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The re-emergence of Agent Orange: why are we still so worried? Part 1:

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“Agent Orange”, “Agent White” and “Agent Purple”. They may sound like characters from Quentin Tarantino’s film, ‘Reservoir Dogs’, but they’re actually chemical herbicides used to remove tree leaves and plants on a massive scale.

Agent Orange recently reemerged in the Canadian news when it was revealed that the Ontario government had permitted the use of this defoliant in northern forests, along the highway system and the power line corridors throughout the province until 1981.

But just what is Agent Orange, and why are people so worried about it?

NOTE: This posting will come in three parts.

- The first part: The basic chemical structure of two herbicides in Agent Orange.
- The second part: How did Agent Orange get contaminated with dioxins?
- The third part: Why dioxins are so toxic?

(Cosmoboy says that the first post was a bit difficult to read, but it provided the necessary background. He found the second post much easier!)

Agent Orange belongs to a family of so-called “rainbow herbicides”, designated by a colour-coded stripe on barrels containing each chemical. The herbicides were formulated by Monsanto, Dow and other international multinational chemical manufacturers.

Use of Agent Orange peaked during the Vietnam War. US forces in jungle regions were constantly under fire from well-camouflaged guerilla fighters. To reduce this threat, the US military requested herbicides, in particular Agent Orange, be used to help their soldiers better see the guerillas. Furthermore, the Canadian government collaborated with the US military to test the effectiveness of those herbicides at the Gagetown Canadian Forces Base in New Brunswick. After the Vietnam, Agent Orange and its chemical cousins also were used to keep many North American highways free of plant growth to improve visibility and safety.

The effectiveness of Agent Orange led to many, many people around the world being exposed to this herbicide. Its toxicity, and that of the other rainbow herbicides, became better understood when exposed people showed obvious and serious health impacts during the 1960′s. All of this has inevitably led to years of controversy and public debate that still rages over half a century later.

Much of the public information available relates to the use of Agent Orange and its herbicide cousins in Vietnam War, Gagetown, New Brunswick and elsewhere. Articles tend to focus on the association of Agent Orange with recorded birth defects, certain types of cancers and other diseases. For example, Wikipedia has several entries which list a reasonably accurate history and also issues associated with Agent Orange in the Vietnam War.

Usually, substances in the herbicide such as “2,4,5-T” and “2,4-D” are mentioned in those discussions. But what exactly is “2,4,5-T” and “2,4-D”? What are dioxins? This type of information can be difficult to find.

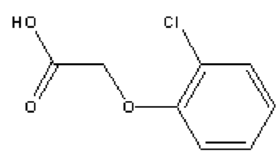
Apart from the highly-technical peer-review scientific literature, there seems to be very little easy access information about the actual substances in Agent Orange, why it is so toxic, and also how it is toxic.

This is probably because detailed chemistry is involved, and is often presented in an inaccessible way. However, understanding the conceptual basics behind the toxicity of Agent Orange is *essential* for public decision-making and public understanding, so here, I'll try to tackle some key aspects of those chemical concepts. Wish me luck!

The primary active constituents of Agent Orange are made of two types of "***chlorophenoxyacetic acids***" . That long scientific name is a way to summarize the basic chemical structure. If you break down this long word into its 4 parts: *chloro*, *phen*, *oxy*, and *acetic-acid*, this name actually tells you what the chemical look like. For example:

- "**Chloro-**" tells us that it has chlorine, which is written like this : Cl.
- "**Phen-**" tells us that it has a a ring of 6 carbons (C) linked together, which is a extremely stable chemical structure. It is often drawn as a hexagon, with each joint representing a carbon atom. This is the backbone for the entire chemical.
- "**Oxy-**" tells us that it has one or more oxygen (O) in the molecule.
- "**Acetic acid**" is the same as as vinegar. It has one carbon linked to a hydrogen (H) and an oxygen-hydrogen (O-H) molecule. Drawn on paper, it looks like a forked tail.

Ok, if we string those components together, we get this chemical structure:



2-chlorophenoxyacetic acid

Do bear with me… all will become clear!

In the diagram above, you can see the 6-carbon hexagon ring. The acetic acid's "forked tail" is linked to the oxygen which is then attached to one of the carbons in the hexagon ring. The chlorine is attached to the second carbon link.

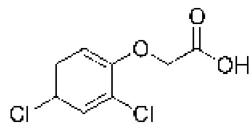
Why is understanding the chemical structure so important? Because the hexagon ring and its attachments holds the clue to the toxicity of many pesticides and herbicides.

The hexagon ring is the basis of many organic compounds. It is stable and does not break apart easily. This is one of the key carbon "backbones" important to all life. Our own biology and the biology of every living creature on the planet uses compounds based on the hexagon ring. In fact, many of our hormones and hormone receptors are actually based on the hexagon ring structure! I will discuss this in the third part oft the blog.

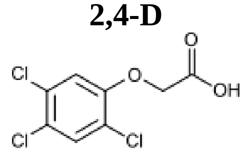
Now, do you see the single "Cl" on the hexagon ring? Precisely how it is attached to the hexagon ring will give the substance its chemical name. What you see above is called "2-chlorophenoxyacetic acid". If you number the carbons in the hexagon ring, starting with the oxy-acetic acid attachment, the chlorine atom is on the second site.

The hexagon ring can hold many chlorine atoms. In fact, all five remaining sites on the hexagon ring can have chlorine atoms. So, when chemists originally formulated Agent Orange, they were looking for certain properties associated with number and location of chlorines. They decided on 2,4,5-trichlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid.

Even chemists don't have time to pronounce long chemical names every day, so those two chemical compounds are shortened to "**2,4,5-T**" and "**2,4-D**". Those names tell you that the first molecule has three chlorine atoms on the hexagon ring, while the second molecule only has two. This is what their chemical structures look like:



2,4-D



2,4,5-T

Take a look at the "Cl" symbols and count their locations around their hexagon ring. You can see how the number of Cl and their location corresponds with the name for each molecule.

This actually affects the chemistry of each molecule so the properties of 2,4-D and 2,4,5-T are slightly different. In combination, they make an effective defoliant because the molecules directly act upon plants as growth inhibitors and cause them to lose their leaves.

Both 2,4-D and 2,4,5-T are also known to be toxic to humans and wildlife, but have short half-life in the environment; i.e., the compounds rapidly break down in the environment to non-detectable concentrations. Long-term toxicity and associated issues are usually not a concern if exposure to those compounds are minimized.

In fact, 2,4-D is still used in some parts of North America as a a broad-leaf weedkiller used for household gardens, agriculture and landscaping. Even so, many regions and municipalities have recently banned this substance.

So why is understanding the chemical structures of chlorophenols in Agent Orange important? I will discuss this in my next post on the formation of dioxin contaminants in Agent Orange tomorrow. For now, take a careful look at the oxygen holding together the acetic acid "forked tail" and the hexagon ring…. this is an important clue in how Agent Orange became even more toxic.

Next - Part 2: formation of dioxin contaminants in Agent Orange.

References & Resources:

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Roland Weber, Mats Tysklind and Caroline Gaus. 2008. Dioxin – Contemporary and Future Challenges of Historical Legacies. *Environmental Science Pollution Research*. 15(2):96-100. [article] DOI: http://dx.doi.org/10.1065/espr2008.01.473. [Subscription required]

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Note: Chemical structure images from Wikipedia Creative Commons image collection.

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