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AFLC ARCHIVES

WRIGHT-PATTERSON AFB, OHIO

PROJECT ON THE DISPOSITION OF HERBICIDE ORANGE

OBTAINED MAY 1976

V. DISPOSAL OF HERBICIDE ORANGE

On 14 August 1972 Headquarters USAF made AFLC responsible for the disposal of some 2.3 million gallons of herbicide Orange. This task was assigned to the DCS/ Distribution. The deputate was also advised that the disposal program had to be ecologically safe and it should cost as little as possible. The problem of disposal was a complex one, and after study, the methods were narrowed down to eleven options.[1]

Herbicide Orange was developed in 1962 for military use as a defoliant.* Orange was a mixture composed of equal parts of the normal butyl ester of 2,4-dichlorophenoxyacetic acid (commonly called 2,4 -D) and the normal butyl ester of 2,4,5-trichlorophenoxyacetic acid (commonly called 2,4,5-T). Orange II was an alternate form of Orange and it was composed by mixing equal parts of butyl 2,4-dichlorophenoxyacetate and iso-octyl 2,4,5-trichlorophenoxyacetate. Orange II was procured in limited quantities when the requirements for 2,4-D and 2,4,5-T exceeded available supplies. The two formulations were used interchangeably in the field, since they could be handled by using the same procedures and they affected plants in the same way. Both types were systemic growth regulators (hormone type), and they killed plants by breaking down their food systems. In a temperate climate, Orange was effective for about one year, but in a tropical climate with a constant growth season, several applications of the herbicide were needed to be effective for a year.[2]

Defoliation in SEA

Herbicides were used in Southeast Asia to improve visibility in dense jungle areas and to destroy enemy crops. The vegetation in some areas was so thick that ground visibility was often limited to 15 feet and aerial observation was almost impossible. Pilots reported that following defoliation, visibility often improved by as much as 90 per cent. Crop destruction served the double purpose of denying food to the enemy and causing morale problems within enemy units.[3]

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* A herbicide is generally defined as an agent used to destroy or inhibit plant growth. The term defoliant refers to a chemical spray or dust which is applied to plants and causes the leaves to drop off prematurely.

In Vietnam, herbicides were sprayed from UC-123B aircraft which were C-123's modified by the addition of A/A 45Y-1 defoliant dispensers. By 1968 the spray aircraft had been further modified by the addition of two jet engines to provide quick getaways after spraying. The planes normally sprayed the herbicides from an altitude of 150 feet at an air speed of from 130 to 135 knots. An area 240 feet wide and 10.4 statute miles long could be sprayed with 950 gallons of herbicide in four minutes. The spray planes carried a crew of three: a pilot, a co-pilot, and a technician who operated the console which controlled the spray.[4]

The Republic of Vietnam managed all of the defoliation operations and the United States operationally supported the programs. Requests for herbicide missions could come from either American or Vietnamese sources, but the Vietnamese government had to approve all targets. Vietnamese personnel handled the herbicides on the ground and accompanied the American pilots on all defoliating and crop destruction missions. Several herbicides were used, the most common being Orange;* Blue, a clear mixture of sodium cacodylate and dimethylarsenic acid with a five per cent surfactant; and White, a dark-colored 4 amino-3,5,6-trichloropicolinic acid and 2,4-dichlorophenoxyacetic acid. Blue and White were both water-soluble. White was a systemic growth regulator, hormone type, which killed plants by disrupting the food system, the same as Orange. Blue was a desiccant contact herbicide which rapidly dried out portions of a plant but did not always kill the plant. Once treated, the foliage became brown and discolored within a day, with complete defoliation of affected areas occurring within two to four weeks.[5]

Of the three types, Orange was preferred because it could be used for both defoliation and crop control, it acted rapidly and produced a response which was visible within four to seven days, and it could be used during the rainy season since it was insoluble in water. White was used as an alternate to Orange, but it had several

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* See p.67 for a description of the chemical properties of Orange.

drawbacks--the type of plants affected by it was much smaller than Orange; it was slower-acting, needing about four weeks to produce a detectable plant response; and it was water-soluble, which meant it could be washed off the plants by a heavy rain or by spraying with water. At the time these herbicides were being used in Vietnam, Orange was believed to be highly volatile.* Consequently, White, which was non-volatile, was normally used in the areas adjacent to the demilitarized zone, the Cambodian border, or near areas under friendly control.**[6]

Blue was used to control rice crops and grasses. It dried foliage on contact and caused rapid leaf kill within one week. However, it could not be applied during precipitation or when rain was expected within 12 hours since it was water-soluble.[7]

All three herbicides had a low toxicity to men, animals, and fish. Under normal conditions, these herbicides were not hazardous to the wildlife which might be present during or after spraying, or to the personnel handling them. However, during June and July 1969, South Vietnamese newspapers reported increased occurrences of birth defects. These reports precipitated wide-spread reactions from governmental agencies, segments of the scientific community, environmental groups, and from the communications media. Various groups such as government-sponsored panels, special commissions established by scientific organizations, Congressional subcommittees, industry, and university representatives studied the problem and examined all of the available data. However, these groups were unable to give a generally acceptable answer as to whether 2,4,5-T (a component of Orange) constituted a risk for human pregnancy. In October 1969 the Bionetics Research Laboratory, Litton Industries, Inc., released a study which reported that mice and rats which had been treated with large doses of 2,4,5-T during early pregnancy gave birth to some defective offspring. Following this announcement, on 4 November 1969, the Assistant Secretary of Defense restricted the use of Orange to remote

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* The term volatile was defined as changing readily to vapor at a relatively low temperature.

** The volatility attributed to Orange was later disproved.

areas until a decision could be reached by the appropriate government agency on whether 2,4,5-T would remain on the domestic market. This restriction permitted the continued use of Blue and White, but did not allow the unlimited substitution of Blue for Orange.[8]

Additional experiments performed in early 1970 confirmed that pregnant mice treated with 2,4,5-T did deliver some malformed offspring. At the time, there was no information on how the 2,4,5-T affected humans. On 14 April 1970 the Secretary of Health, Education, and Welfare advised the Secretary of Agriculture that the Surgeon General felt that exposure to the herbicide might present a hazard to women of child-bearing age. On the following day, 15 April 1970, the Secretaries of Agriculture, HEW, and the Interior jointly suspended the registration of the granular 2,4,5-T which was used in lakes, ponds, or on ditch banks, and the liquid type which was used around the home and in recreation areas. At the same time, the Department of Defense temporarily suspended the use of herbicide Orange in all military operations, pending a more thorough evaluation of the problem. A second notice for cancellation of the registration of 2,4,5-T was announced by the Secretaries of Agriculture, HEW, and the Interior on 1 May 1970. This cancellation covered the granular 2,4,5-T which was used around the home and in recreation areas and the 2,4,5-T which was used on crops intended for human consumption. In November 1970 the Deputy Secretary of Defense instructed the services to discontinue the use of herbicide Blue, pending the results of a Joint Chiefs of Staff study of the herbicide program.[9]

After being notified of these actions, two of the producers of 2,4,5-T, the Dow Chemical Company and Hercules, Inc., petitioned to have the matter referred to a special Advisory Committee. The National Academy of Sciences supplied a list of qualified scientists from universities and research institutes around the country and, from this list, a ninemember Advisory Committee was selected. The committee focused its attention on whether the use of 2,4,5-T constituted an imminent hazard to health, especially in human reproduction. In seeking to make a scientific judgment on the possible effects of this herbicide, the committee took the following considerations into account:[10]

(1) As is frequently the case, available data are insufficient for a definitive statement of conditions under which a specified risk might occur, assuming that freedom from risk is ever attained.

(2) Since most chemicals under suitable laboratory conditions could probably be demonstrated to have teratogenic* effects, and certainly all could be shown to produce some toxic effects if dosages were high enough, it would not be reasonable to consider the demonstration of toxic effects under conditions of greatly elevated dosage to be sufficient grounds for prohibiting further use of a particular chemical.

(3) Benefits are to be expected from the continued use of 2,4,5-T. The necessity of making a value judgment of benefit versus risk, therefore, must be accepted, not only for this herbicide, but for numerous valuable drugs, some natural nutrients, and many other chemicals, some of which are known to be teratogenic in laboratory animals. The risk versus benefit judgment for a particular herbicide or drug can be evaded only if it can be shown that another compound is equally as efficient and involves less risk. This presupposes that the risk potential of a substitute herbicide is at least as well known as that of the original (in this case 2,4,5-T) --a fact that may be difficult or impossible to ascertain. The substitution of a relatively unknown pesticide for an older one with known adverse effects is not a step to be taken lightly.

At this point, one of the producers of 2,4,5-T submitted evidence which showed that the 2,4,5-T used in the Bionetics Laboratory test had been contaminated

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* The term teratogenic was defined as causing the production of malformed fetuses and living offspring in animals.

as a result of a malfunction in the production process. The 2,4,5-T sample had contained 27±8 ppm of an impurity (2,3,7,8-Tetrachlorodibenzo-p-dioxin) commonly called TCDD or dioxin. This compound was shown to be teratogenic in experimental animals. Further studies revealed that the TCDD was responsible for the teratogenic effects originally attributed to the 2,4,5-T, since oral administration of 2,4,5-T containing less than 1 ppm TCDD produced no teratogenic effects on rats, rabbits, mice, and other species. Samples taken from Orange stocks in 1972 and 1973 revealed that the average content of dioxin in the herbicide was only 1.859 milligrams per kilogram, with a total of 20.1 kilograms of TCDD in the entire Air Force inventory.[11]

Herbicides had been used in Vietnam since 1964. As shown in the chart below, the use of all types of herbicides had increased progressively from FY 1964 to FY 1968. In FY 1969, herbicide consumption declined slightly, and sharp drops occurred in FY 1970 and FY 1971. Due to the suspension of its use by the Assistant Secretary of Defense on 15 April 1970, no Orange was consumed during FY 1971. The White and Blue herbicides could only be used around the perimeters of base camps and supply areas pending the outcome of a Joint Chiefs of Staff evaluation.[12]

Fiscal Year	Gallons Used*
1964	265,000
1965	330,000
1966	1,650,000
1967	4,151,000
1968	5,960,000
1969	4,980,000
1970	2,846,000
1971	301,921

Unfortunately, herbicide procurement could not be cut off as sharply as consumption. As the inventory began to build up in Vietnam, the San Antonio Air

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* These figures were rounded off to the nearest thousand and represented the total of all types of herbicides.

Logistics Center temporarily discontinued all herbicide shipments to Southeast Asia. The product was stored at Mobile, Alabama, the port of embarkation for herbicides. The shipments were expected to resume in July 1968; however, herbicide consumption in Vietnam was declining. For a variety of reasons, the Air Force was not flying as many missions as had been projected. As a result, the herbicide inventory continued to pile up at Mobile, which had run out of indoor storage space. As a result, the drums were stored in an outside area belonging to the State of Alabama. This area had been provided without charge to the U.S. Government, but the area would only be available for 90 days, or until 21 September 1968. When the shipments could not be resumed as expected, the San Antonio ALC negotiated for a long term storage site at the Naval Construction Battalion Center at Gulfport, Mississippi. Shipment of the herbicides to the Gulfport facility began in July 1968. At the same time, the San Antonio ALC reduced the quantity of Orange on commercial procurement requests from 7.7 million gallons to 6.5 million gallons and reduced the quantity of Orange being procured from the Army's Weldon Springs, Missouri, facility from 8 million gallons to 5.796 million gallons. Therefore, during CY 1968, the quantity of Orange on procurement was reduced from 15.7 million gallons to 12.3 million gallons. On 16 December 1968 Headquarters AFLC requested that the San Antonio Air Logistics Center begin to terminate all herbicide Orange contracts.* [13]

As a result of the temporary suspension placed on the use of herbicide Orange by the Assistant Secretary of Defense, a total of 833,855 gallons of Orange were in storage on 30 June 1970.** Approximately 1.5 million gallons of Orange were being stored in Vietnam. At the direction of the Secretary of Defense, the Joint Chiefs

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* For more complete information on all phases of the procurement of herbicide Orange, see "Logistics Support to Southeast Asia by the San Antonio AMA, CY 1968," pp. 192-204; "History of SAAMA, FY 1970," pp. 153-154, 157-158; and "History of SAAMA, FY 1971, pp. 108-118.

** See pp. 69-70 for more information on the temporary suspension by the Assistant Secretary of Defense.

of Staff began a study in early 1971 to determine how the remaining supplies of Orange should be eliminated. This study, which was sent to the Office of the Secretary of Defense in April 1971, recommended that the herbicide be used as originally intended in Vietnam. If not used in SEA, the JCS study recommended that the stocks be returned to the Continental United States and separated according to the level of their impurities. The quantities with unacceptable levels of impurities would be incinerated and the remainder would be either used by the government or sold as surplus.[14]

In September 1971 the Environmental Protection Agency began to determine what quantity of TCDD the herbicides could safely contain. On 13 September 1971 the Secretary of Defense directed the Joint Chiefs of Staff to return all of the herbicide in SEA to the CONUS and to arrange for incineration facilities. The Air Force was assigned this task. At the same time, Mississippi State University and the USAF Environmental Health Laboratory at Kelly AFB began a series of studies to determine what monitoring standards and techniques would be needed to insure that incineration would be environmentally safe. In January 1972 a draft environmental statement was distributed to all involved agencies, including those in Texas and Illinois. Companies in both of these states were candidates for the incineration operation. Reaction to the environmental statement resulted in some unfavorable press releases, and the environmental authorities in Illinois announced that they would not grant permission for incineration. The environmental authorities in Texas felt that they could not permit incineration of the herbicide at the time but left open the possibility for some time in the future. The EPA had not as yet made a decision on what constituted a safe level for dioxin.[15]

As a result of the adverse reaction to the draft environmental statement, the Assistant Secretary of the Air Force (I&L) directed the Air Staff to explore all disposal options thoroughly.* The decision was also

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* In April 1973, the USAF Environmental Health Laboratory at Kelly AFB was assigned the task of preparing a revised draft and, ultimately, the final Environmental Statement. The revised draft was completed in April 1974 and released on 13 May 1974. The final Environmental Statement was issued on 4 December 1974.

made to store all of the SEA herbicide stocks on Johnston Island in the South Pacific until an acceptable disposal method could be developed. The herbicides were stored on Johnston Island in April 1972.[16]

After studying the problem of disposal, the Air Staff narrowed the possibilities down to 11 alternatives. These alternatives are discussed in the next section of this chapter.[17]

The Disposal Options

Return to Manufacturers

In March 1972 the Air Force contacted all of the manufacturers* of herbicide Orange to ascertain if any of them could chemically reprocess the herbicide to destroy all of the impurities. The responses indicated that this action would require an extensive investment in equipment and possibly could require the development of an entirely new process.[18] The Air Force subsequently rejected this alternative since the level of technology was not advanced enough to reprocess the herbicide without major capital expenditures and research efforts.[19]

Use of Herbicide in the United States

The possibility of donating or selling the herbicide to a foreign government, private industry, or other U.S. Government agency had been thoroughly investigated since 1970. The material could be used beneficially, in view of its low toxicity to humans and animals, especially if used on U.S. pasture and grazing land. Approximately half of the total land area of the United States was used for pasture and grazing purposes, and weeds and brush presented a major problem on these lands. Various species of brush grew on some 320 million acres of U.S. rangeland and the application of a phenoxy herbicide such as herbicide Orange was found to be the most economical method of increasing grazing capacity.[20]

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* The seven manufacturers of herbicide Orange were the Dow Chemical Company, Uniroyal, Hercules, Inc., Thompson Chemical, Monsanto, Diamond Alkali, and Thompson Howard Chemical.

Until Orange was registered by the Environmental Protection Agency, the herbicide could not be used or sold. The EPA planned to conduct hearings on the registration of the herbicide after the Air Force published its environmental statement on the disposal program.* [21]

Use of the Herbicide Outside the United States

Suggestions to sell or donate the herbicide to a foreign government came from several sources. Orange could be especially useful to a country involved in clearing wilderness areas for roads and settlements, as in the Amazon Basin of South America. After a great deal of discussion, however, the USAF Scientific Advisory Board's Ad Hoc Committee on the Disposal of Herbicide Orange unanimously rejected this alternative for several reasons. Once sold or donated, the United States could not assure that the herbicide would be handled with the proper technical and environmental controls. In addition, the widespread publicity on the use of the herbicide in Southeast Asia had created an "anti-people" image for the material which would probably result in adverse public opinion and political reactions in the event the herbicide was sold to another country. These reactions would undoubtedly harm U.S. relations with the country involved and its neighbors. In view of these considerations, the Scientific Advisory Board felt that the herbicide's sale or donation to a foreign country would be against the best interests of the United States.[22]

Deep Well Injection

This process involved the injection, under pressure, of the herbicide into a sub-surface permeable geologic formation. Once the herbicide was in place, a casing cemented around the well shaft would prevent the liquid from rising along the sides of the well shaft. Impermeable geologic formations surrounding the area would keep the herbicide from migrating either laterally or vertically.[23]

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* See footnote on p. 74.

The Environmental Protection Agency and a number of states objected to this method of waste disposal. They felt that this method was neither desirable nor environmentally safe. In general, environmental policy was opposed to the storage or disposal of wastes in deep wells unless it could be clearly shown that the wastes would not interfere with any present or potential uses of sub-surface water supplies, would not contaminate interconnected surface waters, or would not damage the environment in any other way. Since there was little or no data on how Orange would react to the temperatures and pressures found at these depths, and it was possible that a sub-surface disturbance might occur and release the herbicide, environmental agencies at both the state and federal level refused to issue permits for this type of disposal. [24]

Burial in Underground Nuclear Test Cavities

The Air Force contacted the Atomic Energy Commission about the possibility of burying Orange in the cavities formed by underground nuclear explosions. However, the AEC indicated that a major research, development, and experimentation effort would be required before this action could be taken. As a result, this alternative was rejected for non-feasibility. [25]

Fractionation

Under this process, the herbicide's acid ingredients would be separated by distillation. The 2,4-D and 2,4,5-T would be reformulated for commercial use and the dioxin, TCDD, would be destroyed. A small scale study was performed in April 1972, but the results were inconclusive. The study could not account for all of the ingredients since some were lost during processing. In addition, the study did not identify any standards for either controlling or monitoring the fluid and vapor emissions. The Air Force decided that this process held promise for the future, but it was not sufficiently refined to be feasible. [26]

Chlorinolysis

From the environmental point of view, chlorinolysis was the best method of disposal. During this process, herbicide Orange could be converted by non-polluting

means to such commercial chemicals as carbon tetrachloride, phosgene, and anhydrous hydrogen chloride. The process could be done in several ways, either by converting the herbicide as a whole, or by removing some ingredients by fractionation * and converting the remainder. During experiments, the reaction process destroyed all traces of the dioxin contaminant. ** The process could be stopped and samples collected for analysis and, if necessary, previously treated portions could be processed again. Because of this, the process could be readily controlled and monitored. [27]

Using this process on the entire stock of herbicide Orange was not found to be feasible. The technique held promise, but it was too expensive and complex to be accepted by the Air Force. [28]

No Disposal

If all disposal methods proved too unacceptable, one alternative remained--no disposal. The herbicide Orange could be put into permanent storage in a tank on Johnston Island. The volume required for this tank would range from 1.8 to 2.3 million gallons, depending on whether or not the EPA registered the 500,000 gallons of Orange which contained less than 0.1 ppm of TCDD. *** Permanent storage in this manner would eliminate the continuing cost of redrumming and would allow time for the development of new technological advances in other disposal methods. However, this alternative was really no solution since it only delayed the disposal program. For this reason it was to be used only as a last resort. [29]

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* See p. 77.

** The Environmental Protection Agency and the Department of Agriculture administered these experiments which were conducted by the Diamond Shamrock Corporation.

*** See pp. 71-72.

Microbial Reduction

In the microbial reduction process, the herbicide would undergo biodegradation through the use of microorganisms which had the capacity to feed on herbicide Orange. Although several microorganisms had shown the ability to adapt to hydrocarbons, the microbial degradation of herbicide Orange was complicated by its chemical structure and its insolubility in water. In addition, the dioxin appeared to be somewhat resistant to degradation by microorganisms. In tests, the 2,4-D decomposed rapidly in soil, but the 2,4,5-T was harder to break down and it persisted two to three times longer than the 2,4-D. The results indicated that a mixture of the two ingredients degraded more rapidly than a single component. A 1973 study which used 100 microbial strains showed that only five were capable of degrading the dioxin.[30] Air Force scientists felt that, while this alternative was theoretically possible, two factors--limited information on the fate of the dioxin and the difficulty of adapting bacteria to the herbicide--made the process unacceptable.[31]

Sludge Burial

This method of disposal also dealt with the destruction of Orange through bacterial action. The process required the construction of trenches 10 to 15 feet deep, into which the 55-gallon drums of herbicide would be placed. The drums would then be punctured and secondary sewage plant sludge would be distributed over the drums to provide a growth medium for bacteria. The trenches would then be covered with five feet of compacted dirt and an additional two feet of dirt would be placed along the center line of each drum-filled trench. This landfill was expected to produce the gaseous byproducts of biodegradation.* [32]

The major environmental impact of this process would be concentrated on the 30 acres used for the operation, and the land could not be used for reclamation or recreational purposes for some 15 to 25 years. The construction

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* Sanitary landfills were usually covered with a two-foot layer of compacted earth.

of the trenches would completely alter the soil structure and would cause temporary destruction of all vegetation in the affected area. The construction would also disturb and possibly destroy the area's ecosystem.[33]

The primary drawback to this process was the time which would be needed to complete the biodegradation. Continuous monitoring of the site would be required and there would be some difficulty in adapting the bacteria to the herbicide, as with microbial reduction.* For these reasons, this option was passed over in favor of other methods.[34]

Soil Biodegradation

Under this method, the herbicide would be incorporated into the soil and broken down into harmless byproducts by the combined action of soil microorganisms and soil chemical hydrolysis. Soil biodegradation was based on the fact that when soil microorganisms were exposed to high concentrations of Orange, they would begin to feed on the herbicide after the microorganisms adapted to the chemicals. Once adapted, the microorganisms retained an increased ability to digest the herbicide. Scientists estimated that a complete breakdown would occur within three to five years.[35]

This process would require a minimum of 2,000 acres of land in a remote area with low use potential. The site had to be far enough away from any water source so that there would be no chance of water contamination. The herbicide would be injected into the soil at a depth of six to ten inches, and at the rate of 4,000 pounds per acre. After the injection operation, the soil would be compacted and salt tolerant grasses would be planted throughout the area.[36]

The major environmental impact of this project would be the removal of 2,000 acres of land for any reclamation or recreational purposes for three to five years. The project would require continuous monitoring until biodegradation was complete. Placing the herbicide

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* See p. 79.

into the soil would damage or kill all of the vegetation in the area, greatly alter the soil structure, and disturb or temporarily destroy the local ecosystems. However, these adverse effects would be limited by the use of marginal land.[37]

The USAF Scientific Advisory Board's Ad Hoc Committee for the Disposal of Herbicide Orange felt that this method was promising,but that more data and evidence were needed to insure environmental safety. Since collecting this information might take some time, the committee decided that this process was not the best solution to the problem,but it might be considered if none of the other methods were feasible.[38]

Incineration

The Air Staff felt that site location was probably the most important factor for the incineration of herbicides. The site had to be located as far as possible from both residential and industrial centers and any land used for agriculture. In addition, the facility had to be placed in an area which, as far as possible, would eliminate any possible contact of the herbicide with women of childbearing age in case of a catastrophe. Ideally, the area would be marginal, with little or no commercial value and it would have a prevailing wind of fairly constant force and direction. The site would also have to be accessible to transportation and, to prevent possible adverse environmental effects, would have to be located in an area which minimized contact with any municipal water supplies, shellfish beds, wild life, fisheries, or recreational areas. If possible, the site should be under Federal Government control and, last of all, it "should not result in international controversy, be in conflict with international law,or impair the economic activity of any commercial enterprise."[39]

Incineration in the Continental United States. Tests conducted by Mississippi State University, the Air Force Rocket Propulsion Laboratory at Edwards Air Force Base, and the USAF Environmental Health Laboratory, all indicated that herbicide Orange, including the dioxin contaminant, could be incinerated in an environmentally safe manner in

a conventional liquid waste incinerator. Several such incinerators existed in the United States, but most of the units with the capability to handle 2.3 million gallons of herbicide were located near industrial or residential population centers. In general, these areas already had pollution problems and the local governments did not want any more waste disposed of in their locales.[40]

The U.S. Army Rocky Mountain Arsenal incinerator was one solution to the location problem. This incinerator, which had been used to destroy a mustard agent, operated at temperatures greater than 2000°F, with a stay time of two to six seconds.* These operating conditions would be more than adequate to destroy both the herbicide and the dioxin contaminant. The combustion gases passed through a sodium hydroxide liquid scrubber system to remove acid gases and through an electrostatic precipitator to remove solid particles. An automatic system monitored gases on the facility's perimeters and the spent scrubber water was spray evaporated. The system also had two furnaces to clean 55-gallon drums by burning them. The exhaust from these furnaces was processed in the same way as exhaust from the incineration unit. Once they were burned, the drums could no longer be used for containers and were sold as scrap.[41]

Incineration at the Rocky Mountain Arsenal was made extremely attractive by several factors--the slow rate of incineration which provided almost complete combustion, the combustion gas scrubbing treatment, the monitoring systems, the elimination of the problem of liquid discharge, and the drum cleaning facility. However, at the feed rate of two gallons per minute, incineration of the

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* "Stay time" was the period of time during which a fuel particle remained in the combustion chamber. Stay time (sometimes called dwell time) was determined by the physical characteristics of an incinerator, and in conventional incinerators was about three seconds. The longer the stay time, the more nearly complete combustion became.

entire stock of herbicide Orange would take 27 months. To use this facility for that period of time would be very expensive.[42]

Incineration on Johnston Island. The Air Staff also considered incinerating the herbicide on Johnston Island. The proposed incineration system would consume liquid waste at the rate of 1.4 pounds per second and would require about 200 days to destroy the entire stock of Orange. Combustion gases would be discharged from a high stack on the west end of the island directly into the atmosphere without any scrubbing treatment. The exhaust gases were expected to be free of any detectable levels of herbicide ingredients or the dioxin, but would discharge 18.5 tons of hydrogen chloride gas and 0.3 tons of particulate carbon each burn day. Small amounts of unchlorinated hydrocarbon pyrolyzates would also be released into the atmosphere.[43]

A scrubbing system could remove these impurities from the combustion exhausts, but this would require the development of a new system to dispose of the spent scrubber water. The chemical makeup of the spent water would make it far more dangerous to the island's aquatic environment than the exhaust gases would be to the atmosphere over Johnston Island.[44]

Two types of scrubbing systems were considered: an alkali consisting of either sodium hydroxide or coral carbonate as the neutralizers, or untreated sea water. If sodium hydroxide or coral carbonate were used as the neutralizer, the scrubbing system would require 81,000 pounds of sodium hydroxide or 52,000 pounds of coral carbonate each day. The daily discharge of spent scrubber water would be about 200,000 gallons. This spent scrubber water would be virtually free of herbicide ester acids and the dioxin, and would contain less than 16 micrograms per liter of total hydrocarbon pyrolyzates and hydrolyzates. The spent water would range from 160°F to 170°F. The heat and the free available chlorine, which would amount to about 417 pounds each day, would present the greatest problem.[45]

The processing of the spent water would require cooling towers or spray ponds to reduce the heat and to free the chlorine. After this step, the water would be transferred

to an existing sewage outfall pumping system. The heat and chlorine content would be reduced to acceptable levels after mixing with the sanitary sewage. The sewage would then be discharged about 500 feet from shore.[46]

Using sea water as a scrubber without an alkali agent would remove carbon particulates and hydrogen chloride from the combustion gases, but it would not neutralize the hydrogen chloride. Because of this, the spent water would be highly acidic and would be a hydrogen chloride solution of about one percent. The temperature of this water would be about the same as the alkali water.* However, the spent sea water could not be discharged through existing sewage lines because of material incompatibility. A separate discharge line would be needed to insure that the island's coral reef would not be damaged. The quality of the exhaust gases would be much the same as those for the alkali scrubbed gases, except for a larger concentration of hydrogen chloride.[47]

Because of the nature of the spent water and the problems associated with its treatment and discharge, Air Force planners felt that the use of a scrubbing system could have a far more detrimental effect on the aquatic environment around Johnston Island than the release of unscrubbed effluent gases.[48]

Certain safeguards would have to be built into the incineration system on Johnston Island to minimize the possibility of an accident which could harm the environment. The incinerator complex would have to be constructed in such a way that all herbicide transfers would take place within diked areas to contain any spills. Operating procedures would have to minimize spills and stop the operation if a leak ever developed in the transfer system. The temperature within the combustion zone would have to be continuously monitored, and procedures established to stop the flow of herbicide into the incineration chamber if the temperature fell below a prescribed level. Stack gas would have to be automatically monitored for temperature and inorganic components, and the monitoring

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* See p. 83.

system would have to notify the operator if any of these items deviated from the acceptable levels. In addition, possible accident and power failure modes would have to be investigated and safeguards would have to be incorporated into the system's design.[49]

Incineration at Sea. Incinerating the herbicide on a ship at sea had many advantages: operations could be conducted in a remote area; the impact of the exhaust gases would be distributed over a much larger area; contracting for the use of a ship would eliminate the need to design and construct an incinerating system; and the operation could be finished in a much shorter period of time. Several incinerator ships existed.[50] One of these was the Vulcanus. This ship was a tanker with a double bottom and a double hull, and it was 331.4 feet long, had a beam of 47.2 feet, and a draft of 22.9 feet. The vessel's construction complied with the latest regulations which had been established for the shipment of dangerous chemicals at sea. Due to its size, the ship could operate worldwide and in rough weather. A crew of 16 was required--ten to run the ship and six to operate the continuous incineration process. The cargo tanks were divided into 15 sections, none of which were in direct contact with the hull or bottom; the total cargo tank capacity was 925,493 gallons. The vessel's incineration system consisted of two combustion chambers which were brick-lined and had an outside diameter of 5.5 meters and an inside diameter of 4.8 meters. Each combustion chamber had three burners which used a rotating cup fuel injection system. This fuel injection system provided vortex turbulence and distributed the fuel throughout the chamber.[51]

The incineration operation would be conducted in an area some 50 to 60 miles clear of the normal shipping lanes and on the open tropical sea downwind of Johnston Island. Gas or diesel oil would be used to reach the required combustion temperature, approximately 2550°F (1400°C). The maximum operating temperature was 1650°C. Once the required temperature was reached, feed pumps would begin to feed the herbicide into the combustion chambers. To insure complete combustion, the feed flow and air would be carefully controlled. Each of the combustion chambers would consume about 10 to 12 tons of

herbicide per hour. At this rate, the entire stock of herbicide could be incinerated in about 22 to 26 days of continuous burning. Three voyages would be required to destroy all of the herbicide--approximately 925,000 gallons of Orange, and any solvents used for drum cleaning* would be burned on the last voyage.[52]

A total of 576 tons of Orange could be incinerated daily. The gases would include 178 tons of hydrogen chloride, 1,000 tons of carbon dioxide, 50 tons of carbon monoxide, 3 tons of carbon particles, and .576 tons of Orange feed constituents and pyrolyzates. This system was highly efficient and was expected to destroy about 99.9 per cent of the Orange herbicide.[53]

Special monitoring equipment would continuously indicate the temperature near the center of the incineration chamber, the temperature at the center and about two meters from each incinerator stack, the date and time, the on/off mode of each feed pump and burner, and the grid location of the vessel. The monitoring panel would be photographed at set intervals by an automatic camera. Both the panel and the camera could be sealed by regulatory authorities to prevent tampering and assure accurate documentation. Ecological monitoring would not be required, because the ship would complete the project within a month, and it would always be moving and operating over a large area.[54]

The Vulcanus had no facilities for loading Orange onto the ship or for handling, emptying, or cleaning the drums in which the herbicide had been stored.** For this reason, facilities would have to be provided onshore for storing the herbicide in bulk, pumping it to the ship, and emptying, cleaning, and disposing of the drums. Plans for these facilities were being studied at the close of Fiscal Year 1974.[55]

Any process using mechanical equipment was susceptible to a malfunction. Certain safeguards were planned to minimize any malfunctions or accidents which might occur

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* See p. 87.

** See pp. 87-88 for more information on drum cleaning and disposal.

during this operation. Procedures would be instituted to prevent spills and to contain any spills or leaks which might occur while pumping the Orange to the ship. The ship was designed to provide as many safeguards as possible. The double hull and bottom protected it against collisions or other marine hazards. The crew's quarters were located at a safe distance from both the cargo tanks and the incinerator. The fuel oil for the ship's engines was isolated by double bulkheads. The ship's pumps could only pump the cargo into the incineration chambers. International regulations required that, if the safety of the crew and the vessel were threatened, there must be some way to discharge the cargo into the sea. The ship contained gravity release valves which could be used for this purpose.[56] In the incineration system itself, the fuel feed pumps would stop feeding waste into the incinerator automatically if the temperature of the combustion chamber fell below 1400°C. The incinerator burners were designed to shut off automatically if any of the following fell below preset levels: the air feed pressure to the burner, the herbicide feed rate to the burner, or the flame intensity of the burner. The operational controls and monitoring panels would be manned at all times by an engineer whose only responsibility was to operate the system at the required combustion levels.[57]

Drum Cleaning and Disposal

Disposing of the herbicide also included the problem of drum disposal. A well-drained 55-gallon drum contained about a pound of herbicide Orange. Approximately half of this amount was trapped in the drum because of the size and position of the bung, which was small and located about two inches from the rim.* If the bung were enlarged or the drum top removed, a well-drained drum would contain less than a half pound of herbicide. Air Force planners discussed the possibility of rinsing the drums with a light petroleum, such as kerosene or jet fuel. This rinse would remove about 75 per cent of the remaining herbicide, but the procedure was very expensive. There was also the problem of disposing of the used solvent rinse. The Naval

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* The bung was the stopper which was used for plugging the hole in the drum.

Ordnance Station, Indian Head, Maryland, developed a de-drumming and disposal system which involved puncturing the drums, emptying them into a sump area, draining them on a rack for about five minutes and then crushing them vertically. The crushed drums would then be transferred to the Defense Supply Agency Property Disposal Office to be sold for smelting only. This de-drumming system was scheduled to be tested at the Naval Construction Battalion Center at Gulfport, Mississippi, during the week of 9 September 1974. During this test, some drums would be rinsed and re-drained; some would be drained, set aside, and rinsed about 10 days later; and some would be drained for five to ten minute periods. Liquid samples of the rinse and some metal samples would be taken and analyzed by the Aerospace Research Laboratory at Wright-Patterson AFB. The results of the tests would be included in the final environmental statement which was scheduled to be published in November 1974.* [58]

The drums could be disposed of in three ways but, in all cases, the drums would be crushed first to prevent their reuse. The total herbicide and dioxin content of the 45,000 drums was estimated to be 22,500 pounds (2,100 gallons) of herbicide and .045 pounds of dioxin. After crushing, the drums could be buried in a landfill which was approved for hazardous materials, buried at sea, or smelted to recover raw materials. Rinsing would not be necessary if the drums were to be buried in a landfill or smelted. If they were buried, the herbicide and dioxin content would decompose rapidly in the soil,** and, if smelted, the herbicide and dioxin would be destroyed by the smelting process. The air pollution controls required for smelting the drums in the United States would prevent the release of any herbicide or dioxin into the atmosphere. During burial at sea or in a landfill, a relatively small quantity of Orange would be distributed over a large surface area, thus minimizing the impact of a large concentration of herbicide Orange on the environment.[59]

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* See note on p. 74.

** See pp. 79-81.

Possible Registration with the Environmental Protection Agency for Use

When the Secretaries of Agriculture, HEW, and the Interior suspended the registration of 2,4,5-T (a component of herbicide Orange) for use around the home, recreational areas, lakes, and ponds, they did not restrict its use on range and pasture land, non-agricultural land, or in weed and brush control programs on highways and communication rights-of-way. As a result, in February 1973, AFLC proposed that the EPA register herbicide Orange as a special brush killer. At the time, the EPA was reviewing the continued registration of 2,4,5-T and it requested that the Air Force delay its proposal until the 2,4,5-T problem had been resolved. Late in June 1974 the EPA cancelled hearings on the continued registration of 2,4,5-T because of a lack of sufficient evidence. On 3 September 1974 the Office of the Secretary of the Air Force reopened the matter of registering the herbicide Orange with a low dioxin level. The Air Force Special Assistant for Environmental Quality, Dr. Billy E. Welch, submitted detailed data on the chemical makeup of the herbicide.[60]

The major question concerned the level of dioxin which the EPA would accept. If a level of 0.1 ppm were established, about 530,000 gallons of herbicide would be eligible for registration.* This herbicide had a potential commercial value of about $21,200,000.[61]

The Environmental Protection Agency did not make a decision on the registration of Orange or the acceptable dioxin level by the end of September 1974. The Air Force hoped the decision would be made following the release of its Final Environmental Statement in November 1974. In the meantime, AFLC continued to prepare for incinerating the herbicide at sea. However, the command was ready to stop the operation if it received a positive response from the Environmental Protection Agency.[62]

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* A total of 833,855 gallons of herbicide Orange was stored at Gulfport, Mississippi.

Conclusions

In its Final Environmental Statement on the Disposal of Herbicide Orange, the Air Force selected incineration at sea as the best option. This alternative represented the best choice available from the standpoint of environmental impact, managerial considerations, and economic considerations. Accordingly, on 3 September 1974, Headquarters AFLC directed the San Antonio Air Logistics Center to obtain an option on an incineration vessel through the Military Sealift Command. An amount of $1.5 million was set aside for this purpose. The option was to be exercised by 1 January 1975.[63]

The Defense Supply Agency requested that the drums be rinsed prior to crushing and that either the Air Force or the Environmental Protection Agency certify their cleanliness and freedom from contamination. DSA also requested that the stipulation "for smelting only" not be required in their sale of the drums. The San Antonio ALC was instructed to arrive at an agreement with the DSA on acceptable procedures and conditions for the transfer of the drums which would be sold for scrap. The results of the tests conducted by the Naval Construction Battalion Center would be used to determine these procedures.* [64]

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* See p. 88 for further information on the de-drumming tests.

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76. Min., SISMS Control Panel Mtg., 30 April--2 May 1974, prep. by Chairman, SISMS Control Panel, Doc. D-43; Comdr.'s Special Interest Proj., Rpt. No. 22, prep. by Jt. Activities Div., 10 June 1974, Subj.: SISMS Revn./Expansion Effort, Doc. D-50.
77. Comdr.'s Special Interest Proj., Rpt. No. 25, prep. by Dep. Dir., Mission & Mgmt. Support, DCS/MM, 19 July 1974, Subj.: SISMS Revn./Expansion Effort, Doc. D-52.
78. Ltr., w/Atch., NMC to SISMS Control Panel, 6 Aug. 1974, Subj.: SISMS Control Panel Mtg., 24-25 July 1974, Doc. D-53.
79. Ltr., Dir., Mission & Mgmt. Support, to Office of History, 17 Dec. 1974, Subj.: Review of Hist. Narrative, in Office of Hist. files; Interview, Mr. Stieritz with Mr. Don Weber, Dir., Mission & Mgmt. Support, 18 Dec. 1974.

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1. Memo., Traffic Mgmt. Specialist, D/T, DSC/D, to DCS/D et al., 10 Sept. 1974, Subj.: Herbicide Orange, Doc. E-4, p. 1.
2. Draft Environmental Statement, AF-ES-72-2D, "Disposition of Orange Herbicide by Incineration," Jan. 1972, Doc. E-1, p. 1; "Log. Support to SEA by SAAMA, CY 1968," pp. 172-174, in AFLC Hist. Archives.
3. "Log. Support to SEA by SAAMA, CY 1968," pp. 166-167.
4. Ibid., pp. 168-169.
5. Ibid., pp. 169-171.
6. Ibid., pp. 174-177.
7. Ibid., p. 177.
8. Ibid., p. 177; Revd. Draft Environmental Statement, AF-ES-72-2D(1), "Disposition of Orange Herbicide by Incineration," April 1974, p. 4; "Hist. of SAAMA, FY 1970," p. 175, both in AFLC Hist. Archives.
9. "Disposition of Orange Herbicide by Incineration," April 1974, p. 5; "Hist. of SAAMA, FY 1970," pp. 176-177; "Hist. of SAAMA, FY 1971," p. 110, in AFLC Hist. Archives.

10. "Disposition of Orange Herbicide by Incineration," April 1974, p. 5.
11. Ibid., pp. 6, 30-31; Doc. E-4, p. 1.
12. "Hist. of SAAMA, FY 1971," pp. 109-110.
13. "Log. Support to SEA by SAAMA, CY 1968," pp. 226-231, 233; "Hist. of SAAMA, FY 1970," pp. 166-167.
14. "Hist. of SAAMA, FY 1970," p. 180; "USAF Summary of Major Options Considered for Disposition of Herbicide Orange," Nov. 1972, Doc. E-2, p. 3.
15. Doc. E-2, pp. 3-4.
16. Ibid., p. 4.
17. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 1-2.
18. Ibid., p. 115; "Log. Support to SEA by SAAMA, CY 1968," p. 212.
19. See preceding note.
20. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 113-114.
21. Ibid.; Doc. E-4, p. 1; Interview, Mrs. Patricia Shafts, Historian, with Mr. Sam Heaton, D/T, DCS/D, 21 Oct. 1974.
22. Doc. E-2, p. 13; Doc. E-1, pp. 18-19; "Rpt. of the USAF Scientific Advisory Bd. Ad Hoc Comm. on the Disposal of Herbicide Orange," April 1974, Doc. E-3, pp. 16-17.
23. "Disposition of Orange Herbicide by Incineration," April 1974, p. 115; Doc. E-2, p. 11.
24. See preceding note.
25. "Disposition of Orange Herbicide by Incineration," April 1974, p. 115.
26. Ibid., p. 119; Doc. E-2, p. 9; Doc. E-3, p. 20.
27. Doc. E-3, pp. 17-18; Doc. E-2, p. 10; "Disposition of Orange Herbicide by Incineration," April 1974, p. 119.
28. Doc. E-3, pp. 17-18.
29. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 124-125.
30. Ibid., pp. 118-119; Doc. E-2, p. 7.
31. See preceding note.
32. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 116-117; Doc. E-2, p. 8.
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34. See preceding note.
35. See preceding note.
36. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 120-123.
37. Ibid.
38. Ibid.
39. Ibid.; Doc. E-2, p. 6; Doc. E-3, p. 23.

40. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 12-13.
41. Ibid., p. 109; Doc. E-2, p. 5; Doc. E-1, pp. 10-17.
42. "Disposition of Orange Herbicide by Incineration," April 1974, pp. 111-112.
43. Ibid.
44. Ibid., pp. 17-18.
45. Ibid., pp. 17-18.
46. Ibid., pp. 18-19.
47. Ibid., p. 19.
48. Ibid., p. 19.
49. Ibid., pp. 19-20.
50. Ibid., pp. 17-20.
51. Ibid., p. 22.
52. Ibid., pp. 14-16.
53. Ibid., pp. 14-15.
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56. Ibid., p. 16.
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58. Ibid., p. 21.
59. Ibid., p. 21.
60. Doc. E-3, pp. 2-3, 16, 20, 22; "Disposition of Orange Herbicide by Incineration," April 1974, pp. 1-2; Doc. E-4, pp. 7-8.
61. Doc. E-4, pp. 8-9.
62. Ibid.
63. "Disposition of Orange Herbicide by Incineration," April 1974, p. 23; Doc. E-4, pp. 7-8.
64. See preceding note.

NOTES, CHAPTER VI

/ALL DOCUMENTS CITED IN CHAPTER VI ARE LOCATED IN THE SUPPORTING DOCUMENT COLLECTION OF AFLC HISTORICAL STUDY NO. 384, "AFLC SUPPORT OF PROJ. NICKEL GRASS/9DD, 10 OCT. 1973--14 NOV. 1973."/

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