Evaluation of Coumaphos Exposure Among Tick Eradication Workers

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Objective: To evaluate both the cholinesterase monitoring program and newer field methods of determining coumaphos exposure among tick eradication workers. **Methods:** Measured blood cholinesterase by the Ellman and field testing methods and tested urine for chlorferon pre- and postshift; conducted personal air sampling, patch sampling of clothing, and wipe sampling of hands for coumaphos. **Results:** Fifteen workers had normal plasma cholinesterase and acetylcholinesterase levels. No significant changes occurred pre- to postshift. High correlation was found between plasma cholinesterase and acetylcholinesterase levels by field testing and Ellman methods ($r = 0.91$, $P < 0.01$ and $r = 0.63$, $P < 0.01$, respectively). Chlorferon levels rose 4 to 6 hours after use ($P < 0.01$). Airborne coumaphos was detected in only one sample, in a trace amount. The majority of patch and hand wipe samples detected coumaphos. **Conclusions:** Dermal exposure to coumaphos resulted in significant increases in urinary metabolites of coumaphos.

Learning Objectives

- Demonstrate familiarity with the toxicity of coumaphos and other organophosphate insectides and current approaches to monitoring organophosphate exposure.
- Discuss the special challenges posed by coumaphos monitoring in the Animal and Plant Health Inspection Service's (APHIS's) "tick riders," and the reasons why new approaches to monitoring were sought.
- Summarize the new findings, including evidence for exposure to coumaphos among tick riders and the benefits of the field test kit evaluated.

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the Animal and Plant Health Inspection Service (APHIS), a division of the United States Department of Agriculture (USDA). APHIS was interested in determining if the current cholinesterase monitoring program for its animal health technicians working in the tick eradication program was useful. In addition, APHIS had an interest in evaluating other methods for monitoring organophosphate (OP) exposure, including field test kit measurements of cholinesterase and possible measurement of urinary biomarkers of exposure. APHIS thought these alternative monitoring methods may be more convenient when considering the erratic use of OP pesticides by APHIS employees and the remote locations and harsh conditions under which they worked. The primary OP used by the tick riders was coumaphos. The purpose of this investigation was to determine if animal health technicians were being exposed to coumaphos, and through which routes of exposure, and to evaluate the potential utility of an available field test kit in this setting.

BACKGROUND

The United States initiated a tick eradication program in 1906 to control cattle fever, a disease that has historically decimated livestock populations. The program, managed by the USDA APHIS, successfully eradicated cattle fever ticks from the US by 1961. However, 50% of cattle in Mexico are infested with the cattle fever tick, and many of these animals migrate across the border into the US. The migration of Mexican cattle produces sporadic infestations in US livestock along the Texas border. To control these infestations, the USDA APHIS maintains a quarantine buffer zone along the Texas border with Mexico. Animal health technicians (tick riders) are employees of the USDA APHIS who patrol and inspect cattle in and around the quarantine zone. Cattle found to carry the cattle fever tick are treated over periods of weeks to months with coumaphos, an OP pesticide.

Coumaphos

Coumaphos (CAS number 56-72-4 [Co-Ral]) is an OP insecticide, which inhibits cholinesterase. It is used to control larvae of fecal-breeding pests in livestock and swine bedding by direct application to cattle, horses, sheep, and swine.[1] It is not registered for use on crops or in homes. Cholinesterases are enzymes that control the amount of nerve impulse transmitters at nerve endings. OP and carbamate pesticides cause illness by binding to and inactivating cholinesterase, thereby causing an accumulation of these transmitters at nerve endings. This results in increased and continued stimulation at those sites and can lead to symptoms such as increased sweating; blurred vision; increased tears, saliva, nasal, and lung secretions; chest pain; trouble breathing; wheezing; nausea, vomiting, abdominal cramps, and diarrhea; muscle weakness and twitches; memory problems; and decreased concentration.

In addition to these symptoms of acute OP poisoning, some OPs can cause a delayed neuropathy, which manifests several weeks after the acute exposure.[2] Although coumaphos does cause delayed neuropathy in hens, it does not seem to do so in humans.[3] In the absence of acute poisoning, chronic exposure to low levels of OPs may also lead to adverse health effects on the central and peripheral nervous system.[4]

The American Conference of Governmental Industrial Hygienists (ACGIH) time-weighted average Threshold Limit Value (TLV time-weighted average) for coumaphos is 0.05 mg/m^3 inhalable fraction and vapor.[5] The TLV was based on animal studies, because there was no quantitative information on human exposures. No other occupational exposure criteria exist for coumaphos.

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The serum half-life of coumaphos after oral or intravenous administration is 2 to 3 hours in rats, with 80% excreted in the urine in 24 hours. The primary urinary metabolite is 3-chloro-4-methyl coumarin (chlorferon), reported in animal studies to be specific for coumaphos exposure. No data are available concerning serum half-life of coumaphos after dermal or inhalational exposure. A skin notation was also assigned in the TLV, because two studies in dermally exposed animals resulted in symptoms of OP poisoning.[6] An ACGIH skin notation indicates a potential significant contribution via the cutaneous route.[5]

In 1996, the US Environmental Protection Agency (EPA), in its Coumaphos Reregistration Eligibility Decision (RED) document, reported that cattle dipping did not pose a significant pesticide exposure threat. Similarly, the report stated that although high pressure wand spraying may pose an exposure threat, low pressure spraying did not. This EPA report was not based on chemical-specific exposure data (which was unavailable) but, instead, relied on generic dosimetry data in the pesticide handlers' exposure database to estimate coumaphos exposure. In 2000, the RED was amended, and coumaphos was approved for additional uses provided certain risk mitigation measures are in place. EPA restricts use of the 42% flowable form of coumaphos (which the technicians use) to USDA staff enrolled in a cholinesterase medical monitoring program. For handheld spray applications, individuals are limited to spraying 100 head of cattle per day.[1]

The USDA APHIS employs 59 animal health technicians who typically work alone in rugged remote terrain, often on horseback. They apply coumaphos to cattle by using fixed or portable dipping vats that require the cattle to fully submerge in the OP mixture. They also use a single-cattle spray booth that sprays coumaphos on cattle. They hand spray their own horses and cattle, on a limited basis, by using low pressure spray wands. The technicians mix and dilute the coumaphos solution. Technicians also conduct physical inspections of the cattle by touching areas of the cattle where ticks most likely attach. This activity is commonly referred to as "scratching." These operations begin in the morning and, depending on the total herd size, may last until early afternoon.

Each technician is issued personal protective equipment (PPE) including a half-facepiece respirator (Willson AR 700 or Norton 7500) and a full-facepiece respirator (3M 6892) with particulate filter and organic vapor cartridges; apron; neoprene elbow length gloves; rain coat and pants; and rubber boots. They are required to wear goggles and rubber gloves when applying coumaphos. At their own discretion, the technicians wear a respirator equipped with dual high efficiency and organic vapor cartridges when spraying coumaphos in windy conditions.

For many years, the USDA APHIS has maintained a coumaphos exposure monitoring program for the animal health technicians. This program consists of establishing baseline red blood cell or erythrocyte acetylcholinesterase (AChE) and plasma cholinesterase (PChE) levels, and performing follow-up cholinesterase testing every 60 days regardless of exposure. The only exception is immediate testing after any large unintentional exposure (eg, a spill). All cholinesterase test results are reviewed by a physician. Technicians whose cholinesterase levels are less than 75% of baseline are removed from working with coumaphos. These workers are retested in 30 days; if the cholinesterase levels increase to more than 75% of baseline, the workers are allowed to return to work. Because of changes in laboratories, the current program does not compare cholinesterase levels to true baseline values but, instead, to a mathematically calculated baseline. Typically, two or three technicians were "flagged" each testing period because of depressions in their cholinesterase levels of greater than 75%. Nevertheless, according to the APHIS medical officer, these did not always appear to be temporally related to high usage periods.

MATERIALS AND METHODS

Only those APHIS animal health technicians scheduled to spray horses, dip cattle, or mix coumaphos during our site visit were recruited for this health hazard evaluation. Recruitment was also limited to employees applying coumaphos within a 1-day round-trip travel distance from Laredo. Participants were asked to undergo both preshift and postshift blood and urine testing. The Webb County APHIS field office in Laredo, Texas, was the principal site for processing and storing biological samples, administering some of the questionnaires, and collecting some of the biological samples. The remainder of the questionnaire administration and biological sampling, along with environmental sampling, was conducted at various ranches in the quarantine zone within driving distance of the field office. Each technician gave informed consent before participation. Employees were notified of their blood and urine test results by letter.

Questionnaire

All participants were given a self-administered questionnaire that we designed specifically for this workplace before their shift. The questionnaire was reviewed by NIOSH researchers in the presence of the participant. It included questions concerning the participants' coumaphos application history, presence of symptoms related to previous coumaphos exposure, and general medical history.

Biological Samples

Blood

Preshift blood sampling for cholinesterase activity was performed in the morning, immediately before coumaphos application. Postshift blood sampling for cholinesterase activity was performed 4 to 6 hours after coumaphos application.

Blood sampling and analysis used the following protocol:

A. The venipuncture site was thoroughly cleansed. By using a 21-gauge needle, approximately 5 mL of whole blood was collected into an ethylenediamine tetraacetic acid (EDTA) tube and 5 mL into a red-top tube. Red-top tube blood was allowed to clot, then was spun down in a centrifuge to separate the serum. Both serum and whole blood (EDTA tube) were labeled and refrigerated at 1°C to 4°C until cold packed for shipment to the Pacific Toxicology Laboratory. Samples were delivered and tested within 48 hours of sampling. Pacific Toxicology Laboratory is one of a limited number of laboratories that has had its cholinesterase assay reviewed and compared with known standards at the University of California Davis reference laboratory. PChE and AChE levels were determined using the Ellman method.
B. A fingertip was thoroughly cleansed. By using a lancet, 10 μL of blood was collected into the EQM Test-Mate ChE Cholinesterase Test System (Model 400; EQM Research, Inc, Cincinnati, OH) assay tube. The blood sample was refrigerated and taken to the APHIS field office, where it was analyzed by NIOSH personnel under controlled thermal conditions (~25°C). AChE was measured using the AChE Erythrocyte Cholinesterase Assay Kit model 460 and PChE was measured using the PChE Plasma Cholinesterase Assay Kit model 470 (EQM Research, Inc, Cincinnati, OH).

Urine

Preshift urine sampling for chlorferon was performed in the morning, before the technicians used coumaphos. Postshift urine sampling occurred 4 to 6 hours after they used coumaphos. Because of the limited data available concerning chlorferon excretory kinetics, a second postapplication urine collection for chlorferon was obtained the following morning before the next work shift.

The following protocol was used for urine collection and analysis. Participants submitted samples in urine collection containers. Urine was subjected to enzymatic (β-glucuronidase and sulfatase) hydrolysis to determine the presence of chlorferon (Hawks Scientific, Cheshire, United Kingdom). Urine testing was performed by the NIOSH Division of Applied Research and Technology laboratory. Testing for chlorferon is not commercially available. Chlorferon-glucuronide excreted in urine was converted to free chlorferon via incubation with β-glucuronidase. Solid-phase C18 extraction with acetonitrile was used before analysis by using high-performance liquid chromatography with fluorescence detection (355 nm excitation; 460 nm emission). Recovery of chlorferon-spiked urine was near 100%, over a range of 0.5 to 500 parts per billion (ppb). The chromatographic method used a Zorbax C18-RX column with isocratic elution of 65% acetonitrile and 35% water (water buffered with 0.05 M sodium phosphate, pH = 7) at a rate of 0.8 mL/min. A limit of detection (LOD) of 0.5 ppb and limit of quantification (LOQ) of 1.5 ppb was based on the average values of instrumental baseline noise and the lowest standard that could be reliably measured. The lowest calibrator used for these analyses was 2 ppb, thus, the method limit of qualification was 2 ppb. Urine from five unexposed subjects (NIOSH personnel) was analyzed to confirm that no chlorferon was present. This urine was then pooled and used to prepare all spiked urines and calibrators.

Environmental Sampling

Environmental and biological monitoring was conducted on employees applying coumaphos by horse spraying, article spraying, cattle dipping, and cattle spraying in the spray box; these were identified as the application activities with the highest potential for exposure. The monitoring methodologies are described below.

Bulk Samples

Bulk samples of the coumaphos mixture in the dipping vat were collected. These samples were analyzed to identify potential interfering compounds that may be detected on the wipe samples. The concentration of the coumaphos mixture in the dipping vats was analyzed by the USDA APHIS laboratories after each dip event to verify that the concentration was at acceptable levels.

Skin Exposure Assessment

Polyester AlphaWipes (4 in × 4 in) were used to assess the potential for skin contact to coumaphos during tick eradication activities. All wipe samples were shipped to a contract laboratory (DataChem Laboratories, Salt Lake City, UT) and analyzed by gas chromatography according to NIOSH Manual of Analytical Methods Method (NMAM) 9107.[7]

Whole Body Sampling

AlphaWipes were loaded on precut cardboard holders and pinned to the outside of the technicians' clothing and under aprons, if worn. Technicians wore the patches in five locations: upper right arm, upper left arm, chest, right thigh, and left thigh. Patches were worn during coumaphos application activities, which typically did not last an entire work shift. Twelve technicians were monitored during the evaluation. NIOSH investigators wore a new pair of nitrile gloves when handling each sample to prevent cross contamination. After sampling, each patch was placed in a vial and stored at 4°C.

Hand Wipe Sampling

Hand wipe sampling was conducted at the end of the work shift to assess hand exposures to coumaphos. AlphaWipes were premoistened with 3 mL of 99% reagent-grade isopropanol before conducting the hand wipe. One wipe was used for each hand. The hand and fingers were wiped thoroughly. Thirteen technicians' hands were wiped. One technician's hands were wiped twice in one day: before lunch and at the end of his work shift. NIOSH investigators wore a new pair of nitrile gloves when handling each sample to prevent cross contamination. After sampling, each wipe was placed in a vial and stored at 4°C.

Surface Sampling

AlphaWipes were used to conduct surface sampling of respirators. Two wipe samples were collected on the interior surface of a technician's respirator to determine the presence of coumaphos. The wipes were premoistened with 3 mL of 99% reagent-grade isopropanol before surface sampling. After sampling, each wipe was placed in a vial and stored at 4°C.

Air Samples

Personal breathing zone (PBZ) air samples were collected on Occupational Safety and Health Administration Versatile Sampler-2 sorbent tubes using SKC AirChek 2000 sampling pumps. Flow rates of 1 L/min were used to obtain the samples. The sampling pumps were calibrated before and after each sampling event against a primary standard (BIOS Dry-Cal) to verify flow rate. The filters were placed as close as possible to the workers' breathing zone and connected via Tygon tubing to the sampling pump. After collection, the samples were sent to a contract laboratory (DataChem Laboratories) and analyzed by gas chromatography according to NMAM Method 5600 with modifications using an electron capture detector.[6]

Statistical Analysis

SAS version 9.1.3 software (SAS Institute, Cary, NC) was used for the statistical analyses. The Pearson's correlation coefficient between AChE determined by the Ellman method and AChE by the EQM Test-Mate ChE Cholinesterase Test System was calculated. The Pearson's correlation coefficient between PChE determined by the Ellman method and PChE by the EQM Test-Mate ChE Cholinesterase Test System was also calculated. The difference between pre- and postcholinesterase levels, pre- and posturinary chlorferon, and postshift and next day urinary chlorferon was determined by the paired *t* test. A *P*-value of ≤ 0.05 was considered statistically significant.

RESULTS

Of the 59 APHIS animal health technicians, 15 met the criteria for our evaluation. All 15 agreed to participate, although 2 did not provide postshift venipuncture or urine samples (but did provide fingerstick samples) because of time constraints. The population was 100% men. The mean age of participants was 41 years (range: 21 to 63 years), and the mean tenure as an animal health technician with APHIS was 13 years (range: 1 month to 35 years). Participants reported mixing coumaphos 8.5 days per month and spraying or dipping livestock 11 days per month, on average. Three reported being removed from coumaphos use (one time each) in the past year due to low cholinesterase levels.

Technicians were asked about symptoms consistent with OP poisoning experienced within 6 hours of coumaphos use in the past 3 months. Two technicians reported headache, two reported weakness, two reported tearing eyes, one reported cough, and one reported nervousness.

Only one technician reported eating, drinking, or smoking while using coumaphos. Technicians were asked about their use of PPE when handling coumaphos in a variety of settings. Reported PPE use varied by task and type of PPE (Table 1).

Biological Monitoring

Blood

Ellman Method. None of the technicians who provided blood had PChE or AChE levels outside the laboratory's range of normal. There

TABLE 1. PPE Use During Coumaphos Application, by Task and Type of PPE

	Mixing			Spraying			Dipping		
$n = 15$	Always	Sometimes	Never	Always	Sometimes	Never	Always	Sometimes	Never
Gloves	12	0	3	10	4	1	6	5	4
Respirator	5	3	7	10	4	1	4	7	4
Goggles	3	1	11	5	3	7	2	1	12
Outerwear or apron	1	2	11	3	6	6	0	5	10
Special boots or shoe coverings	1	1	12	2	5	8	0	5	10

TABLE 2. Individual Urinary Chlorferon Levels, in ppb

	Used Coumaphos in 7 d Before Sampling	Used Coumaphos in the 48 hr Before Sampling	Preexposure	4 to 6 hr After Use of Coumaphos	Morning After Using Coumaphos
1	Yes	No	7.53	291.62	192.16
2	Yes	No	ND	62.07	27.21
3	Yes	No	ND	4.17	ND
4	Yes	No	7.12	52.61	11.76
5	Yes	No	56.03	32.07	163.99
6	Yes	No	41.04	68.51	28.02
7	Yes	Yes	127.98	429.72	67.87
8	Yes	Yes	69.53	341.95	162.82
9	Yes	Yes	101.68	339.31	165.41
10	Yes	Yes	202.00	378.69	129.63
11	Yes	Yes	404.88	403.77	114.89
12	Yes	Yes	45.51	78.96	55.28
13	Yes	Yes	36.39	155.99	89.37
14	Yes	Yes	45.06	No sample	No sample
15	Yes	No	14.37	No sample	No sample

was not a statistically significant change in PChE ($P = 0.89$) or AChE ($P = 0.40$) from preshift to postshift. The mean preshift PChE ($n = 15$) was 3.12 international units per milliliter (IU/mL; range: 2.50 to 4.00 IU/mL), and the mean postshift ($n = 13$) PChE was 3.13 IU/mL (range: 2.50 to 3.70 IU/mL). The mean preshift AChE was 10.89 IU/mL (range: 9.60 to 12.00 IU/mL), and the mean postshift AChE was 10.61 IU/mL (range: 9.40 to 11.80 IU/mL).

Test-Mate. Fifteen technicians had both a pre- and postshift fingerstick for cholinesterase analysis by the Test-Mate. None had PChE or AChE levels outside the range of normal. There was not a statistically significant change in either PChE ($P = 0.69$) or AChE ($P = 0.92$) levels from preshift to postshift. The mean preshift PChE was 2.21 IU/mL (range: 1.81 to 3.02 IU/mL), and the mean postshift PChE was 2.20 IU/mL (range: 1.62 to 3.04 IU/mL). The mean preshift AChE was 4.06 IU/mL (range: 2.99 to 5.08 IU/mL), and the mean postshift AChE was 4.05 IU/mL (range: 3.19 to 5.05 IU/mL).

Relationship Between Methods. There was significant positive correlation between PChE levels measured with the Test-Mate and with the Ellman method ($r = 0.91$, $P < 0.01$, $n = 28$). There was also significant positive correlation between AChE levels measured by the two methods ($r = 0.63$, $P < 0.01$, $n = 28$).

Urine

Fifteen technicians submitted urine for chlorferon analysis before coumaphos application. The mean urinary chlorferon was 77.31 ppb, with a range of nondetectable (ND) to 404.88 ppb (Table 2). Two of these 15 technicians had levels below the LOD. All 15 reported coumaphos use within the past 7 days. Chlorferon was detected in the urine of all 13 animal health technicians who submitted urine 4 to 6 hours after using coumaphos (mean: 203.04 ppb; range: 4.17 to 429.72 ppb). Urinary chlorferon levels were significantly higher 4 to 6 hours after use ($P < 0.01$) and declined significantly from the postshift levels by the next day ($P = 0.01$). The mean urinary chlorferon concentration on the next day was 92.97 ppb, with a range of ND to 192.16 ppb.

Environmental Sampling

Samples were collected during a variety of coumaphos application activities including use of a mobile spray box, hand spraying of horses, and dipping and scratching of cattle in fixed vats. Samples were collected only during activities involving application of coumaphos and cattle scratching. Therefore, most samples were not collected over a full work shift. Technicians spent considerable time processing paperwork in the office, coordinating and staging the dipping with ranchers, and traveling to remote locations to conduct coumaphos application.

Whole Body Results

The results of the whole body patch sampling for coumaphos are tabulated in Table 3. Of the 60 patch samples collected, 26 (43%) were either ND or between the analytical LOD and LOQ. Analytical LODs ranged from 0.7 to 3 μg/sample and LOQs ranged from 2 to 10 μg/sample. Detection limits varied by analysis set.

Hand Wipe Results

The results of the hand wipe sampling for coumaphos are summarized in Table 4. Thirteen technicians' hands were wiped, and a total of 28 wipe samples were collected. One technician's hands were wiped before lunch and again at the end of the shift because his work activities took place across lunch time. NIOSH

TABLE 3. Coumaphos Whole Body Sampling Results

Work Activities of Individual Wearing Patch	Amount of Coumaphos by Patch Location (μg/Sample)				
	Right Arm	Left Arm	Right Leg	Left Leg	Chest
Sprayed a horse and tractor for 35 min	(2)	18	110	22	20
Sprayed 1 horse	14	19	100	70	30
Sprayed 2 horses and dipped cattle for 10 min	50	33	14	6.5	ND
Pushed cattle into chute during cattle spray box application	ND	3.5	4.1	ND	10
Scratching cattle in chute during cattle spray box application	13	ND	(1)	ND	(1)
Pushed cattle into spray box	ND	ND	19	(6)	ND
Opened spray box gate and transferred OP mixture from spray box to truck	ND	(6)	23	43	ND
Operated spray box; charged the water in box with coumaphos; and primed transfer pump	230	(8)	11	(4)	ND
Sprayed 27 horses and dipped 5 cattle	56	(7)	220	1200	38
Sprayed 24 horses and 1 backhoe, dipped 6 cattle	75	48	ND	ND	ND
Scratched cattle and dipped 8 cattle	27	29	(2)	10	(1)
Scratched cattle and sprayed 1 horse	20	27	(4)	11	ND

ND results were below the analytical LOD. Values in parenthesis indicates results between the analytical LOD and LOQ.

TABLE 4. Coumaphos Hand Wipe Sampling Results

Work Activities of Individual Sampled	Coumaphos (μg/Sample)		Washed Hands Before Sampling?
	Right Hand	Left Hand	
Sprayed a horse and tractor for 35 min	(7)	12	No
Sprayed 1 horse	110	200	No
Sprayed 2 horses and dipped cattle for 10 min	150	130	No
Pushed cattle into chute during cattle spray box application	38	54	Yes
Scratching cattle in chute during cattle spray box application	73	130	No
Pushed cattle into spray box	4.8	18	Yes
Opened spray box gate and transferred OP mixture from spray box to truck	480	510	No
Operated spray box; charged the water in box with coumaphos; and primed transfer pump	32	9.7	Yes
Sprayed 27 horses and dipped 5 cattle	610 (AM) 1,400 (PM)	410 (AM) 470 (PM)	No
Sprayed 24 horses and 1 backhoe, dipped 6 cattle	74	170	No
Scratched cattle and dipped 8 cattle	130	82	No
Scratched cattle and sprayed 1 horse	83	37	No
Sprayed his own horses	87	62	No

Values in parenthesis indicates concentrations reported between the analytical LOD and the LOQ.

investigators conducted hand wipe sampling after three technicians washed their hands with soap and water at the end of the application process. Coumaphos results ranged from <LOQ to 1400 μg/sample for the employees who did not wash their hands before sampling. Coumaphos results for employees who washed their hands before hand wipe sampling ranged from 4.8 to 54 μg/sample.

Surface Wipe Results

The insides of two respirators were sampled for coumaphos: one did not detect coumaphos, and the other measured 11 μg/sample.

Air Sampling Results

A total of nine PBZ air samples were collected. All samples except one did not contain detectable coumaphos. The minimum detectable concentration for coumaphos was 0.004 mg/m^3, assuming a sample volume of 119 L. One sample, collected on a technician who sprayed horses for the majority of the day, measured 0.003 mg/m^3 and was between the LOD and LOQ.

DISCUSSION

An inhalational health hazard to coumaphos did not exist at the time of the NIOSH visit. Air sampling represented task-specific sampling between 30 and 120 minutes with no other exposures for the rest of the work shift. Nevertheless, exposures could increase if certain work tasks where coumaphos may become aerosolized, such as spray box application of pesticides, occurred over a longer period of time. One PBZ sample detected trace amounts of coumaphos and represented a worst case scenario. This employee sprayed horses and dipped cattle for the entire day. Results of our evaluation suggest that respiratory protection may not be necessary and may act as a source of exposure if not properly cleaned and stored. One wipe sample taken on the inside of the respirator that was reportedly used infrequently found residual coumaphos contamination.

The majority of the whole body patch sampling detected coumaphos. Patches sampled exposures outside of the clothing. Nevertheless, coumaphos could contact the skin if enough were present on clothing to soak through. In addition, contaminated clothing could contaminate the technicians' vehicle and possibly their homes. Ninety-six percent of hand-wipe sampling detected coumaphos, indicating the majority of exposures occur from skin contact with the pesticide. This was verified through observation. Employees were observed having direct skin contact with coumaphos during several work tasks.

Most employees did not wear adequate PPE, particularly gloves. Barriers to wearing PPE included heat stress concerns, comfort, time constraints, and the perception that it was not needed. PPE and work practices are the main methods of reducing pesticide exposure to these employees during these applications. The EPA has established minimum PPE requirements for use when using emulsifiable concentrate and flowable concen-

trate.[8] Mixers, loaders, and others exposed to the concentrate, and all handlers participating in dip-vat applications should wear long sleeve shirt and long pants, chemical-resistant gloves, chemical-resistant footwear and socks, chemical-resistant apron, and face shield or goggles. All other handlers should wear long sleeve shirt and long pants, chemical-resistant gloves, and chemical-resistant footwear and socks.

We did not expect to find significant differences between pre- and postshift cholinesterase levels because more than half of the 15 participants reported using coumaphos in the past 48 hours and all had used it in the past 7 days, therefore, the preshift was not a true baseline value. The significant increases in urinary chlorferon levels postshift compared with preshift indicate absorption of coumaphos. Although this did not seem to lead to acute intoxication, chronic low level exposure may lead to adverse effects on the nervous system.

Despite the very small number of participants, there was good correlation between the Ellman method and the Test-Mate Field ChE Cholinesterase Test System. The US Army found the Test-Mate ChE to be reliable and useful for measuring AChE in the field in detection of OP nerve agent poisoning.[9] Other researchers have noted it can provide useful information on pesticide exposures when measurements are made in a temperature-controlled system.[10] These researchers found a stronger correlation between the Ellman method and the Test-Mate ($r = 0.99$) for AChE than NIOSH did ($r = 0.63$). The other researchers did not evaluate PChE. California requirements state that for a method other than the Ellman to be used, the correlation coefficient squared (r^2) must be at least 0.9, and that field test kit methods are not satisfactory.[11] Nevertheless, the Test-Mate Field ChE Cholinesterase Test System's convenience may make it an option for APHIS if they decide to continue their cholinesterase monitoring program, because it may increase compliance with and timeliness of testing. It would be useful in the event of an acute overexposure. Urinary chlorferon levels were a more sensitive marker of exposure, showing significant increases after application or mixing of coumaphos. However, testing for chlorferon is not commercially available, and its use would require further validation before replacing cholinesterase monitoring.

CONCLUSIONS

USDA APHIS animal health technicians were exposed to and absorbed coumaphos during their routine activities, as evidenced by urinary chlorferon levels. Urinary chlorferon levels rose significantly after coumaphos use. Results from PBZ air, hand wipe, and patch sampling confirmed that employees were primarily exposed to coumaphos via the skin. Use of a field test kit would be convenient and likely less expensive than the current monitoring system.

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