

Dioxin Blood Serum Levels

INTRODUCTION

The many forms of dioxins and furans that are found in the environment are relatively insoluble in water but soluble in many organic solvents and especially soluble in the fatty tissues of animals and humans.

Dioxin levels in the human body are most easily determined from a blood sample. In order to determine dioxin blood serum levels with an accuracy of less than 5 ppt-TEQ (and to allow confirmation re-testing, “splitting” of samples with other agencies and “retain” samples of a small quantity of blood), a sample size of approximately 80 ml (milliliters) (~2.7 ounces) is required.

However, in the event that just a single analysis is required with no “splitting” or “retains”, a much smaller sample (~20 ml) is adequate. The smaller sample required for a single determination of TEQ level would allow the relatively non-invasive testing of children.

The blood sample is separated into the lipid (fatty) portion and the water-based portion of whole blood. The water-based portion of the blood is discarded and the lipid portion is tested for specific dioxins and furans and, typically, a small number of certain PCB's (polychlorinated biphenyls).

Dioxin blood serum levels are commonly reported as picogram (pg) per gram (gm) of serum lipids. A picogram is one trillionth of a gram (10^{-12}). Pg/gm is equivalent to parts per trillion (ppt).

Some researchers have started to report dioxin levels as picograms per kilogram (pg/kg) of total body weight. This is a mathematical conversion from the pg/gm serum lipids levels and takes into account that a human body may be composed of from 15% to more than 35% fat (highly variable between individuals). The more common reporting still remains pg/gm (ppt) serum lipids.

A number of years ago, various health agencies agree to a methodology that allowed comparison of dioxin contamination between sampled locations – the TEQ system.

TEF-TEQ System

TCDD is the most toxic of the 200 to 300 dioxins/furans known to science. It has been extensively studied and a great deal is known about this particular chemical. However, there is a great deal that is unknown about the 16 other highly toxic dioxins and furans. Several regulatory agencies recognized that it was extremely unlikely that the toxicity of these 16 dioxins/furans would be studied extensively. To compensate for this lack of knowledge, regulatory agencies have developed and agreed upon the “TEF-TEQ” system to approximate the relative toxicity of environmental samples containing a varying mix of dioxins and furans.

Over time, the TEF-TEQ system has been extrapolated to blood serum levels in an attempt to quantify the relative health risk of varying levels of dioxins and furans being found in the human body. The basis on which to extend the TEQ system to predict the health risks from different TEQ levels in the body is weak and not substantiated by a great deal of scientific data. The

determination of TEF's, measured in relationship to TCDD, is generally based on feeding studies in laboratory animals, not on blood serum analysis in humans or animals. The use of TEQ in blood serum analysis may be a regulatory convenience rather than a proven scientific hypothesis.

The Toxic Equivalency Factor (TEF) for each of the 17 most toxic dioxins/furans (plus some PCB's) is estimated based on available data on carcinogenicity in laboratory test animals. TCDD is assigned a value of 1 and all other dioxins/furans/PCB's are rated against the carcinogenicity of TCDD. For example, pentachloro-dibenzo-p-dioxin (PeCDD) has been assigned a TEF = 1.0 indicating that is a human carcinogen equal in effect to TCDD. Octachloro-dibenzo-p-dioxins (OCDD) has been assigned a TEF = 0.0001 indicating that its human carcinogenicity is estimated to be 1/10,000 that of TCDD.

The quantity of each dioxin/furan/PCB in a soil, water or blood serum samples is measured and then multiplied by the respective TEF. The 17 or more subtotals are then summed and the combined total is the Toxic Equivalency Quantity (TEQ) expressed, most normally, in units that are equal to ppt-TEQ.

A key assumption is that the cancer risk associated with a given level of TEQ is equal to the cancer risk from the same amount of pure TCDD. A soil sample contaminated with 17 dioxins and furans with a TEQ = 200 ppt is assumed to have the same increased risk of cancer as would a soil sample containing 200 ppt of pure TCDD.

Another assumption is that the cancer effect for each dioxin and furan is additive ($1+1+1 = 3$) and that the total toxicity is equal to the sum of each individual toxicity. There is laboratory animal data that suggests that the additive assumption is true. However, this is also some laboratory data that suggests that the toxicity of certain combinations of dioxins/furans are synergistic ($1+1+1 = 6$) and that the total toxicity is actually much higher than expected.

Despite the reliance of the regulatory agencies on the TEF-TEQ system, it is very certain that there is no actual data, whether laboratory animal or human, on the exact toxicity of the specific combination of dioxins and furans that might be present in a soil sample found in Midland or along the Tittabawassee River. It is a leap of faith to assume that two soil samples with widely varying levels of dioxins and furans – but having the same TEQ – will have the same carcinogenicity or other health effect. Only long term human exposure can confirm this assumption.

In 1996, the DEQ sampled a number of locations in the Dow plant and in the Midland community for dioxin contamination. Two of the community locations were found to have very similar TEQ levels.

Table A
Midland Dioxin Levels, 1996 - ppt

Sample ID	Location	TEQ	TCDD	Total Dioxin
NE-47	(a)	598	288	74,659
NE-20	(b)	652	86	30,116

(a) Intersection, Saginaw Rd & Bay City Road
(b) Intersection, Salzburg Rd & Rackwell Dr

As can be seen, the location with the lowest TEQ (598 ppt) had the highest level of TCDD (288 ppt) and the highest level of total dioxins (74,650 ppt). Total dioxin levels in NE-47 were more than twice the levels found in NE-20.

Based on the TEF-TEQ system, the location with the highest TEQ (652 ppt) should have the highest health risk even though the other location had a much higher number of TCDD and dioxin molecules per unit of soil.

One thing must be kept in mind – TEQ does not attack the human body, actual molecules of dioxins do. The total number of dioxin molecules, as measured by ppt-TCDD or ppt-total, is a critical factor in increased health risk.

TEF Variability

Periodically, health agencies review new or revised information on the toxicity of dioxins and furans and determine if the agreed-upon TEF should be adjusted. The most recent adjustment occurred in 1997 by the World Health Organization. In the 10 years since the EPA first developed the TEF-TEQ system, the relative toxicity of some of the dioxins and furans have increased based on laboratory data. This increase indicates that many of the dioxins and furans are much more toxic than originally thought.

Four dioxins and one PCB (PCB-126) account for approximately more than 80% of the dioxins/furans/PCB's that are found in human tissues. The table below shows the impact that improved estimates of dioxin and furan toxicity (TEF) has had on blood serum levels of TEQ. The dioxin and furan levels are hypothetical. Unfortunately, information on the 1987 TEF of PCB-126 is not available and the TEQ of PCB-126 has not been added to the table.

Table B
Dioxin Blood Serum Levels – 1997 vs. 1987

<u>Dioxin-Furan</u>	<u>Total Dioxin</u> (ppt)	<u>EPA, 1987</u>		<u>WHO, 1997</u>	
		<u>TEF</u>	<u>TEQ</u> (ppt)	<u>TEF</u>	<u>TEQ</u> (ppt)
2378-TCDD	23.7	1.0	23.7	1.0	23.7
12378-PeCDD	58.8	0.5	29.4	1.0	58.8
123678-HxCDD	832.0	0.04	33.3	0.1	83.2
23478-PeCDF	68.6	0.1	6.86	0.5	34.3
Total			93.3		200.0

Based on the same amounts of total dioxins, TEQ levels based on WHO₉₇ (200.0 ppt-TEQ) would be more than twice the level calculated in 1987 using EPA₈₇ TEF values (93.3 ppt-TEQ). As more information on the toxicity of the other dioxins and furans is developed, it is likely that TEQ levels will increase as the TEF for each individual dioxin and furan is better defined.

TEQ Variability With Time

The Dow Chemical Company recently reported dioxin blood serum levels in some of its Midland plant employees previously exposed to pesticide plant dioxins. The results were based on blood samples taken in 2003.

Dow reported results of the study to the DEQ and MDCH in a confidential meeting and to the general public via PR release. The presentation and PR release also reported levels of dioxins in blood serums of U.S. residents supposedly not exposed to any sources of dioxin other than diet and background levels of dioxins in the environment.

The PR release failed to indicate that the CDC-ATSDR study was based on blood sampling that occurred in 1996 to 2001 (time weighted average ~ 2000). Since dioxin levels in the human body are constantly changing, it is extremely important to compare blood serum levels taken in the same year, or, at the very minimum, re-calculate levels to the same year.

The four dioxins that represent approximately 80+% of the total body burden have an average biological half-life of 5.3 years. With only small amounts of additional dioxin intake, body burden levels should be decreasing from year to year.

Table C
Recalculated CDC-ATSDR Dioxin Serum Levels by Age

<u>Age</u>	<u>TEQ</u> <u>2000</u> (ppt)	<u>TEQ</u> <u>2003</u> (ppt)	<u>DowTEQ</u> <u>2003</u> (ppt)
15-29	6.4	4.3	
30-44	11.8	8.0	
45-49	16.9	11.4	
50-59	21.0	14.2	
60-69	27.0	18.2	33 (a)
70-79	34.0	23	
80-89	39.0	26.3	

(a) Midland workers not exposed to pesticide plant dioxins

The correct comparison would be between the results of Dow's 2003 blood sampling and the CDC-ATSDR data recalculated to 2003 levels.

More information on the Dow study is available in Part II of this section of the web site.

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