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Balancing the Risks: Vector Control and Pesticide Use in Response to Emerging Illness

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ABSTRACT *The competing public health concerns of vector-borne disease and vector control strategies, particularly pesticide use, are inherently subjective and difficult to balance. Disease response decisions must frequently be made in the absence of data or clear criteria. The factors to be weighed include the vector control measures versus those posed by the disease itself; short-term versus long-term disease management goals, specifically with regard to the issue of pesticide resistance; the need to distinguish among diseases of differing severity in making response choices; and the issue of pesticide efficacy. New York City's experience with West Nile virus has illustrated each of these issues. A framework for assessing the appropriate response to West Nile virus can serve to guide our response to likely new pathogens.*

Balancing the competing public health concerns of vector-borne disease and vector control strategies is inherently subjective. Decisions are frequently made in the absence of data or clear criteria. At the outset of each season, it is not possible to foresee the severity of a particular disease. We might not even know the disease is here. Repeated experience with each disease in a given geographic area can help hone these predictions, but they will never be perfect. At the same time, there are innumerable gaps in our understanding of both the immediate effects of many vector control chemicals and the long-term consequences of their use. Although the foundation for disease response decisions is imperfect, decisions must still be made.

DIRECT HEALTH RISKS

The first set of risks to be balanced is the most obvious: the hazards of a chosen vector control measure versus those posed by the disease itself. In general, preventive vector control measures, such as monitoring, surveillance, breeding site reduction, biological controls, and biopesticides for larval control, are on the low end of the risk continuum. Some pose no risk at all. The greatest controversy in the response to West Nile virus, and the most difficult issue when it comes to risk balancing, is the use of adulticides, insecticides that kill adult mosquitoes.

Adulticides pose both acute risks, including neurologic, allergic, and respiratory risks, and chronic hazards, which are considerably less well defined.[1] Although chronic effects can occur with even single exposures in critical amounts or at critical junctures in human development, they become a more pressing question with repeated exposures, such as occurred in many New York areas during the response to West Nile virus.

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The chronic effects of concern include developmental toxicity, endocrine disruption, carcinogenicity, genotoxicity, and immune system damage. Many of these effects have been linked in the medical literature with the adulticides used in the West Nile virus response. In some cases, only one or two studies have suggested a given association.

Compared to the record on acute effects and considering the widespread use of these pesticides, the evidence for chronic health effects of many adulticides is thin. However, this should not be misconstrued as an absence of risk, but rather as an absence of information because the appropriate testing has not been done. Yet there is ample evidence in the literature to prompt concern. Despite the impulse to focus on acute pesticide effects as the more direct parallel to acute disease risks, potential chronic effects need to be accounted for in the decision-making process as well.

It is also necessary to account for the fact that the risk of the disease and the risk of the pesticide may not fall on all people equally. The majority of the morbidity and mortality produced by the West Nile virus infection was seen in elderly people.[2] Organophosphate insecticides, such as malathion, which was used to control the mosquito carrying the West Nile virus, may have more serious acute and long-term effects on children. Therefore, we need to consider vulnerable populations when making public health response decisions that affect everyone.

There are also ecological risks beyond those to humans, such as direct hazards to nontarget and beneficial insects, to aquatic organisms, to birds, and indirectly, to the organisms who feed on these living things. While we do not think of cities like Manhattan as nature preserves, it and any other urban area are entwined with and close to sensitive environments—wetlands, bodies of water, woodlands—where the potential to disrupt ecological balance is real.

PESTICIDE RESISTANCE

In choosing response options, we must also balance short-term versus long-term disease management goals, specifically with regard to the issue of pesticide resistance. Ideally, adulticides are used as a last resort. For West Nile virus, the state and local response plans all take this approach. In 2000, preventive measures aimed at staving off adulticide use were instituted across the New York City region.[3] In practice, however, "last resort" is not a clearly defined term. The criteria for judging when preventive measures have failed and a disease outbreak is imminent—in other words, the trigger for adulticide use—differ widely from community to community.

Setting the triggers low (the first detection of virus in a migratory bird, for example, as opposed to the first detection in an infected mosquito pool or a human case) and deploying adulticides early in a season can lead to repetitive spraying in the same location because such control is short term. Adulticides only temporarily depress insect populations for a few days until the next larval hatching. Repeated pesticide applications not only result in greater pesticide exposure and all its concomitant risks, but also are a reliable method of generating pesticide resistance in the target vector population. Resistance can also be generated by making the response area too broad, as opposed to more "surgical" responses to single-infected mosquito pools.

There are numerous examples of vector resistance to pesticides.[4–9] The growing concern with bacterial antibiotic resistance is a parallel from another part of the public health domain. Resistance defeats ultimate disease management goals because of the threat of disease resurgence. Gubler, of the Centers for Disease Control and Prevention, has stated that decreased emphasis on surveillance and prevention and "the technical problems of insecticide and drug resistance, as well as too much emphasis on insecticide sprays to kill adult mosquitoes, contributed greatly to the resurgence of diseases such as malaria and dengue."[10]

Fine-tuning the triggers for response will require that we more precisely understand those factors that contribute to viral amplification and transmission. In 2000, the simple detection of West Nile virus in migratory birds or infected mosquito pools was not in itself a reliable indicator of wider local transmission. Indeed, even human cases do not necessarily herald an epidemic. Single or clustered cases of various viral encephalitides occur in New York State on an ongoing basis without broader consequences, and sporadic cases of West Nile virus have been shown to occur in the years following an epidemic.[11,12] Understanding the true harbingers of an epidemic will allow us to set appropriate triggers and avoid poorly targeted use of pesticides that will diminish their effectiveness over the long run.

BALANCING AMONG DISEASES

The problem of resistance leads to a third balancing problem, namely, managing the risk between diseases. Just as different pesticides pose different degrees and kinds of hazards, so do different illnesses. In addressing emerging and existing illnesses alike, we need to consider how to assess which illnesses warrant which level of response and how our response to one disease could affect our ability to respond to another.

Illness from West Nile virus pointedly illustrates this problem because it is not one of the most dangerous vector-borne diseases. Malaria, dengue fever, yellow fever, and eastern equine encephalitis are among a host of more serious diseases already with us in the New York region or on the horizon. Global warming and increased global travel will only accelerate the process and increase our vulnerability.

Any decision-making process must therefore differentiate among diseases to husband our various response options. A short-term, eradication-oriented approach for every vector-borne disease may generate resistance that hinders our ability to respond during true outbreaks of that same disease or to outbreaks of comparatively more virulent illnesses. Such outbreaks, in turn, could lead to an escalation of pesticide use in future responses. We must, instead, develop criteria for judging when to move from a crisis reaction mode to more sustainable, long-term management of endemic disease agents. If we do not, we run the risk that the crisis mode will become the de facto routine.

EFFICACY

Finally, we have the risk that we may not always be balancing hazards, but inadvertently compounding them. This speaks to the question of vector control efficacy. If adulticides—even when deployed in ways that all parties agree truly meet the criteria of last resort—are not effective at their task, we will merely have layered one hazard on top of another. The question of pesticide efficacy must be framed not just in the narrow sense of a decrease in mosquito populations, but in the deeper sense of whether their use affects the course of an epidemic.

There is ample precedent for this kind of analysis and for the conclusion that pesticide spraying can be ineffective, even as a stopgap measure, for some vectors and some diseases. Research on dengue in the Caribbean has indicated that some long-standing mosquito control programs did not have any demonstrable effect on the course of outbreaks there.[13–16] Although this failure may be due to features of the natural ecology of the dengue vector (*Aedes aegypti*) not shared by all other mosquito species, the fact that spraying programs of long standing were ultimately found futile indicates that pesticide efficacy is an open question with each new climate/mosquito/disease combination that we confront. Before predicating response plans on the notion that adulticides are effective as a last resort, it is imperative that this assumption be examined in each instance to determine whether or under what conditions it is true for a particular outbreak. If this examination does not happen, we run the risk of engaging in pointless spraying. Posing the question of which control methods are effective is not meant to imply that it has a simple or quick answer. But the question is no less real for being complex.

PESTICIDE USE DURING THE WEST NILE VIRUS OUTBREAK

The West Nile virus outbreak of 1999 and 2000 focused attention on these issues more dramatically than for any other vector-borne disease outbreak in this country in recent memory. Questions ranged from the fundamental (whether the severity of the disease warranted the dramatic response of widespread aerial pesticide applications) to the specific (whether spraying occurred at the times mosquitoes were active and accessible to the chemicals; whether it occurred under hazardous, windy conditions; and whether applications near bodies of water violated label directions).

At the heart of the controversy was the tension between the two competing public health risks, the spraying and the disease, and the relative unfamiliarity of both to local public health authorities. The illness and the health effects of the pesticides used to combat it were new territory for decision makers and the public alike. Despite routine use of pesticides in the New York City region, spraying for West Nile virus placed the issue of pesticide risks at center stage in the public discourse in a way it had never been before.[17]

The pesticides used to control mosquitoes carrying West Nile virus were the organophosphate insecticide malathion and the pyrethroid insecticides resmethrin and sumithrin. Malathion, like all organophosphate insecticides, is a cholinesterase inhibitor. Although it is one of the less acutely toxic of this family of pesticides, exposure to malathion nonetheless may cause respiratory distress, headaches, dizziness, and nausea.[1] During the period 1977 to 1982, malathion was the second leading cause of hospitalization for occupational pesticide poisoning in the United States.[18] A recent study of acute adverse effects in the community from aerially applied malathion bait for medfly control in Florida found 123 probable or possible cases of symptoms tied to the spraying, including respiratory, gastrointestinal, and neurological effects; dermatitis; and eye damage.[19] Infants and children, whose immature nervous systems are more vulnerable to injury, and newborns, whose metabolisms are less capable of detoxifying malathion, are more susceptible than adults to its toxic effects.[20]

Information on chronic effects of pesticides is less abundant. Reports have indicated that malathion may compromise the immune system, cause reproductive harm, and cause genetic mutations or interfere with normal cell replication.[21–28] One study of aerially applied malathion for medfly control in California found an association between malathion exposure during the second trimester of pregnancy and the occurrence of gastrointestinal abnormalities in infants.[29] In 2000, malathion was at the center of a controversy regarding its carcinogenicity. The US Environmental Protection Agency (EPA) classified it as a "likely human carcinogen," only to downgrade that classification in the face of an industry-prompted reassessment.[30]

As a broad spectrum insecticide, malathion kills many insects, including honeybees, for which it is highly toxic. It is also toxic to many aquatic organisms and the aquatic stages of amphibians.[31]

Resmethrin and sumithrin are both pyrethroid insecticides. Like organophosphates, pyrethroids affect the nervous system, although they do not inhibit cholinesterase. They are of relatively low acute toxicity, although poisoning can occur.[32–33] There are also reports of persistent symptoms when exposures occurred indoors.[34]

The EPA has not yet classified resmethrin and sumithrin with regard to carcinogenicity, although products that contain pyrethroids often include the synergist piperonyl butoxide (PBO), which has been classified as a possible human carcinogen, as have several other related pyrethroid insecticides.[20] There are indications that pyrethroids may interfere with the immune and endocrine systems.[35–38] Other adverse chronic effects, such as damage to the liver and thyroid, have been reported in toxicology testing of resmethrin.[39] Like all pyrethroids, resmethrin and sumithrin are extremely toxic to beneficial insects, including bees, and aquatic organisms.[40]

During the first year of the outbreak, the media viewed pesticide risks as less significant than the risks of West Nile virus, but they became increasingly important in the second year, when it became apparent that the virus was not a one-time phenomenon. As we look to the 2001 season, pesticide questions will grow even larger. To make vector control decisions, we will need to have examined every aspect of the experience to date, including the impact of the pesticide spraying on human health and the ecosystem, the actual course of the West Nile virus outbreak, and the efficacy of the full range of control measures, both preventive and reactive.

MODEL POLICY RECOMMENDATIONS

In fall 2000, the American Public Health Association (APHA) passed a resolution, "Maximizing Public Health Protection with Integrated Vector Control."[41] The resolution recommends guidelines for disease prevention, including surveillance and risk communication, increased federal funding to the Centers for Disease Control and Prevention, and the minimization of unnecessary use of pesticides in vector management. The resolution is provided in the Appendix and is reprinted with the permission of the American Public Health Association.

CONCLUSION

Each response decision in an infectious disease outbreak shifts the balance of risk. With imperfect knowledge, the magnitude and implication of those shifts are not always apparent and often cannot be understood in the available time. Devising a sound framework for assessing the appropriate response to West Nile virus, however, will help guide our response to likely new pathogens.

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APPENDIX

The American Public Health Association,

Noting that integrated pest management is a combination of educational, cultural, biological, physical, chemical, and legal measures to control pests and that the application of pesticides is reduced by the use of pest parasites, pathogens, pheromones, predators, and resistant crops, thus reducing the unnecessary exposure of humans to harmful chemicals; and

Observing that numerous arthropods and rodents serve as the vector of serious human diseases such as viral encephalitis, Rocky Mountain spotted fever, Hantavirus, and malaria[1]; and

Noting that hazard surveillance (monitoring environmental conditions to identify conditions that may contribute to the emergence or re-emergence of vectors), disease health surveillance, laboratory identification, vector management and medical intervention continue to be important factors in preventing morbidity and mortality from vector-borne disease[2]; and

Recognizing that recent experience with West Nile encephalitis and Hantavirus indicate that efforts to combat vector-borne diseases are becoming more complex and difficult to manage and can have transnational implications[3,4]; and

Noting that public health agencies in health and environmental departments in state and local government have primary responsibility for management of vectors[5]; and

Noting that the capacity of local and state health and environmental agencies to conduct basic functions such as hazard surveillance for the purpose of early identification of vector borne outbreaks has been seriously eroded or eliminated over the past several decades; and

Recognizing that integrated vector management that seeks to minimize unnecessary health and environmental side effects of vector control activities while assuring maximum protection to the public and workers is a long-standing and well established public health principle and practice[6,7]; and

Noting that in 1996 under the Food Quality Protection Act (FQPA) the Congress mandated that the Department of Health and Human Services assess vector control needs as part of Environment Protection Agency's review of pesticides, including insecticides and rodenticides; furthermore, the FQPA allows for public health benefits to be considered in weighing the risks of public health pesticides as part of EPA's regulatory process[8]; and

Recognizing that in the U.S., despite the 1996 mandate of the FQPA, the DHHS has no evident activities in this area, leaving state and local vector control agencies with great uncertainty about what tools will be available to them for managing public health vectors; and

Noting that while pesticides can and do play an important public health role, the use of IVM (integrated vector management) can decrease the problems associated with pesticides and difficulty controlling disease outbreaks[9]; and

Observing that the public has become more concerned about any use of a pesticide in populated areas even when the intended use is for public health vector control[10]; and

Recognizing that the public health use of pesticides constitutes only a very small fraction of the total pesticides manufactured and used in the US and further recognizing that some pesticides used for public health vector control may become unavailable due to actions taken to protect public health by reducing the uses of some highly toxic pesticides in agriculture, homes, and other commercial markets[11]; and

Noting that debates over the use of pesticides for public health vector control have sometimes divided the public health and environmental communities at the local, state, national, and international levels at a time when maximizing public health and environmental protection requires close coordination and mutual trust between those communities, therefore, encourages and supports

1. Efforts to expand the use of integrated vector management techniques and to minimize the unnecessary use of toxic pesticides in vector control while maximizing public health protection from vector-borne diseases;
2. Aggressive environmental and disease surveillance and early identification of conditions that promote the growth or introduction of vectors, as well as vector borne disease outbreaks, to prevent morbidity and mortality and to ensure that outbreaks can be controlled when they are small, thus minimizing the potential need for pesticides;
3. Increased federal funding to CDC to help support the efforts by the CDC, states and local government to strengthen efforts in laboratory identification, vector management, and nationwide surveillance of vectors and vector-borne disease with the goal of an integrated surveillance effort;
4. Efforts by and the provision of resources to the Centers for Disease Control and Prevention to establish the needed capability to carry out toxicology and vector management assessments of pest control agents as required by the 1996 Food Quality Protection Act, such efforts including evaluation of non-pesticides alternative means of vector control;
5. Promotion and funding by federal, state and local public health and environmental health agencies of the use of integrated vector management techniques to control public health pests;
6. Funding to state and local governments for larvicides and other preventive measures should be available to state and local health departments along with resources and the ability to act quickly when necessary;
7. Efforts by the Centers for Disease Control and Prevention in coordination with state and local agencies, involvement of stakeholders in decision making, risk communication and education to bring the public, states, and others together to address this issue;
8. Efforts by HUD and state and local agencies to assure healthier home environments through appropriate prevention and management of vectors;
9. Increased health communication and education efforts regarding risks, concepts of integrated vector management, personal protection actions, and individual efforts that can decrease transmission through outreach and advocacy programs for the general population and populations at risk; and
10. International efforts by the World Health Organization, United Nations Environment Program, Food and Agriculture Organization and the US government, in support of the treaty negotiations on Persistent Organic Pollutants and other efforts to reduce pesticide risks internationally, to rapidly identify effective methods of vector control that do not rely on highly hazardous pesticides while recognizing the current important public health role of pesticides.

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