-Felt, Red**

Authors: T. M. Poston; K. M. McFadden; R. M. Bean; M. L. Clark; B. L. Thomas

Abstract: The acute toxicity of three obscurants was determined for nine freshwater organisms. The materials tested were white phosphorus-felt smoke, red phosphorus-butyl rubber (RP-BR) smoke, and smoke generator fuel (SGF) No. 2 fog oil (bulk and vaporized). The chemistry of WP-F and SGF No. 2 fog oil is studied for its influence on the results of the Purkinje effect. The blue phosphor produced about 2.5 the amount of red phosphor produced about 1/5 the amount.

**The Purkinje Effect in Luminance Measurements of Air Force Phosphorus**

Authors: S. A. Trushin; A. N. Mikhaylov; D. G. Revin

Abstract: The degree of the enhancement increases with the P dose, ... The influence of an additional ion doping by the phosphorus on the results of the Purkinje effect showed that colors furthest removed from that of the standard 2360 deg K source exhibited the most pronounced change in B'/B with decreasing luminance. The blue phosphor produced over 4 times as much visual response per unit energy at the lowest luminances than at luminances above 1 fl lambert; the red phosphor produced about 1/5 the amount.

**The Influence of Annealing Temperature and Doping on the Red/Near-Infrared Luminescence of Ion Implanted SiO2:nc-Si**

Authors: V. A. Burdov; D. G. Revis

Abstract: Averaged values agree with the B'/B curves. Weaver's data is tentatively accepted for conversion between effective and photopic units in luminance measurements of luminescent materials. A study of the effect of color on the results of the Purkinje effect showed that colors furthest removed from that of the standard 2360 deg K source exhibited the most pronounced change in B'/B with decreasing luminance. The blue phosphor produced over 4 times as much visual response per unit energy at the lowest luminances than at luminances above 1 fl lambert; the red phosphor produced about 1/5 the amount.

**Toxicity to Aquatic Organisms and Chemistry of Nine Selected Waterborne Pollutants from Munitions**

Authors: F. A. Lenfesty; J. C. Brosheer; P. L. Imes; G. W. Richardson

Abstract: The chemical and physical properties of the aerosols produced from the combustion of red phosphorus containing butyl rubber (RPBR) and white phosphorus impregnated in felt (WPF) have been examined. The aerosols were produced at a uniform concentration by extruding softened raw material and burning the emerging filament or by igniting fragments of the formulations in a convective air flow. Aerosol particle sizes were found to be within the respirable range, varying from 0.4 to 1.0 ...

**Manufacture - A Literature Evaluation**

Authors: J. C. Dacre; R. S. Brazell-Ramsey

Abstract: In experiments on modification of the physical properties of the P fillings, a procedure was developed for conversion of white P to red P in the munition itself. The resultant massive red P filling is very stable ballistically, but it ignites and burns somewhat less rapidly than is desirable. Most of the work done concerned mixtures of granulated white P and fluid binders which set to solid masses at room temperature. Attempts to ...
to be conducted on the first seven of the listed compounds. No further toxicity studies have been proposed for red phosphorus and the strontium compounds.

**Metallurgical and Mechanical Analyses of a Failed Fuse Holder from the XM264 Rocket**

Authors: Wego Wang, John C. Beck, Martin G. Wells; ARMY LAB COMMAND WATERTOWN MA MATERIAL TECHNOLOGY LAB

... warhead consists of an aluminum case, an M439 electronic time fuse, an expulsion charge assembly, 72 smoke pellets made from a red phosphorus composition, 18 felt separators, a base nose cone assembly, and an outer nose cone assembly. The fuse, enclosed by a ... in the warhead base. The fuse is detonated at a predetermined time to ignite the expulsion charge. One aluminum fuse holder from the XM264 red phosphorus smoke rocket that failed during testing was analyzed to determine the cause of failure. Cracks were observed on both sides of the die ...

**Medical Criteria for Respiratory Protection in Smoke: The Effectiveness of the Military Protective Mask**

Authors: James C. Eaton, John Y. Young; ARMY BIOMEDICAL RESEARCH AND DEVELOPMENT LAB FORT DETRICK MD

... be chosen from among the approved orinal dust, fume, and mist respirators, but this type of protection would not be appropriate for HC, metal, or phosphorus smoke; (c) the greatest uncertainty in the assessment of health hazards from smoke and obscurants involves measurement of exposure, which determines the duration of effectiveness of the protection ... smoke, which has caused fatalities when used improperly -- the masking policy must be strictly enforced, and HC should never be deployed in and enclosed space. Keywords: Hexachloroethane, White phosphorus, Red phosphorus, Toxic hazards. (aw)

**Smoke and Obscurants: A Health and Environmental Effects Data Base Assessment. A First-Order, Environmental Screening and Ranking of Army Smokes and Obscurants**

Authors: Joseph H. Shinn; Stanley A. Martins; Patricia L. Cederwall; Lawrence B. Gratt; LAWRENCE LIVERMORE NATIONAL LAB CA

... when ingested by animals, the aquatic toxicity, the environmental mobility when freshly deposited, and the ultimate mobility and fate in the environment. The major smoke types considered were various forms of white phosphorus, red phosphorus, hexachloroethane-derived smokes (HC), fog-oil (SGF-2), diesel fuel smokes (DF), and some infrared obscuring agents. The results were ranked according to: Device Impact Area and Environmental Concentration; Inhalation ...

**Smokes and Obscurants: A Health and Environmental Effects Data Base Assessment. A First-Order, Environmental Screening and Ranking of Army Smokes and Obscurants, Phase 1**

Authors: Joseph H. Shinn; Stanley A. Martins; Patricia L. Cederwall; Lawrence B. Gratt; LAWRENCE LIVERMORE NATIONAL LAB CA ENVIRONMENTAL SCIENCES DIV

... concentration, the relative inhalation toxicity, the relative toxicity when ingested by animals, the aquatic toxicity, the environmental mobility when freshly deposited, and the ultimate mobility and fate in the environment. The major smoke types considered were various forms of white phosphorus, red phosphorus, hexachloroethane-derived smokes, fog oil, diesel fuel smokes, and some infrared obscuring agents.

**A Catalog of Optical Extinction Data for Various Aerosols/Smokes**

Authors: Merrill Milham; EDGEWOOD ARSENAL ABERDEEN PROVING GROUND MD

Extinction spectra in the 3- to 5-, 8- to 13-, and 0.4 to 2.4-micrometer spectral region have been obtained for FS (Chlorosulfonic acid + Free SO3), red phosphorus, HC (Zinc oxide, Aluminum, Hexachloroethane), and fog oil smokes. A limited number of theoretical predictions based on Mie theory are also presented and compared with the experimental results. The experimental and computational procedures are described in some detail. These findings are subject to revision; the final report will be published later.

**Chemical Characterization and Toxicologic Evaluation of Airborne Mixtures**

Authors: John E. Ballou; BATTELLE PACIFIC NORTHWEST LABS RICHLAND WA

Generators were constructed to produce both petroleum (SGF-2) and red phosphorus/butyl rubber (RP/BR) smoke aerosols. The petroleum smoke generator produced smoke concentrations of 2 to 10 mg/l for several hours with standard deviations less than 12%. Aerosol particles ranged in size from 0.6 to 1.6 micrometers MMAD with sigma sub g 1.5 to 1.9. Chemical composition of particles was not related to particle size. Using the Battelle-designed exposure chamber, male and female Sprague-Dawley rats were exposed to the petroleum ...

**ANTIGENIC STUDIES ON INFLUENZA VIRUS**

Authors: Thomas G. Ward; JOHNS HOPKINS UNIV BALTIMORE MD

... study was made of relationships between tissue culture and in fluenza virus with radioactive phosphorus as the indicator system. Lee, PR8, and Thompson influenza virus strains were absorbed and eluted from normal chicken red blood cells (rbc's). When a constant amount of inorganic radioactive phosphorus was added to the rbc's, the virus-treated cells acquired more phosphorus than cells treated with ... alatic fluid. The yolks of 7-day-old chick embryos were inoculated with radioactive phosphorus. The embryos were then reincubated for 5 days, after which the rbc's were ...
An evaluation of the terrestrial transport, transformations and ecological effects of phosphorus red phosphorus-butyl rubber (RP/BR) smoke obscurant was performed at Pacific Northwest Laboratory. A similar evaluation using white phosphorus (WP) smoke/obscurant is currently proceeding. Future testing with other smokes are planned. The objective of this research program is to characterize the effects of smokes and obscurants on: (1) natural vegetation characteristic of U.S. Army training sites in ...