SUMMARY OF PESTICIDE REMOVAL/ TRANSFORMATION EFFICIENCIES FROM VARIOUS DRINKING WATER TREATMENT PROCESSES

Prepared for the Committee to Advise on Reassessment And Transition (CARAT)
October 3, 2000

The Office of Pesticide Programs (OPP) wants to produce reliable and accurate estimates of pesticide concentrations in drinking water for use in Food Quality Protection Act (FQPA) aggregate and cumulative human health risk assessments. For most pesticides, measurements of pesticide levels in finished water (i.e., water that has gone through the treatment process) are not available. Instead, model-based estimates or actual measurements of pesticide concentrations in raw drinking water are available. OPP recognizes that some water treatment technologies may effectively reduce concentrations of certain pesticides in raw water. OPP also recognizes that pesticides may be transformed into other products a result of treatment. In these cases, what people are exposed to in the "glass" from which they drink may be different from what is present in raw water.

In order to assess these potential effects and to determine whether the Office of Pesticide Programs (OPP) should addresses the treatment issue in the human health risk assessments, OPP has worked with EPA's Office of Research and Development (ORD) and others to research available scientific literature to prepare a paper that is intended to succinctly capture the state-of-the-science on the impact of drinking water treatment on pesticides. A draft of that paper was presented to the FIFRA Scientific Advisory Panel (SAP) on September 29, 2000. The objective of the paper is to provide a preliminary assessment of the impact of water treatment processes on pesticide removal and transformation in treated drinking water derived from ground water and surface water. This assessment would serve as the technical foundation for the new OPP policy on how to factor the impacts of water treatment into drinking water exposure assessment under FQPA.

Conclusions of OPP's Preliminary Literature Survey

In general, conventional water treatment methods used at most community water systems (CWS) – specifically coagulation-flocculation, sedimentation, and conventional filtration – do not appear to facilitate pesticide removal and transformation in finished drinking water. This finding is important because these are commonly used treatment processes at community water systems in the United States. Disinfection and water softening, which also routinely occur at treatment can facilitate pesticide transformation and, in some cases, pesticide degradation. Chemical disinfection can also result in pesticide transformation products. There is, however, limited information on the nature and toxicological importance of pesticide disinfection by-products. The type of disinfectant used and the length of contact time with the disinfectant are important factors in assessing water treatment effects.

Powdered activated carbon (PAC) filtration, granulated activated carbon (GAC) filtration, and reverse osmosis have been demonstrated to be highly effective water treatment processes for removal of organic chemicals, including certain pesticides (primarily acetanilide herbicides), but specific removal

data on most pesticides are not available. Among these treatment processes, PAC is the more common method because it can be used in concert with conventional water treatment systems with no significant additional capital investment. Available data suggest that about 46% of large community water systems (those that serve > 100,000 people) use PAC at some time during the year, and that most of these systems are surface water-based systems. Air stripping is an effective water treatment for volatile pesticides, but this method is used at less than 1% of the community water systems.

A preliminary comparison of the environmental fate properties of pesticides considered in the survey paper with removal efficiencies from the treatment processes does not indicate any trends or relationships, making it difficult to predict removal efficiency for specific compounds without additional data.

The attached tables summarize the effectiveness of various water treatment technologies on the removal and/or transformation of pesticides in drinking water sources, and serve as the basis for the conclusions drawn from this paper.

Key Issues Associated with Factoring Treatment Effects into Drinking Water Assessments

Several key issues in factoring the effects of water treatment into the drinking water assessments emerge from this preliminary survey:

- Certain treatment technologies appear to be ineffective in removing certain pesticides in raw water.

- Some treatment technologies appear to result in the formation of transformation products which may have toxicological significance. However, not a lot of information exists on what is formed, how much is formed, or how long it persists in the treated water.

- Factoring the impacts of drinking water treatment into the drinking water exposure assessment is complicated by the following issues:
    - The limits of laboratory tests to predict treatment plant-scale impacts
    - The impact of the quality of the intake water, the level of the pesticide(s) in the water, and the specifics of the treatment method on the removal efficiency for pesticides
    - Variations in removal efficiency among different treatment methods and within the same treatment methods
    - A significant proportion of the population drinks untreated water, primarily from ground water sources

Removal of Pesticides in Surface Water Sources by Coagulation (Miltner et al., 1989).

Pesticide	Coagulant (dose, mg/L)	Initial Concentration (: g/L)	% Removal
Atrazine	Alum (20)	65.7	0
Simazine	Alum (20)	61.8	0
Metribuzin	Alum (30)	45.8	0
Alachlor	Alum (15)	43.6	4
Metolachlor	Alum (30)	34.3	11
Linuron	Alum (30)	51.8	0
Carbofuran	Alum (30)	93.2	0

Removal of Pesticides Associated with Softening-Clarification at Full-Scale Treatment Plants (Miltner et al., 1989).

Pesticide	Initial Concentration (: g/L)	% Removal and/or Transformation *
Atrazine	7.24	0
Cyanazine	2.00	0
Metribuzin	0.53 - 1.34	0
Simazine	0.34	0
Alachlor	3.62	0
Metolachlor	4.64	0
Carbofuran	0.13 - 0.79	100

* This study did not distinguish between the removal of the pesticide from the system and transformation of the pesticide into another by-product. In the case of carbofuran, evidence suggests that the compound was transformed into carbofuran-phenol and hydroxy-carbofuran.

Removal of Alachlor by Chemical Oxidation (Miltner et al., 1987).

Oxidant	Oxidant dose (mg/L)	Alachlor Concentration (: g/L)	Contact Time (Hr)	% Removal and/or Transformation +
Ozone	6.9	139 (DW)*	0.22	95
	2.6-9.3	145 (GW)**	0.22	79 - 96
	2.3-13.7	0.39 - 5.0 (SW)***	0.22	75 - 97
Chlorine	4.0-6.0	31 - 61 (SW)	2.5 - 5.83	0 - 5
ClO_2	3.0	61 (SW)	2.5	9
	10.0	58 (DW)	22.3	0
H_2O_2	10.0	58 (DW)	22.3	0
$KMnO_4$	10.0	58 (DW)	22.3	0

+ This study did not distinguish between the removal of the pesticide from the system and transformation of the pesticide into another by-product.
*DW=distilled water **GW=Groundwater ***SW=Surface water

Removal of Pesticides in Surface Water Due to Chlorination at Full-Scale Treatment Plants (Miltner et al., 1989).

Pesticide	Initial Concentration (: g/L)	% Removal and/or Transformation +
Atrazine	1.59 - 15.5	0
Cyanazine	0.66 - 4.38	0
Metribuzin	0.10 - 4.88	24 - 98*
Simazine	0.17 - 0.62	0 - 7
Alachlor	0.94 - 7.52	0 - 9
Metolachlor	0.98 - 14.1	0 - 3
Linuron	0.47	4
Carbofuran	0.13	24

+ This study did not distinguish between the removal of the pesticide from the system and transformation of the pesticide into another by-product.
* Metribuzin removal may be the result of sample storage without oxidant quenching. Similar removals in water treatment plants may not be expected.

Removal of Atrazine and Alachlor Using PAC during Full-Scale Treatment.

PAC* (dose, mg/L)	Water Source**	C_o (:g/L)		% Removal	
		Atrazine	Alachlor	Atrazine	Alachlor
WPC (2.8)	Sandusky River (C)	7.83	1.67	28	33
WPC (3.6)	Sandusky River (C)	2.61	1.49	38	36
WPC (8.4)	Sandusky River (R)	12.05	2.84	35	41
WPC (11)	Sandusky River (R)	4.43	2.53	41	41
HDB (18)	Maumee River (R)	8.11	8.21	67	62
HDB (33)	Maumee River (R)	2.39	0.97	87	94

From Miltner et al., 1987 and Miltner et al., 1989.

* PAC type: WPC = WPC Calgon and HDB = Hydrodarco, ICI, America

** (C) = Clarified Water; (R) = Raw Water

Removal of Pesticides by Granulated Activated Carbon Adsorption.

Pesticide	GAC	C_o (:g/L)	% Removal
Atrazine	Calgon Filtrasorb 300*	4.83 (SW)+	47
Cyanazine	Calgon Filtrasorb 300*	1.62 (SW)+	67
Metribuzin	Calgon Filtrasorb 300*	0.89 (SW)+	57
Simazine	Calgon Filtrasorb 300*	0.39 (SW)+	62
Alachlor	Calgon Filtrasorb 400*	3.70 (SW)+	72
	Calgon Filtrasorb 300**	20 (SW)++	95
	Calgon Filtrasorb 300**	50 (SW)++	98
	Calgon Filtrasorb 300**	10 (SW)++	90
Metolachlor	Calgon Filtrasorb 300*	5.60 (SW)+	56
Pendimethalin (dinitroaniline)	Calgon Filtrasorb 400*	0.20 (SW)+	>99

From Miltner et al., 1989

* bed depth = 3 ft, loading = 4 gpm/ft^3, Empty Bed Contact Time (EBCT) = 5.62 min.

** bed depth = 1.5 ft, loading = 4 gpm/ft^3, EBCT = 2.81 min.

+ clarified Sandusky River water

++ Filtered Ohio River water

Removal Efficiencies of Reverse Osmosis Membranes for Different Pesticide Classes.

Pesticide Class	% Removal		
	Cellulose Acetate (CA)	Polyamide	Thin film Composite
Triazine	23 - 59	68 - 85	80 - 100
Acetanilide	70 - 80	57 - 100	98.5 - 100
Organochlorine	99.9 - 100		100
Organophosphorus	97.8 - 99.9		98.5 - 100
Urea Derivative	0	57 - 100	99 - 100
Carbamate	85.7	79.6 - 93	> 92.9

Removal of Pesticides in Ground-Water Sources Using Ultrafiltration With Thin Film Composite Membrane.

Pesticide	Initial Concentration (ug/L)	% Removal
Organochlorine		
Chlordane	< 100	~ 100
Heptachlor	< 100	~ 100
Methoxychlor	< 100	~ 100
VOC		
Dibromochloropropane	< 100	19 -52
Ethylene dibromide	< 100	~ 0
Others		
Alachlor	< 100	~ 100

From Fronk et al., 1990