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IDENTIFICATION AND CHARACTERIZATION OF EMISSIONS AND AND RESIDUES FROM OPEN BURNING AND DETONATION OF MUNITIONS

by

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ABSTRACT

This paper presents background and information about the ongoing study to sample air emissions and soil residues from open burning and open detonation operations. Test methods are presented along with summary of the project status.

INTRODUCTION

Passage and implementation of the Environmental Protection Act (EPA), Clean Air Act (CAA) and Resource Conservation and Recovery Act (RCRA) have brought increasing pressure by state and federal environmental protection agencies on open burning and open detonation (OBOD) operations at Department of Defense installations. In the mid 1970's, the Army initiated plans to construct several incinerators to minimize the need for OBOD operations, as part of the Army Pollution Abatement Program. Since 1980, five Explosive Waste Incinerators (EWI), and eight Contaminated Waste Processors (CWP) have been installed at various Army installations. However, operational experience has proven that disposal of munitions using incinerators, including the existing deactivation furnaces, is more costly than using OBOD operations.

In view of the increased competition for funds with demilitarization generally having lowest priority for funding, the most economical method of demil consistent with environmental policy, must be available to destroy the growing stocks of munitions awaiting disposal. However, actual data to prove/disprove that OBOD is/is not a polluting method of disposal was limited. For this reason, four projects have been conducted, starting as early as 1980, to evaluate the environmental impact of OBOD operation. They include two studies by the U.S. Army Environmental Hygiene Agency of soil residues and analyses of ground water at OBOD sites, a study of parameters affecting migrations of residues by U.S. Army Toxic and Hazardous Materials Agency, and a study of emissions from OBOD operations.

DISCUSSION

The latter project, the Identification and Characterization of Emission and Residues from Open Burning and Detonation of Munitions was begun in November 1983 by the Ammunition Equipment Directorate (AED) at Tooele Army Depot (TEAD), Utah, under funding and guidance from U.S. Army Armament, Munitions and Chemical Command (AMCCOM). Purposes of the study are to obtain actual OBOD emissions data for use in:

1. Supporting development of standards and regulations that DOD will propose to state and federal EPAs for adoption, to permit and control OBOD sites.

2. Supporting the preparation of OBOD permits.

3. Negotiating with state EPAs for obtaining/renewing OBOD permits for DOD installations.

Published theoretical calculations of OBOD products, and results from small scale tests conducted by Battelle Columbus Laboratories inside of a detonation chamber in 1980-1982 were used as a starting point for the project. The tests planned for in the study have been conducted at Dugway Proving Ground (DPG), Utah, with the support of DPG personnel, under the project management and direction of the U.S. Army Armament, Munitions and Chemical Command (AMCCOM), technical direction of the U.S. Army Environmental Hygiene Agency (USAEHA), with consultation of the Environmental Protection Agency at Research Triangle Park for quality and audit assistance.

The Navy is providing assistance in computer model development to predict emissions from OBOD operations.

TEST SUMMARY

Thirty-two tests have been conducted during the period of 19 November 1985 to 13 August 1986. In general, tests where ammunition and explosives were detonated involve five different size detonations, 100 lbs., 500 lbs., 1,000 lbs., 2,000 lbs., and 5,000 lbs. Propellant burns, in general, involve burns of 5,000 and 10,000 lbs. quantities. A summary of the tests and test items is shown in Table 1. It should be noted that some of the earlier test items were repeated to gain confidence in and better validate the data by having repetitions for comparison. In all cases, weight of explosive includes weight of explosive in the munitions or bulk being tested, plus weight of booster and initiator explosive.

A UH-1H helicopter provided by the U.S. Army Aviation Development and Test Activity, Ft. Rucker, Alabama, has been equipped with air sampling and monitoring equipment for collecting data from the plumes produced from the above tests.

Air samples are drawn into a sampling manifold through a 20 ft. long probe which extends forward of the helicopter. The instruments and equipment collecting data are of two types, real time/direct reading instruments, and air sample collecting equipment. Data output from direct reading instruments is recorded as millivolt readings onto an on-board computer which records the millivolt output of each instrument every 0.5 seconds. The time of helicopter entry and exit from the plume is also recorded on the computer. A list of information recorded real time by the computer is shown on Table 2.

In addition to information from direct reading instruments, air samples are collected with an evacuated cylinder, a Volatile Organic Sampling Train or VOST and a bulk particulate filter. These samples have been sent to three separate laboratories for analysis. The evacuated cylinder that has been used for all but last test is a 2.8 l stainless steel canister. Attempts are being made to collect a larger bulk air sample of approximately 100 l to increase lower detection levels in the plume. The VOST consists

Table 1

SUMMARY OF PHASE I TESTS

Date	Item	Tests Quantities in lbs.	
19 Nov 1985	Bulk TNT	100, 500, 1000, 2000, 5000	
11 Dec 1985	Bulk TNT	100, 500, 1000, 2000, 5000	
12 Dec 1985	Bulk Explosive D	100, 500, 1000, 2000, 5000	
22 Jan 1986	Bulk Explosive D	100, 500, 1000, 2000, 5000	
22 Jan 1986	3.5" Rockets (Comp B)	100, 500, 1000	*1
5 Mar 1986	Bulk Comp B	100, 500, 1000, 2000, 5000	
16 Apr 1986	MK 54-1 Depth Bombs (HBX)	250, 495, 990, 1985, 4950	*3
16 Apr 1986	M82 500 lb Bombs (tritonal)	100, 500, 1000, 2000, 5000	*3
12 May 1986	MK 4-0 Depth Charge (HBX)	95, 500, 1000, 2025, 5010	*3
12 May 1986	Hand Grenades (TNT)	100, 500, 1000, 2000, 5000	
14 May 1986	MK 4-0 Depth Charge (TNT)	100, 500, 1000, 2000, 5000	*3
14 May 1986	90mm M71 Projectiles (TNT)	100, 500, 1000, 2000, 5000	
14 May 1986	M26E1 Propellant	5440, 10560	
16 May 1986	MK 16-6 Torpedo Warhead (HBX)	643, 643, 1286, 1929, 5144	*3
16 May 1986	Propellant SPDF	5333, 10667	
21 May 1986	Propellant SPCF	5000, 10000	*4
21 May 1986	Military Dynamite	100, 500, 1000, 2000, 5000	
22 May 1986	Navy Manufacturing Waste	2677, 5329	
29 May 1986	Bulk Explosive D	100	*2
4 Jun 1986	Bulk Explosive D	100, 500, 1000, 2000, 5000	
4 Jun 1986	Bulk TNT	100, 500, 1000, 2000, 5000	
5 Jun 1986	Propellant SPD	5333, 10666	
5 Jun 1986	3.5" Rockets (Comp B)	100, 500, 1000, 2000, 5000	
5 Jun 1986	175mm Projectiles (TNT)	92, 488, 1005, 2010, 5025	
5 Jun 1986	Bulk Comp B	100, 500, 1000, 2000, 5000	
10 Jun 1986	M30 Propellant	4915, 9830	
10 Jun 1986	MK 82 500 lb Bombs (H6)	100, 500, 1000, 2000, 5000	*3
17 Jun 1986	MK 81 250 lb Bombs (H6)	192, 576, 960, 1920, 4992	*3
17 Jun 1986	M10 Propellant	5333, 10666	*4
17 Jun 1986	5"/38 Projectiles (Expl D)	100, 500, 1000, 2000, 5000	
1 Jul 1986	Bulk Explosive D	100, 500, 1000, 2000, 5000	
1 Jul 1986	5"/38 Projectiles (A3)	100, 500, 1000, 2000, 5000	
13 Aug 1986	90mm M71 Projectiles (TNT)	100, 500, 1000, 2000, 5000	*5

Table 1 (cont'd)
SUMMARY OF PHASE I TESTS

*1 Fragments from the 1000 lb. test ignited the 2000 lb. stack of rockets. Test was aborted due to subsequent helicopter mechanical problems.

*2 Test aborted due to helicopter mechanical problems.

*3 Quantities vary from the 100, 500, 1000, 2000, 5000 lb. quantities due to the fixed explosive of the item. Quantities of each item were used such that overall explosive weight would be as close to the 100, 500, etc., quantities as practicable.

*4 Heat generated from initial burn resulted in ignition of second propellant train resulting in a single burn of the total quantity.

*5. Munitions were buried under 12 feet of earth cover, except for 2000 lbs detonation, which was buried under 4 feet of earth cover.

Table 2

INFORMATION OBTAINED FROM REAL TIME/DIRECT READING INSTRUMENTS

Altitude (feet above ground level)
Sulfur Dioxide concentration (ppm)
Chlorine concentration (ppm)
Hydrogen chloride concentration (ppm)
Hydrogen cyanide concentration (ppm)
Nitric oxide concentration (ppm)
Nitrogen dioxide concentration (ppm)
Hydrogen sulfide concentration (ppm)
Carbon monoxide concentration (ppm)
Ozone concentration (ppm)
Hydrogen concentration (ppm)
Oxygen concentration (%)
Ammonia concentration (ppm)
Carbon dioxide concentration (ppm)
Temperature (°C)
Sampling Manifold Pressure (inches water)
Air speed of helicopter (knots)
Manifold velocity (ft/sec)
Relative humidity (%)
Time in the plume of each pass (sec)
Cumulative particle count in the following ranges:
    0.3- 0.5 microns
    0.5- 0.7 microns
    0.7- 1.0 microns
    1.0- 5.0 microns
    5.0- 10.0 microns
    >10.0 microns *

* Particles greater than 20.0 microns are removed with a Stokes Separator to avoid plugging of the sensor.

of two cartridges in series, one packed with conditioned XAD-2 resin and the other with XAD-2 resin and activated charcoal separated by a glass wool filter. Purpose for these sample methods is to detect organic species that may result from incomplete destruction of explosives or products of formation during the OBOD reaction.

In addition fallout trays are placed as close to the 5,000 lb. detonation as possible without them being overturned by the explosion. Throw out from the detonation and soil fallout after the detonation is collected in those trays. The soil fallout samples from the nine trays on each 5,000 lb. test are composited and homogenized into one sample which is sent for analysis. All of the above samples are analyzed for the presence of any of the items listed in Table 3, which includes RCRA listed hazardous materials.

Video records of each test are made such that the volume of the plume could be estimated for each pass of the helicopter. By combining the cloud volume with the measured concentration of each emission product, an estimate of the total quantity of the product emitted to the atmosphere is obtained. The accuracy of the estimate is limited to the accuracy of the cloud volume measurements and instrument detection capabilities of the emission product concentrations. This information will also aid in the prediction of down wind concentrations of each emission product measured.

Reduction of Data from Real-Time/Direct Reading Instruments

Instruments selected for the study had to be portable and light weight due to the limited load carrying capacity of the helicopter. This limited the selection of instruments. The short sampling time available for each helicopter pass through the plumes created an additional major challenge in the determination of product concentrations. The majority of the instruments do not reach full steady state response for 25-30 seconds or longer (This is a problem not only of the instruments selected but of most other instruments that could have been used except for space and weight restrictions). Without a specific and unique calibration method, the instrument readings at shorter sampling times do not give accurate values of

Table 3

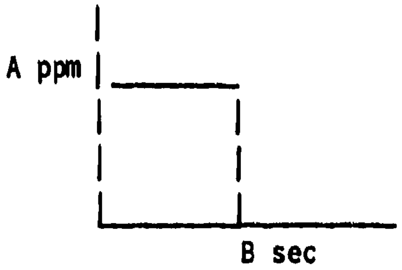
SPECIES TO BE ANALYZED IN FALLOUT PARTICULATES, VOST, BULK FILTER PARTICULATES, AND SOIL SAMPLES

Acetophenone
Ammonium Picrate
Aniline
Benzene
Dibutyl Phthalate
Mono- and dinitrobenzenes
Mono- and dinitrophenols
Mono- and dinitrotoluenes
Diphenylamine
HMX
Nitrocellulose
Nitroglycerins
Nitroguanidine
PETN
Phenol
Phthalic Anhydride
Phthalic Acid
Picric Acid
Polycyclic Aromatic Hydrocarbon
RDX
Tetryl
Toluene
1,3,5-Trinitrobenzene
2,4,6-Trinitrotoluene
Arsenic and Compounds
Barium and Compounds
Cadmium and Compounds
Chromium and Compounds
Lead and Compounds
Mercury and Compounds
Silver and Compounds
Selenium and Compounds
Carbon

the concentrations entering the instruments. To resolve this problem, AED personnel developed a five point calibration method which generates calibrated instrument response curves for sample times of 5, 10, 15, 20 and 30 seconds, with input gas concentrations of 0, 10, 20, 30 and 40% or 0, 20, 40, 60, and 80% of the full scale of the instrument.

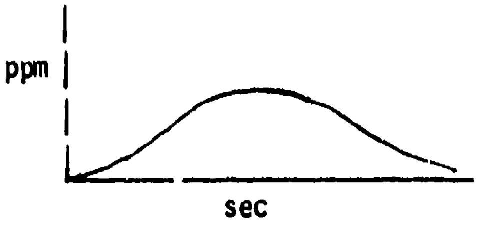
The resulting information recorded by the computer is a concentration curve rising from the background concentration to some point, then falling back to the background concentration with time. By integrating the area under the curve, a value of recorded concentration (in parts per million (ppm)) x time (seconds) is obtained. Plotting each measured concentration x time point versus the input concentration x time pulse that the calibrated input gas is fed to the instrument, a calibrated instrument response curve is generated. During plume sampling, the recorded concentration x time value can be compared to the calibration curve which corresponds to the length of time in the plume and the actual concentration determined.

For example, an input of A ppm for B seconds



Input

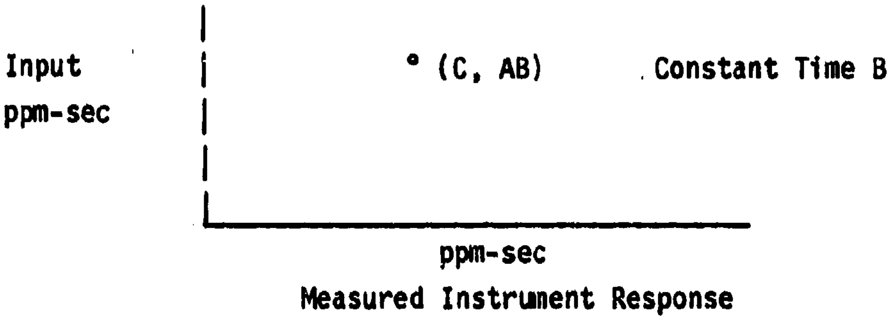
May yield this response



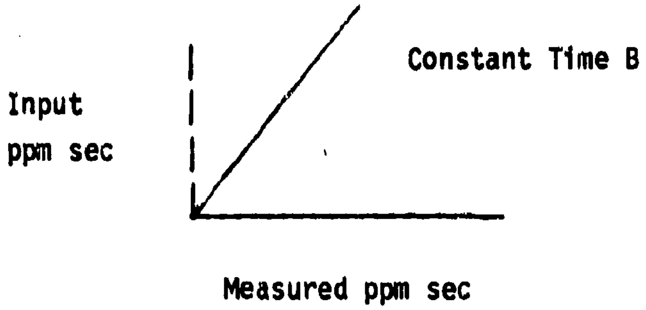
Instrument Response

Integrating the area under the curve yields an input of AxB ppm-sec and an instrument response of some corresponding value C ppm-sec.

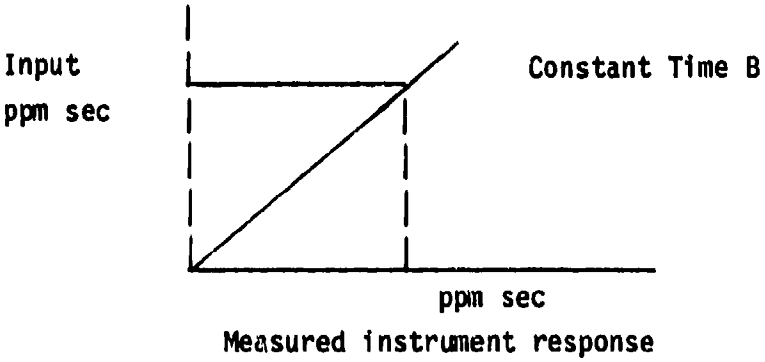
Plotting these values on an XY graph yields one point (C, AB) as follows:



Inputting a number of different concentrations over the same time B, yields a calibration curve for the time pulse B as follows:



For a sample time of B seconds in a plume, the measured instrument response can be found on the calibration graph and the input ppm sec determined from the curve as follows:



Dividing the input ppm-sec by the time B yields the true concentration in ppm that is in the plume for any particular helicopter pass. It should be noted that this would be an average concentration for that pass.

A computer program developed by AED personnel and programmed by a software consultant, takes the raw data from the instruments in millivolts, converts the millivolt readings to appropriate engineering units, i.e., ppm, temperature, ft/min, etc., integrates the areas under the concentration curves for the instruments measuring concentration, to yield the measured instrument response in ppm-seconds. The program then compares this value to the most recent calibration curve equations before and after the test, and the actual concentration in the plume for each pass is determined as explained above. The program has greatly reduced the time required to process the thousands of data points generated for each test and simplifies a very complex data reduction process.

PLUME VOLUME DETERMINATION

In order to determine the total quantity of a particular combustion/detonation product emitted from OBOD operations, it is necessary to compute the volume of the plume at a point in time when the concentration of that product is measured. Multiplying the concentration by the plume volume results in the total quantity of the product emitted.

Initial tests used two video cameras at fixed locations to record the detonations/burns and track the plume progression.

As efforts to calculate the plume volume progressed, it was determined that additional information was necessary to more accurately determine the volume. Two additional video cameras, four Auto-max film cameras and two thermal imaging cameras were added for all tests in June 1986 to obtain better plume data and permit more accurate plume tracking. Plume volumes are currently being calculated using the measured wind speed and direction to track the location of plume and hence determine the distance from the camera location to the plume. The irregularities in the plume shape and lack of good definition of plume boundaries, especially against backgrounds of other clouds, make the plume volumes difficult to measure accurately. Determination of plume shapes and sizes is subjective and will vary with the operator making measurements. Some variation will occur even when the same operator repeats the measurements as a quality control check. More refined, and hopefully more accurate, plume volume calculation methods and programs are being jointly developed by AED and DPG.

CONCLUSIONS

The data reduction, validation, and analysis have not progressed to the point of making exact statements about test results. However, the concentrations of emission products from OBOD of the munitions tested measured at approximately two minutes after detonation when the helicopter can safely enter the plume, appear to be well below levels generally considered as safe in places such as the occupational environment.

This information coupled with the results from the other three OBOD related studies indicate that OBOD of munition produces negligible impact on the environment while providing for safety and efficiency of operations.