

# Environmental Medicine, Part 1: The Human Burden of Environmental Toxins and Their Common Health Effects

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## Abstract

Chemical compounds ubiquitous in our food, air, and water are now found in every person. The bioaccumulation of these compounds in some individuals can lead to a variety of metabolic and systemic dysfunctions, and in some cases outright disease states. The systems most affected by these xenobiotic compounds include the immune, neurological, and endocrine systems. Toxicity in these systems can lead to immune dysfunction, autoimmunity, asthma, allergies, cancers, cognitive deficit, mood changes, neurological illnesses, changes in libido, reproductive dysfunction, and glucose dysregulation. Chemicals and their effects on these systems are reviewed in this article. Subsequent articles in this series will focus on therapeutic regimens to combat the toxic effects of these and other compounds.

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## Environmental Toxic Load

The twentieth century, with its promise of "Better Living Through Chemistry," brought a host of chemical toxin-related illnesses, often referred to as environmental illness. Recent articles in the medical literature have shown the rate of cancers not associated with smoking are higher for those born after 1940 than before, and that this increase in cancer rate is due to environmental factors other than smoking.<sup>1</sup> New medical diagnoses include sick (closed) building syndrome,<sup>2,3</sup> and multiple chemical sensitivity (MCS),<sup>4-6</sup> both of which are known to be related to overexposure to environmental contaminants. The primary action of the major pesticide classes and solvents is to disrupt neurological function.<sup>7,8</sup> In addition to being neurotoxic, these compounds are profoundly toxic to the immune and endocrine systems.<sup>9-11</sup> The adverse health effects are not limited only to those systems, as these compounds can cause a variety of dermatological, gastrointestinal, genitourinary, respiratory, musculoskeletal, and cardiological problems as well.<sup>12</sup>

Our environment is currently flooded with chemicals that are present in our air, water, and food. Since 1976 the U.S. Environmental Protection Agency (EPA) has been conducting the National Human Adipose Tissue Survey (NHATS). NHATS is an annual program that collects and chemically analyzes a nationwide sample of adipose tissue specimens for the presence of toxic compounds. The objective of the program is to detect and quantify the prevalence of toxic compounds in the general population. Specimens are collected from autopsied cadavers and elective surgeries from all regions of the country. In 1982 the EPA expanded beyond their

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Individually meaningless  
 BUT ADDED TOGETHER??  
 LETHAL

**Table 1. Xenobiotic Compounds in Adipose Tissue of U.S. Citizens.** US EPA National Adipose Tissue Survey 1982

Compound	Frequency of Observation (%)	Wet Tissue Concentration (ng/g)
Styrene	100	8-350
1,4-Dichlorobenzene	100	12-500
Xylene	100	18-1,400
Ethylphenol	100	0.4-400
OCDD (dioxin)	100	19-3,700
HxCDD (dioxin)	98	ND-620
1,2,3,4,7,8,9-HpCDD	98	ND-1,300
Benzene	96	ND-97
Chlorobenzene	96	ND-9
Ethylbenzene	96	ND-280
p,p'-DDE	93	ND-6,800
1,2,3,4,6,7,8-HpCDF	93	ND-79
1,2,3,7,8,-PeCDD	91	ND-5,000
Toluene	91	ND-250
2,3,4,7,8-PeCDF	89	ND-90
Beta-BHC	87	ND-570
Total PCBs	83	ND-1,700
Chloroform	76	ND-580
Hexachlorobenzene	76	ND-1,300
2,3,7,8-TCDD	76	ND-14

DDE. DDE is formed by a partial dechlorination of DDT, which can occur in the human body within six months of exposure to DDT. It also occurs in nature, but studies vary as to the t1/2 of DDT in the environment. Previously the t1/2 of DDT was thought to be two years, but recent findings in Yakima, Washington indicate it may be decades in certain circumstances. Upon degradation, DDT becomes DDE or DDD.

In addition, PCBs were found in 83 percent of all samples and beta-BHC in 87 percent, yielding a total of 20 toxic compounds found in 76 percent or

more of all samples. Seventy-six percent of individuals had as much as 25,704 ng of total toxic compounds per gram of fat.

Additional studies yielded similar results. A CDC study of 5,994 persons aged 12-74 years found 99.5 percent had p,p-DDE at serum levels equal to or greater than 1 part per billion (ppb), in a range of 1-379 ppb.<sup>14</sup> A study of adipose levels taken from autopsies of older subjects who had been Texas residents showed the presence of p,p-DDE, dieldrin, oxychlordan, heptachlor epoxide, and para-BHC in 100 percent of samples.<sup>15</sup> A study of four-year-old children in Michigan revealed the presence of DDT in 70 percent, PCB in 50 percent, and PBB in 21 percent.<sup>16</sup> Nursing was the primary source of exposure for these individuals. These ongoing assessments have shown quite clearly it is not a question of if

normal list to look for the presence of 54 different environmental chemical toxins. Their results were astounding. Five of these chemicals – OCDD (a dioxin) and four solvents: styrene, 1,4-dichlorobenzene, xylene, and ethylphenol – were found in 100 percent of the samples (see Table 1). The quantitative ranges of these five compounds were also alarming. OCDD levels ranged from 19-3,700 ng per gram of fat, styrene 8-350 ng/g, 1,4-dichlorobenzene 12-500 ng/g, xylene 18-1,400 ng/g, and ethylphenol 0.4-400 ng/g. These alone would give each person a total toxic burden ranging from 57.4-6,350 ng of toxins per gram of fat.

Another nine chemicals were found in 91-98 percent of all samples, including such toxins as benzene, toluene, chlorobenzene, ethylbenzene, one furan, three dioxins, and

we are carrying a burden of toxic xenobiotic compounds, it is a question of how much and how they affect our health.

### Sources of Environmental Toxins

Multiple chemical load comes from daily exposure to chemical compounds in our indoor and outdoor air, food, and water. The EPA's TEAM study documented the following chemicals to be "ubiquitous" in the air: p-xylene, tetrachloroethylene, ethylbenzene, benzene, 1,1,1-trichloroethane, and o-xylene. Those listed as "often present" were: chloroform, carbon tetrachloride, styrene, and p-dichlorobenzene.<sup>17</sup> This study found air samples taken with a monitor attached to the study individuals had higher levels of chemicals in the personal air space over a 24-hour period than what was recorded in outdoor air samples. These elevated personal and breath levels were more directly attributable to indoor air pollution. However, researchers noted persons who visited a service station or dry cleaner, smoked, or drove a vehicle had elevated personal exposure and breath levels of solvents. They also found certain occupations, such as painting or working in chemical or plastic manufacturing plants resulted in higher exposure levels.

Testing for chemical residues on food, which is routinely done throughout the world, consistently reveals multiple contaminants. The most comprehensive testing in the United States is the ongoing FDA Total Diet Survey.<sup>18</sup> While the Total Diet Survey looks for the presence of many different chemicals, their findings of chlorinated pesticides are alarming. DDE was found in 100 percent of samples of raisins, spinach (fresh and frozen), chili con carne (beef and bean), and beef. Ninety-three percent of American processed cheese, hamburger, hot dogs, bologna, collards, chicken, turkey, and ice cream sandwiches contained DDE. DDE was found in 87 percent of lamb chops, salami, canned spinach, meatloaf, and

butter, and in 81 percent of samples of cheddar cheese, pork sausage, hamburger, white sauce, and creamed spinach. Of all items sampled, 42 had DDE in 63 percent or more of all samples. Foods with the highest concentration of DDE, in descending order, were: fresh or frozen spinach (mean concentration 0.0234 ppm), butter (mean concentration 0.0195 ppm), collards (0.0126 ppm), pork sausage (0.0124 ppm), lamb chops (0.0113 ppm) and canned spinach (0.0109 ppm). Since DDT and DDE have been banned for use in this country since 1972, it is likely some of this contamination is from produce imported from other countries where these chemicals are still used.

**Table 2. The 12 Most Contaminated Fruits & Vegetables.**

Strawberries  
Bell Peppers  
Spinach  
U.S. Cherries  
Peaches  
Mexican Cantaloupe  
Celery  
Apples  
Apricots  
Green Beans  
Chilean Grapes  
Cucumbers

Unless these volatile pesticides, such as DDT and toxaphene, get trapped in the soil, tree bark, or other stable materials, they can begin a wind-driven leapfrogging around the globe. The more volatile the chemical, the faster it enters the air and the less readily it enters the fat of plants or animals it contacts.

**Table 3. Immunotoxicity of DDT**

Reduces killing capacity of polymorphs  
 Reduces the number of plasma responder cells  
 Degranulates mast cells  
 Decreases leukocyte count  
 Decreases phagocytic ability  
 Changes in spleen, thymus, lymph glands  
 Variation in complement  
 Disturbances in fetal and perinatal immune regulation

OCCs, DDT has been found to have the following effects on the immune system: reduced killing capacity of polymorphs, reduced number of plasma responder cells, increased degranulation of mast cells, leukopenia, decreased phagocytic ability, changes in the

DDT is less volatile and tends to stay longer where it lands. Volatile chemicals applied in tropical regions evaporate into the atmosphere and then condense in cooler climates. As the ambient temperature falls, the compound becomes less volatile, slowing the spread of the compound. In other words, if two forests were exposed to identical amounts of a volatile pesticide, trees in the colder climate would become more heavily contaminated.

This global leapfrogging may account for the results of a study on the diet of arctic indigenous women. The diets of two groups of women (from the eastern and western Canadian Arctic) were found to be very high in organochlorine compounds (OCCs). The primary sources of these compounds were the meat and blubber of ringed seal, walrus, mattak, and narwhal, as well as caribou, whitefish, inconnu, trout, and duck.<sup>19</sup> Since these OCCs were transported in the air, they landed in the arctic, but due to the low temperature were unable to volatilize again.

### Adverse Immune Effects of Environmental Pollutants (Immunotoxicity)

Environmental chemicals have a wide range of effects on immune system function, ranging from decreased cell-mediated immunity (with a decrease in ability to fight infections and tumors) to increased sensitivity (allergy) and autoimmunity.<sup>11,19,20</sup> Among the

spleen, thymus, and lymph glands, variation in complement, and disturbances in fetal and perinatal immune regulation. Similar effects have also been found from exposure to chlordanes (used as termiticides in the United States and Canada until 1978, when they were banned for home use; they are still used on certain crops and in some seed treatment) and hexachlorobenzene (HCB – a chlorinated pesticide used as a fungicide, and also found in chlorinated solvents such as perchloroethylene used in dry cleaning). Studies of thousands of patients at the Environmental Health Center in Dallas have shown that persons with two or more OCCs present in their serum have some form of immunotoxicity.<sup>21</sup>

Chemicals produced by combustion, the polycyclic aromatic hydrocarbons (PAH), have similar depressing effects on the immune system, including: decreased T-cell-dependent antibody response, decreased splenic activity, diminished T-cell effector functions, suppression of T-cytotoxic induction, depressed natural killer cell activity, as well as being highly carcinogenic.<sup>22</sup> Organophosphate pesticides, which are not as biologically persistent as OCCs, are also toxic to the immune system. They have been found to cause decreased percentages of CD4 and CD5 cells, increased number and percentages of CD26 cells, increased incidence of atopy and antibiotic sensitivity, and high rates of autoimmunity. This elevation in autoimmunity is reflected by high

levels of antibodies to smooth muscle, parietal cells, brush border, thyroid, and myelin, in addition to elevated ANA.<sup>23</sup> Similar immunosuppression has also been found for organotins and heavy metals.<sup>22</sup>

The mode of exposure to a pesticide appears to have an effect on the persistence of immunotoxicity, as demonstrated by two polybrominated biphenyl (PBB) mass exposures. One exposure took place in Taiwan, when rice bran cooking oil was contaminated with PBBs. This oil was used for cooking and the persons who used it were found to have immune system abnormalities. One year after exposure, these persons were found to have decreased concentration of IgM and IgA (with normal IgG), low T-suppressor cells, low B-cells, and suppression of delayed hypersensitivity to recall antigens. When rechecked two years after exposure, the above indices had returned to normal. This was not the case in Michigan, where a massive PPB exposure occurred in 1973-74. During that time period a PBB-containing flame retardant called "Firemaster" was inadvertently sold as an animal feed called "Nutrimaster." This mistake was devastating to both the livestock and the humans who raised them and consumed their products. Exposed individuals were found to have lower levels of circulating T-lymphocytes and reduced lymphoproliferation response, resulting in reduced cell-mediated immunity. These individuals also had a high prevalence of persistent skin, neurological, and musculoskeletal symptoms.<sup>24</sup> These changes have persisted on all subsequent studies, which seems to indicate that when these toxins are concentrated in the food chain before reaching humans, their effect can be longer lasting.

The development of autoimmunity has been linked with chemical exposure as well. The notion of chemically-induced autoimmune states is not new, since many chemicals are known to induce the onset of systemic lupus erythematosus (SLE). Some chemicals, including formaldehyde and other

volatile organic compounds, are thought to induce tissue-specific autoimmune reactions by acting as haptens. These low molecular weight molecules bind to various tissues in the body, making a new antigenic combination. The immune system then produces antibodies to this new combination, which can attack the parent tissue with or without the chemicals being present. Chemically-exposed individuals often present with elevated antibodies to certain body tissues, including anti-myelin, anti-parietal, anti-brush border, and anti-smooth muscle antibodies.<sup>25</sup> A study of 298 patients with exposure to industrial chemicals showed the following abnormalities:<sup>26</sup>

- a. NK activity – chemically exposed patients when compared to controls show either very low activity or very high activity.
- b. Lymphocyte blastogenic response to T-cell mitogens (PHA, CONA) and B-cell mitogens were 30-45 percent lower than controls.
- c. Elevated IgG and IgM levels against formaldehyde, trimellitic anhydride, phthalic anhydride, and benzene. These levels were usually higher in persons with elevated T4/T8 ratios, noted in almost 15 percent of the exposed patients.
- d. Autoantibodies against their own tissue.

For a good review of the numerous studies on the immunotoxicity of pesticides, the author recommends the book, *Pesticides and the Immune System; The Public Health Risks*, published by World Resources Institute, in Baltimore, MD. For a broader view of toxin-related autoimmunity, refer to the papers developed for the Workshop on Linking Environmental Agents to Autoimmune Diseases.<sup>27</sup>

**Table 4.** Home Chemical Use and Childhood Cancer Risk.

Chemical	Association	Odds Ratio
2,4,D	Soft Tissue Sarcomas	4.0
No Pest Strips	Leukemias	3.0
Insecticide Use	Brain Tumors	2.3 (<age 20)
Insecticide Use	Nonlymphocytic Leukemia	3.5
Household Pesticide Use	Leukemias	4.0
Garden Pesticide Use	Leukemias	5.6

### Toxin-Associated Cancers

As mentioned earlier, the Davis study<sup>1</sup> revealed men born in the 1940s had twice the cancer incidence as those born from 1888-1897, even when smoking was factored out. Women born in the 1940s had 50 percent more total cancers; with 30 percent more cancer not linked to smoking in white women.

Three studies have shown elevated levels of OCCs in adipose tissue of breast cancer patients as compared to controls. The chemicals found in higher amounts in the malignant persons were: DDT, DDE, PCBs, and hexachlorocyclohexane (HCH – also known as lindane, Kwell shampoo, or BHC, a chlorinated pesticide commonly used to treat lice infestations).<sup>28-30</sup> Not only are these compounds higher in the adipose tissue of breast cancer patients, but they are actually found in higher levels in malignant tissue than in adjacent healthy tissue. These studies indicate that breast tissue concentrates OCCs more than adipose stores in other body locations. Serum levels of OCCs have also been associated with increased risk of breast cancer. Elevated levels of DDE and PCB in the serum can result in a four-fold increased risk of breast cancer,<sup>31</sup> although other studies have not found such a correlation between breast cancer and serum pesticide levels.<sup>32,33</sup>

The epidemiological association between chemical exposure and childhood cancers has also been examined (see Table 4). In one study, 45 childhood brain cancer patients

were compared to 85 friend controls. A significant positive association was found between brain cancer and exposure to No-Pest Strips, termite treatment, Kwell Shampoo (lindane), flea collars on pets, diazinon use in the garden or orchard, and the use of herbicides in yards (odds ratio [OR] 6.2). When compared to 108 cancer controls, a significant positive association was found between brain cancer and home pesticide bombs, termite treatment, pet flea collars, and garden use of insecticides, carbaryl, and herbicides.<sup>34</sup>

Several other studies have found 2,4-D (a common weed killer) use around the home was associated with soft tissue sarcomas (OR 4.0).<sup>35</sup> Having No-Pest Strips in the home was associated with leukemia (OR 3.0); insecticide use in the home was associated with brain tumors for ages <20 (OR 2.3); household pesticide use was associated with leukemia (OR 4.0); garden pesticide use with leukemia (OR 5.6); and, household insecticide use with non-lymphocytic leukemia (OR 3.5).

For adults the use of chlorophenoxy acid herbicides (such as 2,4-D) has been strongly associated with increased incidence of lung cancer, stomach cancer, leukemia, Hodgkin's lymphoma (two studies found a five-fold risk), non-Hodgkin's lymphoma (NHL – five to six-fold increased risk), and soft tissue sarcomas (many studies have shown a five to seven-fold increased risk, and one review study reported a 40-fold increased risk).<sup>36</sup> 2,4-D gained notoriety from its combination with 2,4,5-T to form a mixture known

as Agent Orange. 2,4-D is commonly used by municipalities and states as a spray on roadways and right-of-ways to inhibit weed growth. It can be purchased at home stores for home lawn care and is often applied by chemical lawn care companies. It contains several dioxin contaminants and, in the author's opinion, is toxic to animals, children, and adults. One study showed Kansas farmers using herbicides 20+ days per year have six times the risk of developing lymphoma and soft tissue sarcomas compared to non-exposed individuals. Those who mixed and applied herbicides and were exposed 20+ days per year were eight-times as likely to contract NHL.

Other factors associated with increased risk of NHL from 2,4-D exposure are:

- (a) increased period of time of exposure;
- (b) not using protective equipment;
- (c) using backpack or hand sprayers;
- (d) employing tractor mounted or mist blower sprayer; and
- (e) aerial spraying of herbicides.

### **Hematological Malignancies**

Several studies have associated exposures to solvents with acute myelogenous leukemia, multiple myeloma, and other forms of leukemia. A retrospective cohort study of 14,457 workers exposed to trichloroethylene between 1952 and 1953 showed mortality was raised for multiple myeloma and NHL in white women.<sup>37</sup> In a Finnish study, workers exposed to 1,1,1-trichloroethylene showed increased cancers of the cervix and lymphohematopoietic tissues. After 10 years (from first personal measurement) increased rates of pancreatic cancer and NHL were seen. At a 20-year follow-up, increased multiple myeloma and cancer of the nervous system were found. Workers exposed to trichloroethylene showed (after a 20-year follow-up) an increase in rates of cancers of the stomach,

liver, prostate, and lymphohematopoietic tissues.<sup>38</sup>

A review article by Fleming and Timmeny revealed there have been 280 cases of aplastic anemia associated with pesticide exposure reported in the literature. The majority of these cases were young (average age 34) with a short latency (mean, five months) and had a history of occupational exposure to pesticides.<sup>39</sup> Another study which examined the cancer risk for painters showed an increased incidence of multiple myeloma (OR 1.95, 95% CI), bladder tumors (OR 1.52, 95% CI), as well as kidney and other urothelial tumors (OR 1.45, 95% CI).<sup>40</sup> A Swedish study of 275 confirmed multiple myeloma diagnoses found a clear association between farming and multiple myeloma, with exposure to chlorophenoxy acid herbicides (2,4-D) and DDT being prime risk factors.<sup>41</sup>

### **Neurotoxicity**

Most of the major classes of pesticides are neurotoxins by design; i.e., they kill pests by attacking the nervous system. OCCs affect the nerve by disrupting ion flow along the axon. Organophosphate pesticides, which were developed from nerve gas research, and carbamates affect acetylcholinesterase, resulting in excessive acetylcholine levels in synapses. Solvents, some of which were originally used as anesthetics, dampen the propagation and transmission of electrical impulses along nerve axons. These agents produce various forms of toxic encephalopathy (acute or chronic, selective or diffuse toxic encephalopathies), as neuronopathies, axonopathies, myelinopathies, or vasculopathies.

Neuronopathies can be diffuse or selective, depending on whether specific neurons are affected, or if the damage is more broadly spread throughout the nervous system. The target site of toxic agents producing neuronopathies is the nerve cell body, with the consequence of either axonal or dendritic breakdown.

**Table 5.** Common Symptoms of Toxic Damage to the Endocrine System

1. Sleep disturbances or changes in energy level or mood.
2. Alterations in weight, appetite, and bowel function.
3. Sexual interest and function change. In female, any menstrual change.
4. Changes in temperature perception, sweating, or flushing.
5. Alterations of hair growth and skin texture.

An example of a neurotoxin causing diffuse neuronopathy is methylmercury, which has been found to preferentially damage the granule cells of layer IV in the visual cortex, granule cells in the granular layer of the cerebellum, and sensory neurons of the dorsal root ganglia.<sup>22</sup> This results in neuronal degeneration progressing to necrosis with axonal dystrophy and demyelination. Another example is aluminum, which has been found to cause fatal dialysis encephalopathy following 3-7 years of intermittent dialysis. Although brain aluminum levels were elevated, there was no evidence of neurofibrillary tangles in these patients, indicating the presence of aluminum alone is insufficient to lead to senile dementia of the Alzheimer's type.

The neuronopathies can also be selective, affecting only certain neurons. Examples of agents causing selective neuronopathies include doxorubicin (Adriamycin), which affects the dorsal root ganglia; cisplatin, which affects sensory neurons; and manganese (metal fume fever), which produces a Parkinson-like syndrome. Manganese-induced damage is found in the substantia nigra, globus pallidus, and caudate nucleus, with depletion of dopamine and serotonin levels. Symptoms begin as psychiatric changes, followed by impaired motor activity with muscle rigidity and tremors. Parkinsonism can also be caused by MPTP, an illicit synthetic opioid derivative.<sup>42</sup> This compound can cause sudden Parkinson-like symptoms after exposure. MPTP is metabolized in monoamine oxidase (MAO)-containing tissues to MPP<sup>+</sup>, the ultimate neurotoxin to MAO-containing tissues. MPP<sup>+</sup> is

selectively toxic to substantia nigra cells, effectively knocking out dopamine production.<sup>43</sup>

The area of the axon affected differentiates axonopathies. The proximal axon is different in its ability to initiate action potentials and synthesize protein. Damage to this part of the axon is referred to as proximal axonopathy, and is the type of damage seen in amyotrophic lateral sclerosis (ALS). Proximal axonopathies are often caused by volatile organic compounds (halomethane, methylene chloride, carbon tetrachloride, and butane), all of which decrease the excitability of the neuron by stabilizing membranes and decreasing ion flux. Distal axonopathies have been shown to be caused by a variety of compounds, including acrylamide (a polymerizing agent used to strengthen paper), which primarily affects sensory fibers. Carbon disulfide (a solvent for fats and lacquers and for extraction of oil from olives, palmstones, and other oil-bearing fruits), affects sensory and motor fibers. Hexacarbon solvents lead to multifocal distal progressive sensory-motor axonopathy with giant axonal swelling; paranodal demyelination of swollen axons occurs frequently with exposure to these solvents. Organophosphate pesticides (parathion, malathion, diazinon, etc.) destroy available acetylcholinesterase by phosphorylation, which is irreversible (unless an antidote is given within 24 hours). Exposures may be additive and the effects can last until more acetylcholinesterase is synthesized. Carbamates (carbaryl, sevin, aldicarb) carbamylate the acetylcholinesterase, which is reversible since it is not a stable bond and can be hydrolyzed easily.



Myelinopathies are caused by organotins, which are used as stabilizers in plastic polymers and catalysts in silicon and epoxy curing. They are also used in wood and textile preservation as fungicides, bactericides, and insecticides. Examples of organotins are TET and TMT. Hexachlorophene (HCP), added to soap for antimicrobial action, also causes myelin damage. It is readily absorbed through intact skin and mucus membranes, and like TET and TMT can cause blurred vision and muscular weakness, progressing to paralysis. The optic nerve is particularly susceptible to HCP and to particular solvents such as ingested methanol and ethanol, inhaled trichloroethylene, toluene, CS<sub>2</sub>, and benzene. Other solvents can lead to specific myelinopathies; for example, the trigeminal nerve is especially sensitive to trichloroethylene (found in dry cleaning fluid). Hearing loss is commonly caused by toluene, styrene, xylene, and trichloroethylene, which cause myelin damage to the vestibulocochlear nerve. Other toxins, such as carbon monoxide and Cuprisone (a copper-chelating agent used in the treatment of Wilson's disease), are examples of toxins affecting the maintenance of myelin.

### Endocrine Toxicity

In addition to the well-documented estrogenic effects of OCCs, actual damage to the endocrine organs can also occur. The most common symptoms of toxic damage to the endocrine system are:

- (a) sleep disturbances or changes in energy level or mood;
- (b) alterations in weight, appetite and bowel function;
- (c) sexual interest and function change; in females any menstrual change;
- (d) changes in temperature perception, sweating, or flushing; and
- (e) alteration of hair growth and skin texture.

With the exception of reproductive effects, most of these endocrine symptoms occur only after immunological and/or neurological symptoms are already present.

Aliphatic solvents, such as n-hexane, cause necrosis of zona fasciculata and zona reticularis of the adrenals, where glucocorticoids are produced. OCCs and carbamates have demonstrated histological changes to these areas in animal models.<sup>22,44</sup> Cadmium and carbon tetrachloride have both been shown to cause non-specific inhibition of steroidogenesis. Occupational lead workers showed decreased secretion of glucocorticoids (17-hydroxy) and androgenic steroids (17-keto). In these persons, the lesion was apparently at the hypothalamus/pituitary level, because a normal ACTH response was found with stimulation.<sup>22</sup> Dioxins and mirex (used to treat fire ants) caused direct suppression of glucocorticoid synthesis, resulting in hypoglycemia.<sup>45</sup>

The thyroid is not immune to environmental toxins, as many chemicals can cause a reduction of both T<sub>4</sub> and T<sub>3</sub> levels. Inducers of hepatic cytochrome P450, such as phenobarbital, benzodiazepines, calcium-channel blockers, steroids, retinoids, chlorinated hydrocarbons, and polyhalogenated biphenyls can lead to reduction in T<sub>4</sub>. Phenobarbital and PCBs (found in 83 percent of NHATS samples, ranging up to 1,700 ng/g) have both been shown in animal models to increase the activity of hepatic UDP-glucuronyl transferase, leading to increased bile flow and biliary excretion of tyrosine-glucuronide. Feeding PCB to rats produced a dose-dependent significant reduction in serum T<sub>4</sub> levels, along with marked hypertrophy and hyperplasia of thyroid follicular cells compared to controls. Rats exposed to soil, dust, and air extracts of landfill containing the dioxins TCDD, PCDD, and PCB showed reduced total serum T<sub>4</sub> in a dose-response relationship.<sup>46</sup> Animals fed a diet of fish from the Great Lakes have also exhibited thyroid dysregulation.<sup>47</sup>

Depressed thyroid function has been correlated with exposure to lead, carbon disulfide, and PBBs. It appears the decrease in thyroid hormone secretion in lead workers is secondary to problems with the hypothalamus. In Michigan, PBB-exposed persons showed non-goitrogenic thyroid dysfunction. PCBs are structurally similar to thyroid hormones (both are polyhalogenated compounds with two phenolic rings), allowing them to interact with thyroid hormone receptors, binding proteins, and transport systems. Depending on the dose and the congener, they could either facilitate or impede thyroid-hormone-directed gene regulation. Hydroxylated PCBs (PCBs that have undergone phase-I biotransformation) have actually been shown to bind to transthyretin (serum binding protein) with a higher affinity than thyroid hormones. They can change the kinetics of thyroid hormone transport within the circulatory system or across target-cell membranes and exhibit T3-like or anti-T3-like properties. They can also interfere with the intracellular production of T3. For infants exposed to PCBs this can have a devastating effect on neurological and anatomical development.<sup>48</sup>

In addition to causing reduced functioning, some compounds such as polycyclic hydrocarbons, nitrosamines, and other compounds can initiate thyroid carcinogenesis. A common component of permanent hair dye preparations, 2,4-diaminoaniline sulfate (2,4-DAAS), when fed at high doses caused a 58-percent incidence of thyroid neoplasm in male rats and 42-percent incidence in females, compared to 7-8 percent in controls.<sup>22</sup>

The effects of environmental chemicals, especially the estrogenic OCCs, are well documented. While many were found to be estrogenic, when combined their estrogenicity can increase as much as 1,600 times. Some combinations also cause previously non-estrogenic compounds to become estrogenic.<sup>49</sup> The facts about environmental estrogens have been cogently discussed in Coburn, Dumanski, and

Myers' recent book, *Our Stolen Future*.<sup>50</sup>

There are also non-estrogenic toxic effects of OCCs on male and female reproduction. High levels of OCCs in the serum have been strongly linked to infertility, stillbirths, and miscarriages.<sup>51</sup> Urban air pollution has been associated with reduced male fertility.<sup>52</sup> While there appears to be a worldwide decline in the sperm levels of males,<sup>53</sup> organic farmers have very high sperm density.<sup>54</sup> This gives rise to the theory that exposure to environmental chemicals will lower sperm levels, and avoidance of such chemicals may help return the levels to normal. There have been multiple studies on sperm counts related to one agricultural OCC, dibromochloropropane (DBCP). Exposure to DBCP can lead to azospermia and severe oligospermia.<sup>55</sup> This effect on fertility may be only associated with DBCP or it may serve as a model for other OCC-induced spermatogenesis problems.

### Summary

Humans are now struggling under a burden of multiple environmental toxins. For many individuals, this is not from workplace exposure, but from simply living in a polluted world. Some individuals appear to be less able to clear the daily chemical exposure from the body than others, leading to a total load of toxins that exceeds the ability of the body to adapt. When the toxic load reaches this point, damage to certain organ systems can occur. The major organ systems affected are the immune, neurological, and endocrine systems. Immunotoxicity may be the major factor in the increasing rates of asthma, allergies, cancers, and chronic viral infections. Neurological toxicity can affect cognition, mood, and cause chronic neurological illnesses. Endocrine toxicity can affect reproduction, menses, libido, metabolism, stress-handling ability, glucose regulation, and other important functions. While this all seems overwhelming, there are ways to approach these problems. Subsequent

articles in this series on environmental medicine will address chemical classes and what can be done to help deal with their toxic effects.

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