When Work Makes You Sick: A Farmworker's Experience in the Field

by
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Part I – That Memorable Morning

"When will you be back this time, Daddy?" asked Juan with teary eyes.

"It will not be too long," replied Roberto as he embraced his 7-year-old son.

Roberto was a father who worked as a migrant farmworker in the United States so that he could make money for his family to have a better life. It saddened him greatly to leave his family, but this was an opportunity to provide for the very ones he loved. Roberto hugged his wife and headed off on his journey. Roberto's wife Melissa, son Juan, and five-year-old daughter Gloria watched him from the door as he walked off into the night.

Over several months, Roberto moved from farm to farm, typically traveling by bus. This time he would work at a California farm that harvested iceberg lettuce as its main crop. He knew that he would work long days, reporting at 7 am, but was up for the challenge. Also, the other migrant farmworkers were very friendly and instantly felt like family to him. They always looked out for one another, and he always had an ear to talk to when he missed his family.

One morning at around 9 am while he was harvesting lettuce just a few days after starting employment on the farm, Roberto began to feel sick. He noticed that several other farmworkers appeared ill as well. Roberto was dizzy, his eyes started to tear up and he had trouble seeing. He also developed a headache and felt incredibly nauseated. Even though it was still cool outside, Roberto was sweating profusely. "What is going on?" he thought to himself. "I can't get sick now." He then noticed that some of the other farmworkers became frantic. A crew leader in the field drove to the machine shop to alert the farm owner. The owner of the farm rushed out to the field to figure out what was happening. When he discovered that the farmworkers were sick, the owner encouraged the workers to go to the hospital immediately. The ride to the hospital in the owner's truck was almost unbearable. Roberto also started to develop a pain in his chest, and he was having difficulty breathing. He groaned softly in discomfort.

Questions

1. What is/are the *most likely* cause(s) of Roberto's symptoms? Explain your answer.
2. It is possible that Roberto has experienced toxicity. What is the *most likely* type of toxicity Roberto is experiencing? Using primary sources, explain your answer.

Photo credit: James Daniels

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Part II – At the Hospital

At the hospital, Roberto was assigned a bed in the emergency department. When Dr. James came to see Roberto, she asked him through an interpreter, "How are you feeling?" Roberto responded, "It is hard to take a deep breath. I am dizzy and feel like I am going to throw up. My eyes won't stop watering, and I have a headache." "How long has this been going on?" she asked. "Just this morning after I worked in the farm for a couple of hours," he replied. "And what do you do for work, Roberto?" "I am a farmworker and pick lettuce."

Dr. James examined Roberto and noticed that his pupils were very small, that he was sweating excessively, drooling, had a runny nose and labored breathing, and was holding his stomach. Dr. James suspected that Roberto's symptoms were due to organophosphate poisoning and took a blood sample to confirm.

She explained to Roberto, "If you are exposed to certain types of pesticides, you may have a group of special symptoms. When you get sick from these pesticides, your body produces lots of excess fluids—you may have tearing (like from cutting an onion), a runny nose, excessive drooling, and profuse sweating. You might also have a stomachache, vomiting, and diarrhea. Your head may hurt and you may feel dizzy and tired. The most important way for someone else to know if you are sick from these pesticides is to look at your eyes—the pupils in the center of the eye will be very small. It is very good that you came to the hospital, Roberto. If you have a very bad case of this poisoning and you wait before seeking medical care, you may have trouble breathing, seizures, or you may even 'black out' or die."

Roberto asked, "Is there anything that will make me feel better?"

"Yes. I will prescribe an antidote, a medication that will help treat your poisoning. First, you will need to wash with soap and water and change out of your contaminated clothing into a hospital gown. You will also be admitted to the hospital to manage your condition."

Questions

1. What is the *most likely* route of exposure through which Roberto came into contact with the organophosphate pesticide? Explain your answer.
2. Using a diagram on which all key enzymes and chemicals are identified, explain how organophosphates could be responsible for the symptoms Roberto experienced.
3. Outline what you would tell Roberto about how organophosphate pesticides work, bearing in mind that he does not have much science background.
4. Using your knowledge of cholinergic signaling, propose a potential mechanism of action for an antidote to organophosphate poisoning.
5. What could Dr. James measure in the blood sample to confirm organophosphate poisoning? Form a hypothesis of what Dr. James would expect to find for the proposed test when examining Roberto's blood. Explain your answer.
6. Using a reliable source, distinguish between acute and chronic toxicity.
7. Access the Acute Pesticide-Related Illnesses Charts hosted by the Centers for Disease Control and Prevention at <https://wwwn.cdc.gov/NIOSH-WHC/chart/sensor-pe/exposure>. Perform a query for *Illnesses by Pesticide Functional Class* to find an estimate of the *distribution* (%) of acute occupational pesticide-related illnesses *in California* for *all years* (1998–2011). Answer the questions below using the output generated.
   - a. Which functional classes of pesticides have the highest acute illness estimates? List the top three and their estimated percentages.
   - b. Which functional class(es) of pesticide do you hypothesize could have contributed to Roberto's poisoning? Explain your reasoning. (Note that the database does not extend back to 1981 when actual incidents of poisoning from the pesticide featured in this case occurred on a California farm.)

Part III – Test Results

From the hospital Roberto called his family back home to notify them of the events that transpired and his condition. "You won't believe this Melissa, but I was poisoned on the farm," described Roberto. "But don't worry, I am at the hospital and the doctors will treat me, so I will be fine. Please tell my little Juan and Gloria that daddy misses them." After this somewhat somber conversation, Roberto replayed the words that his wife had said to him, "I am so worried about you, Roberto." Roberto tried to stay strong for his family despite feeling very ill.

Soon after the conversation, Roberto's test results came back. His levels of plasma and red blood cell (RBC) cholinesterase were within normal limits. "This is quite unexpected," thought Dr. James. She had initially predicted that Roberto had suffered from organophosphate poisoning because of his clinical symptoms and possible exposure to pesticides as a farmworker. Additional information also supported Dr. James' diagnosis. Mevinphos, a pesticide classified as an organophosphate, was mistakenly sprayed on the lettuce the morning just prior to the farmworkers' arrival to the fields despite cancellation of the order. After this incident, the farm owner made sure that the fields would not be sprayed again with this pesticide. Still, however, it was unclear why Roberto had seemingly normal levels of plasma and red blood cell cholinesterase.

Investigators from the National Institute for Occupational Safety and Health (NIOSH) interviewed Roberto and the other farmworkers to try to pinpoint what had happened. Although Roberto still felt ill from the effects of exposure, he tried to answer their questions as best he could with the help of an interpreter, as he understood that they were there to help him and his fellow farmworkers. "This is so hard," Robert thought to himself. "I hope it will get better soon."

The doctor discharged Roberto from the hospital when he regained his health after a few days. "I feel so much better, what a relief," thought Roberto. Six days after the exposure event, an order was sent to re-assess the plasma and red blood cell cholinesterase levels of all of the farmworkers from the site including Roberto. They had all experienced improved health. The results showed an increase in cholinesterase levels since the last measurement. NIOSH continued to monitor the cholinesterase levels of the farmworkers over 12 weeks. The statistically significant increases seen over time further confirmed mevinphos poisoning.

Roberto finished his time on the farm and returned to his home country to be with his family. Regardless of all that he had gone through, he was grateful for his returned health and newfound awareness of pesticide toxicity and its impacts on him as a migrant farmworker.

Questions

1. LD50 is defined as the lethal dose of an acute toxicant estimated to kill half of the test animals in an experiment. Find and report the LD50 for mevinphos in rats. How does this compare to LD50s for other pesticides? What toxicity signal word is listed on the label for mevinphos? What is the relationship between the LD50 and toxicity signal word for a pesticide?

2. Explain why it was important for the investigators to monitor levels of cholinesterase over an extended amount of time rather than solely use the results of the blood samples taken just after the initial mevinphos exposure. Distinguish between the rate of recovery for plasma and RBC cholinesterase and describe the reason for the difference.

3. Plasma cholinesterase is produced by the liver. RBC cholinesterase is the same enzyme that functions in nerve tissue. Which of these versions of cholinesterase is *more likely* to be a reliable measure of cholinesterase levels in this scenario? Explain your reasoning.

4. There are currently two antidotes for organophosphates, atropine and 2-PAM. Describe how the mechanisms of each of these antidotes could overcome the downstream effects of acetylcholinesterase inhibition. Use reliable sources to support your answer.

5. Examine the graph below showing mean hypothetical levels of cholinesterase in farmworkers (n = 30) at different times of the year. What conclusions can you draw from this information? Explain your answer.

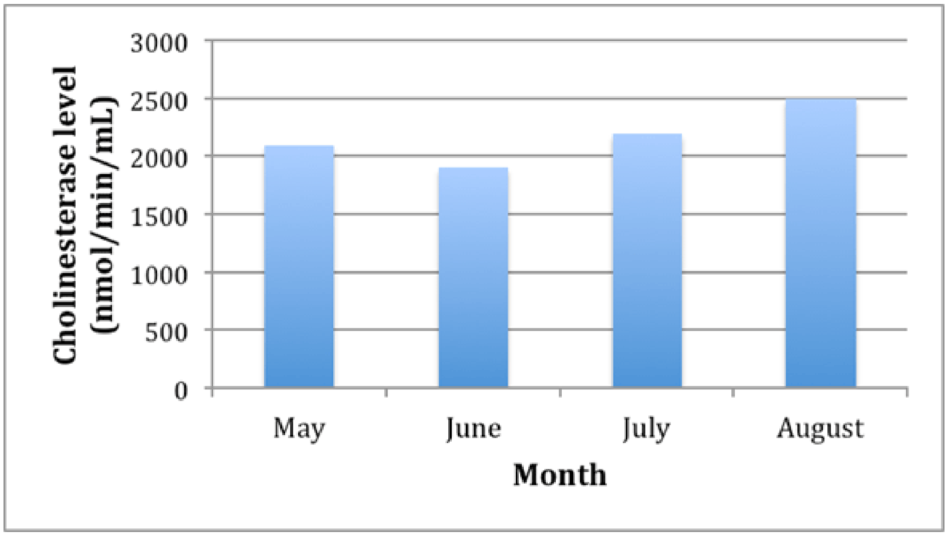

Figure 1. Mean Cholinesterase Levels in Farmworkers during Growing Season.

Part IV – Intimate Debate: Should Mevinphos be Banned?

Introduction

The United States Environmental Protection Agency (EPA) reviews each pesticide at least every 15 years to determine if it continues to meet the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) standard for registration. After reviewing the scientific data and consulting the general public and regulatory partners, the EPA will issue a review decision for reregistration if the pesticide can be used without posing unreasonable risks to human health or the environment. Mevinphos, an organophosphate insecticide, was initially registered as a pesticide in 1957 and the EPA continued to have concerns about its safety and use through the 1980s. On July 1, 1994 all mevinphos registrations were cancelled. Mevinphos is known to exert its effects by direct contact, ingestion, and inhalation and, once in the body, organophosphates like mevinphos are known to inhibit the cholinesterase enzyme, which allows the acetylcholine to build up in the synaptic cleft. This buildup causes continuous firing of the nervous system, which could lead to headaches, dizziness, and muscle tremors. You are being charged with debating whether mevinphos should be registered again.

Procedure

Step 1: Get Informed on Your Position (10 minutes)

Form teams of 4–5 students. These students will be given a list of facts on mevinphos. Some teams will be given facts that support a Pro position (reregister mevinphos), while some teams will be given facts that support the Con position (maintain the current cancellation of mevinphos). You will have 10 minutes to review this information with your team and organize your arguments.

Step 2: Convince Others of Your Position (10 minutes)

Split your team into two teams of 2–3 people. Each mini-team should meet with a mini-team of an opposing position. Each mini-team has five minutes to convince the opposite team of its position.

Step 3: Convince Others of the Opposite Position (10 minutes)

If you were initially Con, look for a different Pro mini-team and assume the Pro position; likewise if you were Pro, look for a different Con mini-team and assume the Con position. Now you will have five minutes to convince your new opposing team of your new position.

Step 4: Decision (10 minutes)

Rejoin your original team. Decide whether your team is for or against the reregistration of mevinphos with the EPA.

Pro: Mevinphos Should Be Reregistered with the EPA

1. Mevinphos is a broad-spectrum insecticide once registered for use on a variety of vegetable and fruit crops, such as alfalfa and lettuce. It has been effective on many insects including aphids, mites, and grasshoppers. [1,2]
2. During the reregistration evaluation by the EPA, there was minimal toxicological data for mevinphos, except for a teratology study conducted in the rat. This includes both acute and chronic toxicity (carcinogenicity, reproductive and developmental toxicity, mutagenicity, and acute delayed neurotoxicity). [3,4]
3. The EPA states that there is insufficient data available to fully assess the environmental fate of mevinphos, including the potential for groundwater contamination, persistence in the environment and the need for crop rotational label restrictions. [2]
4. To determine if mevinphos was a reproductive toxicant, Sprague Dawley rats were exposed to concentrations of mevinphos between 0 and 0.5mg/kg prior to mating, during mating and through weaning of the pups. There were no reproductive effects observed during the study. [5]
5. In rats and rabbits orally exposed to mevinphos, no developmental toxicity was observed at any dose. [2]
6. Mevinphos is unlikely to contaminate groundwater, due to the fact that it is rapidly hydrolyzed in water and rapidly metabolized in soil (half-life is less than 25 hours in soil). [6]
7. To assess mevinphos for genotoxicity, an unscheduled DNA synthesis assay was performed using primary rat hepatocytes treated with increasing concentrations of mevinphos. Following exposure there was no increase in unscheduled DNA synthesis at any dose. [7]
8. An 18-month mouse study, conducted by Atkinson in 1989, assessed mevinphos for oncogenicity. No adverse effects were noted at any of the doses in either sex. [8]
9. There were no neurotoxic effects on hens dosed twice with mevinphos, as well as no signs of delayed neuropathy. [9]

Con: Mevinphos Should Remain Canceled with the EPA

1. Mevinphos is readily absorbed through the skin, lungs, and mucous membranes, and it is a potent inhibitor of the acetylcholinesterase. [1,2]

2. Poisoning symptoms may include: headache, vomiting, blurred vision, diarrhea, muscle twitching, hypersecretion, abdominal cramps, and death. [2]

3. Rats were exposed to various doses of mevinphos from 0-10mg/kg. Doses above 1.75 exhibited some clinical signs of a neurotoxicant, while rats dosed at 5mg/kg and 10mg/kg died within moments of being treated. Clinical signs such as tremors, salivation, and constricted pupils were observed, as well as reduced neuromuscular performance and inhibition of brain cholinesterase activity, indicating acute neurotoxicity. The NOEL for acute neurotoxicity was 0.1 mg/kg. [10]

4. Both humans and laboratory animals acutely exposed to mevinphos exhibited the same level of sensitivity. [2]

Table 1. Human and Laboratory Animal Comparison of Cholinergic Signs

Sign/Symptom for Acute Toxicity	*Organism*	*Dose*
Cholinergic signs	Humans	0.025 mg/kg*
Pin-point pupils	Rats	0.005mg/kg+
Nasal and oral discharge	Rats	0.05 mg/kg*
Tremors	Rats	0.1mg/kg*
Vomiting	Dogs	0.025mg/kg*
Diarrhea	Rabbits	0.05 mg/kg*
* NOEL, +LOEL		

5. The United Farm Workers organization targeted mevinphos for banning because of its high acute toxicity and numerous worker poisonings. Mevinphos was the leading cause of pesticide induced hospitalization and the second most common cause of occupational pesticide poisoning between 1980–1986. [1]

6. In November of 1989, more than 80 farmworkers were poisoned in Florida by entering a mevinphos treated cauliflower field 20 hours after application. [11]

7. The EPA recorded 356 illness reports involving mevinphos between 1966 and 1980. Within the state of California there were 563 reported mevinphos poisonings involving workers from 1982 to 1991. [2]

8. Mevinphos is toxic to a variety of wildlife, including birds, fish, marine invertebrates and honeybees. [1]

9. The oral LD50 for mevinphos in rats was less than 10 mg/kg, while the dermal LD50 in rabbits ranged from 5.7 to 60 mg/kg. The LC50 for rats that were exposed to mevinphos for one hour via inhalation was 8.2 to 10 ppm. [2]

Cited Works for Pro and Con Positions

[1] Chemical Watch Factsheet. 1990. *Pesticides and You* 10(3). <http://www.beyondpesticides.org/pesticides/factsheets/Mevinphos.pdf>.

[2] Mevinphos: Risk Characterization Document, Medical Toxicology and Worker Health and Safety Branches, Department of Pesticide Regulation, California Environmental Protection Agency; June 30, 1994. <https://sciencecases.lib.buffalo.edu/files/Supplemental/UploadFolder/migrant_farming_sup.pdf>

[3] U.S. EPA. 2000. Report on FQPA tolerance reassessment progress and interim risk management decision, Mevinphos. Office of Pesticide Programs. Washington, DC.

[4] U.S. EPA. 1988. Guidance for the reregistration of pesticide products containing mevinphos as the active ingredient. Office of Pesticide Programs. Washington, DC.

[5] Beyer, B.K. 1991c. Multi-generation rat reproduction study MRD-88-331: Mevinphos. Exxon Study No. 233135 DPR Vol. 157-050.

[6] Halls, T.D.J. 1989. Supplemental report: Identification of the major product of photolysis of 14C mevinphos in water. *AmVac Study* No. 352901 DPR Vol. 157-029.

[7] Curren, R.D., 1990. Unscheduled DNA synthesis in rat primary hepatocytes with mevinphos. AMVAC Study No. T8858.380 DPR Vol. 157-035.

[8] Atkinson, J.E., 1989. An eighteen month oncogenicity feeding study in mice with mevinphos. AMVAC Study No. 86-3006. DPR Vol. 157-028 #73163.

[9] Barrett, D.S., 1988. Acute delayed neurotoxicity study in mature hens with mevinphos. Biodynamics Inc., Study No. 4685-87 DPR Vol. 157-053 #114192.

[10] Lamb, I.C., 1993. An acute neurotoxicity study of mevinphos in rats. Wil Research Laboratories, Inc. Study No. WIL-188006 DPR Vol. 157-066.

[11] Karr, Catherine. 1989. Eighty workers fall ill to Phosdrin. *Pesticides and You* 9(5):3.

Additional Case References

Agency for Toxic Substances and Disease Registry. <http://www.atsdr.cdc.gov/csem/csem.asp?csem=11&po=5>

Chemical Watch Factsheet. 1990. *Pesticides and You* 10(3). <http://www.beyondpesticides.org/pesticides/factsheets/Mevinphos.pdf>

Dictionary of Agromedicine. <http://agromedicinedictionary.ces.ncsu.edu/>

Cornell University Cooperative Extension, Pesticide Safety Education Program (PSEP): Toxicity of Pesticides. <http://psep.cce.cornell.edu/Tutorials/core-tutorial/module04/index.aspx?format=pes>.

Karr, Catherine. 1989. Eighty workers fall ill to Phosdrin. *Pesticides and You* 9(5):3.

Mevinphos: Risk Characterization Document, Medical Toxicology and Worker Health and Safety Branches, Department of Pesticide Regulation, California Environmental Protection Agency; June 30, 1994. <https://sciencecases.lib.buffalo.edu/files/Supplemental/UploadFolder/migrant_farming_sup.pdf>

Thomson, W.T. 1984. *Agricultural Chemicals: Insecticides.* Thomson Publications: Fresno, CA.

U.S. Department of Labor. 2005. Findings from the national agricultural workers survey (NAWS) 2001: a demographic and employment profile of United States farm workers. Office of the Assistant Secretary for Policy, Office of Programmatic Policy. Washington, DC.

U.S. Environmental Protection Agency. 2000. Report on FQPA Tolerance Reassessment Progress and Interim Risk Management Decision, Mevinphos. Office of Pesticide Programs. Washington, DC.

U.S. Environmental Protection Agency. 1988. Guidance for the reregistration of pesticide products containing mevinphos as the active ingredient. Office of Pesticide Programs. Washington, DC.