

Review and Analysis: Did the United States Transport, Off-Load and Use Commercial 2,4,5-T Herbicides with Unknown Amounts of Dioxin TCDD on Military Base Grounds in Panama Canal Zone between 1948 and 1999?

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Abstract

The 84 km Panama Canal connecting the Atlantic and Pacific oceans has historically been a strategic waterway for shipping and the location of United States (US) military bases. Since the construction of Lake Gatun reservoir, canal locks and navigation channel through the Isthmus of Panama tropical forests in the 1910s, chemicals, pesticides, and herbicides have been essential for controlling upland and wetland vegetation as well as managing mosquito-borne diseases. Chemicals and pesticides flowed into Lake Gatun via land surface runoff and subsurface drainage either attached to the sediment or in solution during the rainy season. Lake Gatun and the Panama Canal was the drinking water source for most of the civilian and military population living in the Panama Canal Zone. Between 1948 and 1999, US military base commanders had the ability to order, from the Federal Supply Catalog, commercially available herbicide 2,4,5-T with unknown amounts of dioxin TCDD for use on the military base grounds in the Panama Canal Zone. The herbicide 2,4,5-T was transported to Panama Canal Zone ports, including the ports Cristobal on the Caribbean and Balboa on the Pacific, and distributed to the US military bases in Panama by rail or truck. The US National Toxicology Program and the International Agency for the Research on Cancer listed dioxin and TCDD as known human carcinogens. Dioxins are endocrine disruptors and can cause certain chloracne, cancers, developmental and reproductive effects. In 1985, the United States government banned the manufacture of the herbicide 2,4,5-T, with unknown amounts of dioxin TCDD, after it was

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shown to cause cancer in animals. The objectives of this study are to determine: 1) the fate of dioxin TCDD, a contaminant in the herbicide 2,4,5-T, sprayed on the US military base vegetation in the Panama Canal Zone from 1948 to 1999, 2) the transport of dioxin TCDD rich sediment via soil erosion and overland flow into Lake Gatun and Panama Canal waterways and 3) the human health impacts of dioxin TCDD, a known carcinogen, on US military and Panamanian civilians exposed to dioxin TCDD in the Panama Canal Zone.

Keywords

Dioxin, TCDD, Agent Orange, 2,4,5-T, Panama Canal Zone, Commercial Herbicides, US Department of Defense, Fort Sherman, Monsanto, Ezra Kraus

1. Introduction

University of Chicago plant physiologist, Dr. Ezra Kraus experimented with plant growth regulators and identified potential uses for their weed killing properties of value to agriculture and chemical warfare. Dr. Kraus [1] obtained funding for his Department of Botany research program from the United States (US) Department of Defense (DOD) during World War II (WWII) (Figure 1) to further his research on these herbicides as military chemical weapons. Scientists at Camp Detrick (Biological Weapons Laboratory) (Figure 2) later obtained samples of newly created 2,4,5-T which contained unknown amounts of dioxin TCDD [2]. Fort Detrick military scientists, in the 1950s and 1960s, created the herbicide Agent Orange, which was a 50 - 50 mixture of 2,4-D and 2,4,5-T.



Figure 1. Dr. Ezra Kraus, the father of herbicide (chemical) weapons, in his laboratory at the University of Chicago. Photo credit: University of Chicago Library, University of Photographic Archive. Hanna Holbord Gray Special Collection. Individual groups, Informal 5, apfi-03586 Reprinted with permission from Editor of Open Journal of Soil Science.



Figure 2. Fort Detrick biological weapons laboratory headquarters in Maryland: Photo credit: Photograph courtesy of Andrew Dutton.

These dual-purpose herbicides, 2,4,5-T and 2,4-D were used by CIA, DOD, and USDA. New Zealand, American, European, Canadian and Australian farmers in the late 1940s started using 2,4,5-T herbicide to eliminate weeds from cropland including cotton and pastureland. Synthetic herbicides (and pesticides) development continued, after WWII, in addition to breeding of high-yield plant varieties and production of synthetic fertilizers. As part of the Green Revolution these new agricultural products were then shipped worldwide to increase crop yields. This new system of agricultural technologies engineered by plant breeders and agriculture chemists was intended to increase food production by increasing field and farm crop yields in the major production regions. The result today is agriculture's ability to reduce global starvation, improve nutrition and help solve the problem of local and world food insecurity. In contrast, the goal of military use of herbicides, as military and environmental chemical weapons, was to destroy food crops and defoliate jungle forests as a tactic with other weapon systems to win battles and wars [1].

Sills [3] reported “*the dioxin class consists of about 300 chemicals which are formed when chlorine at very high temperatures binds to a molecule that contains carbon (C), such as in the bleaching of paper pulp and chemical manufacturing processes [2]. The International Agency for the Research on Cancer and US National Toxicology Program both listed dioxin and TCDD as known human carcinogens. Dioxins are endocrine disrupters and can cause reproductive and developmental effects and certain cancers, and chloracne*” [3].

Dioxin TCDD can adhere to fine soil particles, organic materials, leaf surfaces and sediments that can be carried by runoff into downstream waters and deposited in wetlands, lakes and ponds. Dioxin TCDD is not water soluble nor absorbed by plants. TCDD bioaccumulates in aquatic species and can become bio-magnified throughout the food chain via fowl, fish and mollusks eaten by animals and humans. The objectives of this study are to determine: 1) the fate of dioxin TCDD, a contaminant in the commercial herbicide 2,4,5-T, sprayed on the US military base ground vegetation in the Panama Canal Zone from the 1948 to 1999, 2) the transport of dioxin TCDD rich sediment via soil erosion and

overland flow into Lake Gatun and Panama Canal waterways and 3) the human health impacts of dioxin TCDD, a known carcinogen, on United State military and Panamanian civilians exposed to dioxin TCDD in the Panama Canal Zone.

2. Findings

2.1. The Herbicide 2,4,5-Trichlorophenoxyacetic Acid

Olson and Morton [2] reported “*chlorophenoxyacetic acid herbicide, 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T), is a synthetic auxin created to defoliate broad-leafed plants. It was developed in the late 1940s and was slowly phased out in United States in the late 1970s due to toxicity concerns and was not manufactured after 1985. However it took additional years to utilize (agricultural use mostly on cotton or to destroy the residual herbicide stockpile)*” [2]. Sills [3] reported that “*herbicide 2,4,5-T itself is toxic. An intake rated of 10 mg/kg/day 2,4,5-T can cause adverse alterations in organisms. In addition, the manufacturing process for 2,4,5-T can contaminate this commercial herbicide with unknown amounts of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)*” [3]. Hsieh *et al.* [4] found “*the half-life of 2,4,5-T is similar to 2,4-D. The degradation of 2,4-D and 2,4,5-T are rapid (half-life of 6.2 days) in an aerobic mineral soil but have a 15-day half-life in anaerobic mineral soils. The herbicides are moderately persistent to persistent (half-life of 41 to 333 days) in anaerobic aquatic environments*” [4].

2.2. The By-Product 2,3,7,8-Tetrachlorodibenzo-p-Dioxin

Olson and Morton [2] reported that “*the by-product 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is an unanticipated contaminant created during the manufacture of the herbicide 2,4,5-T. TCDD has a very long half-life and does not degrade easily. Each batch of commercially available 2,4,5-T herbicide has an average concentration of about 2 to 3 ppm of TCDD but can vary between 0.05 ppm to 50 ppm*” [2]. Stoye [5] determined that “*TCDD is an endocrine disrupter and can cause a variety of chloracne, cancers and developmental and reproductive effects. TCDD is not water soluble and can adhere to leaf surfaces, organic material, fine soil particles and sediments which can be carried downstream by runoff water flow into wetlands, ponds and lakes such as Lake Gatun (Figure 3). Dioxin TCDD can bio-accumulate in aquatic species and become bio-magnified throughout the food chain via mollusks, fowl and fish eaten by humans and other animals*” [5]. Olson and Tornoe [6] recommended “*Lake Gatun and Panama Canal sediment be checked for concentrations of TCDD which is most likely bound to soil particles and organic materials within the lake, waterways, wetlands, and ponds. TCDD could be diluted in Lake Gatun depending on the distance from shore. TCDD can be eliminated from the surface of Lake Gatun waters by photo degradation. The half-life of TCDD in the clear waters of Lake Gatun is based on high intensity of ultraviolet radiation hitting the lake waters. The largest fraction of TCDD, in most waters, binds to*

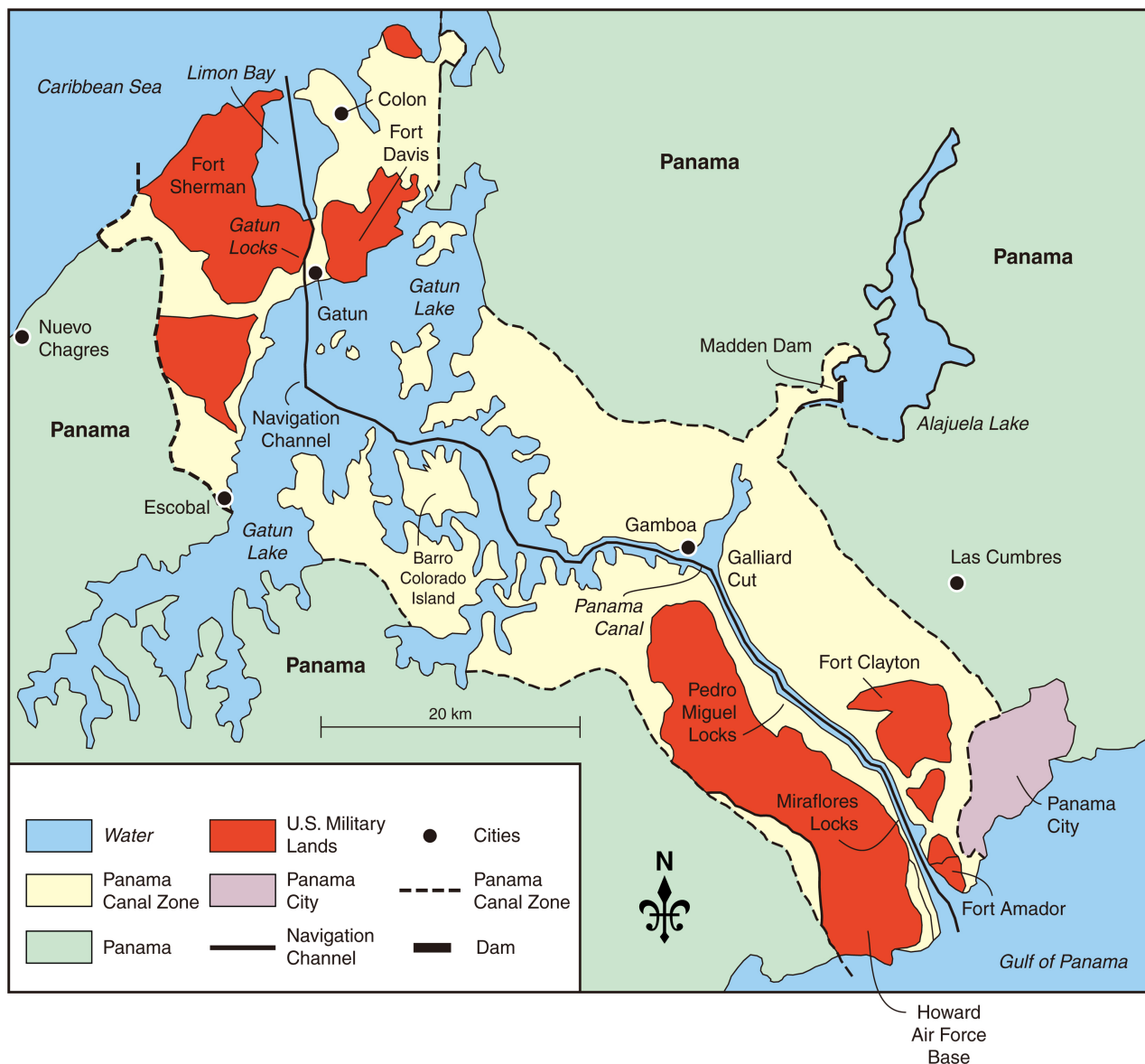


Figure 3. Panama Canal Zone map showing the Panama Canal, Lake Gatun, US military bases and Panama City (reprinted with permission from editor of Open Journal of Soil Science).

detritus, algae, organic materials and mineral matter. These TCDD particles do not remain in the water column but attach to and are deposited with the sediment” [6].

By measuring particle settling rate and concentration in water, their rate of loss can be calculated. Due to its hydrophobic nature very little TCDD is dissolved in water. TCDD in the sediment particles can be returned to the water when sediment is re-suspended [7]. Panama lake and river waters, which are shallow and easily churned by wind and wave action, results in sediment re-suspension [8]. When TCDD particles found in sediments are buried deeply in waterways or lakes or via microbial degradation within sediments, TCDD is ultimately eliminated from the aquatic system [5]. Degradation by permanently

saturated soils can occur over 10-, 20-, 50- or 100-year time periods or by anaerobic microorganisms in sediments [5]. Panamanian capacity to derive livelihoods from aquatic plants, fish and animals and their own health is threatened by TCDD in the food chain. The half-life of dioxin varies with site conditions.

2.3. The 2,4,5-T Herbicide Manufacturing Locations in Canada and United States

A less frequently told story was the human health and environmental impacts on the chemical plant workers who manufactured 2,4,5-T contaminated with dioxin TCDD during the manufacturing processes. The communities affected include one site in Canada and seven locations in the United States (Figure 4) [9]. The pollution at these chemical plant sites, groundwater and adjacent rivers is well known within each affected province or state but not widely recognized beyond their communities. Olson and Speidel [9] assessed: “*The national long-term effects on land, groundwater and river resources where 2,4,5-T herbicide with unknown amounts of dioxin TCDD were manufactured, transported, and temporarily stored. The sites where 2,4,5-T herbicide with contaminated by-products*



Figure 4. The North American locations of the eight 2,4,5-T (Agent Orange) chemical manufacturing plants, the primary Agent Blue chemical manufacturing site and the two Ports on the Gulf of Mexico where tactical herbicides were loaded on ocean-going ships. Map created by Cruz Dragosavac (reprinted with permission from editor of Open Journal of Soil Science).

(*dioxin TCDD*) during the manufacture, transport and disposal by civilian and military workers within Canada and United States are identified. After 60 years, these communities are still adversely affected by the United States and Canadian decisions to manufacture 2,4,5-T with unknown amounts of dioxin TCDD” [9].

2.4. Use of 2,4,5-T on Worldwide US Military Bases and Other Areas

On military bases in the Panama Canal Zone and around the world, the United States decision to use 2,4,5-T has also impacted the local environment and human health. The chemical manufacture, transport, disposal and storage of 2,4,5-T herbicide has affected human health. The civilian and military workers, who handled and moved this commercial 2,4,5-T herbicide from Canada and United States to countries around the world including Panama as part of the Green New Deal, have been affected [9]. Between 1948 and 1999, the United States military base commanders around the world had the ability to order and use commercial herbicides containing dioxin TCDD. The herbicide 2,4,5-T could be purchased from the Federal Supply Catalog and used on their military base grounds worldwide which included the eight bases in the Panama Canal Zone. The herbicide 2,4,5-T, with unknown amounts of dioxin TCDD, was transported, according to shipping records, to Panama Canal Zone ports, including Balboa and Cristobal, and distributed to the US military bases in Panama Canal Zone by rail or truck.

3. Results

3.1. 2,4,5-T Product Liability Litigation

Olson and Speidel found [9] “*there was an 1976 explosion at a 2,4,5-T manufacturing plant in Seveso, Italy. More than 170 workers and residents had chloracne and cancer and thousands of animals died providing additional evidence that dioxin TCDD contaminant associated with 2,4,5-T is extremely toxic. Liability litigation for 2,4,5-T herbicide products after 1975 continues to gather evidence of the toxic effects associated with the herbicide manufacturing processes*”.

In the late 1970s, Caro Van Strum, living in Rivers Valley region of Oregon and a mother of five children created CATS (Citizens Against Toxic Sprays). CATS challenged the Forest Service (USDA) continued use of 2,4-D (*Agent Orange component*) (**Figure 5**) obtained primarily from the Fort Kelly Air Force base residual stockpile left over after the American-Vietnam War ended in 1973 [6].

Elmore found [9] [10] “*Monsanto workers from Nitro, West Virginia (Figure 6) who were suffering a variety of medical issues approached Attorney Stuart Calwell in the late 1970’s. They believed that their illness was caused by their work environment. They produced 2,4,5-T with by-product dioxin TCDD, for the Vietnam War effort and for agricultural and domestic use. Attorney Calwell’s*



Figure 5. Spraying of 2,4-D by contractors for the USDA, Forest Service in Oregon. Reprinted with permission from Editor of Open Journal of Soil Science.



Figure 6. A black and white photograph taken in the 1950s at Monsanto Chemical Plant in Nitro, West Virginia. Photo Credit: Terry Humphreys. Pinterest.

client list included James Ray Boggess (a plaintiff). Their initial health concerns related to the 1949 Nitro plant autoclave explosion that injured Nitro chemical plant workers. However, that event occurred more than 30 years before and the plant workers continued to become ill, including the new workers hired long after the explosion and subsequent clean-up. They assumed that their health issues related to the 2,4,5-T product production process itself. In 1985, the US government ordered Monsanto to stop making 2,4,5-T with by-product dioxin TCDD, at its chemical plant in Nitro, West Virginia. The chemical plant was eventually shut down and the remaining chemical residues wastes were buried at the site” (Figure 7) [9] [10].

“Many of these sick workers did not work in the Nitro Chemical plant during the time of the explosion and clean-up of the explosion chemical residues.



Figure 7. The Solutia Inc monitoring facilities behind a controlled gate with guard dogs. A bridge on the Interstate is visible in the background. Photo Credit: Pam Olson.

Monsanto feared a negative verdict in the 2,4,5-T case and tried to keep Nitro worker's health problems, associated with 2,4,5-T production with the by-product dioxin TCDD, out of the public spotlight. Monsanto was successful" [9] [10] for many years.

"In January of 1979, railroad cars transporting dioxin-contaminated wood treatment chemicals produced at the Monsanto's Sauget Plant in Illinois crashed in Sturgeon, Missouri. President Jimmy Carter's administration acted, in December of 1979, to create an Interagency Task Force. An internal Monsanto document dated January 24, 1979 indicated, Ours (the Monsanto process at Nitro) was a 'dirty' process with higher dioxin levels than were produced by Dow and other chemical companies (was manufactured at a higher temperatures) [9] [10]. That statement would be used later in the Nitro workers 1980s legal case. Marie-Monique noted in an article that Monsanto understood in 1978, that it 'controlled' all of the dioxin TCDD health data going back to Nitro Chemical Plant explosion in 1949. The company had become the 'lord of information' which, unfortunately, shaped the dioxin toxicity discourse for many years. Monsanto company doctors at Nitro, West Virginia did examine the workers affected by the 1949 explosion over the years and kept health records" [9] [10].

"After the autoclave explosion at the Nitro plant, Monsanto contracted with University of Cincinnati Kettering Professor Raymond Suskind to examine the Monsanto workers. Professor Suskind conducted a Monsanto funded study (\$90,000) involving 120 Nitro employees and associated family members of the plant accident. Suskind and Zack co-authored a paper in the Journal of Occupational Medicine, which followed a group of workers exposed to high levels of dioxin. Vicki Hertzberg and Professor Suskind co-authored a paper which was published in the prestigious Journal of American Medical Association. The study included 436 Monsanto employees at the Nitro plant who may or may not have

been exposed to dioxin between 1949 and 1969. Beyond chloracne there were no ‘noted’ serious health effects or mortality rate effects from their associated dioxin exposure” [9] [10].

“This became a ‘huge legal asset’ for Monsanto leadership team since it appeared to show that dioxin was ‘not a carcinogenic’ and did not increase the death rate in this and ‘company’ funded study with a rather small sample. Monsanto attorneys in future legal benefit cases filed by Attorney Calwell (Charleston, West Virginia) working on behalf of exposed Nitro chemical plant workers, used this data in Federal Court. In 1991, Marilyn Fingerhut of the National Institute of Occupational Health and Safety conducted a much larger study which included mortality data and all types of cancers in dioxin exposed workers. In all, there were 5172 people selected at 12 U.S. chemical plants, which manufactured products 2,4,5-T with dioxin TCDD. The data and findings contradicted the Monsanto funded studies, which were previously published by Professor Raymond Suskind [9] [10] and his colleagues at the Kettering Institute of the University of Cincinnati” (Figure 8).

Elmore [9] [10] reported “The National Institute of Occupational Health and Safety then conducted a second study with 21,863 workers. The findings of their first study were supported casting considerable doubt on the original Monsanto funded study conducted by Professor Suskind. Chemical pathologist and University of Leeds professor Alastair Hay and Ellen Silbergeld, of the Environmental Defense Fund, published a 1985 article in Nature [11], which noted 19 people died of circulatory disease or cancer while working at the Nitro chemical plant and found the Suskind papers were inconsistent with other research study findings. Dr. Linda Birnbaum, Environmental Health Sciences found that dioxin adversely affected the heart, vascular and immune systems, and that ‘dioxin is a human carcinogen’. In 2001, U.S. Department of Health and Human Services, National Toxicology Program found dioxin to be a ‘human carcinogen’. Boston University Cancer epidemiologist Richard Clapp called dioxin the ‘Darth Vader’



Figure 8. Kettering Health Main Campus in Kettering, Ohio. Formerly the Kettering Medical Center. Photo Credit: In the public domain.

of toxic chemicals because it affects so many of the body systems. So how did Dr. Suskind and fellow researchers get the medical science so wrong and why? In court, Lawyer Stuart Calwell alleged Dr. Suskind was doing the bidding of Monsanto who funneled thousands of dollars towards Professor Suskind program at the Kettering Institute (Figure 8). Perhaps, a poor research design and small sample size in the Professor Suskind study may have contributed to the Suskind findings that subsequent research did not support” [9] [10].

3.2. Panama Vietnam Era Veterans and Panamanian Civilian Exposure to Dioxin TCDD

While serving in Panama Canal Zone including Fort Sherman (Figure 9), the US Jungle School (Figure 10), many Vietnam Era veterans came in contact with 2,4,5-T with unknown amounts of dioxin TCDD that was sprayed on military bases [6]. The military personnel, serving in the Panama Canal Zone, were told that the herbicides, including 2,4,5-T with unknown amounts of dioxin TCDD, were harmless. The herbicide handlers, including both Panamanian civilians and United States soldiers, were apparently told they did not need protective gear (since it was a harmless agricultural herbicide widely used by American farmers), such as facemasks goggles, gloves and suits (*personal communications with Panama Vietnam Era Veterans who claim to have been exposed to dioxin TCDD and who have filed for VA benefits but were denied*). The herbicide 2,4,5-T often came in contact with the skin of the military personnel and civilian ground crews who were spraying dioxin TCDD. The empty herbicide barrels (Figure 11) containing 2,4,5-T with unknown amounts of dioxin TCDD were washed often without protective gear and poured out on the ground by hand. After cleaning the barrels, the rinse water was poured on the soil surface. Dioxin TCDD was either leached into the soil and groundwater or transported off-site



Figure 9. A former battery at Fort Sherman. The jungle vegetation is reclaiming the site.



Figure 10. Symbol of the Jungle School at Fort Sherman. Photo Credit: In the public domain.



Figure 11. Rusted Agent Orange barrels which contained 2,4,5-T more than 50 years ago. Was part of a 2020 barrier protecting the Fort Sherman parking lot. Photo credit: Eric Dziekan.

during monsoon rains. Dioxin TCDD was attached to sediment and transported by overland flow (**Figure 12**) into the waterways (**Figure 13**) and Lake Gatun (**Figure 14**).



Figure 12. Gully erosion of a Lake Gatun tributary stream channel. Photo Credit: Pam Olson.



Figure 13. Overland flow into Lake Gatun waterways. Photo Credit: Pam Olson.



Figure 14. Lake Gatun shoreline stream bank erosion. Photo Credit: Pam Olson.

Unfortunately, 2,4,5-T herbicide formulations had a contaminant 2,3,7,8-Tetrachlorodibenzodioxin (TCDD), which under anerobic conditions did not easily degrade and had a very long half-life. The term “dioxin” includes about 300 chemicals which are formed when chlorine, at very high temperatures,

binds to a carbon (C) molecule. The most toxic of all the dioxins and dioxin-like compounds is TCDD [4]. Sediment and soil sampling of the military base grounds (Figure 15), Lake Gatun (Figure 16) and Panama Canal (Figure 17) and (Figure 18) could demonstrate that only commercial herbicides were used in the Panama Canal Zone. Commercial spraying could have resulted in TCDD remaining in the soils. TCDD is not water soluble; however, it can adhere to fine soil particles, organic materials, leaf surfaces, and sediments that can be carried by runoff into downstream waters (Figure 13) and deposited in wetlands, lakes and ponds [4]. TCDD can then bio-accumulate in aquatic species (Figure 19) and (Figure 20) and can become biomagnified throughout the food chain via aquatic and terrestrial vegetation, fowl (Figure 21), fish (Figure 22) and mollusks being eaten by humans (Figure 23) and other animals (Figure 24) [4].



Figure 15. Former Fort Clayton buildings, fence and grounds. Photo Credit: Pam Olson.



Figure 16. Lake Gatun forested. Forested islands and peninsula uplands in Lake Gatun. Published with the copyright permission from Editor of the Open Journal of Soils Science.



Figure 17. Miraflores locks sign on Panama Canal building.



Figure 18. Panama Canal Miraflores locks. Two ships passing through the classic locks at the same time.

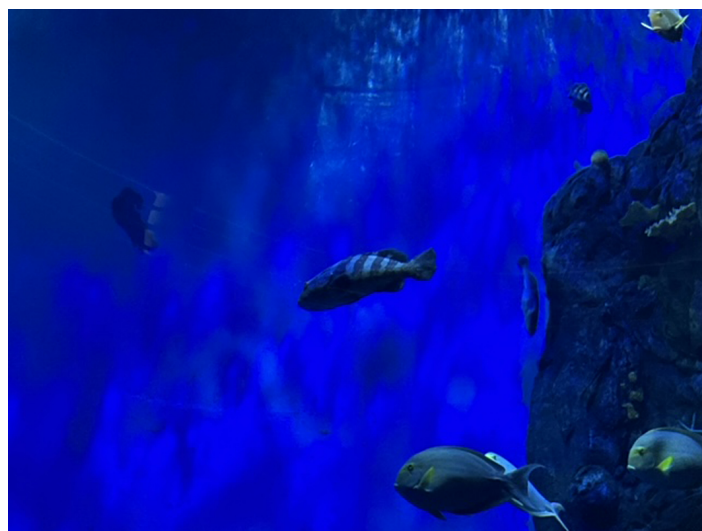


Figure 19. Fish tank at the Biomuseo (Smithsonian) on Amador Causeway. Photo Credit: Pam Olson.



Figure 20. American crocodile on shore of Lake Gatun. Photo Credit: Pam Olson.



Figure 21. Bird at the boat dock on man made peninsula. Photo Credit: Pam Olson.

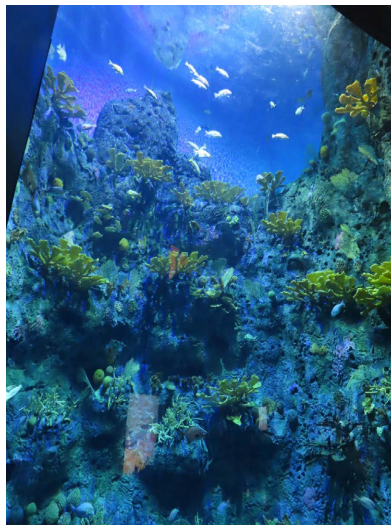


Figure 22. Fish in tank at the Punta Culebra Nature Center (Smithsonian) on Amador Causeway in the Pacific Ocean. Photo Credit: Pam Olson.



Figure 23. Tourist eating clams at a restaurant on the Panama Canal.



Figure 24. Monkey on island in Lake Gatun. The monkey boarded the tourist boats to eat peanuts and bananas. Photo credit: Pam Olson.

3.3. Transport and Fate of Commercial Herbicide 2,4,5-T Containing Contaminant Dioxin TCDD

Chisholm, Chisholm and Kilpatrick [12] found “a recently released report of the United States Government Accountability Office (GAO) focused on the actions needed to improve the communication and accuracy of information regarding testing and storage locations of 2,4,5-T herbicides outside of Vietnam [13] [14] including Kelly Air Force Base in Texas [12]. This GAO report confirmed that the Military Sea Transportation Service chartered merchant vessels directly to

carry tactical herbicides (Figure 25) through the Panama Canal (Figure 26) and (Figure 27) during the American-Vietnam War. There are shipping documents [15] [16] which support the presence of commercial 2,4,5-T herbicide containing unknown amount of dioxin TCDD having been in the Panama Canal Zone. A December 1976 Environmental Sampling Report for the Panama Canal Zone showed chlorophenoxy herbicides were detected in the soil samples from the Canal Zone [12]. The Centers for Disease Control and Prevention identified the chlorophenoxy herbicides as 2,4,5-T based herbicide containing TCDD^a [12].

3.4. US Federal Government and Military Use of Commercial Herbicides with 2,4,5-T with Dioxin TCDD Contaminant in Panama Canal Zone

A GAO review of DOD and Veterans Administration (VA) documents [12] “identified multiple examples of incomplete and inaccurate information on the DOD’s list of tactical herbicides storage and test sites such as Kelly Air Force



Figure 25. Incineration of Agent Orange (2,4,5-T with unknown amounts of dioxin TCDD). Published with the copyright permission from Editor of the Open Journal of Soil Science.



Figure 26. Cranes unloading container cargo at a Port on the Panama Canal. Photo credit: Pam Olson.

Base (Figure 28) in Texas. GAO obtained command histories and original DOD reports which provided operational details about the procurement, distribution, use, and disposition 2,4,5-T herbicide containing unknown amount of dioxin TCDD. GAO concluded that there was extensive documentation on the herbicide management program at Kelly Air Force Base for the American Vietnam War time period and more specifically years 1966-1973” [12].

According to an Air Force Logistics Command’s Office of History monograph [12], “the command directly responsible for managing 2,4,5-T herbicide was the Directorate of Aerospace Fuels at the San Antonio Air Material Area located at Kelly Air Force base. During the Vietnam War Kelly Air Force Base was also a subcomponent of the U.S. Air Force Logistics Command”. GAO documentation [12] shows “that quantities of 2,4,5-T were stored at Kelly Air Force Base in Texas in 1972. There were 38,940 gallons of 2,4,5-T containing TCDD stored in



Figure 27. The Pan-American bridge over the Panama Canal. Photo Credit: Pam Olson.

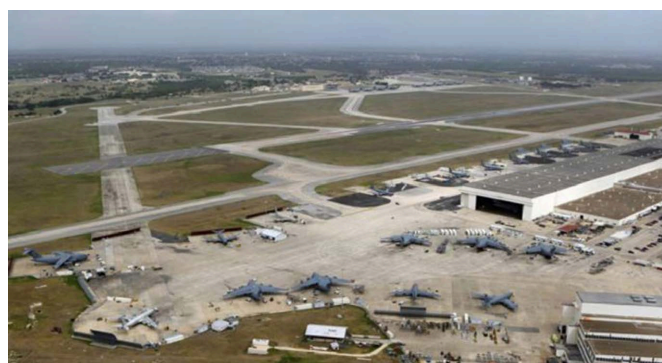


Figure 28. Kelly Air Force Base in Texas. This was the command headquarters for shipping tactical herbicides through the Panama Canal Zone. Agent Orange and Agent Blue were stored at the Base. Credit Line: Photograph courtesy of Kelly Heritage and the Houston Chronicle. Published with the copyright permission from Editor of the Open Journal of Soil Science.

barrels on the base [12]. After the American Vietnam War ended in 1973, the 2,4,5-T herbicide containing an unknown amount of dioxin in the stockpile was apparently transferred to the United States Department of Agriculture (USDA) and other federal agencies for brush control [12].

Olson and Tornes [6] found “DOD could have been one of the sources of the 2,4,5-T herbicides used by the USDA, Forest Service in the Western United States in the 1970s to control the brush and broadleaf weeds after clear cutting. This was the subject of a 2021 PBS documentary *Independent Lens* on ‘People vs. Agent Orange (herbicide 2,4,5-T with unknown amounts of dioxin TCDD)’ [6] and a Vietnam Veteran News podcast number 2086 by Mack Payne [17].

As the US military demanded greater quantities of Agent Orange, the manufacturing processes were speeded up by raising the temperature. Olson and Morton [2] reported “a 3% increase in temperature or about 5 degrees centigrade increased the byproduct dioxin 2,3,7,8-Tetrachlorodibenzodioxin (TCDD) in the waste stream about three thousand times (between 6 and 10 thousand ppm). The average concentration of dioxin in each batch of 2,3,5-T herbicide was about 2 - 3 ppm but the range ran from 0.05 ppm to almost 50 ppm. Many batches of Agent Purple, Agent Pink and Green had more dioxin than Agent Orange” [2].

Panama Vietnam Era veterans who were exposed to commercial herbicides including 2,4,5-T containing unknown amount of dioxin TCDD have filed for VA benefits but have been repeatedly denied benefits [12] [15] [16] since the “tactical herbicides” were not officially offloaded and/or applied to the Panama Canal Zone landscape [15] [16]. Tornoe [16] reported “during a recent visit to Fort Sherman a Panama Vietnam Era Veteran (personal communication) found nine rusted Agent Orange barrels on Fort Sherman (Jungle School) (Figure 11). The barrels were held together by a metal cable to prevent thieves from parking and entering the buildings. If no Agent Orange was officially off-loaded and used on the military bases, how did the empty Agent Orange barrels reappear on the remote side of the Panama Canal Zone at the abandoned Fort Sherman? These barrels appear to have been buried or stored in a bunker or battery (Figure 9) for 50 years. Once the photographs were posted to the internet the barrels disappeared (personal communication)? Why? Who took them? Why did they take them? The area has a category 4 travel warning due to cartel and gang drug activities along the Caribbean coast so it appears any effort to remove the empty barrels would require assistance or protection of the Panamanian military or police. What happened to the Agent Orange barrels (Figure 11) after removal? The United States gave total control of the Panama Canal Zone in 1999. Fort Sherman has been under control of the Panamanians since 1999. These rusty barrels with an orange stripe, labeled as Agent Orange, would have previously been full of dioxin TCDD, and would have been shipped to the Panama Canal Zone ports between 1965 and 1971 (Agent Orange was not manufactured after 1970). The remaining Agent Orange in Vietnam was shipped to Johnston Atoll island near Hawaii in 1972 were not transported back through

the Panama Canal [13]. All the Agent Orange was stored in barrels for five years on Johnston Island and was destroyed by incineration-at-sea (Pacific Ocean) (Figure 25) in 1977” [13].

Much of the remaining Agent Orange residual in the US manufacture pipeline, stored at Gulfport [9], was destroyed by incineration at sea (Gulf of Mexico) [13] and was not transported to Johnston Atoll Island. At the seven manufacturing sites, the TCDD contaminated soil, manufacture’s machinery, tanks, underlived Agent Orange barrels and a number of unauthored dump sites were cleaned up and incinerated by the EPA 1979-89 [9].

However, commercial herbicides containing 2,4,5-T and unknown amount of dioxin TCDD were used on the U.S. military base grounds in the Panama Canal Zone [15] [16] [18] [19]. The DOD did not really claim (*my opinion*) that “*unrestricted commercial herbicides such as 2,4,5-T with unknown amounts of dioxin TCDD*” were never requisitioned, handled, offloaded, and applied by military personnel or Panamanian civilians to the perimeter fences and military base grounds [15] [16] [18] [19] at the direction of the Base Civil Engineer Commanders. DOD only stated that tactical herbicides including Agent Orange were never “off load”. The VA has since used this claim to justify not providing benefits to those exposed to herbicides containing dioxin TCDD (both tactical and commercial) while serving in Panama Canal Zone. It is also assumed that any spraying done only involved commercially available herbicides which officials have long indicated were harmless to humans including herbicide 2,4,5-T with unknown amounts of dioxin TCDD [6]. There is now a mountain of evidence that this is not true. Why did the US Government ban the manufacture all 2,4,5-T in 1985? The reason was that it was cancer causing in animals and humans.

3.5. Fate of 2,4,5-T Stored in 1972 at Kelly Air Force Base

DOD transferred 2,4,5-T herbicide with unknown amounts of dioxin TCDD to USDA, including the Forest Service and many other federal agencies [6], for brush control (Figure 5). If DOD transferred the Kelly Air Force base chemical stockpile to USDA and other federal agencies along with 2,4,5-T containing an unknown amount of TCDD for brush control, these likely would have been one of the primary sources of the herbicides used by USDA, Forest Service in the Western United States [17] [20] in the 1970s. If so, the military base personnel handling the transfer of the 2,4,5-T herbicide could have been exposed to dioxin TCDD. Some Kelly Air Force Base Vietnam Era Veterans [6] [12] have already filed VA claims for benefits as a result of exposure to TCDD.

3.6. Fate of Commercially Available Herbicides on Military Bases in Panama Canal Zone

Tornoe [15] [16] reported “*the herbicide 2,4,5-T was commercially available and thus could be ordered and used separately by any Federal Agency, including the military and shipped to (Figure 29) and used on the Panama Canal Zone mili-*

tary base grounds (from 1948 to 1999) (Figure 30). There are commercial ship transport records, which show commercial herbicide 2,4,5-T containing the contaminant TCDD was used on military bases in the Panama Canal Zone [15] [16] the commercial herbicides including 2,4,5-T by-product containing unknown levels of TCDD were used from 1948 to at least 1985 and probably 1999 on the military base grounds and perimeter fences by military base personnel including civilians to control the vegetation and insect pests and would have added TCDD to the Panama Canal Zone environment. There is evidence that 2,4,5-T



Figure 29. Barrels containing 2,4,5-T on a ship passing through the Panama Canal. Photo Credit: Alvin L. Young. US Air Force.



Figure 30. Former Fort Clayton. Photo Credit: Pam Olson.

with the contaminant dioxin TCDD was sprayed on Panama Canal Zone highways, structures, military grounds (Figure 30) and perimeter fences using sprayers mounted on trucks in the Panama Canal Zone. These trucks were washed out at the motor pool each day and the runoff flowed into the Panama Canal and Lake Gatun” [15] [16].

4. Conclusions

The objectives of this study are to determine the fate of dioxin TCDD, a conta-

minant in the herbicide 2,4,5-T, sprayed on the US military base vegetation in the Panama Canal Zone from the 1948 to 1999, the transport of dioxin TCDD rich sediment via soil erosion and overland flow into Lake Gatun and Panama Canal waterways and the human health impacts of dioxin TCDD, a known carcinogen, on United States military and Panamanian civilians exposed to dioxin TCDD in the Panama Canal Zone.

For Panama Canal security reasons (*to protect the canal from attack*), eight military bases were established in the Panama Canal Zone. The jungle fauna (**Figure 31**) and flora needed to be controlled to improve the living conditions of the US military personnel. The 2010 U.S. Medical Department and Center and School sub course [19] and 1967 U.S. Army grounds manual [18] gave very specific instructions to the grounds crews on how to deal with kudzu. Kudzu was to be killed by spraying a commercially available herbicide, 2,4,5-T. The use of herbicides containing 2,4,5-T with unknown amounts of TCDD continued on the Panama military bases after the American-Vietnam war was over. The dioxin TCDD levels in the Panama Canal Zone environment, including the water and soils, continued to increase with seasonal and annual applications of herbicides containing the contaminant dioxin TCDD. Pesticides and chemicals flowed into



Figure 31. Fauna (insects) on display at Punta Culebra Nature Center (Smithsonian) on Amador Causeway in the Pacific Ocean. Photo Credit: Pam Olson.

Lake Gatun via surface runoff either in solution or attached to the sediment. These pesticides included 2,4,5-T containing TCDD, can bio-accumulate in fish and birds and enter into the food supply and were eaten by humans. The extent of the current pesticide, herbicide and chemical contamination on former U.S. military base grounds in Panama Canal Zone, in Lake Gatun and the Panama Canal channel is unknown. Systematic sampling of the Lake Gatun and the Pa-

panama Canal sediments and soil sampling of former military bases grounds, chemical disposal sites, and is needed to determine if mitigation is still required.

The Panama Canal Zone military base personnel and Panamanians handling the transfer of the 2,4,5-T herbicide could have been exposed to dioxin TCDD. Some Vietnam Era Veterans, who served in Panama Canal Zone, have already filed VA claims for benefits, as a result of exposure to TCDD. The 2022 PACT act provided the “*presumption of exposure to dioxin TCDD*” of US Air Force veterans who served in Guam and Thailand during the Vietnam War. However, the US veterans who served or were trained at one of the eight Panama Canal Zone military bases including Fort Sherman’s Jungle School Training Operations Center, were not covered by the PACT act. Why? This omission needs to be corrected. Many of the US Vietnam Era Veterans who served or trained in Panama Canal Zone have died from various diseases on the official VA list of diseases that can result from exposure to dioxin TCDD. Their advocates are asking that these veterans also be extended the “*presumption of exposure*” granted by the 2022 PACT Act to the Vietnam Era Veterans, as those who served in Guam and Thailand. The draft versions of the original 2022 PACT Act did include Panama Veterans but for some “*reason*” Panama Veterans were not included in the PACT Act before passage of the bill in October of 2022. Who blocked the Panama Vietnam Era Veterans from being included in the PACT act and why? Was it done to prevent Vietnam Era Veterans who served in Panama from the “*presumption of exposure to dioxin TCDD*” provisions? More than 300,000 Vietnam Era Veterans who served in the Panama Canal Zone and may have had been exposed to dioxin TCDD during the Vietnam War and their families would like these veterans to be included in the “*presumption of exposure to dioxin TCDD*” provisions of the PACT act or similar future legislation.

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ment; and the residual effects of these chemicals (arsenic and dioxin TCDD) on the soil and water of Panama Canal Zone and the health of Panamanian people who continue to work these contaminated lands and waters for their living.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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