About the White Paper

This paper was produced by staff of the *Pesticides & the Chesapeake Bay Watershed Project*, with content contributed by a diverse group of scientists, public health and policy experts from among the Project's stakeholders. Topical technical reviews were provided by scientists from federal agencies and research institutions. While research is limited and more data are needed, certain pesticides have been shown to have a potential adverse impact on the Chesapeake Bay watershed. In response, the Maryland Pesticide Network and the Johns Hopkins Center for a Livable Future launched the Project in May 2007 – a collaborative effort of more than 100 stakeholders and technical experts, whose shared mission is to reduce risk of adverse effects to living resources from pesticides in the Chesapeake Bay and its tributaries.

PROJECT WORKING GROUPS, STAKEHOLDERS AND TECHNICAL EXPERTS

The Project's stakeholders comprise five issue-specific working groups: 1) Sharing Research and Identifying Data Gaps; 2) Federal and State Laws and Policies Addressing Pesticides; 3) Preventing Pesticides from Entering Waterways; 4) Building Collaborative Relationships with the Agricultural Community, and 5) Increasing Demand and Production of Healthier Alternatives. The working groups have met at least quarterly since May 2007 and to date have come together for two day-long annual meetings.

Stakeholders include: Scientists from federal agencies with regulatory responsibilities (NOAA, US EPA, USFWS); as well as representatives from state agencies (Maryland Departments of Natural Resources, Health and Mental Hygiene, Agriculture and Environment); local government agency representatives; scientists from research institutions; public health experts; waterkeepers; watermen; Maryland tributary team chairs; extension service experts; farmers; environmental organizations, and landscape industry representatives.

Technical experts include scientists from federal agencies and research institutions, including USGS and USDA.

WORKING GROUP INITIATIVES AND OUTPUTS

The Project Working Groups are: 1) developing a methodology to assess the risks of pesticides in the Bay watershed; 2) identifying data gaps; 3) identifying best management practices for reducing/eliminating pesticide occurrence and impacts in the watershed and, 4) working to implement certain solutions which include educating target populations in order to reduce occurrence and impact of pesticides, and making policy recommendations.

REVIEW OF THE WHITE PAPER

The Project stakeholders and technical experts mentioned in the Acknowledgements section of this paper have extensively reviewed and critiqued this document. This paper has not been reviewed by independent reviewers. The recommendations included in this paper were developed by the working groups; their inclusion does not indicate full endorsement of all or any of them by individual working group members.

The intent of this white paper is to inform stakeholders, regulators, policymakers and the public about the current data and data gaps regarding the impact of pesticides on the watershed and to provide proposed actions to address this salient issue.

ACKNOWLEDGMENTS

The *Pesticides and the Chesapeake Bay Watershed Project* co-sponsors, Maryland Pesticide Network and the Johns Hopkins Center for a Livable Future, as well as project participants, wish to thank the following people for their input and editorial efforts that were critical to the production of this publication:

Greg Allen, M.E.M., Environmental Scientist, U.S. Environmental Protection Agency, Environmental Scientist, Chesapeake Bay Program

Scott W. Ator, M.S., Hydrologist, U.S. Geological Survey

Vicki Blazer, Ph.D., Fishery Biologist, U.S. Geological Survey

Joel D. Blomquist, M.S., Hydrologist, U.S. Geological Survey

Diana Eignor, M.S, Biologist, U.S. Environmental Protection Agency, Office of Water , Health & Ecological Criteria Division

Jay Feldman, M.A., Executive Director, Beyond Pesticides

Sherm Garrison, B.S., Program Manager, Maryland Department of Natural Resources, Water and Habitat Quality,

Rolf U. Halden, Ph.D., P.E., Associate Professor, Johns Hopkins School of Public Health, Department of Environmental Health Sciences

Cathleen Hapeman, Ph.D., Research Chemist, U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD

Leo Horrigan, M.P.H., Program Officer, Farming for the Future, Johns Hopkins Center for a Livable Future

Richard L. Humphrey, M.D., Associate Professor, Johns Hopkins School of Medicine, Department of Internal Medicine, Pathology and Oncology

Andrew K. Leight, M.S., Fishery Biologist, National Oceanic and Atmospheric Administration

Laura McConnell, Ph.D., Research Chemist, U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD

Toni Nunes, M.P.H., former project director, *Pesticides & the Chesapeake Bay Watershed Project*

Fred Pinkney, Ph.D., Senior Biologist, U.S. Fish & Wildlife Service, Chesapeake Bay Field Office

Polly Walker, Ph.D., Associate Director, Johns Hopkins Center for a Livable Future

Warren Porter, Ph.D., Professor of Zoology & Environmental Toxicology, University of Wisconsin-Madison

Contributing Staff

Ruth Berlin, LCSW-C, Executive Director, Maryland Pesticide Network

Michael Boeck, J.D., Project Director, Maryland Pesticide Network Integrated Pest Management Project

Robert SanGeorge, M.A., Project Director, *Pesticides & the Chesapeake Bay Watershed Project*

Sarah Isbell, B.S., Research Assistant

The Maryland Pesticide Network is grateful for the generous support for this publication – and for the *Pesticides and the Chesapeake Bay Watershed Project* – from the Bancroft Foundation, Morris & Gwendolyn Cafritz Foundation, Clayton Baker Trust, Fund for Change, Zanvyl and Isabelle Krieger Fund, Rauch Foundation and the Wallace Genetic Foundation.

The Maryland Pesticide Network is also grateful for the generous support vital to our coalition's work from the Bancroft Foundation, Jacob and Hilda Blaustein Foundation, Clayton Baker Trust, Educational Foundation of America, Fund for Change, Zanvyl and Isabelle Krieger Fund, Rauch Foundation, Aaron Straus and Lillie Straus Foundation, Leonard and Helen Stulman Charitable Foundation, Lucy R. Waletzky Fund and the Wallace Genetic Foundation.

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THE PROBLEM

The Chesapeake Bay watershed is the largest and most biologically diverse estuary in the United States. Living resources in this economically important watershed are stressed by various pollutants resulting from human activity, including the use of chemical pesticides. Exposure to pesticides also presents risk to human health. Recent U.S. Geological Survey (USGS) reports (Gilliom et al. 2006; Phillips et al. 2007), suggest to the author(s) of this White Paper that reducing current levels of chemical pesticides flowing into the Bay should be a priority for agencies working to protect the Bay.

The 2007 USGS report found that *"synthetic organic pesticides and their degradation products have been widely detected at low levels in the watershed [Susquehanna River Basin, Potomac River Basin, Delmarva Peninsula], including emerging contaminants such as pharmaceuticals and hormones."* Pesticides were detected more frequently in streams than in ground water. While the most commonly detected pesticides were herbicides used on corn, soybean and small grain crops in agricultural regions, pesticides were also detected in streams and groundwater in urban areas at lower concentrations. Pesticides in ground water were found at higher concentrations in areas underlain by permeable soils and aquifer material than in areas underlain by less permeable materials.

Other recent reports indicate that pesticides and their degradation products have occurred at concentrations that exceed water quality benchmarks for the parent compounds. For example, a USGS team found that while concentrations of parent compounds were lower than drinking water standards in ground water samples from the Maryland coastal plain, degradation products for some pesticides were found to exceed the parent compounds. Pesticides detected in the streams in the Potomac River Basin (Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia), included atrazine, metolachlor, simazine, prometon, tebuthiuron, diazinon, carbaryl, and 18 other compounds. (Ator and Denver, 2006).

Certain pesticides are frequently detected in Bay waters and its tributaries. For example:

- Liu et al. (2002) concluded that the annual mass loads for atrazine, CIAT, metolachlor, simazine, and CEAT from the Susquehanna River to the Chesapeake Bay ranged from high to low (1600, 1600, 1100, 820, and 720 kilograms/year, respectively.) Annual loadings of insecticides and organochlorine compounds ranged from 2.8 kg/year for alpha-HCH to 34 kg/year for diazinon. While the Susquehanna contributes a significant portion of river inputs to the Bay, it is but one of many sources of pesticide loadings to the Bay.
- McConnell et al. (2004) found herbicides and two triazine degradation products, 2-chloro-4- isopropylamino-6-amino-s-triazine (CIAT), and 6-amino-2- chloro-4-(ethylamino)-s-triazine (CEAT), in surface water from four sites sampled at regular intervals from April 4 through July 29, 1996 in the Patuxent River estuary. Of the pesticides measured, atrazine was most persistent and was present in the highest concentrations (maximum = 1.3 µg/L). This is below the U.S. Environmental Protection Agency (EPA) drinking water standard of 3 µg/L. Metolachlor, CIAT, CEAT, and simazine were frequently detected (with maximum concentration values of 0.61, 1.1, 0.76, and 0.49 µg/L, respectively).
- In a study of Chesapeake waters in 2004, researchers detected atrazine in 100% of water samples taken at sixty different stations spread across five different Bay tributaries (McConnell et al., 2007).

A growing body of evidence has shown that many pesticides, which are designed to affect specific organisms, may also be toxic to non-target species, such as aquatic life, wildlife, and humans that co-inhabit the ecosystem. Even at low levels, the toxic effects of pesticides place additional stress on resident microbiota, plants, fish and other wildlife. Reduction in the growth of key living resources of the Chesapeake Bay have been observed in the laboratory at low part per billion concentrations for some pesticides. The cumulative effect of pesticides and their degradation products on aquatic life is poorly under-

"Chesapeake Bay Program Executive Level Goal: Reduce the potential risk of pesticides to the Bay by targeting education, outreach and implementation of Integrated Pest Management and specific Best Management Practices on those lands that have higher potential for contributing pesticide loads to the Bay (2000)"

stood and may present additional challenges to the living resources of the Chesapeake Bay watershed.

The Chesapeake Bay Program (CBP) is a regional partnership which includes the states of Maryland, Pennsylvania, Virginia, and the District of Columbia; the Chesapeake Bay Commission, a tri-state legislative body; US EPA representing the federal government; and participating advisory groups. Its vision for the Chesapeake Bay watershed is *"a system with abundant, diverse populations of living resources, fed by streams and rivers, sustaining strong local and regional economies, and our unique quality of life." One the CBP's six goals is to "achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health."* Reduction of chemical contaminants, including pesticides, is part of CBP's strategy; however, in recent years only three to five percent of CBP's resources have been devoted to issues of toxic chemicals.

There are many sources of pesticide contamination in U.S. waters such as in the Chesapeake Bay watershed. Although the agricultural sector accounts for about 80% of pesticide use in the United States, pesticides are also found in a wide range of everyday household products – including weed and insect killers, hand soap and kitchen cleansers – and often end up in ground and surface waters flowing into Chesapeake Bay. Runoff from non-residential turf areas, such as golf courses, rights-of-way and landscaping, is another source of pesticide pollution. The following is a more complete accounting of pesticide pollution sources:

Common Sources of Pesticides in Water (NOAA, 2005)

- Runoff from lawns, gardens and or golf courses.
  - * May enter storm drains discharging into surface waters.
- Runoff from treated agricultural fields, especially during storms; even proper use and handling may lead to runoff into surface waters.
- Proper or Improper disposal of pesticides. Even proper use and handling may lead to runoff into surface waters.
- Accidents, improper handling and disposal.
  - * Spills or careless use of pesticides, such as over-spraying drainage ditches or water courses, or careless disposal of empty containers or leftover pesticides.
- Land-based applications for agriculture, lawn care and on golf courses.
- Spray Drift
  - * Occurs when pesticides are sprayed over an area by ground application equipment (trucks, tractors) or airplanes for agricultural purposes; large lawn areas or for insects such as mosquitoes. Pesticides are transported through air, and wind blows this spray into an adjacent body of water (NOAA, 2005).
- Atmospheric Deposition
  - * Occurs in the form of rainfall or dry deposition as airborne particles settle on land or in bodies of water.
- Direct discharge from treated wastewater effluent.
- Sewage sludge from wastewater treatment plants.
- Disinfectants such as triclosan occur in sewage sludge, and these bio-solids may later be applied to agricultural land (Kinney et al., 2006).

DATA GAPS

While a growing body of research underscores that pesticides, along with certain of their degradation products, are being widely detected in groundwater and streams in the watershed, there is a need to define further their occurrence and impact on aquatic life, human health and water quality. For example, when thresholds are set for pesticides, each chemical is evaluated in isolation; however, in a real-life setting, simultaneous exposure to multiple chemicals is more likely. Very little research has been done on the multiple and synergistic effects of multiple pesticides or the impacts of pesticides when combined with non-pesticide stressors. Virtually no research has been done on the 'other' ingredients in pesticide mixtures that alter solubility properties of 'active' ingredients. What research has been done indicates biological activity by the solvents/surfactants in the mixes, as well as magnified total biological effects.

The current risk assessment process, in some cases, lacks key toxicological data on both animal and human health effects and does not consider or account for the cumulative and aggregate risks of exposure to pesticides and other synthetic chemicals. Of emerging concern are pesticide degradation products whose toxicity is sometimes uncertain and whose concentrations have been observed to equal or exceed those of the corresponding parent compounds. Yet these pesticide by-products remain largely unregulated today, both for drinking water and aquatic life.

Another important concern is that many pesticides are now being shown to cause harm even at low doses to the environment or to humans. For example, low-dose exposures to the herbicides aldicarb and atrazine in well water, along with nitrate used as fertilizer, may cause adverse effects on behavior and on the immune and endocrine systems (Porter, et al. laboratory study, 1999). Epidemiological data suggest seasonal changes in atrazine and nitrate in water may alter genitalia, language and mathematical skills and other subtle biological responses in children conceived in months when concentrations are high (Winchester et al, 2009). Chronic exposure to low levels of atrazine leaves phytoplankton more susceptible to a short-term exposure to higher levels (Pennington and Scott, 2001).

In addition, the effects of some pesticides and their degradation products on aquatic life have not been explored because they were not thought to occur in water. This point is illustrated by the antimicrobial consumer product additives triclosan and triclocarban, whose widespread occurrence in Chesapeake Bay and other U.S. water resources has been recognized only recently.

The role pesticides may play as endocrine disruptors triggering reproductive abnormalities is an alarming possibility. In September 2006, the discovery of male fish bearing immature oocytes in the Potomac River caused continuing concern (Chesapeake Research Consortium, 2006). Shortly after these findings, a Mid-Atlantic science forum was held to discuss the effects of possible endocrine disrupting chemicals, including herbicides, insecticides, and antimicrobials (Chesapeake Research Consortium, 2006). However, the specific agents causing these episodes of intersex fish have not yet been determined with any certainty.

In March 2008, USGS scientists identified several pesticides in the Potomac River that could be responsible for "intersex fish," or male fish with testicular oocytes. One of these – atrazine, a common herbicide used in agriculture and on lawns – is already linked to sexual abnormalities in frogs (Hayes et al, 2006). EPA does not currently evaluate or consider the endocrine-disrupting properties of pesticides during registration or re-registration, but in 2009 EPA released a list of 67 pesticides that will be evaluated as potential endocrine disruptors.

RECOMMENDATIONS

Given the limitations in the risk-assessment process and in containing nonpoint sources such as land-based applications, policymakers, businesses and consumers should collaborate on implementing best management practices to prevent pesticides from entering the watershed and, following a precautionary approach, to reduce pesticide use.

The following recommendations are offered to prevent pesticides from entering the Chesapeake Bay Watershed and to promote efficacious alternatives to pesticide usage:

1. Provide incentives that encourage farmers to use best management practices, including the creation of buffer zones to reduce the amount of pesticides entering the watershed.
2. Encourage farmers to transition from unsustainable agricultural methods to strategies that reduce or eliminate reliance on pesticides. Critical to effecting this transition are financial incentives that reward farmers who implement pest management techniques that go beyond minimum requirements. Programs such as USDA's Environmental Quality Incentives Program should responsibly address pesticides in its funding criteria.
3. Educate farmers about the dangers pesticides pose to their health and the health of their families.
4. Encourage the commercial sector to be more proactive in developing and offering healthier technologies, services and products.

"A growing body of evidence has shown that many pesticides, which are designed to affect specific organisms, may also be toxic to non-target species, such as aquatic life, wildlife and humans that co-inhabit the ecosystem."

5. Promote the use of Integrated Pest Management (IPM), a strategy focusing on non-chemical prevention techniques and the use of least-toxic pesticides as a last resort. IPM is applicable to residential and commercial use as well as agriculture.
6. Educate consumers about the public health and environmental concerns related to pesticide exposures.
7. Encourage consumers to question aesthetics-based behaviors (i.e., desire for visually attractive lawns or produce) in lieu of decision-making based on human health and ecological concerns. Promote IPM, preventative and organic land care practices as efficacious alternatives.
8. Educate consumers about the hazards of antibacterial soaps containing pesticides and the false assumption that they are necessary for preventing illnesses.
9. Promote awareness of the importance of reducing mosquito breeding habitats to reduce mosquito-borne illnesses and lessen the need for pesticide spraying. Favor the use of low-toxicity larvicides.
10. Support research on the synergistic impact/interaction of using multiple pesticides over time on the watershed and public health.
11. Support federal and state funding for research on the effects of endocrine-disrupting chemicals, including pesticides in the watershed and their suspected link to sex alteration in fish and other adverse effects in fish.
12. Identify data gaps regarding the impact of pesticides and their degradation products that are or may be expected to be found in the watershed on water quality, aquatic life, wildlife, and public health, and promote further research regarding pesticides of greatest concern in the watershed.
13. Expand the charge of the Chesapeake Bay Program beyond nutrient management to include pesticide management.
14. Assess the need for strengthening and expanding existing policies and laws and identify needed policies to reduce the impact of pesticides on the watershed.
15. Assess the applicability of the European Union's Regulation on Registration, Evaluation, Authorization and Restriction (REACH) program, as well as California's Green Chemistry program. REACH puts the burden on manufacturers to evaluate the safety of their products prior to registration – in contrast to existing federal policy, whereby pesticides are registered and sold unless they are proven to be unsafe after the fact – and endorses the principle that hazardous chemicals should be replaced with safer ones. The Green Chemistry program aims to reduce the use of toxic substances that endanger public health and the environment. The program evaluates ways to use less-toxic materials, less energy and produce less waste. It strives to identify data gaps on problem chemicals, explore safer alternatives, and educate the public.
16. Implement state-based centralized systems for pesticide use data collection and requirements for reporting pesticide use by certified applicators, so government agencies and research institutions can accurately determine pesticide use patterns and their relationship to occurrence and impact in the watershed.

Introduction

The Chesapeake Bay watershed, the largest and most biologically diverse estuary in the United States, is threatened by multiple stressors produced by human activities. Because of the presence, persistence, toxicity and amount used in the watershed, pesticides represent a significant risk factor to aquatic life and the health of local residents. Although water quality mitigation in the watershed is focused mainly on nutrient loadings, recent reports indicate that a wide variety of pesticide contaminants are also found throughout the watershed and sometimes at levels that exceed water quality benchmarks for protecting drinking water, aquatic life and safety of fish consumption. For example, USGS found that while concentrations of parent compounds in Maryland coastal plain samples were lower than drinking water standards, concentrations of pesticide degradation products exceeded the parent compound concentrations (Ator and Denver, 2006).

A growing body of evidence has shown that many pesticides, which are designed to affect specific organisms, may also be toxic to non-target species, such as aquatic life, wildlife, and humans that co-inhabit the ecosystem. Even at low levels, toxic effects from pesticides place additional stress on resident microbiota, plants, fish and other wildlife. In addition, some pesticides can bioaccumulate in the food web, sometimes leading to higher levels in larger fish and fish-eating birds, where they have been linked to reproductive dysfunctions. Contamination of drinking water and edible fish may also harm people. Comprehensive data on the health effects of chronic, low-level pesticide exposure in the Chesapeake Bay watershed have not been collected, and understanding of these risks remains unknown. Data are missing for vulnerable populations, such as infants (with developing immune systems) and people with weakened immune systems. While municipalities test public water and wells serving over 25 people, those who depend on smaller private wells (serving less than 25 people) may have an increased risk of exposure to unregulated pesticides in their drinking water.

Many pesticides previously thought to cause relatively little harm to the environment or to humans are now being shown to have harmful effects. The current risk-assessment process suffers from key toxicological data gaps for both animal and human health effects and from the lack of consideration for cumulative and aggregate risks of exposure to multiple pesticides and other synthetic chemicals. The process is also unable to keep up with the rapid introduction of new pesticide products. Pesticide breakdown products, many of uncertain toxicity, remain largely unregulated today for both drinking water and aquatic life, despite observed concentrations equal to or exceeding those of the corresponding parent compounds. In addition, the effect of some pesticides and their by-products in aquatic environments remains under-explored because these toxics were not expected to be transported to water. For example, the termiticide chlordane has been found in high levels in fish tissues even though this was thought to be soil-bound and would not migrate to water; triclosan and triclocarban used as antibacterial compounds in soaps have been found in Chesapeake Bay and other U.S. waters.

Given limitations in the risk assessment process linking pesticide usage to effects on aquatic species and in non-point source control, policymakers, regulators, businesses, and consumers should collaborate on implementation of best management practices that prevent pesticides from entering the watershed and should follow the precautionary principle, reducing use of pesticides wherever possible. The Precautionary Principle states:

"When an activity raises threat of harm to human health or their environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."

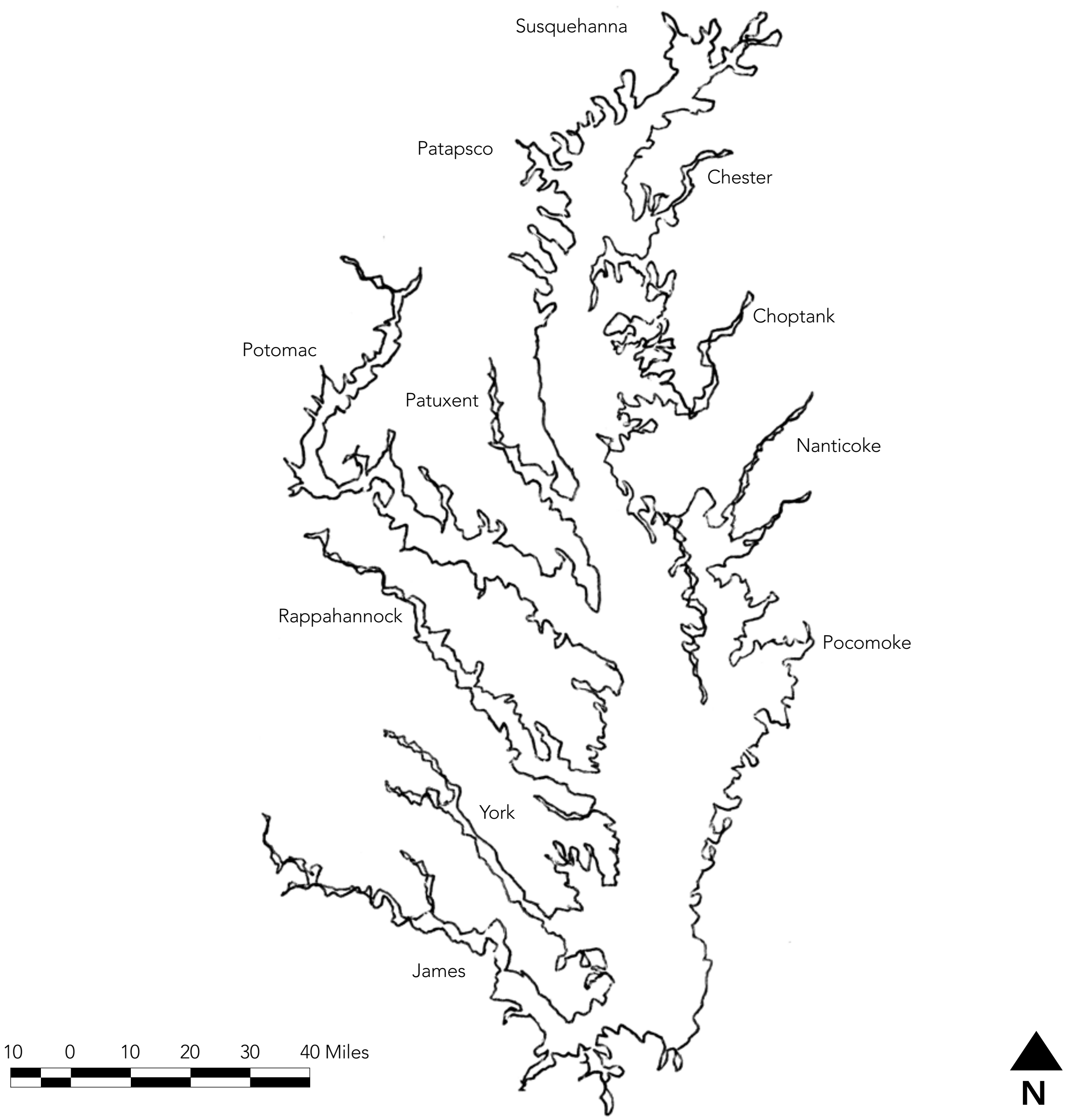
Businesses (manufacturers, vendors, distributors) should be proactive in developing and offering healthier technologies, services, and products. Educated consumers can demand and use these more environmentally-friendly methods, services and products in their businesses and at home. Governments and educators should collaborate with businesses to:

- Inform the public on how to prevent pesticides from being transported to non-target ecosystems;

- Develop non-chemical and least-toxic strategies, methods and products;
- Reward businesses that engage in "best management practices," such as pest control and lawn care companies that use Integrated Pest Management (IPM).

Government agencies should enforce existing laws more rigorously to better meet pesticide water-quality benchmarks. Federal and state funding to ensure capacity for proper enforcement is critical. Federal and state agencies should develop new standards for recently identified pesticides and degradation products that are found to commonly occur in the watershed – and to prioritize those with the greatest potential for causing harm to the environment and humans. Meanwhile, scientists should continue to research this important issue and draw more frequently on collaborations and data sharing for advancing the knowledge base.

The Chesapeake Bay and its Major Tributaries



Source: Chesapeake Bay Program

WHAT IS THE CHESAPEAKE BAY WATERSHED AND WHY FOCUS ON MARYLAND?

Chesapeake Bay is the largest estuary in the United States, with a watershed that spans the District of Columbia and parts of six states. The Bay is fed by six major river systems: the Susquehanna, Potomac, Patuxent, Rappahannock, York and James Rivers.

The watershed includes both surface and ground waters that are hydraulically connected (Winter et al, 1998). More than 16 million people now live in the Chesapeake Bay watershed (U.S. Census Bureau, 2000).

While developing and implementing solutions at a watershed level is a long- term goal, this White Paper focuses initially on Maryland because 93% of the state falls within the Bay watershed. Also, about a third of the watershed's population resides in Maryland (U.S. Census Bureau, 2000).

WHAT ARE PESTICIDES?

Pesticides are substances used to prevent, destroy, mitigate or repel any unwanted insects, plants, fungi, rodents, prions,[1] and microorganisms such as viruses and bacteria (U.S. Environmental Protection Agency, 1999). Pesticides include insecticides, herbicides, fungicides, rodenticides or antimicrobials. Commercial pesticide products contain both active and so-called "inert" ingredients. Inert ingredients, frequently listed as "other ingredients" on product labels, support the effectiveness of active ingredients. The health effects or other properties of inert ingredients are not considered during the pesticide registration process, and inert ingredients designated as proprietary or "trade secrets" may not be included on a product label, regardless of their concentration or potential hazard to public health and the environment (U.S. Environmental Protection Agency, 2008).

While the agricultural sector accounts for about 80% of pesticide use in the United States, pesticides are also found in everyday products, such as weed killers and hand soap, and often end up in ground and surface waters serving as drinking-water sources.

PESTICIDE DEGRADATION PRODUCTS

Degradation products of pesticides are breakdown products created by abiotic (i.e., physical and chemical) or biological reactions. Evidence is mounting that the environmental occurrence and concentrations of some pesticide degradation products may equal or substantially exceed that of the corresponding parent compound (Ator et al, 2005; Debrewer et al, 2007; Ator and Denver, 2006). These findings are discussed below in Section I.B. No pesticide degradation products are currently regulated under the Safe Drinking Water Act (U.S. Environmental Protection Agency, 2003a). However, degradation products of two commonly used pesticides, atrazine and alachlor, are on EPA's 2005 Contaminant Candidate List (CCL) (U.S. Environmental Protection Agency, 2005) and under consideration for regulation under the Safe Drinking Water Act. The CCL is a list published periodically by EPA that identifies unregulated contaminants which may require a national drinking water regulation in the future. This list is used by EPA to prioritize research and data collection efforts and to determine if a specific unregulated contaminant should be regulated.

PESTICIDES: AN ENVIRONMENTAL HEALTH THREAT IN THE CHESAPEAKE REGION

Pesticides are an important issue with respect to the health of Chesapeake Bay. While pesticides are designed to kill specific target organisms, they also can be toxic to aquatic life, wildlife and humans, even at low levels. Emerging evidence, as noted in this paper, suggests that toxic chemicals are contributing to the waning health of waterways and may adversely impact the health of people living in the Chesapeake Bay watershed.

A USGS report, (*Pesticides in Our Nation's Streams and Ground Water* 1992-2001, Gilliom et al, 2006) found pesticide concentrations above water quality benchmarks in surface and ground water throughout the U.S., including the Chesapeake Bay watershed. A 2007 USGS report (Phillips et al, 2007) found that "synthetic organic pesticides and their degradation products have been widely detected at low levels in the watershed, including emerging contaminants such as pharmaceuticals and hormones."

Another concern is the effect of pesticides as endocrine disruptors triggering reproductive abnormalities. Endocrine disruptors mimic hormones and may be mistaken for hormones by the body, altering the functions of the endocrine system. In spring 2003, scientists found male fish in the Potomac River with immature oocytes in

[1] Abnormal prion proteins can become infectious agents that may be responsible for diseases such as "transmissible spongiform encephalopathies." Prions were recently added to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as a type of pest.

"The role pesticides may play as endocrine disruptors triggering reproductive abnormalities is an alarming possibility."

their testes (Blazer et al. 2007). Shortly after the discovery of these "intersex" fish, a Mid-Atlantic science forum was held to discuss the effects of possible endocrine-disrupting chemicals, including herbicides, insecticides, and antimicrobials (Chesapeake Research Consortium, 2007).

The specific agents causing intersex fish have not yet been determined with any certainty, but in March 2008, USGS scientists identified several pesticides in the Potomac River that could be responsible; researchers also are considering whether intersex fish are caused by complex mixing of such compounds after they enter the watershed. The suspected chemicals include atrazine, the most commonly used herbicide in the United States (Hayes et al, 2003), which is used in agriculture and on lawns. It is a suspected endocrine disruptor. It already has been linked to sexual abnormalities in frogs (Hayes, et al, 2006), although other studies have produced differing results and research is ongoing. EPA does not currently evaluate or consider the endocrine-disrupting properties of pesticides during registration or re-registration, but in 2009 EPA released a list of 67 pesticides that will be evaluated as potential endocrine disruptors. Some scientists believe that wildlife provide early warnings of endocrine-disrupting effects that may, as yet, be unobserved in humans.

While a growing body of research indicates that a number of pesticides pose a risk to the health of the Chesapeake Bay watershed, agencies working to protect the Chesapeake Bay have more recently become focused almost solely on nutrient load and not on chemical pesticides. While excessive nitrogen and phosphorus runoff from intensive farming practices throughout the Chesapeake watershed pose a substantial threat, these are not the only threats to the health of the Bay.

One of the Chesapeake Bay Program (CBP)'s goals to restore the watershed is to "achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health." Reduction of toxic chemicals, including pesticides, is part of the CBP's strategy. However, in recent years, only three to five percent of CBP's resources have been devoted to issues of "toxics."

Usage, Loading and Concentration in the Chesapeake Bay

PESTICIDE USAGE

Data on pesticide usage throughout the Chesapeake watershed are sparse and recent data is not readily available. Estimates for Maryland are based on 2004 and earlier voluntary surveys of certified applicators conducted by the Maryland Department of Agriculture, reported only on a statewide level **(in 2004)**, and do not include home and garden pesticide use or personal care products usage (Maryland Department of Agriculture, US Department of Agriculture, 2002, 2006).

Home and Garden Usage of Pesticides in Chesapeake Region

Data on residential use are largely unavailable, but estimates can be made by scaling from nationwide usage data. Accordingly, at a per-capita loading of 0.42 pounds of pesticides per person per year, the total usage of home, garden and personal care pesticides in the Chesapeake Bay watershed is estimated to be about 6.5 million pounds (Kiely et al, 2004; U.S. Census Bureau, 2000).[2]

Agriculture, Industry, Commercial, Government Pesticide Usage in Maryland

About 11 million pounds and 281 different types of pesticides are estimated to have been used in the agriculture, industry, commercial, and government sectors in Maryland in 2004 (Maryland Department of Agriculture and U.S. Department of Agriculture, 2006). This represents an estimated 18% increase since 1988, although yearly usage rates have fluctuated considerably (Table 1). Table 1 summarizes the estimated usage rates of the top 20 pesticides in Maryland in four sectors: agriculture, industry, commercial and government (Maryland Department of Agriculture and U.S. Department of Agriculture, 2002, 2004 and 2006). Pesticide usage in Maryland has increased for most of these products. Only seven of the top 20 pesticides – namely atrazine, metolachlor, potassium salts of phosphoric acid, 2,4-D, thiophanate-methyl, vinclozolin and dicamba – decreased in usage by relatively modest amounts during that period.

Estimates provided by the Maryland Department of Agriculture (MDA) were based on a sample of voluntary survey responses from farmers (response rate: 56%), private applicators (response rate: 51%), commercially licensed businesses (response rate: 41%), and public agencies (response rate: 70%). It is not clear whether the surveys were distributed randomly; hence the sample may exhibit selection bias. While earlier reports provided county-wide data, the most recent 2004 survey design only enabled collection of State-level statistics, consequently not providing those having regulatory and public health interests with adequate usage data (by watershed) to assess occurrence and impact of pesticides. MDA no longer conducts the triennial voluntary survey due to lack of funding.

[2] 18% of 5 billion lbs annually = 900 million lbs of conventional pesticide usage in U.S.
13% of 900 million lbs annually = 117 million lbs of home and garden pesticide usage in U.S. 117 million lbs/ 281,421,906 (U.S. population in 2000) = 0.42 lbs/person/year
0.42 lbs/person/yr on average x 15,594,241(Chesapeake Bay Watershed Population in 2000)
= 6.5 million lbs of home and garden pesticide usage in the Chesapeake Bay Watershed

Table 1. Estimated Rate of Change in Pesticide Usage Rates in Maryland (1988-2004): Farms, Private Applicators, Commercial Businesses & Public Agencies (Top 20; Total)

Rank in 2004	Pesticide Common Name	Type*	Usage Estimate in Maryland (lbs of Active Ingredient)				
			1988	1994	2000	2004	% Rate of growth (decline) 1988-2004
1	Glyphosate	H	480,000	410,291	950,269	2,821,085	488
2	Chlorothalonil	F	1/*	76,600	115,194	1,529,493	1897
3	Atrazine	H	1,810,000	1,166,064	618,515	1,109,475	-39
4	Fosetyl aluminum	F	195,000	13,355	19,592	980,072	403
5	S-Metolachlor	H	1,170,000	1/	109,566	872,768	-25
6	Mancozeb	F	210,000	17,572	38,107	254,254	21
7	Metolachlor	H	295,000	2,166,308	1,000,654	246,509	-16
8	Chlorpyrifos	I	128,000	240,325	136,670	237,508	86
9	Potassium salts of phos. Acid	F	345,000	1/	1/	201,112	-42
10	2,4-D	H	1/	226,054	225,426	199,141	-12
11	Thiophanate-methyl	F	250,000	6,502	19,939	130,637	-48
12	Imidacloprid	I	46,000	186	131,773	128,707	180
13	Paraquat	H	54,000	175,607	156,131	127,869	137
14	Vinclozolin	F	318,000	40,104	43,706	122,853	-61
15	Dithiopyr	H	1/	1,028	83,224	101,247	9749
16	Mesotrione	H	62,000	1/	1/	85,138	37
17	Diuron	H	1/	29,473	9,875	82,342	179
18	Dicamba	H	172,000	52,007	85,414	79,937	-54
19	Simazine	H	54,000	153,240	301,427	72,883	35
20	Cypermethrin	I	1/	5,637	57,280	63,871	1033
	Total Pesticide Usage		**9,070,325**	**13,881,629**	**17,123,643**	**10,722,796**	**18**

* 1/ = not reported because the product is either a new formulation or used for only 1 or 2 crops
Sources: Maryland Department of Agriculture and U.S. Department of Agriculture. Maryland Pesticide Statistics for 2000. 2002 August, MDA-265-02; Maryland Department of Agriculture and U.S. Department of Agriculture. Maryland Pesticide Statistics for 2004. 2006 September. MDA 14-01-07. Estimates are based on voluntary surveys.
* F=Fungicide; H=Herbicide; I=Insecticide

Impact of Best Management Practices (BMPs) to Reduce Nutrient Load

Some BMPs designed to reduce nutrient loadings also may serve to reduce pesticide runoff. However in some cases, BMPs implemented for nutrient management may increase pesticide use and subsequent runoff. For example, many corn and soybean growers use no-till farming practices, which reduce the amount of nutrients needed, but increase reliance on the herbicide atrazine. Best management practices must introduce methods that address both concerns.

Monitoring Data for Selected Pesticides and their Degradates

The 2007 USGS report on the Chesapeake Bay watershed indicated that pesticides are present year round in streams of the Bay watershed and that changes in pesticide concentration over time generally reflect changes in application rates, as well as physical and chemical properties that determine fate and transport of compounds. The following pesticides and degradation products were found in one or more headwater streams during spring base flow, shallow groundwater in agricultural areas, groundwater used for domestic supply or groundwater used for public supply:

- acetachlor
- acetochlor ESA
- acetochlor OA
- alachlor
- alachlor ESA
- alachlor OA
- atrazine
- bromacil
- carbofuran
- cyanazine
- deethylatrazine
- desiopropylatrazine
- dieldrin
- flumetsulam
- glyphosate
- imazaquin
- imazethapyr
- lindane
- metalachlor
- metolachlor ESA
- metolachlor OA
- pendimethalin
- prometon
- simazine
- tebuthiuron

While usage and loading estimates are needed for identifying potential pesticides of concern, concentrations of pesticides (typically measured in micrograms per liter, mg/L) are the determinant of potential environmental and human health effects. McConnell et al. (2004) reported that water concentrations of herbicides and two triazine degradation products, CIAT and CEAT, were measured in surface water from four sites sampled at regular intervals from April 4 through July 29, 1996 in the Patuxent River estuary, part of the Chesapeake Bay system. Atrazine was most persistent and present in the highest concentrations (maximum = 1.29 μg/L). Metolachlor, CIAT, CEAT and simazine were frequently detected (with maximum concentration values of 0.61, 1.1, 0.76, and 0.49 μg/L, respectively.) In a study of Chesapeake waters in 2004, researchers detected atrazine in 100% of water samples taken at 60 different stations in five Bay tributaries (McConnell et al., 2007). This report detected atrazine, simazine, metolachlor and their degradation products in 21 sample sites throughout the Chesapeake Bay, with the highest herbicide concentrations in the Chester River, located on the Eastern Shore. The highest concentration for any analyte in these studies was for the ethane sulfonic acid of metolachlor (MESA) at 2,900 ng/L in the Nanticoke River. The degradation product MESA also had the greatest concentration of any analyte in the Pocomoke River (2,100 ng/L) and in the Chester River (1,200 ng/L; McConnell et al., 2007).

USGS found that pesticides or their degradation products are frequently found in streams and ground water throughout the United States (Gilliom et al., 2006). During 1993-2000, on average 57% of stream water samples in agricultural areas contained at least one pesticide that exceeded safety thresholds for aquatic life (Gilliom et al., 2006). During this same time period, about 83% of all urban streams sampled had at least one pesticide that exceeded safety thresholds and 42% of mixed-land-use streams exceeded safety thresholds (Gilliom et al., 2006). Degradation products – the natural decomposition products of pesticides – are often found in much higher concentrations than the parent compound and are not regulated because they are not defined as an active ingredient nor are found to any great extent in the applied product. The McConnell et al. (2007) study indicated persistence of metolachlor's degradation product, finding its concentration surpassed that of its parent compound in almost all of the samples.

USGS found that while concentrations of parent compounds in ground water in the Eastern Shore were lower than federal/state drinking water standards, concentrations of pesticide degradation products exceeded those of the parent compounds. Drinking water standards only exist for four of the 29 compounds the team detected (Ator and Denver, 2006). Ator, et al. (1998) found concentrations of organochlorine pesticides in the Potomac River Basin to be among the highest of 19 study areas in the United States. Major field investigations in the remaining National Water Quality Assessment (NAWQA) study units have not been completed.

These researchers also detected five or more pesticide compounds in all 23 surface water samples in a separate study on *Water Quality in the Delmarva Peninsula* (Denver et al., 2004). The Delmarva Peninsula is bordered on the west by the Chesapeake Bay and on the East by the Atlantic Ocean. Herbicides were detected year round in streams throughout the Delmarva Peninsula, although concentrations were highest in the spring during spring applications on cropland (Denver et al., 2004). Authors of these reports found that concentrations of pesticides in their surface water samples rarely exceeded harmful benchmarks for aquatic life, but only 40% of the pesticides they analyzed have such benchmarks. Observed concentrations of agricultural herbicides are believed to exceed thresholds for ecological effect for key components of the Bay ecosystem (e.g., phytoplankton and submerged aquatic vegetation) at least during the spring application period. For example, chronic exposure to low levels of atrazine may reduce the primary production of phytoplankton and its value in the food chain in the Chesapeake Bay (Pennington and Scott, 2001).

Evidence shows that many pesticides which are designed to kill target organisms in terrestrial environments and homes may also be toxic to aquatic life, wildlife and humans. Even at low levels, the toxic effects of pesticides place additional stress on resident microbiota, plants, fish and other wildlife. Also, reduction in the growth of key living resources of the Chesapeake Bay, such as fish and invertebrates, have been observed in the laboratory at concentrations as low as 23 parts per billion. (Reregistration Eligibility Science Chapter for Atrazine, p.57-64. April 2002).[3] The cumulative effect of pesticides and their degradation products may further threaten the living resources of the Chesapeake, the largest and most biologically diverse estuary in the United States.

Table 2. Concentration of Pesticide or its Degradate or Metabolite

		Mean Concentration Reported in Chesapeake Bay Tributaries					
Pesticide Common Name, Degradation Product or Metabolite	Type*	2/97-3/98 Susquehanna (ng/L)	3/92-2/93 Potomac (ng/L)	3/92-2/93 James (ng/L)	2/97-11/97 Patuxent (ng/L)	5/97-11/97 Choptank (ng/L)	Gwynns Run, MD (ng/L)
References:		Liu et al. 2002	Foster, Lippa 1996	Foster, Lippa 1996	Lehotay et al. 1998	Lehotay et al. 1998	Halden,Paull 2004, 2005
Alachlor	H	9	12	10			
Atrazine	H	67	160	61	47	245	
Metolachlor	H	39	96	31	9	20	
Simazine	H	37	62	50	18	121	
Cyanazine	H	25	160	61	47	245	
Diazinon	I	6	10	7	3.3		
A-HCH	I	0.1					
y-HCH	I	0.3			0.45	0.3	
P,p'-DDE	I	2			1.6		
Triclocarban	PCP						33 – 5,600 6750**
Triclosan	PCP						1600**

* H=Herbicide; I=Insecticide; PCP= Personal Care Products ** Baltimore City streams impacted by raw sewage

Sources: Liu B, McConnell LL, Torrents A. Herbicide and insecticide loadings from the Susquehanna River to the northern Chesapeake Bay. J Agric Food Chem. 2002 Jul 17;50(15):4385-92. Foster GD, Lippa KA. Fluvial Loadings of Selected Organonitrogen and Organophosphorus Pesticides to Chesapeake Bay. J. Agric. Food Chem.,1996 44 (8), 2447 -2454. Lehotay SJ, Harman-Fetcho JA, McConnell LL. Agricultural pesticide residues in oysters and water from two Chesapeake bay tributaries Mar. Pollut. Bull. 1998, 37, 32-44. Halden R.U., Paull D.H. Analysis of Triclocarban in Aquatic Samples by Liquid Chromatography Electrospray Ionization Mass Spectrometry, Environmental Science & Technology. 2004 38(18):4849-55. 28. Halden, R.U. and D. H. Paull. 2005. Co-Occurrence of Triclocarban and Triclosan in U.S. Water Resources. Environ. Sci. Technol. 39(6):1420-1426.

[3] http://www.thecre.com/pdf/exhibit-a-efed_redchap_22apr02.pdf

"...Chesapeake Bay is the most biologically diverse estuary in the United States."

USDA also studies the environmental fate of pesticides in the Chesapeake Bay. Table 2 above summarizes the mean concentration reported in five Chesapeake Bay tributaries for four herbicides and four insecticides as well as the estimated concentration for two antimicrobial compounds in Gwynns Run in Maryland. Among other findings, researchers discovered much higher concentrations of atrazine, metolachlor, simazine and cyanazine in the Potomac River than in the Susquehanna River (Liu, McConnell and Torrents, 2002). Simazine and cyanazine were also found in greater concentrations in the Potomac, James, and Choptank Rivers. Atrazine was found in much higher concentrations in the Potomac (160 ng/L) and the Choptank (245 ng/L), than in the Susquehanna River (67 ng/L).

Banned DDT and Chlordane Still Occur in Chesapeake's Streambed Sediment

Although use of DDT was banned in the U.S. in 1972, USGS researchers still detected this persistent organic pollutant in 1998 in most streambed sediment sites in the Potomac basin (Ator et al., 1998). Chlordane, which was banned in 1988, was found in 13 of 26 sites monitored. At four of these locations, pesticide (or chlordane) concentrations were found to exceed benchmark(s) for aquatic life (Ator et al., 1998). In addition to this information, toxic contaminants data are also available on the Chesapeake Bay Program's (CBP) website, which draws on information from the USGS, NOAA, and USDA.

Ecological and Human Health Risks

Assessing the risks of pesticides in terms of aquatic life, wildlife, and human health is immensely difficult because of vast data gaps due to deficiency in research, as well as a lack of regulations and standards for pesticide concentrations in water. The USGS summary of compound detections in the Potomac River Basin lists 28 herbicides and 14 insecticides that were detected in ground and surface waters (Ator, 2008). By examining the existing federal standards and benchmarks used to protect aquatic life, wildlife, and human health for these compounds, it is apparent that some of these pesticides exceeded existing criteria for aquatic life, fish-eating wildlife, or humans – including alachlor, atrazine, metolachlor, cyanazine and diazinon (Ator, 2008; US Environmental Protection Agency, 2003b). It is also apparent that standards are lacking for many of the pesticides detected in this study (EPA, 2003).

Table 3 lists nine of the pesticides found in the Potomac River Basin (Ator, 2008). The EPA's list of contaminants and their standard maximum contaminant limits (MCL) was used to show that pesticide contaminations present in the Chesapeake Bay watershed in the Potomac have reached or exceeded levels that are harmful to drinking water (Ator, 2008; US Environmental Protection Agency, 2003b). Table 3 also shows the lack of standards for several of the pesticides found during the USGS study.

Table 3. Existing national primary drinking water standards and adverse effects on humans for risk and action prioritization

Pesticide	MCL[1] (mg/L)	MCL Goal[2] (mg/L)	Standards for drinking water exceeded?	Potential health effects from ingestion of water
Reference:	US Environmental Protection Agency 2003a	US Environmental Protection Agency 2003a	Ator 2008, Gilliom et al. 2006[3]	US Environmental Protection Agency 2003a?
Alachlor	0.002	0.000	Yes	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer
Atrazine	0.003	0.003	Yes	Cardiovascular system or reproductive problems
Simazine	0.004	0.004		Problems with blood
Metolachlor	No EPA standard	No EPA standard	Yes	
Cyanazine	No EPA standard	No EPA standard	Yes	
Diazinon	No EPA standard	No EPA standard	Yes	
A-HCH	No EPA standard	No EPA standard		
y-HCH	No EPA standard	No EPA standard		
p,p'-DDE	No EPA standard	No EPA standard		

[1] Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards (US Environmental Protection Agency 2003a).

[2] Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals (US Environmental Protection Agency 2003a).

[3] Selected water-quality standards and guidelines (Gilliom et al, 2006)

Gilliom et al., (USGS National Water Quality Assessment Program, 2006), in a study, Pesticides in the Nation's Streams and Ground Water, 1992 – 2001, documented levels at which adverse effects of several of these pesticides have been observed. Atrazine was found to have adverse effects at 17.5 µg/L (0.0175 mg/L), diazinon at 0.1 µg/L (0. 0001 mg/L), and p,p'-DDE at 0.001 µg/L (10-6 mg/L). Alachlor had adverse effects on non-vascular plants at 1.64 µg/L (0.000164 mg/L). Another study done by Halden and Paull (2005) looked at the water in three tributaries to the Patapsco River - Gwynns Run, Gwynns Falls and Jones Falls. This study found that triclocarbon exceeded the standards for drinking water in this location, and had adverse effects at 240 µg/L (0.24 mg/L). Study results suggest that the magnitude and frequency of triclorcarbon contamination (regional, 6750 ng/L, 68%)) were markedly higher than non-peer reviewed numbers (240 ng/L, 30%, U.S.) currently used by EPA for evaluating triclorcarbon's ecological and human health risks.

The lack of water quality standards for most pesticides found in the Chesapeake reveals a regulatory deficiency. Only a small percentage of all pesticides have benchmarks associated with their use. Degradation products often exceed concentrations of their parent compounds but resulting ecological or human health risks are difficult to assess in this vacuum of knowledge gaps and lacking regulations.

Another concern is that only a fraction of all pesticides currently in use and few of their degradation products are assessed by the USGS National Water Quality Assessment (NAWQA) Program, which provides an assessment of water-quality conditions throughout the nation (USGS, 2006) (see Section VII below). In this report, only 75 pesticides and eight degradation products were analyzed nationally, whereas in the state of Maryland, 281 types of pesticides are used – not including those used in homes and gardens (MDA, 2006). While USGS studied the use of 80% of the most heavily used herbicides, only 64% of the most heavily used insecticides, and very few fungicides, fumigants or other types of pesticides were monitored.

EFFECTS OF PESTICIDES ON AQUATIC LIFE AND WILDLIFE

Home to more than 3,600 species of plants, fish and animals, Chesapeake Bay is the most biologically diverse estuary in the United States (Chesapeake Bay Program, 2003). Pesticides may adversely impact the Bay's most important aquatic species and major sources of income such as blue crabs and oysters.

Pesticides in Fish

Pesticides that occur in streambed sediment can make their way up the food chain and bio-accumulate in edible fish increasing human exposure risk. Although there are few documented cases of pesticide lethality to aquatic organisms in large estuaries, chronic effects and bioaccumulation have been detected. A few examples:

- Chlordane and DDT were found in samples of the Asiatic clam, *Corbicula fluminea* and in fish tissues obtained in 1992 and 1996 from the Potomac River Basin (Zappia, 1996) (Field Study).
- Studies on atrazine have documented potential adverse effects to fish at exposure levels below those predicted by EPA and recorded through monitoring (Saglio and Trijasse, 1998). Documented effects include renal system damage (Fischer-Scherl et al., 1991; Oulmi et al., 1995); also disruption to endocrine and olfactory systems affecting behavioral functions related to survival and reproduction (Moore and Waring, 1998; Moore and Lower, 2001).
- Microbial communities can be altered by exposure to Roundup (Perez et al, 2007) or atrazine (Thom et al, 2003). Roundup affected the structure of phytoplankton and periphyton communities. Total micro- and nanophytoplankton decreased in abundance, while the abundance of picocyanobacteria increased by a factor of about 40. Primary production also increased in treated mesocosms (roughly by a factor of two). Observed changes in the structure of microbial communities are consistent with a direct toxicological effect of glyphosate.
- Increased sensitivity of phytoplankton to atrazine occurred after long-term exposure to low levels (Pennington and Scott, 2001) (lab study).
- Fiprinol negatively impacted populations of grass shrimp (40% survival at 355 ng/L and 0% survival at 5000 ng/L) but not juvenile clams or fish (Wirth et al, 2004) (lab study).

POSSIBLE PUBLIC HEALTH EFFECTS OF EXPOSURE TO PESTICIDES IN WATER

Long-term, chronic exposure to low-level concentrations of pesticides may be a chronic-disease health risk for residents of the Chesapeake Bay watershed. A growing body of epidemiological research suggests an association between pesticide exposures and chronic diseases such as certain cancers, as well as reproductive, neurological, respiratory and developmental disorders. Many pesticides have not been studied for their carcinogenic or other toxic effects (US Environmental Protection Agency, 2007), and health care providers often overlook or misdiagnose health problems caused by pesticide exposure. (Goldman and Links, 2004).

Acute and Chronic Health Effects of Pesticide Exposure

Pesticides may cause a wide range of acute and chronic illnesses. Low-dose, short- and long-term exposures to pesticides have been linked to cancers, reproductive dysfunction, developmental disabilities, immune system disorders, asthma and other respiratory diseases, and neurological and behavioral disorders.

Exposure to glyphosate can more than double one's risk of developing non-Hodgkin lymphoma (Eriksson et. al, *International Journal of Cancer,* 2008) . Some pesticides on the market today are known to be highly toxic, particularly for pregnant women, children, seniors, and those with compromised immune systems. A study published in the *Journal of the National Cancer Institute* found that household and garden pesticide use can increase the risk of childhood leukemia as much as seven-fold (Lowengart et al. 1987). Studies show that children living in households where pesticides are used suffer elevated rates of leukemia, brain cancer and soft-tissue sarcoma (Leiss, J., et al. 1995; Gold, E. et al. 1979; Lowengart, P., et al. 1995; Reeves, J. 1982; Davis, J., et al. 1993; Buckley, J., et al. 1994).

EPA has classified nearly 100 pesticides in use today as probable or likely carcinogens, and nearly 90 pesticides as possible carcinogens. Pesticides are one of the many potential causes for cancer. In 2006, Maryland was ranked out of the 50 states as the 17th highest in both cancer incidence and mortality (Lee, 2007).

In 1990, 24 of 51 pesticides demonstrated carcinogenicity in chronic bioassays after being evaluated by the U.S. National Cancer Institute and the U.S. National Toxicology program (Zahm, Hoar and Ward, 1998). Some pesticides may cause or promote cancer through: a) genotoxic effects that change DNA; b) promotion, causing proliferation of abnormal cell clones; c) hormone disruption; and d) immunotoxic effects that may interfere with the body's normal cancer surveillance mechanisms. Low doses of a genotoxic chemical can initiate the conversion of a normal cell into a malignant one.

Duke University School of Medicine researchers linked pesticides to the epidemics of obesity and type 2 diabetes. (T. Lassiter, et. al, *Environmental Health Perspectives*, 2008). Researchers at the University of California Los Angeles, found chronic exposure to commonly used fungicides contribute to Parkinson's disease development (Chou et. al; J. Biol. Chem, 2008). Pesticide exposure can increase the risks for developing Parkinson's disease by 70% (Ascherio et. al; Ann Neurol. 2006). Toxic chemicals are key drivers in Alzheimer's and Parkinson's diseases, according to the report, *Environmental Threats to Healthy Aging.* (Stein et. al; Greater Boston Physicians for Social Responsibility & Science and Environmental Health Network, 2008).

There is also growing evidence that pesticides are linked to autism. A recent study found that children born to mothers living within 500 meters of pesticide-treated fields are six times more likely to develop autism spectrum disorders (Roberts et. al; *Environmental Health Perspectives*, 2007).

Another study found that low-dose exposures to the herbicides aldicarb and atrazine in well water, along with nitrate used as fertilizer, may cause adverse effects on behavior and on the immune and endocrine systems (Porter, et. al , 1999). Another study found that a common lawn herbicide mixture, 2,4-D, Mecoprop and Dicamba can induce abortions and resorption of fetuses in mice at levels well below those considered safe by EPA (Cavieres et. al.,2002). Moreover the greatest effects were at the lowest ppb doses.

Furthermore, some people may have genetic or developmental susceptibilities to certain pesticides or combinations of chemicals. Fetuses, infants, and children are particularly vulnerable to pesticide exposure; their organs are still developing and they eat and breathe more compared to adults (on a per-body-weight basis).

Endocrine Disruptors

Pesticides can affect the endocrine – or hormonal – systems of fish, birds, other wildlife and humans. Hormones act as chemical messengers directing long-term changes such as growth and development. Some pesticides may disrupt this system and interfere with normal development. Even at low-dose exposures, certain pesticides act as "environmental estrogens" and endocrine disruptors (Hayes et al., 2006). Endocrine disruptors function by mimicking the action of a naturally-produced hormone such as estrogen or testosterone, thereby setting off similar reactions in the body. They can additionally block the receptors in cells receiving the hormones thereby preventing the action of normal hormones and can also affect the synthesis, transport, metabolism and excretion of hormones, thereby altering the concentrations of natural hormones.

Potential Higher Risk

* *Bioaccumulation*
  When pesticides bioaccumulate in edible fish, there is an increased exposure risk for individuals who consume contaminated fish, especially mothers who may pass the pesticides on to their offspring through the placenta or breast milk. Mothers may also pass pesticides to their offspring (Wu et al., 2001)
* *People who use small private wells have increased risks*
  The majority of metropolitan area residents obtain water for drinking, bathing, etc., from surface water sources, while those living in small or rural areas often rely on groundwater from private wells (US Environmental Protection Agency, 2006b). Federal laws that require testing for water-borne contaminants do not apply to private water systems that serve fewer than 25 people. While pesticides have been found to occur less frequently in groundwater than in surface water (Ator and Denver, 2006; US Geological Survey, 2006; Ator et al., 1998), rural populations relying on well water may still be at risk.

About 15% of the U.S. population receives its drinking water from private wells that are not subject to national standards and are not regulated by EPA (U.S. Environmental Protection Agency, 2006b). It would be too costly for the average household to use a state-certified laboratory to test its well water for a large number of pesticides, metals and other contaminants. Such a household would need to test several times per year to avoid missing seasonal hot spots for pesticide use.

THE RISK ASSESSMENT PROCESS AND ITS LIMITATIONS

As part of the pesticide registration process, EPA conducts a risk assessment. That process does not measure aggregate and cumulative exposures to the thousands of pesticides and other toxic chemicals that are in common use. As many pesticides are detected at concentrations of < 1 microgram/liter, they may not appear to cause significant risks in isolation (a single exposure to a single product). Yet multiple compounds are often detected in a single water sample (Ator et al., 1998; Denver et al., 2004), raising concern that true ecological and human health risks are seriously underestimated. Furthermore, there are many exposure pathways (respiration of indoor or outdoor air sprayed with pesticides, ingestion of foods with pesticide residues, skin exposure to insect repellents or chlorine, etc.). In addition to the above problems with risk assessment, people may be exposed to other types of chemicals besides pesticides, and research regarding the synergistic effects of multiple chemical exposures is limited.

EPA's risk assessment is only for pure 'active' ingredients, and not for the end product sold to consumers containing solvents and surfactants that are not assessed in combination with the 'active' ingredients and contaminants of production. While there is a provision that allows the agency to ask for such testing if the agency has reason to believe that the end product may be more toxic than the active ingredient, in practice, that rarely happens. For example, 2,4-D contains forms of 'small' dioxins not monitored by the EPA. These dioxins are a consequence of the synthesis process of 2,4-D production (Sears et al, 2006).

Many new pesticides are thought to be less persistent in the environment, but most have not been completely assessed for risk, because of insufficient toxicological data. In addition, important recent research has identified that the "dose does not necessarily make the poison." For example, one study found harmful effects of pesticide mixtures on frogs, even though the levels of the individual pesticides were 10 to 100 times below EPA standards (and therefore considered harmless) (Hayes et al., 2006). Similar research has demonstrated that exposure to doses of atrazine as small as 0.1 parts per billion – a level permitted in drinking water by EPA – turns tadpoles into hermaphrodites, which have both male and female sexual characteristics (Hayes et al., 2002a).

However, other studies have produced differing results, and more research is ongoing. It is interesting to note that although these are different species with different routes of exposure, nonetheless this is the level of exposure permitted by EPA. Other research by Dr. Warren Porter at the University of Wisconsin has shown that very low levels of pesticide exposure can disrupt an endocrine system – specifically thyroid hormone levels in mice. Thyroid hormone controls brain development, bone development, sexual development, interacts with the immune system to alter immune function and recently has been shown to interact with a key very early developmental hormone that determines whether or not adrenal glands and gonads will develop. In addition, it has been found that atrazine upregulates aromatase (Sanderson et al., 2000), which alters the ratio of testosterone to estrogen in organisms, thereby inducing feminization of males not only in the gonads but possibly in the brain, where sexual behavior is controlled. Other research from Dr. Paul Winchester, neonatologist at St. Francis Hospital in Indianapolis, Indiana, suggests the important impact on early human fetal development of the presence of atrazine in surface and ground waters. Concentrations found during springtime when compared against month of conception suggest impacts on human learning abilities both in quantitative math skills and language skills (Winchester et al., 2007).[4]

[4] http://medicine.indiana.edu/news_releases/viewRelease.php4?art=686&print=true

"Understanding Water-Borne Pesticide Risks and Solutions

SOURCES OF PESTICIDES IN WATER

The major categories of pesticide users include: 1) agriculture; 2) commercial, including golf courses and landscaping; 3) government; and 4) residential for home and garden.

Agriculture

Our traditional reliance and growing dependency on pesticides are the root cause of pesticides occurring in our waterways and the Bay. In large part, this is due to agricultural practices used to support a rising population. The undesirable side effects of modern agriculture may threaten the lands and the very livelihood that farmers are trying to sustain. For example, monoculture, i.e., the large-scale and long-term cultivation of a single crop on agricultural land, is seen as a more efficient way to grow food. However, this common practice makes crops more susceptible to damaging pests and requires extensive use of both pesticides and fertilizers.

Sustainable agriculture necessitates farmers reaching the goal of producing adequate yields and good profits following production practices that minimize any negative short-and long-term side effects on the environment and the well-being of the community. The major goals of this approach are thus to develop economically viable agro-ecosystems and to enhance the quality of the environment, so that farmlands will remain productive indefinitely.

Commercial

While the pest control and lawn care industries increasingly have been moving toward embracing IPM, conventional pest and land care management continues to rely, for the most part, on pesticides as a first line of defense.

Government

State agency use of pesticides in rights of way, for forest management and for mosquito control, for example, add to the potential pesticide load in the watershed. In addition, a variety of federal and state agencies use herbicides on public lands to control invasive species.

Residential

Public perception of what is aesthetically acceptable in foods, lawns and gardens is another major factor in pesticide use; Americans have grown accustomed to large, weed-free lawns that are maintained using a variety of chemical pesticides and fertilizers. Consumers falsely believe that antibacterial soaps and other personal care products containing persistent chemical compounds, including registered pesticides, are necessary for protecting family health. The public has become accustomed to produce that is free of blemishes – an outcome requiring pesticides. (Pollan, 2006).

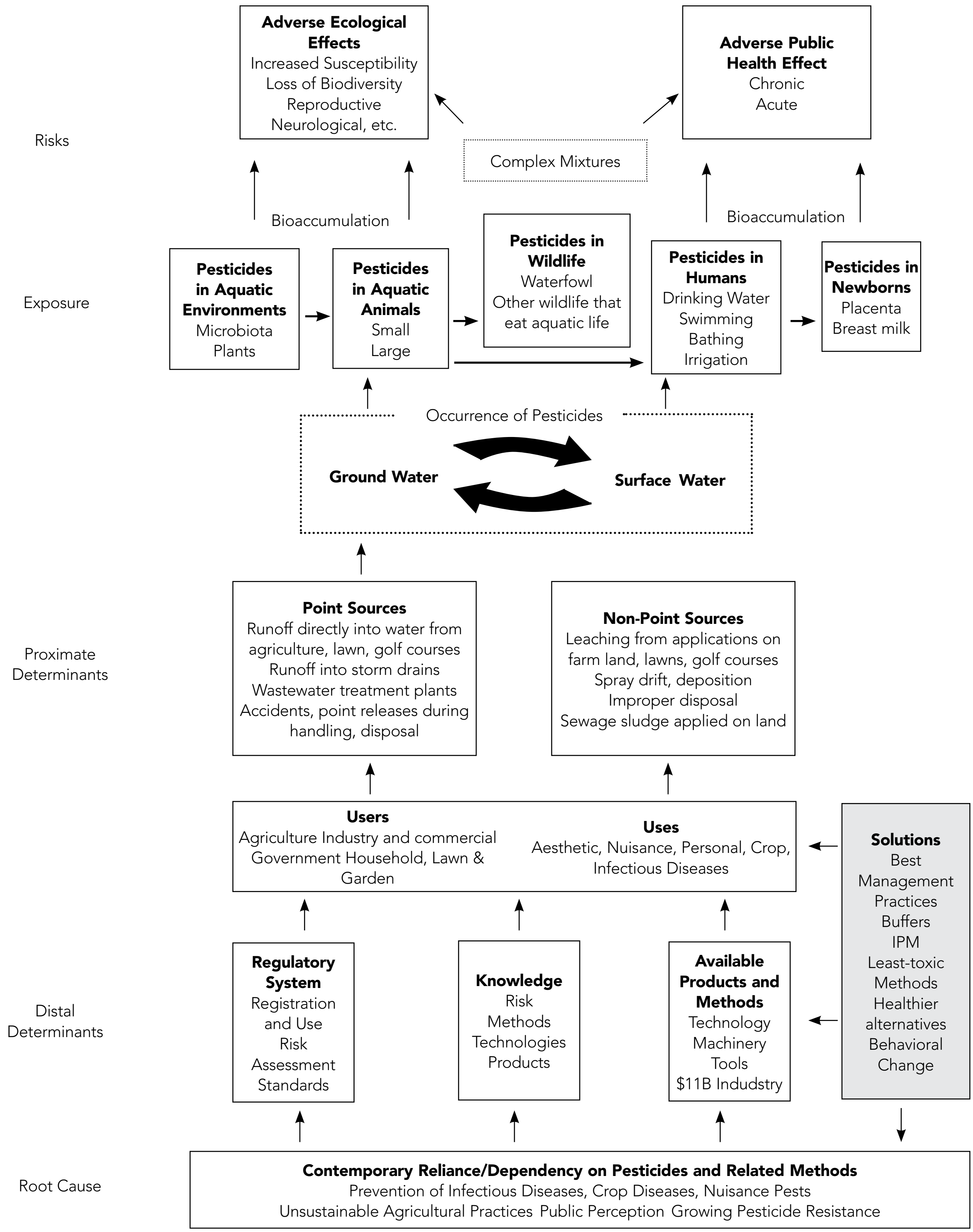
Indirect Sources of Pesticides in Water

As illustrated in Figure 1 (next page), the first major determinant of pesticide occurrence in water is the regulatory system governing the use and registration of pesticides. At least a dozen national and local laws and policies affect the use and monitoring of pesticides. Registration of pesticides is based upon weighing certain ecological and human health risks against the benefit of the chemical to users. A second important underlying determinant is that most consumers lack knowledge about the risks of exposure to pesticides, and about the existence of effective and healthier alternatives – including organic practices and products, Integrated Pest Management methods and least-toxic products. A third determinant is the available products, tools, machinery, technology and methodologies for applying traditional pesticides, many of which were developed without regard to sustainability and external societal costs resulting from pollution.

How Pesticides Enter Ground and Surface Water

Figure 1 summarizes a number of proximal causes for the occurrence of pesticides in water. Pesticides used for agriculture, lawns and even those in common antibacterial

Figure 1. Framework illustrating pathways and risks of pesticide exposures through water as well as important sources and opportunities for intervention.



soaps may end up in streams and groundwater (Ator et al. 2006, USGS, 2006; Halden and Paull, 2005). A variety of factors can influence how they enter a water source. While some pesticides can enter water directly through point sources such as storm drains or sewage pipes, the majority enter indirectly through nonpoint sources. Fissures, cracks and holes in the ground, as well as infiltration, can provide a conduit for pesticides to reach the underlying groundwater (Gustafson, p. 194, 1993).

Common Point Sources of Pesticides in Water

- Runoff from lawns, gardens and or golf courses
  - May also enter storm drains discharging into surface waters (NOAA, 2005).
- Accidents, improper handling and disposal
  - Spills or careless use of pesticides, such as over spraying drainage ditches or water courses, or careless disposal of empty containers or leftover pesticides.

Common Nonpoint Sources of Pesticides in Water

- Storm events
  - Even proper use, handling and disposal may lead to runoff or sewage overflows into surface waters due to heavy storms.
- Land-based applications for agriculture, lawn care and on golf courses.
- Runoff from treated agricultural fields, especially during storms; even proper use and handling may lead to runoff into surface waters.
- Spray Drift
  - Occurs when pesticides are sprayed over an area by trucks or airplanes (e.g., for agricultural purposes, large lawns or mosquito control) and wind blows this spray into an adjacent body of water (NOAA, 2005).
- Atmospheric Deposition
  - Occurs in the form of rainfall or dry deposition as airborne particles settle onto land or bodies of water.
- Proper or Improper disposal of pesticides.
  - Even proper use and handling may lead to runoff into surface waters.
- Sewage sludge from wastewater treatment plants.
  - Disinfectants such as triclosan occur in sewage sludge, and these biosolids may later be applied to agricultural land (Kinney et al., 2006)
- Direct discharge from treated wastewater effluent.

Pesticide Properties that Affect Movement into Water

The persistence and mobility of a pesticide is a key determinant of its potential for reaching surface and groundwater via, e.g., soil runoff and chemical leaching (Gustafson, 1993). Water-soluble pesticides may readily migrate in water, whereas hydrophobic ones tend to become attached to organic material or sediment particles, and may therefore be transported along with such suspended material in streams. Also, such suspended transport is mainly limited to surface water conditions; groundwater loads are nearly always dissolved. This mechanism is important for chemical migration in both surface and groundwater and may help explain the detection in drinking water of compounds with low water solubility. For example, the herbicide atrazine has low water solubility (33 mg/L) (Gustafson, 1993), yet its degradation products are among the most commonly found pesticides in surface and ground waters of the Chesapeake (Ator et al., 1998; Ator and Denver, 2006; Denver et al., 2004; and Liu et al., 2002). Atrazine occurs widely in dissolved form in stream and ground water. Also, selected degradation products are soluble and move in dissolved form in both streams and ground water.

Pesticides enter ground water through soil and can flow to and from surface water

Studies indicate that pesticides applied on cropland may contaminate the underlying groundwater and later can enter surface waters through natural outflows (Winter et al., 1998). Conversely, contaminants from surface waters can enter groundwater. Soil type and usage also affect mobility. Agriculture accounts for about 80% of pesticide use in the United States (Ator et al. 1998, US Geological Survey, 2005). However, pesticide use on golf courses and lawns is also a pathway for groundwater contamination.

ENVIRONMENTAL AND HEALTH RISKS FROM EXPOSURE TO PESTICIDES IN THE CHESAPEAKE

Water-borne pesticides pose health risks to aquatic life, wildlife and humans. The diagram shown in Figure 1 illustrates potential receptors for pesticide exposure. It also may be used to identify potential problems and solutions, as discussed further in subsequent sections.

As indicated earlier in this White Paper, pesticide concentrations have been observed to exceed national water-quality benchmarks for aquatic life. These toxic chemicals that contaminate Chesapeake waterways may harm the environment and endanger human health. Human health effects, including low birth weights (Munger et al., 1997),

"Natural control factors regulate pest populations and are maximized in Organic farming and IPM as the primary means of management; if this strategy fails to maintain pests below economic levels, in IPM, then pesticides in combination with other tactics are used as a last resort."

– UMD Extension Services

breast cancer (Kettles et. al, 1997), low sperm counts (Adams, 2003) and immune dysfunction (Fiore et al, 1986) are linked to herbicide-contaminated water. As pesticides enter water systems, plants and other aquatic life such as blue crabs and oysters, or fish and their related food chains may also be affected (see Section VI. A.).

HOW TO REDUCE PESTICIDE IMPACTS ON WATER

We can reduce pesticide runoff by using certain technologies, buffers and other best management practices. We can reduce and even eliminate many common uses of pesticides outlined in Figure 1 (Framework Illustrating Pathways and Risks Pesticide Exposures Through Water as well as Important Sources and Opportunities for Intervention) by transitioning to Integrated Pest Management, a method of pest management based on preventive, non-chemical strategies and least-toxic products as a last resort. Organic farming and landcare utilize practices that do not rely on pesticides. Interventions are most effective when they address root causes. Potential solutions and initial recommendations are discussed in Sections VIII and IX.

LAWS AND POLICIES AFFECTING THE CHESAPEAKE BAY WATERSHED

Laws and policies that affect the health of the Bay and its watershed cross several subject areas, principally water quality, food safety, and toxics reduction. The principal legal and policy tools for promoting Bay health include the Clean Water Act, the Safe Drinking Water Act, the Federal Insecticide, Fungicide, and Rodenticide Act, and the Food Quality Protection Act. These federal laws and programs are supplemented by state and regional laws, policies, and delegations of authority. For example, the groundbreaking Maryland Integrated Pest Management in Schools law, enacted in 1998, established pesticides as a public health issue in Maryland, and created a model for balanced, sustainable pest management for the nation. A description of these tools and how they can affect Bay outcomes is included in the Appendix.

Solutions: Preventing Pesticide Pollution

"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."

– Wingspread Statement on the Precautionary Principle, January 1998

The Precautionary Principle is gaining in popularity in the United States. After World War II, heavy organopesticide use became the industry norm for preventing crop disease and destruction, meeting the growing demand for food, and preventing illnesses and infectious diseases. Pesticides are also now relied upon to achieve aesthetic goals in lawn care and are incorporated into other products – e.g., personal care products – such as hand soaps and sunscreen lotions, cosmetics and cleaning products. Over time, increasing resistance to pesticides has led to an increase in the number of pesticide formulations and their potency. To restore the health of Chesapeake Bay, we need to replace this ongoing race between increasing pest resistance and reformulation of new pesticides with a more comprehensive strategy for dealing with various "pests" and limiting pesticide occurrence and impact.

AGRICULTURE: VEGETATED BUFFER ZONES AND INTEGRATED PEST MANAGEMENT

Vegetated buffer zones that prevent nutrients from entering surface waters can also prevent pesticide runoff (Norris, 1993). A recent bill was passed in Pennsylvania to provide economic incentives for farmers to create these buffer zones around the perimeters of their farms.

Federal and state agencies, agricultural extension services, NGO's, and other watershed and/or agricultural stakeholders should work to educate farmers and provide incentives – including financial incentives – to enable implementation of best management practices (BMPs) that prevent pesticides from entering nearby waterways (buffer zones, etc.) as well as BMPs for transition to sustainable agriculture.

The use of Integrated Pest Management (IPM) strategies that focus on non-chemical prevention, monitoring, and least-toxic methods for pest control should also be promoted by state and federal agencies and private sector organizations and business associations. Financial incentives (e.g., NRCS - the Natural Resources Conservation Service's Environmental Quality Incentives Program (EQUIP), which reward farmers who implement pest management techniques that go beyond the minimum requirements of the NRCS Pest Management standard-Code 595), are critical to such transition. Farmers will need assistance transitioning to these new methods. A collaborative effort is needed to fully understand this complex issue and develop effective solutions and transition strategies. Farmers successfully using IPM as well as organic farmers can also help educate conventional farmers on how to transition to practices that reduce or even eliminate pesticide use and provide evidence of cost savings.

COMMERCIAL AND HOME LAWN AND GARDEN PESTICIDE USE

While examples abound of healthy green lawns and landscapes grown relying on non-chemical methods, public perception remains that a weedless green lawn requires chemical fertilizers and pesticides. When the goal is not met quickly, there often are additional applications or fertilizers and pesticides. However, increasing numbers of lawn care companies now offer natural or organic program

"While examples abound of healthy green lawns and landscapes grown relying on non-chemical methods, public perception remains that a weedless green lawn requires chemical fertilizers and pesticides."

options to customers. In addition, pesticide manufacturers are increasing their production and sales of non-chemical products .

Organic land care is a problem-solving strategy that prioritizes a natural, organic approach to turf grass and landscape management without the use of pesticides. It focuses primarily on soil health as the key preventative measure against turf and landscape pests. Other key practices include selection of appropriate grasses and other plants, aeration of compacted soil, timely thatch removal, proper mowing, correct watering, and organic fertilizing methods.

The use of various media sources, publications, and awareness programs, such as city, county and state-sponsored IPM demonstration projects, can help change perceptions and foster use of healthier alternatives, such as IPM and organic land care.

Collaboration among various stakeholders (e.g., federal and state agencies, extension services, waterkeepers, associations such as the Northeast IPM Center; non-profit organizations such as the Maryland Pesticide Network, Clean Water Action, the Chesapeake Bay Foundation and Beyond Pesticides; and businesses, including pest management and lawn care companies that practice IPM and natural and/or organic land care) is critical to bringing about fundamental change.

COMMERCIAL AND HOME PESTICIDE USE

A campaign must also educate the public about safer alternatives for cleaning products, cosmetics and other household products that include pesticides. Major retailers from Whole Foods to Wal-Mart sell alternative products that do not include pesticides, and major companies such as Clorox are introducing lines of "natural" products as alternatives to their chemical products. These trends should be encouraged by consumer education.

Antimicrobial Products

Thousands of products marketed for protection against germs contain pesticides; many people have the false impression that washing with antibacterial soaps is necessary for preventing illness. For example, antimicrobial hand soaps often contain the pesticides triclosan or triclorcarban. However, antimicrobial soaps only kill some bacteria and do not prevent illnesses caused by viruses, the most common causes of infectious diseases. Hand washing with any type of soap before eating and after using bathrooms is an effective method of preventing infectious illnesses (Centers for Disease Control and Prevention, 2007).

INSECT-BORNE DISEASES

A sustainable mosquito management strategy should emphasize education, prevention (source reduction and larval control) and monitoring for both mosquito-borne and pesticide-related illnesses. This strategy will ensure that the use of pesticides does not add to health problems associated with insect-borne diseases. Successful control of mosquito populations requires that local governments and community leaders educate residents and business owners on how to reduce breeding habitats and mosquito bites.

While larvicides are considered less toxic than the common pesticides sprayed to reduce adult mosquito populations, they too can present health impacts. However, it may be necessary to use larvicides, which kill mosquito larvae, where it is not possible to eliminate breeding sites, especially when dealing with mosquito-borne diseases. Several municipalities have supplemented tight budgets and/or small staff sizes by enlisting volunteers at critical times to help apply larvicides.

FOREST PEST MANAGEMENT

The blue crab populations of Maryland and neighboring states have diminished to the point of serious economic impact on the watermen in those states. As noted in a September 24, 2008 article in the Washington Post ["Blue Crab 'Fishery Failure' Declared"], "The crabs' numbers have fallen by more than 70% since the 1990s" and "the value of the bay's crab harvest, including hard- and soft-shell crabs, had declined 41% since the late 1990s." Dimilin/diflubenzuron used for gypsy moth eradication

"The blue crab populations of Maryland and neighboring states have diminished to the point of serious economic impact on the watermen in those states."

in Maryland is known to be toxic to aquatic invertebrates and may also account for the blue crab's declining population by disrupting their molting process (A. Walker and M. Horst, 1992) (lab study). In addition, a 1996 lab study found that dimilin is toxic to juvenile blue crabs, but said data were not yet conclusive as to whether dimilin in the watershed environment retains its toxicity to blue crabs, and further research is needed (Rebach and French, 1996).

EPA classifies Dimilin as "moderately toxic" to humans. Two breakdown products of diflubenzuron are classified as probable carcinogenics according to EPA, p-chloroaniline (PCA) and p-chlorophenylurea (CPU). CPU is the major degradation product found in water and therefore could be widely distributed in certain waterways following aerial application of dimilin. Because of dimilin's toxicity to crab, shrimp, and other aquatic invertebrates, it is a restricted pesticide and the label warns of hazards to aquatic invertebrates. The state would benefit from investigating the work of other states that have suspended the use of chemical means for suppressing forest pest infestations, such as gypsy moth. Rhode Island, for example, no longer uses pesticides for gypsy moth eradication.

RESEARCH NEEDED

Consensus among participants in the *Pesticides and the Chesapeake Bay Watershed Project* is that while the growing body of research underscores the threat of pesticides and degradate products throughout the watershed, there is a need to further define the occurrence of these threats and their potential impact on aquatic life, wildlife and human health. This includes aggregate and cumulative impacts as well as the interaction/impact and synergistic effects of pesticides and non-pesticide stressors.

The current thresholds for estimating effects of pesticides on living organisms are established on a compound-by-compound basis, rather than on the basis of multiple stressors (i.e., pesticides, other contaminants and even natural stressors) that can have a combined negative impact. While scientists are aware of the need to assess the impact of multiple stressors, to date there is little published data on such effects. The Project's *Research and Data Gaps Working Group* reported that watershed research has generally focused on individual stressors, and also tends to use effects thresholds such as 50% reduction in SAV photosynthesis as toxicity end points. Such thresholds are not sufficiently protective of this Bay living resource and are not supportive of Bay restoration goals. EPA's 2002 *Reregistration Eligibility Science Chapter for Atrazine Environmental Fate and Effects* concluded "Atrazine could be contributing to reductions in submerged aquatic vegetation and primary productivity at certain sites in the Bay" (U.S. Environmental Protection Agency, p.59). Underwater vegetation in the Bay watershed is subjected to multiple stressors such as reduced light, nutrient contamination and pesticides, including atrazine. It would be worthwhile, for example, to look at the combined impact of light and atrazine on SAV.

Conclusion and Recommendations

Water-borne pesticides present policymakers, government agencies, scientists and public experts with serious challenges. Health threats include a wide range of acute and chronic illnesses, such as cancers, reproductive dysfunction, developmental disabilities, and other diseases and disorders. Even low-dose exposures to some pesticides may harm human health and aquatic life.

The current risk-assessment process is not designed to fully evaluate pesticide contamination in our waters as health hazards, especially in terms of aggregate and cumulative exposures to pesticides, their degradation products and other chemicals. Given these limitations and the dearth of toxicological data, policymakers, regulators and consumers would do well to follow the precautionary principle. Policymakers and government agencies should encourage the implementation of best management practices that prevent pesticides from entering the watershed as well as the use of non-chemical alternatives and Integrated Pest Management, in order to replace practices that rely on routine use of pesticides. Pesticide products should be registered only after their health impacts have been properly assessed, particularly for endocrine disruption and the synergistic and cumulative effects of chemical mixtures.

Stakeholders need better data on pesticide use within the watershed, and must reach consensus on how to reduce pesticide runoff as well as the use of pesticides – and therefore their impact on aquatic life, fish-eating wildlife and humans. The *Pesticides and the Chesapeake Bay Watershed Project,* launched in May 2007, is an example of the kind of collaboration that is needed. The project's mission is to reduce the occurrence and risks of pesticides in the watershed in order to protect water quality, aquatic life, wildlife and public health. Project participants – who include scientists, regulators and policymakers from local, state and federal government agencies; technical experts; representatives from industry; nonprofit organizations; tributary teams; extension services; watermen; waterkeepers; and the agricultural community – conduct quarterly meetings of five working groups to:

- Identify relevant research and data gaps regarding the impact of pesticides and their degradation products on water quality, aquatic life, wildlife, and public health, and to identify the main pesticides of concern.
- Identify Best Management Practices (BMPs) that prevent pesticides from entering waterways or allow substitution of non-chemical and less-toxic alternatives.
- Develop a strong and interactive relationship with the agricultural community to educate farmers about better practices, inform them about the potential health hazards of certain pesticides, and help them implement changes.
- Educate homeowners and businesses about preventing pesticides from entering the watershed and encourage them to adopt IPM and natural land care, which stress non-chemical and least-toxic alternatives to pesticides.
- Assess how pesticide impact can be reduced through better policies and laws, or better enforcement.

While pesticide degradation products are not currently regulated by drinking water standards, recent scientific findings have prompted their careful consideration. Policymakers and other stakeholders also need to reassess the aesthetic and nuisance benefits of pesticide use in light of the risks to humans and aquatic life in the Chesapeake Bay watershed. For example, the Canadian province of Quebec and more than 70 Canadian towns and cities (including Montreal, Toronto and Vancouver) have banned or restricted all public and private use of lawn care pesticides.

In the U.S., and specifically in the Chesapeake Bay watershed region, the greatest obstacles may be overcoming public perceptions. Attitudes about the use of pesticides can be changed through environmental and health communication campaigns. Increased demand for existing alternatives would ensue. Negotiating with the industry to develop and offer healthier services and products will be crucial; approximately $110 million is spent each year on home and garden pesticides in the Chesapeake region alone. A combination of targeted policies and market-based incentives will likely be most effective in reducing the amount of pesticide usage for ornamental and nuisance purposes.

State and county departments should also collaborate to increase use of least-toxic methods for such state-sponsored programs as spraying for mosquito control, pesticide applications on rights of way, and aerial applications of pesticides for infestations such as gypsy moth. Such broad-based applications have serious implications for the health of the watershed and the public. These agencies would also benefit from being better informed about the risks pesticide pose to public health and the watershed in weighing the risks and benefits of certain applications. Pesticides should be prioritized in terms of their relative occurrence and potential for serious adverse health effects.

Reducing the use of pesticides for prevention of infectious diseases is not as simple to justify, as acute and chronic risks may result from both. Health professionals and the public must be sufficiently educated on the immediate and long-term efficacy of preventive and least-toxic alternatives.

Policymakers are also encouraged to assess the applicability of the European Union's REACH (Registration, Evaluation and Authorization of Chemicals) program, which puts the burden on manufacturers to evaluate the safety of their products prior to registration, in contrast to our existing federal policy whereby pesticides are registered and sold unless they are proven to be unsafe after the fact. REACH mandates that chemicals with higher usage and chemicals of concern be evaluated for safety data (as opposed to the U.S. system of seeking thresholds of allowable harm). Chemicals considered "of highest concern" include carcinogenic, mutagenic or reproductive toxins and persistent, bio-accumulative and toxic chemicals. REACH endorses the principle that hazardous chemicals should be replaced with safer ones. REACH's provisions to seek least-toxic alternatives can generate new markets with positive incentives that will help correct the externalities of chemical manufacturing and make more evident the true cost of chemical production and use. Less harmful chemicals will also have an easier entry into the market.

Policy makers should review California's Green Chemistry Initiative to assess its applicability to Maryland. Launched in April 2007, the program is aimed at reducing the use of toxic substances that are endangering public health and the environment. The plan could serve as a model to look at ways to use less-toxic materials, less energy and produce less waste – thereby improving air quality and drinking water, and creating safer workplaces. California's Green Chemistry Initiative has much in common with the *Pesticides and the Chesapeake Bay Watershed Project.* It is striving to identify data gaps on problem chemicals, explore safer alternatives, and educate the public.

The Pesticides and the Chesapeake Bay Watershed Project participants urge the Chesapeake Bay Program (CBP) to play a stronger role in the effort to significantly reduce the pesticide load in the watershed. The charge of the CBP should expand to encompass pesticide management, in addition to nutrient management. To meet its goals for reducing toxics in the Bay, the CBP must address the toxic threat posed by pesticides.

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Appendix

Laws and Policies Affecting the Chesapeake Bay Watershed

EXISTING FEDERAL LAW POLICIES AFFECTING THE CHESAPEAKE BAY WATERSHED

The Clean Water and Safe Drinking Water Acts
Discharges of pollutants into the nation's water are regulated under the Clean Water Act (CWA), while the Safe Drinking Water Act (SDWA) is the principal federal law for ensuring drinking water quality. While there is considerable overlap in how these two laws operate, together they are the principal authorities for protecting ground and surface water resources in the US (US Environmental Protection Agency, 2006a).

How the CWA Works
The CWA protects the nation's waters through a framework of shared responsibilities between the federal and state governments with jurisdiction over a body of 'navigable' water (Getches, 1997). The CWA prohibits all unpermitted discharges of pollutants from point sources into navigable waters of the United States. A "point source" is a single identifiable 'point', such as a pipe or storm water outfall. Discharge permits under the CWA's National Pollutant Discharge Elimination System (NPDES) place effluent limitations on dischargers, with a goal of pollution elimination. Compliance with and enforcement of permit requirements are the principal means of regulating pollution from these sources.

The CWA also requires statewide planning for control of nonpoint source (NPS) pollution. Pesticides, applied as they are, for example, in agriculture, mostly fall under this second category of pollution. NPS pollutants are much more difficult to monitor and regulate, and quickly became the leading cause of water quality degradation after the point source discharge permit program was implemented (EPA, 2006).

How the SDWA Works
The SDWA requires that public water supplies must be below maximum contaminant levels (MCLs) for pollutants. EPA sets these national standards to protect human health and enforces compliance by public water suppliers. Systems that supply water to 25 or more people must comply with MCLs set forth in the SDWA. The SDWA also establishes more stringent, non-enforceable, health-based maximum contaminant level goals (MCLGs) for each contaminant. In practice, MCLs are set as close to MCLGs as possible, subject to limitations such as the best available technology, treatment technique, and cost.

Amendments to the SDWA enacted in 1996 made standards more stringent to protect vulnerable populations, including individuals with weakened immune systems. Toward this end, EPA is "conducting additional research regarding possible impacts of various contaminants on children and other vulnerable populations, and on new and emerging contaminants." (US Environmental Protection Agency, 1999). Today, MCLs are in place for 91 contaminants, whereas only 23 contaminants were so regulated in 1986.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
This law regulates the distribution, sale, and use of pesticides. FIFRA is a licensing statute that requires registration of pesticide products with EPA before they can be marketed. EPA evaluates the risks and benefits of a product prior to registration. FIFRA requires all pesticides registered to demonstrate "they will perform their intended functions without causing 'unreasonable adverse effects on the environment" (Percival, 1996, p.522). Over 50,000 pesticide products are currently registered under FIFRA. These products also include 900 inert ingredients (Percival, 1996), which are considered proprietary and are not subject to risk/benefit review.

Food Quality Protection Act of 1996
In amending FIFRA and the Federal Food, Drug, and Cosmetic Act (FFDCA), the Food Quality Protection Act (FQPA) of 1996 fundamentally changed the way EPA regulates pesticides (US Environmental Protection Agency, 2003b) by changing the way the FFDCA sets

residue limits, also referred to as tolerances, for pesticides on foods. The FQPA also required EPA to consider the aggregate impact of pesticide exposure on both foods and water used for drinking (US Environmental Protection Agency, 2007).

As a result, EPA now employs a health-based safety standard that "there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue" (United States Public Laws, 1996). This more stringent safety standard regulates trace amounts of pesticides (residues), while food tolerances limit the amounts of pesticides that can be used. The law requires the EPA to: (1) publish specific safety findings before a tolerance can be established; (2) "tighten" tolerances by a factor of ten to protect the health of infants and children; (3) facilitate re-registration of existing pesticides; (4) consider the special vulnerability of infants and children to pesticide risks; and (5) to first address those pesticides that pose the greatest health hazards. The FQPA required EPA to complete review of the registration of all existing pesticides within 15 years, and to reassess existing residue tolerances whenever it reevaluates a pesticide's registration (Percival et al, 1998).

It should be noted that despite its mandate to use an extra ten-fold margin of safety to ensure that tolerances are safe for infants and children, EPA has not consistently applied the 10X safety factor in its review of pesticides and has been known to reduce the safety factor down to 1x for certain pesticides. Although funding has prevented EPA from implementing all of the proposals in this law, after an outbreak of contaminated beef, oysters and raspberries, the Clinton Administration proposed a significant increase in food safety inspection and research in December 1997 (Broder, 1997).

Consumer Labeling Initiative

The consumer labeling initiative is implemented by the EPA, the Consumer Product Safety Commission, the FDA, key industry groups, parents, and health professionals with a goal to "expand the amount of hazard and health information on pesticide labels, similar to new food nutrition labels" (US Environmental Protection Agency, 2000).

Despite the laws, policies, and regulations under CWA, SDWA, FIFRA and FQPA, EPA has not established drinking water standards for all pesticides found in water. Also, degradation products, mixtures and synergisms have not been considered or studied, even though pesticides normally occur in mixtures of several compounds and not individually. Combinations of pesticides with other contaminants in water have also not been taken into account. In addition, EPA has yet to assess the significance of sublethal doses.

REGIONAL LAWS, POLICIES, AND OTHER INSTRUMENTS

Chesapeake 2000 Agreement

The Chesapeake 2000 Agreement follows on similar cooperative efforts established in 1983 and 1987 to protect and restore the ecosystem through the Chesapeake Bay Program partnership (Chesapeake Bay Program, 2000). Signatories include the Chesapeake Bay Watershed Partnership, including the District of Columbia, the states of Maryland, Virginia, and Pennsylvania, U.S. EPA and the Chesapeake Bay Commission. Among other goals, the signatories agreed to fulfill the goal of a toxics-free Chesapeake Bay by "reducing or eliminating the input of chemical contaminants from all controllable sources to levels that result in no toxic or bioaccumulative impact on the living resources that inhabit the Bay or on human health" (Chesapeake Bay Program, 2000). With specific regard to pesticides, the Agreement states:

"Reduce the potential risk of pesticides to the Bay by targeting education, outreach and implementation of Integrated Pest Management and specific Best Management Practices on those lands that have higher potential for contributing pesticide loads to the Bay" (Chesapeake Bay Program, 2000).

CWA Delegated State Authority

Forty-plus states (including Maryland, Virginia, West Virginia, Pennsylvania, and New York, but not the District of Columbia), implement the NPDES permit program within their jurisdictions under delegated CWA authority. Delegated state NPDES programs retain substantial discretion when issuing permits to facilities, and may impose more stringent standards than those set forth by the EPA, though they may not impose less stringent standards.

Key responsibilities of a delegated State include:

- verifying facility qualifications for an NPDES permit;
- issuance of individual or general permits for industrial and municipal sources;

- review and revision of water quality standards every three years, including submittal to U.S. EPA for review and approval; and
- compliance assurance and enforcement.

The Operation of the CWA's Permit Program

All facilities that discharge pollution into the nation's surface waters must obtain an NPDES permit. Standards in permits usually include technology-based treatment requirements that specify the minimum level of control that must be imposed in an issued permit. Specifically, these technology standards comprise the following:

- best practicable control technology (BPT), which represents the minimum level of required treatment for all pollutants;
- best conventional technology (BCT), which applies to discharges of conventional pollutants;
- best available technology (BAT), which applies to discharges of toxic and non-conventional pollutants; and
- best available demonstrated technology (BADT), for new sources, which is generally similar or equal to BAT (CWA sections are 122.44(a), 122.44(e), and 125.3.) (Marshall, 1995).

These standards afford the permitting agency a means of controlling effluent discharges and also offer industry a fair degree of "certainty" that compliance can be easily demonstrated. Though the CWA retains water quality-based controls as a safety net to back technology-based controls, enforcement of water quality-based controls in a water body subject to multiple discharges is impractical. This was historically demonstrated by years of failed enforcement efforts by the original Federal Water Pollution Control Act (1948), which relied on statues that stipulated "water quality standards" as a performance standard.

Strengths and Weaknesses of CWA

The effectiveness of CWA relies on a complex array of cooperative relationships between Congress, the EPA, state agencies, industry, and the public to set the standards and implement the program. For example, permit issuance follows a 14-step process. Moreover, the States must review and revise their water quality standards every three years, submitting them to the EPA for approval, a substantial administrative burden for State agencies. The States bear the majority of the administrative costs for implementation.[5]

As stated by Salamon (1989), "regulatory programs function by imposing restrictions." CWA regulations are no exception. At base, regulated parties are restricted from discharging unchecked levels of pollution into our nation's surface waters. From this perspective, CWA regulation is a coercive policy instrument; however, the burden on permittees is substantially reduced by reliance on 'knowable' technology, rather than performance, standards.

OTHER RELEVANT CHESAPEAKE BAY LAWS, POLICIES AND INSTRUMENTS

Chesapeake's Healthy and Environmentally Sound Stewardship of Energy and Agriculture Act of 2007 (CHESSEA)

The CHESSEA bill was introduced in the U.S. Congress in March 2007. Its primary goal is reduction of nitrogen pollution from agricultural runoff entering the watershed annually by 65 million pounds, achieved by providing matching funds for implementation of conservation efforts. Researchers estimate that 40% of Chesapeake Bay's nutrient contamination can be attributed to agricultural runoff.

If passed, CHESSEA would become the federal government's largest investment in addressing the Chesapeake's water quality and help fund the region's Tributary Strategies to help meet the goals of the Chesapeake 2000 Agreement (discussed above). Under this Act, Farm Bill funding would improve water quality and farm viability throughout the watershed and target farms that have developed a strategy and commitment for reducing nutrient pollution. It also would establish a technical assistance pilot program for conservation planning.

[5] Title II of the CWA originally proposed the Construction Grants Program, which provided Federal grants for the construction of wastewater treatment plants. Congress phased out this program in favor of the State Revolving Loan (SRL) fund in the 1987 amendments, which helped local governments and others build projects that would improve water quality.

Glossary

Best Management Practices (BMPs) - Policies, practices, procedures, or structures implemented to be the most effective means of controlling point and non-point pollutants.

Bioaccumulation - The uptake and storage of a substance, such as a toxic chemical, in various tissues of a living organism.

Carcinogenic - Substances that have the ability to produce cancer or cancer growth.

Degradate - A breakdown product of a pesticide. Degradation products may be more harmful than the original chemical.

Endocrine Disruptor - A chemical agent that interferes with natural hormones in the body. Hormones are secreted by endocrine glands, are transported through the body in the bloodstream, and regulate body growth and metabolism, other endocrine organs, and reproductive functions. Hormones are biologically active at very low concentrations (at parts per billion or less), so low levels of endocrine disruptors may be similarly active.

Epidemiological - Relating to the study of incidences, distribution, control and prevention of diseases in populations.

Genotoxic - Capable of damaging genetic material such as DNA, and thus causing mutations or possibly cancer.

Hermaphroditic - An organism possessing both female and male reproductive structures.

Integrated Pest Management (IPM) - IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of commonsense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interactions with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment. IPM programs take advantage of all pest management options possible, seeking to reduce reliance on chemical treatments and utilizing least-toxic pesticides as a last resort.

Metabolite - A compound produced from chemical changes of a chemical.

Microbiota - Microscopic organisms in a certain area, including microflora and microfauna.

Monoculture - The growth of only one species in a given area; such as a cornfield or other agricultural field.

Non-point Source – A source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct, identifiable sources.

Organochloride - Any of many chlorine substituted organic compounds, many of which are insecticides. Also called an organochlorine or chlorocarbon.

Point Source - A source of pollution that is distinct and identifiable with a confined discharge point.

Maryland Pesticide Network
544 Epping Forest Road
Annapolis, MD 21401

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