Journal of the American Mosquito Control Association, 36(2S):98–102, 2020

OPERATIONAL NOTE

MEETING INCREASED DEMAND FOR MOSQUITO ADULTICIDES CONTAINING THE ACTIVE INGREDIENT NALED FOLLOWING HURRICANES AND TROPICAL STORMS

JASON M. TRUMBETTA,[1] VERONICA PLACENTIA[2] AND PETER H. CONNELLY[2,3]

ABSTRACT. The occurrence of tropical storms and hurricanes is a certainty in the Atlantic Basin each year. Many of these never make landfall. Those that do can range in intensity from a weak tropical depression to a very destructive Category 5 hurricane. These storms often produce large amounts of rainfall and flooding, resulting in increases in the mosquito populations in the affected areas. In order to deal with this problem, aerial applications of insecticides over wide areas can provide relief to the impacted area, assisting in the recovery efforts. Meeting the demand for these sudden and large increases in the volume of the insecticide most commonly used in aerial applications requires great coordination, communication, and commitment. We describe the diverse entities involved in the manufacture, distribution, and use of the product and how this increase in need is recognized, managed, and satisfied in a compressed period of time.

KEY WORDS Aerial application, Dibrom Concentrate, load to truck ratio, Saffir–Simpson Wind Scale, Trumpet EC

In a post–hurricane period in populated areas, one of many problems to deal with is the large increase in the mosquito population, a result of flooding and standing water. While aerial applications of mosquito adulticides can provide a great benefit to the rebuilding effort, there are too few products labeled for this specific use. The active ingredient naled, found in Dibrom® Concentrate (AMVAC, Newport Beach, CA) and Trumpet® EC (AMVAC, Newport Beach, CA), has characteristics that make it very suitable for this work and as such is in high demand each year, even more so in the event of storm-related flooding. Although there are "trends" in use of these products during a non–storm year that allow for some production planning, anticipating storms and building inventories each year for the possible demand generated by them is simply not financially viable. Considering the frequency of storms and the impact on product demand over time, there is a positive correlation between a 3-month period and increased demand for a number of years. This tells us when the demand is *most likely* to occur. Since these storms often take weeks to reach our shores, we can then begin to plan scenarios for increased production beyond a normal year. As the storm approaches and immediately after, the importance that communication plays among governmental agencies, the manufacturer, and distributor as well as the contract applicators in a compressed and dynamic period, cannot be overstated. Frequently, the increased demand often occurs during a 5-wk window. Although this presents huge logistical challenges, in the 20 years that AMVAC has owned naled, there has never been a year when the company or its distributors failed to meet the demand.

For >168 years, reliable storm records have been kept for the continental USA. In this geography and during this time period, >364 tropical storm landfalls have been recorded, some in multiple states. Many of these tropical storms also developed into hurricanes, which made landfall 296 times (NOAA 2019a). The severity of storms is measured on the Saffir–Simpson Wind Scale reflecting increasing intensity from categories 1 through 5 (NOAA 2019c). A summary of the storms at or above a Category 1 during the 168-year period is shown in Fig. 1. Storms in categories 3 through 5 are considered major hurricanes and tend to be the most destructive in terms of injury to humans, homes, and other structures. However, some very significant flood damage can result from storms that fail to qualify as hurricanes. One such storm, Tropical Storm Fay, (NOAA 2019b) in 2008 crossed the Florida Keys as a Category 1 hurricane, meandered through Florida, made a total of 4 landfalls, and soaked 3 additional states in the Southeast for days and left widespread flooding behind, causing massive amounts of damage. Severely affected areas are often classified by the Federal Emergency Management Agency (FEMA) as Federal Disaster Areas (FDA) (FEMA 2019). The designation is important since once an area is deemed an FDA, FEMA brings a large group of federal and state agencies together to deal with many areas of community life that require assistance after disasters. Infrastructure, transportation, health, food, shelter

[1] ADAPCO, an Azelis Americas Company, 550 Aero Drive, Sanford, FL 32771.
[2] AMVAC An American Vanguard Company, 4695 MacArthur Court, Suite 1200, Newport Beach, CA 92660.
[3] To whom correspondence should be addressed.

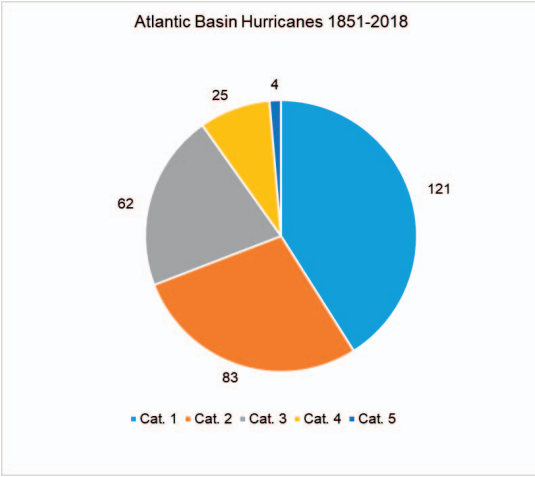


Fig. 1. United States Weather Service data showing Atlantic Basin storms in relative strength categories 1 through 5 on the Saffir–Simpson Wind Scale (NOAA 2019c).

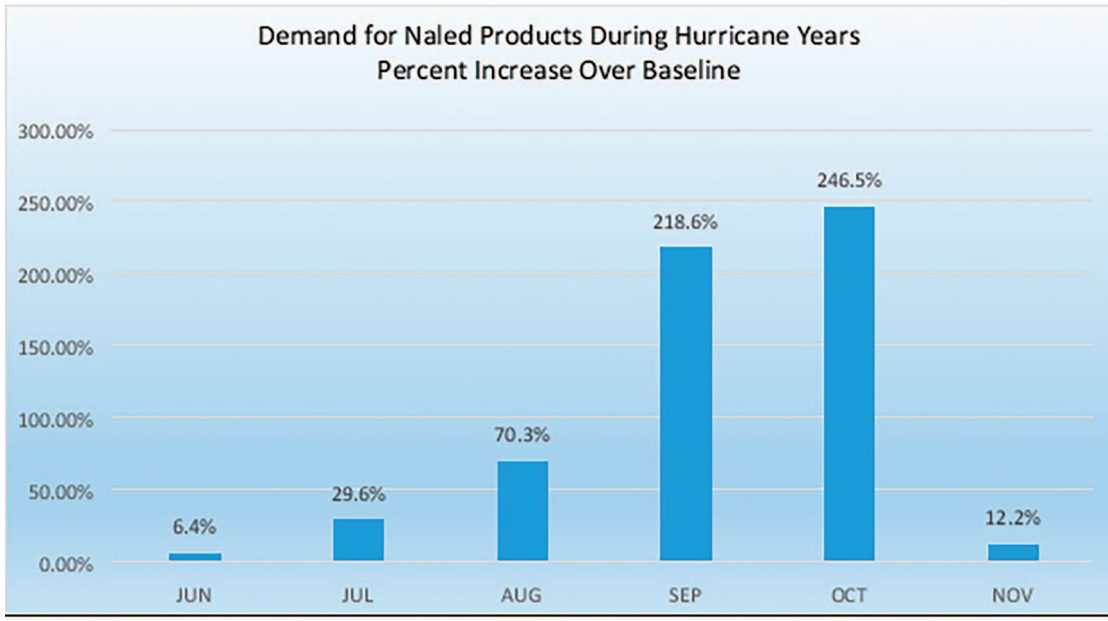
needs, and many others, including mosquito abatement or control, are all dealt with in a coordinated approach to try to get the affected area back on its feet as quickly as possible.

During these types of storms, several inches of water may fall in a short period of time. The resulting flooding not only allows mosquito eggs that may have been dormant to hatch, but standing water also provides a much greater density of oviposition sites for gravid mosquitoes to lay a fresh batch of eggs. Even when the water recedes to normal levels, the low areas, depressions, and containers, natural and man-made, may still hold water and serve as attractive development sites for mosquito larvae for weeks. The problem increases exponentially in a very short period of time as more eggs are laid by increasing numbers of gravid females; when left unchecked the cycle repeats itself. In situations like these, special taxing districts, public works departments, county mosquito programs, and health departments responsible for mosquito and vector control become overwhelmed by the need to control adult mosquitoes over large areas as quickly as possible.

In the USA, natural disasters involving heavy rains and flooding do not usually result in an increase in disease transmission (Nasci and Moore 1998); however, adult mosquitoes may be a hindrance to recovery efforts (CDC 2019a). It is worth mention that after these major storms reach land, it is very common that a high percentage of the human population may be without electrical power. In the absence of air conditioning, faced with damage to the home, or injury to friends and family, a large population increase in blood-seeking female mosquitoes only worsens the burden on the human population. In response to such conditions, the aerial application of mosquito adulticides to the air column over wide areas is often conducted to rapidly suppress populations of blood-seeking female mosquitoes.

Currently there are only 2 classes of chemistry labeled for use in wide-area aerial adult mosquito control in the USA: pyrethroids and organophosphates (USEPA 2019). The organophosphate naled, manufactured for both Dibrom and Trumpet, is the active ingredient most often used in posthurricane–postflooding aerial applications of adulticides due to the favorable characteristics of density, efficacy, and the short-lived nature of the product in the environment. In addition, there are growing significant concerns over resistance in the mosquito populations to the class of pyrethroids used in public health mosquito control (Estep et al. 2018). Naled formulations include Dibrom Concentrate and Trumpet, and are valuable tools when rapid suppression of large amounts of adult mosquitoes in the shortest time possible is required (CDC 2019b). Evaluating demand for naled products in major hurricane years versus non–hurricane years is used to help guide manufacturing in properly anticipating market needs. Using 20 years of manufacturing experience with naled chemistry, AMVAC will typically build 70% of an average non–storm year's requirement prior to the season, and maintain materials at manufacturing facilities in the USA to produce the remainder of the anticipated volume for the year. In addition, the manufacturer will ensure access to additional raw materials in the event of storm-driven volumes that exceed the plan. To illustrate this point, a baseline of zero, defined as a season with no major hurricane–tropical storm landfall events, was determined using purchasing patterns over the course of 10 full years with no storm landfall. When comparing the surge demand in major hurricane years (5 full years), a clear picture emerges of how hurricane landfall events impact demand. Furthermore, in 9 of the 12 calendar months in a full year, there is little to no, or even a reverse correlation, to a hurricane landfall event. As a general conclusion, the months of August–October are influenced the greatest, with monthly demand increasing on average from 70% to a staggering 246%. Figure 2a shows this increased hurricane-related demand for naled products as it relates to the baseline determined from the analysis of non–storm years. The vehicle for procurement of naled products after a weather event is usually through a formal Request for Proposals or government contract. When the material requirements or demand is being driven at the state or local government level, distribution is typically working directly with the government-employed applicator or contract applicator. If treatment efforts are being driven from a federal level, an emergency procurement intermediary such as FEMA is involved in determining the needs for the federal applicators. The need for accurate communication at this juncture for all parties is key. Often, the best available data, as it

a



b

Storm and Application Sequence Timeline

TIME

	Storm Named	Storm Landfall	FEMA Evaluation	Consultation with FEMA and Affected State/Area	Supply Contract Issued by Federal Gov	Aerial Base Established	Application	
ADAPCO (Distributor in Region)	Communicate with mfgr	Forecasts from field Reps	Plan for stocking product	Inventory Staging	Contractor Secures Base of Operations	Aerial applications	Delivery to Contractor	Additional Supply or move to next site
AMVAC (Manufacturer)	Pre season Inventory Build	Confirm Production Plan with Distributor	Prestaging product in regional Whse's	Reconfirm forecasts/ Manufacturing Product	Build Inventory	Delivery to base of operations/ Manage return of Drums	Meet with Distributor	

Fig. 2. (a) ADAPCO analysis of 20 years of sales data on the demand for naled products. (b) Storm and application sequence—timeline for manufacturer (AMVAC) and distributor (ADAPCO).

relates to demand or use rate for naled products, typically reside with the applicator(s) rather than an intermediary. When multiple applicators are involved, the need for regular communication among all parties involved in the supply, delivery, and the use of the products continues to be critical to ensure an uninterrupted supply is available for all parties. Contract aerial applicators will typically be assigned an area to work in and be given a general time frame in which to complete the application. Depending on the insect pressure and the development of successive generations of mosquitoes, repeat applications in the same geography may be necessary. The size of the area to be treated and the time required for the completion may require that the contractor acquire additional aircraft. This could be aircraft that the contractor rents or buys but could also mean subcontracting portions of the total area to other applicators.

The applicators (mosquito control district employees, military, and private contractors) must provide information to the distributor about the capacity of their equipment and the areas in which they are planning to work. Using this information, the distributor can then determine how quickly the available stock will be depleted (burn rate). The flow of product from distribution to the applicators must be checked and rebalanced daily as the areas needing attention can and often do change dramatically by day (Fig. 2b). In this planning for providing the products to multiple sites, contract applicators understand that there is a certainty that the supply

plan will change both dramatically and rapidly as counties and political jurisdictions opt in or out of a treatment plan. Local weather can change the suitability of the missions planned and other variables can and often change the scope and the timing and/or the size of the area planned for application.

A major concern in these emergency response events is working with the trucking agencies to ensure that the shortage of transportation assets, caused by the need to move goods and equipment into the affected areas, is anticipated and the impact minimized. In 2017, AMVAC simultaneously supplied 2 major hurricane recovery efforts with Dibrom, during Hurricane Irma in Florida and Hurricane Harvey in Texas. This required leverage with logistics–trucking partners utilizing internal trucking industry expertise and supporting delivery efforts. This occurred at a time of one of the largest strains on commercial truck capacity seen in the last 20 years. The "load to truck average" increased >30% during that time (DAT Freight and Analytics 2019). The facilitation of consistent delivery of product in conjunction with optimizing asset shortages requires a strategic coordination of efforts.

Logistics accompanied with supply chain management are crucial in executing efficient delivery of Dibrom Concentrate or Trumpet EC for use in aerial applications. This is especially important when an emergency declaration is issued, and an FDA is established. The funding agency for the project, regulatory agencies, state Departments of Agriculture, transportation and logistics firms, applicators, manufacturers, and distributors all need to clearly understand the expectations of each of the contributors. In these supply logistics discussions for naled products, the various parties involved in the project are brought together to ensure critical information is shared by all involved. Working with the agency responding to a recovery effort, the manufacturer of the product, the distributor, and the contract applicators work together to provide the relief needed in the area.

Safety is a primary concern in any response to flooding and or storms that involves aerial applications. Frequently, power is limited or possibly interrupted in large areas. Consequently, cell phone towers may not have the appropriate lighting to ensure that the tower is visible to the pilots of aircraft, often working at night during the peak activity period for flying mosquitoes in the treatment area. To ensure safety during these conditions, the pilots may need to prefly the proposed area in daylight as a recon mission in order to "mark" unlit cell towers and other possible obstructions. As both Dibrom Concentrate and Trumpet are restricted use products, preparation by applicators should include a comprehensive safety audit to make sure that the delivery, storage, loading, and use of the product can be completed using all necessary personal protective equipment and the closed loading system technology required by the product label. Additionally, security of the inventory at the base(s) of operations for the aerial work—often a neglected or abandoned airstrip—is very important. Finally, as part of the manufacturer's commitment to proper stewardship, the collection of the empty drums is managed and funded by AMVAC.

The commitment to supply Dibrom Concentrate to military operations, aerial applicators, and local districts in their recovery plan of action while leveraging delivery equipment shortages includes the following:

1) Managing resources—from sourcing raw materials to positioning product ready for application to designated base of operation sites coordinating local relief efforts that provide safe and proper working conditions to areas devastated by the aftermath of the storm.
2) Establishing a staging location warehouse(s) that meets storage requirements including hours of operation to support relief efforts.
3) Coordinating delivery efforts while managing time constraints in a dynamic and rapidly changing project scope.
4) Implementing proper product stewardship recommendations.
5) Managing product deliveries, from locations such as military base and/or local airports designated as command centers for the operation.
6) Redundant planning for fluctuations in scope and location of application area.
7) Anticipating contract applicators' needs based on past performance.
8) The recovery of the empty containers, managed by the manufacturer, needs to be carefully coordinated as containers should be collected as soon as possible after use.
9) Any significant site remediation at a temporary base of operations must also be part of the overall work plan for the applicator.

In summary, conditions that arise from a major hurricane or slow-moving tropical storm can make life unbearable for those in affected areas. With proper and thorough resource planning, and strong commitment to frequent communication with all involved parties, aerial adult mosquito control can continue to be a very welcome and positive event in the recovery from these storms.

REFERENCES CITED

CDC [Centers for Disease Control and Prevention]. 2019a. *Mosquitoes and hurricanes* [Internet]. Atlanta, GA: Centers for Disease Control and Prevention [accessed September 2, 2019]. Available from: https://www.cdc.gov/zika/vector/mosquitoes-and-hurricanes.html.

CDC [Centers for Disease Control and Prevention]. 2019b. *Information on aerial spraying* [Internet]. City, ST: Centers for Disease Control and Prevention [accessed

September 2, 2019]. Available from: https://www.cdc.gov/zika/vector/aerial-spraying.html.

DAT Freight and Analytics. 2019. *Dry van load to truck ratio* [Internet]. Beaverton, OR: DAT Freight and Analytics [accessed May 20, 2020]. Available from: https://www.dat.com/.

Estep AS, Sanscrainte ND, Waites CM, Bernard SJ, Lloyd AM, Lucas KJ, Buckner EA, Vaidyanathan R, Morreale R, Conti LA, Becnel JJ. 2018. Quantification of permethrin resistance and *kdr* alleles in Florida strains of *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse). *PLoS Negl Trop Dis* 12:e0006544. doi: 10.1371/journal.pntd.0006544

FEMA [Federal Emergency Management Agency]. 2019. *Federal declaration process* [Internet]. Washington, DC: Federal Emergency Management Agency [accessed September 2, 2019]. Available from: https://www.fema.gov/disaster-declaration-process.

Nasci RS, Moore CG. 1998. Vector-borne disease surveillance and natural disasters. *Emerg Infect Dis* 4:333–334.

NOAA [National Oceanic and Atmospheric Administration]. 2019a. *Atlantic Oceanic a Meteorological Laboratory—hurricane, climate, coastal and ocean research* [Internet]. Silver Spring, MD: National Oceanic and Atmospheric Administration [accessed September 2, 2019]. Available from: https://www.aoml.noaa.gov/.

NOAA [National Oceanic and Atmospheric Administration]. 2019b. *Tropical Storm Fay* [Internet]. Silver Spring, MD: National Oceanic and Atmospheric Administration [accessed May 18, 2020]. Available from: https://www.wpc.ncep.noaa.gov/tropical/rain/fay2008.html.

NOAA [National Oceanic and Atmospheric Administration]. 2019c. *Saffir-Simpson Hurricane Wind Scale* [Internet]. Silver Spring, MD: National Oceanic and Atmospheric Administration [accessed September 2, 2019]. Available from: https://www.weather.gov/mfl/saffirsimpson.

USEPA [United States Environmental Protection Agency]. 2019. *Mosquito control* [Internet]. Washington, DC: United States Environmental Protection Agency [accessed September 2, 2019]. Available from: https://www.epa.gov/mosquitocontrol.