Draft Final Report

Appendix 1

Food mutagens

Food mutagens include polycyclic aromatic hydrocarbons (PAHs) and heterocyclic amines (HCAs). HCAs are carcinogens formed in or on the surface of well-done meat when cooked at high temperature, and include 2-amino-1-methyl-6-phenylimidazo-[4,5-b]pyridine and PhIP2-amino-3,8-dimethylimidazo[4,5-f]quinoxaline (MeIQx). Cooking conditions can alter the ratios of HCAs in foods, e.g. ratio of PhIP:MeIQx found in meat [1]. The PAHs are a group of around 250 related compounds, including benzo[a]pyrene (BaP), benz[a]anthracene (BaA) and dibenz[ah]anthracene (DBahA). PAHs are present in foods (e.g vegetable oil, fish) following contamination of the environment by combustion of fossil fuels and refuse and are also generated in foods by smoking (FSA 31/02). Although one study using a gastrointestinal simulator concluded that PAH compounds are not estrogenic, but that human intestinal microbiota can bioactivate PAHs and form more estrogenic metabolites [2], other studies have reported estrogenicity of PAHs without deliberate bioactivation, see table.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Heterocyclic amines							
2-amino-1-methyl-6-phenylimidazo-[4,5-b]pyridine (PhIP)	estrogenic in vitro [3] [1]	Grilled salmon, flesh: 29 ng/100g [4]; Cooked meat: 30-4800 ng/100g [5]; Restaurant steak: 2992 ng/100g [6]		Japan, various; 2000-2002	Urine: 0.12-1.97ng/24hr [7]; 5M, 5F, Japan Breast milk: 13-59pg/mL [8]; 9F, Canada		
N2-hydroxy-PhIP	ER antagonist in vitro [1]						
2-amino-3,8-dimethylimidazo[4,5-f]quinoxaline (MeIQx)	ER antagonist in vitro [1]	Grilled salmon, flesh: 10 ng/100g [4]; Cooked meat: 40-2370 ng/100g [5]; Restaurant steak: 128 ng/100g [6]		Japan, various; 2000-2002	Urine: 11-47ng/24hr [7]; 5M, 5F, Japan		
2-amino-1,6-dimethylfuro[3,2-e]imidazo[4,5-b]pyridine (IFP)	ER antagonist in vitro [1]	Restaurant steak: 1438 ng/100g [6]		Various; 2000			
2-amino-3,4,8-trimethylimidazo[4,5-f]quinoxaline (DiMeIQx), aka 4,8 DiMeIQx		Grilled salmon, flesh: 0 (zero) ng/100g [4]; Cooked meat: 20-200 ng/100g [5]; Restaurant steak: 42 ng/100g [6]		Japan, various; 2000-2002			
Polycyclic aromatic hydrocarbons (PAHs)							
Benzo[a]pyrene (BaP)	estrogenic in vitro [9] antiandrogenic in vitro [10]; metabolite is ER antagonist in vitro [11]				Breast milk: below LOD [12]; 21F, Italy		

Benz[a]anthracene (BaA)	estrogenic in vitro [13]; antiandrogenic in vitro [10]; metabolite is ER antagonist, BaA increases E2 metabolism in vitro [11]			Breast milk (mean): 0.325ug/kg milk [12]; 21F, Italy
Dibenz[ah]anthracene (DBahA)	estrogenic in vitro [13] androgenic in vitro [10]; increases E2 metabolism in vitro [11]			Breast milk: below LOD [12]; 21F, Italy
7,12-dimethylbenz[a]anthracene (DMBA)	antiandrogenic in vitro [10]			
Fluoranthene	antiandrogenic in vitro [10]			Breast milk (mean): 0.530ug/kg milk [12]; 21F, Italy
Chrysene	antiandrogenic in vitro [10]; metabolite is ER antagonist in vitro [11]	Chrysene was the most abundant PAH detected in a dietary supplement survey (FSIS 86/05)		Breast milk (mean): 0.281ug/kg milk [12]; 21F, Italy
Pyrene	Weakly antiandrogenic in vitro [10]			Breast milk (mean): 0.775ug/kg milk [12]; 21F, Italy
Phenanthrene	Weakly antiandrogenic in vitro [10]			Breast milk (mean): 0.799ug/kg milk [12]; 21F, Italy
Anthracene	Weakly antiandrogenic in vitro [10]			Breast milk (mean): 0.448ug/kg milk [12]; 21F, Italy
benzo[k]fluoranthene	Metabolite is ER antagonist, increases E2 metabolism in vitro [11]			Breast milk: undetectable [12]; 21F, Italy
indenol[1,2,3-cd]pyrene]	Metabolite is ER antagonist, increases E2 metabolism in vitro [11]			Breast milk: undetectable [12]; 21F, Italy
benzo[b]fluoranthene	Metabolite is ER antagonist in vitro [11]			Breast milk (mean): 0.262ug/kg milk [12]; 21F, Italy
benzo[e]pyrene	Metabolite is ER antagonist in vitro [11]			

PCBs, PCDDs, PCDFs

Persistent organochlorine pollutants (POPs) include polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans(PCDFs). There are 209 PCB congeners, 75 PCDDs and 135 PCDFs; 68 of the PCBs are coplanar molecules, and 12 of these are considered to be "dioxin-like". **PCBs** have many applications, including their use in transformers and other electrical equipment; and have been released into the environment particularly between the 1920s, when production began, and the 1970s, when limits on production were introduced. Due to their persistence and lipophilicity, PCBs have been found to accumulate in biological tissue and to bioconcentrate in the food chain. In the US, serum levels of PCBs decreased from 17ng/ml in 1973, to 4-5ng/ml in 1983, and to around 1ng/ml in 1994-1996; food levels of PCBs decreased from mid-1970s to mid-1980s but remained relatively steady thereafter (at least until 1997)[14]. The so-called 'indicator PCBs' are congeners ~~25~~28, 52, 101, 138, 153 and 180. **PCDD/Fs** are formed by incomplete combustion of organic materials in the presence of chlorine, for example in waste incinerators, fuel burning, manufacturing of pesticides and petroleum products and building fires.

The toxicity of POPs is often assessed using the toxic equivalency factor (TEF) approach which considers toxic effects via the aryl hydrocarbon (AhR) receptor, and relates toxicity of individual POPs to the toxicity of dioxin (TCDD). However, the TEF approach does not consider effects via the receptors for estrogen (ER) or androgen (AR). The presence of the TEQ/TEF systems may have focused attention on this subset of dioxin-like POPs, whereas 1% or less of the total amount of PCBs in fish, for example, are 'dioxin-like'. Estrogenicity might not be predicted for coplanar PCBs, PCDDs and PCDFs which have a flat shape that gives them poor fit into the ER, however non-coplanar PCBs may have the potential to activate the ER because their conformation is not flat. As an alternative to direct receptor-mediated effects, PCBs, PCDDs and PCDFs may have indirect effect on estrogens by inducing enzyme systems that are involved in steroid hormone metabolism (for example, cytochrome P450 1A1). Significant levels of hydroxylated PCB intermediates can be detected in human tissues, and the hydroxylated molecules may have effects that are not caused by the parent compound alone.

Literature: The ATSDR have a toxicological profile for PCBs [14].

Note: where possible data on individual congeners has been sought, rather than group data.

PCBs	
	General comments: Food is the main route of human exposure to PCBs, particularly fish [14] In foods, the PCB congeners detected most frequently and at highest concentrations were **138**, **153** and **118**. The most commonly detected congeners in fish are **138**, **153**, 180, **118**, 110, 101 and 95. *Drinking water.* In 2000 the estimated daily exposure to total PCBs through drinking water was <200ng/day [14] **Additional data available but not tabulated:** *For 12 'dioxin-like' PCBs:* Blood, lung, liver, bile, pancreas, spleen, kidney, mesentery fat; post-mortem samples, Japan, 2001-2002 [15] *For 14 PCBs:* Plasma levels for Latvian and Swedish men, stratified by fish consumption [16]

PCB #	Notes	Endocrine effects	Food level	Human tissue level			
			Food type, level (mean, range etc): value, units; geog. year	*mean ng/g lipid*	*median ng/g lipid*	*reference*	*subjects, location, year, tissue*
1		estrogenic in vitro[17]					
3		estrogenic in vitro[17]					
8	present in human tissue [18]	Shows ER binding[19]; not estrogenic in vitro[18]. Shows AR binding[20].					
9		estrogenic in vitro[17]					
10		estrogenic in vitro[17]					
11				0.39		[21]	Korea, <2007, serum
		not estrogenic in vitro[18]					
14		estrogenic in vitro[17]					
15				0.43		[21]	Korea, <2007, serum
		shows no ER binding[19] not estrogenic in vitro[18] shows no AR binding[20] ,					
16				0.34		[21]	Korea, <2007, serum
17		estrogenic in vitro[18]		0.26		[21]	Korea, <2007, serum
18		estrogenic in vitro[18]		0.58		[21]	Korea, <2007, serum
21		estrogenic in vitro[17]					
22				0.41		[21]	Korea, <2007, serum
24		estrogenic in vitro[17]					
26		estrogenic in vitro[17]					
28	indicator PCB	not estrogenic in vitro[18]; estrogenic in vitro, not anti-estrogenic in vitro[22].		1.12		[23]	Greece, 2002-4, breast milk
				1.35		[23]	Greece, 2002-4, serum
				2.46		[21]	Korea, <2007, serum
				3		in [24]	Swedish women, plasma
				3		[25]	US, adults, <2003, serum
				4.75		[26]	Canadian women, <1994, breast milk (milk fat)
					2	[27]	pregnant women, Sweden, 2000, plasma
					u.d.	[24]	Belgium women, plasma
30		estrogenic in vitro[18]					
31		not estrogenic in vitro[18]		0.86		[21]	Korea, <2007, serum

32				0.29		[21]	Korea, <2007, serum
33				0.34		[26]	Canadian women, <1994, breast milk (milk fat)
				0.66		[21]	Korea, <2007, serum
37				0.62		[21]	Korea, <2007, serum
				1.96		[26]	Canadian women, <1994, breast milk (milk fat)
40				0.64		[26]	Canadian women, <1994, breast milk (milk fat)
41				0.28		[26]	Canadian women, <1994, breast milk (milk fat)
				0.37		[21]	Korea, <2007, serum
43	measured with 49			0.46		[21]	Korea, <2007, serum
44		estrogenic in vitro[18]		0.79		[21]	Korea, <2007, serum
				2		[25]	US, adults, <2003, serum
				6.75		[26]	Canadian women, <1994, breast milk (milk fat)
					u.d.	[24]	Belgium women, plasma
47		Shows no ER binding[19]. Shows AR binding[20].		0.4		[21]	Korea, <2007, serum
					<0.5	[27]	pregnant women, Sweden, 2000, plasma
48		estrogenic in vitro[17]					
49	measured with 43	estrogenic in vitro[18]		0.46		[21]	Korea, <2007, serum
				1.3		[25]	US, adults, <2003, serum
				13.4		[26]	Canadian women, <1994, breast milk (milk fat)
52	indicator PCB	Not estrogenic in vitro[18]; estrogenic in vitro, not anti-estrogenic in vitro[22] ; not ER antagonist, not estrogen modulator in vitro (mitogen), abstract: [28].		0.04		[23]	Greece, 2002-4, serum
				0.73		[23]	Greece, 2002-4, breast milk
				0.87		[26]	Canadian women, <1994, breast milk (milk fat)
	measured with 73			1.06		[21]	Korea, <2007, serum
				2.5		[25]	US, adults, <2003, serum
					<0.5	[27]	pregnant women, Sweden, 2000, plasma
					u.d.	[24]	Belgium women, plasma
56				0.27		[21]	Korea, <2007, serum
59				0.34		[21]	Korea, <2007, serum
60		estrogenic in vitro[17]		0.85		[21]	Korea, <2007, serum
				4.59		[26]	Canadian women, <1994, breast milk (milk fat)
61		estrogenic in vitro[17]		1.13		[21]	Korea, <2007, serum

64				0.63		[21]	Korea, <2007, serum
65		estrogenic in vitro[17]					
66		estrogenic in vitro[18]; estrogenic in vitro, not anti-estrogenic in vitro[22].		1.66		[21]	Korea, <2007, serum
				2.95		[26]	Canadian women, <1994, breast milk (milk fat)
				13.8		[25]	US, adults, <2003, serum
					u.d.	[24]	Belgium women, plasma
70		not estrogenic in vitro[18]		0.75		[21]	Korea, <2007, serum
	present in human tissue [18]						
73	measured with 52			1.06		[21]	Korea, <2007, serum
74		estrogenic in vitro[18] estrogenic in vitro, not anti-estrogenic in vitro[22]		3.69		[21]	Korea, <2007, serum
				13.3		[26]	Canadian women, <1994, breast milk (milk fat)
				55.2		[25]	US, adults, <2003, serum
					13.8	[24]	Belgium women, plasma
75		estrogenic in vitro[17]					
76				0.29		[21]	Korea, <2007, serum
77	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF	Shows no ER binding[19]; not estrogenic in vitro[18].		0		[23]	Greece, 2002-4, serum
	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0		[23]	Greece, 2002-4, breast milk
	non-ortho PCB		Salmon (range): 190-622 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 3.2 pg/g fw. Butter (consensus mean): 4.3 pg/g fw. Salmon (consensus mean): 27 pg/g fw.[30]		u.d.	[24]	Belgium women, plasma
81	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0		[23]	Greece, 2002-4, serum
	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0		[23]	Greece, 2002-4, breast milk
	non-ortho PCB				u.d.	[24]	Belgium women, plasma
82	present in human tissue[18]	estrogenic in vitro[18]					
84	present in human tissue[18]	not estrogenic in vitro[18]					
85				0.33		[21]	Korea, <2007, serum
87		not estrogenic in vitro[18]		0.53		[21]	Korea, <2007, serum
				3.38		[26]	Canadian women, <1994, breast milk (milk fat)
				9.3		[25]	US, adults, <2003, serum

90				0.39		[21]	Korea, <2007, serum
	measured with pcb101			1.64		[26]	Canadian women, <1994, breast milk (milk fat)
92				0.4		[21]	Korea, <2007, serum
95				0.91		[21]	Korea, <2007, serum
99		estrogenic in vitro[18]; partially estrogenic in vitro, not anti-estrogenic in vitro[22].		5.76		[21]	Korea, <2007, serum
				13.2		[26]	Canadian women, <1994, breast milk (milk fat)
				119.7		[25]	US, adults, <2003, serum
					14.5	[24]	Belgium women, plasma
101	indicator PCB	not estrogenic in vitro[18]; not estrogenic in vitro[31]		0.27		[23]	Greece, 2002-4, serum
				0.86		[23]	Greece, 2002-4, breast milk
				1		in [24]	Swedish women, plasma
				1.45		[21]	Korea, <2007, serum
	measured with pcb90			1.64		[26]	Canadian women, <1994, breast milk (milk fat)
				10.3		[25]	US, adults, <2003, serum
					4	[27]	pregnant women, Sweden, 2000, plasma
					u.d.	[24]	Belgium women, plasma
103		estrogenic in vitro[18]					
105		not estrogenic in vitro[18]; partially estrogenic in vitro, not anti-estrogenic in vitro[22]		0.02	0.01	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				0.04	0.02	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				2.15		[21]	Korea, <2007, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			2.5		[23]	Greece, 2002-4, breast milk
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			3.4		[23]	Greece, 2002-4, serum
	mono-ortho PCB		Salmon (range): 4040-9240 pg/g lipid adjusted; UK, 1999 [29].	4.9		[26]	Canadian women, <1994, breast milk (milk fat)
				6.6		in [24]	Swedish women, plasma
				48.4		[25]	US, adults, <2003, serum
					2	[27]	pregnant women, Sweden, 2000, plasma
					7.1	[24]	Belgium women, plasma
106		estrogenic in vitro[17]					
108				0.42		[21]	Korea, <2007, serum

110				0.99		[21]	Korea, <2007, serum
		estrogenic in vitro[18]		1.27		[26]	Canadian women, <1994, breast milk (milk fat)
				4.4		[25]	US, adults, <2003, serum
					u.d.	[24]	Belgium women, plasma
112		not estrogenic in vitro[18]					
114	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.26		[23]	Greece, 2002-4, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.34		[23]	Greece, 2002-4, breast milk
				0.5		[21]	Korea, <2007, serum
					4	[27]	pregnant women, Sweden, 2000, plasma
115				0.34		[21]	Korea, <2007, serum
116		estrogenic in vitro[17]					
118		not estrogenic in vitro[18]; not estrogenic in vitro, not anti-estrogenic in vitro[22]; estrogen modulator in vitro (mitogen) by estrogen depletion, abstract: [28]		0.09	0.07	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				0.19	0.13	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			6.7		[23]	Greece, 2002-4, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			6.9		[23]	Greece, 2002-4, breast milk
				9.57		[21]	Korea, <2007, serum
	mono-ortho PCB		Salmon (range): 14811-31873 pg/g lipid adjusted; UK, 1999 [29].	16.6		[26]	Canadian women, <1994, breast milk (milk fat)
				28		[33]	pregnant women, Holland, 1988-2000, plasma
				31		in [24]	Swedish women, plasma
				204		[25]	US, adults, <2003, serum
					8	[27]	pregnant women, Sweden, 2000, plasma
					29.2	[24]	Belgium women, plasma
122					1	[27]	pregnant women, Sweden, 2000, plasma
123	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.1		[23]	Greece, 2002-4, serum

	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			1.1		[23]	Greece, 2002-4, breast milk
126	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF	not estrogenic in vitro, not anti-estrogenic in vitro[22]		0.0078		[23]	Greece, 2002-4, serum
	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0.0284		[23]	Greece, 2002-4, breast milk
	non-ortho PCB		Salmon (range): 65-203 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.94 pg/g fw. Butter (consensus mean): 1.9 pg/g fw. Salmon (consensus mean): 9.7 pg/g fw.[30]		101.9	[24]	Belgium women, plasma
128		estrogenic in vitro[18]		0.5		[21]	Korea, <2007, serum
				1.76		[26]	Canadian women, <1994, breast milk (milk fat)
				14.7		[25]	US, adults, <2003, serum
					u.d.	[24]	Belgium women, plasma
129				0.62		[26]	Canadian women, <1994, breast milk (milk fat)
130				2.35		[21]	Korea, <2007, serum
133		estrogenic in vitro[17]					
135				0.3		[21]	Korea, <2007, serum
136		estrogenic in vitro[17]					
137				1.63		[21]	Korea, <2007, serum
				14.5		[26]	Canadian women, <1994, breast milk (milk fat)
138	indicator PCB	not estrogenic in vitro[18]; not estrogenic in vitro, estrogen modulator in vitro[22]; estrogen modulator in vitro (gene, mitogen)[34]; estrogen modulator in vitro (mitogen) by estrogen depletion and ER, abstract: [28]. Anti-androgenic in vitro (gene), not androgenic in vitro[34].		0.67	0.55	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				1.49	1.05	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				24		[23]	Greece, 2002-4, breast milk
				28		[26]	Canadian women, <1994, breast milk (milk fat)
				33.93		[23]	Greece, 2002-4, serum
	measured with 163			34		[21]	Korea, <2007, serum
				73		[33]	pregnant women, Holland, 1988-2000, plasma
				120		in [24]	Swedish women, plasma
	measured with 158			374.6		[25]	US, adults, <2003, serum

					39	[27]	pregnant women, Sweden, 2000, plasma
					91.8	[24]	Belgium women, plasma
141				0.36		[21]	Korea, <2007, serum
				0.48		[26]	Canadian women, <1994, breast milk (milk fat)
146				6.93		[21]	Korea, <2007, serum
				10		[33]	pregnant women, Holland, 1988-2000, plasma
				83.6		[25]	US, adults, <2003, serum
149				1.23		[21]	Korea, <2007, serum
				4.3		[25]	US, adults, <2003, serum
					u.d.	[24]	Belgium women, plasma
151				0.51		[21]	Korea, <2007, serum
				0.7		[26]	Canadian women, <1994, breast milk (milk fat)
				9.4		[25]	US, adults, <2003, serum
153	indicator PCB	Not estrogenic in vitro[18]; not estrogenic in vitro, estrogen modulator in vitro[22]; estrogen modulator in vitro (gene, mitogen)[34]; estrogen modulator in vitro (mitogen) by estrogen depletion and ER, abstract: [28]. Not androgenic in vitro(gene), not anti-androgenic in vitro(gene) [34]		1.05	0.92	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				2.29	1.66	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				38.3		[26]	Canadian women, <1994, breast milk (milk fat)
				43.9		[23]	Greece, 2002-4, breast milk
				54.9		[21]	Korea, <2007, serum
				59.8		[23]	Greece, 2002-4, serum
				101		[33]	pregnant women, Holland, 1988-2000, plasma
				210		in [24]	Swedish women, plasma
				514.2		[25]	US, adults, <2003, serum
					56	[27]	pregnant women, Sweden, 2000, plasma
					167.6	[24]	Belgium women, plasma
156		not estrogenic in vitro, weak estrogen modulator in vitro[22]		3.22		[21]	Korea, <2007, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			3.72		[23]	Greece, 2002-4, breast milk
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			4.6		[23]	Greece, 2002-4, serum
	mono-ortho PCB		Salmon (range): 1029-2532 pg/g lipid adjusted; UK, 1999 [29].	6.33		[26]	Canadian women, <1994, breast milk (milk fat)

				12		[33]	pregnant women, Holland, 1988-2000, plasma
				21		in [24]	Swedish women, plasma
				45.6		[25]	US, adults, <2003, serum
					5	[27]	pregnant women, Sweden, 2000, plasma
					15.8	[24]	Belgium women, plasma
157	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.68		[23]	Greece, 2002-4, breast milk
				0.99		[21]	Korea, <2007, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			1		[23]	Greece, 2002-4, serum
	mono-ortho PCB		Salmon (range): 337-689 pg/g lipid adjusted; UK, 1999 [29].	1.26		[26]	Canadian women, <1994, breast milk (milk fat)
				3.9		in [24]	Swedish women, plasma
				12.4		[25]	US, adults, <2003, serum
					1	[27]	pregnant women, Sweden, 2000, plasma
					2.6	[24]	Belgium women, plasma
158				0.57		[21]	Korea, <2007, serum
	measured with 138			374.6		[25]	US, adults, <2003, serum
163	measured with 138			34		[21]	Korea, <2007, serum
166		not estrogenic in vitro[18]					
167	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			1		[23]	Greece, 2002-4, breast milk
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			2		[23]	Greece, 2002-4, serum
	mono-ortho PCB			7.7		in [24]	Swedish women, plasma
				21.1		[25]	US, adults, <2003, serum
					0.8	[24]	Belgium women, plasma
					<0.5	[27]	pregnant women, Sweden, 2000, plasma
168				0.36		[21]	Korea, <2007, serum
169	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0.022		[23]	Greece, 2002-4, serum
	dioxin-like, non-ortho PCB; tissue value back-calculated from TEQ/TEF			0.024		[23]	Greece, 2002-4, breast milk
				1.37		[21]	Korea, <2007, serum

	non-ortho PCB		Salmon (range): 12.4-30.1 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.18 pg/g fw. Butter (consensus mean): 0.37 pg/g fw. Salmon (consensus mean): 1.5 pg/g fw.[30]		112.4	[24]	Belgium women, plasma
170		not estrogenic in vitro[18]; not estrogenic in vitro, estrogen modulator in vitro[22]		0.4	0.4	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				0.93	0.68	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				7.01		[21]	Korea, <2007, serum
				9.19		[26]	Canadian women, <1994, breast milk (milk fat)
				52		in [24]	Swedish women, plasma
				105.6		[25]	US, adults, <2003, serum
	includes pcb190				15	[27]	pregnant women, Sweden, 2000, plasma
					40.1	[24]	Belgium women, plasma
171				0.98		[21]	Korea, <2007, serum
172				1.81		[21]	Korea, <2007, serum
				22.5		[25]	US, adults, <2003, serum
174				0.34		[21]	Korea, <2007, serum
177				2.39		[21]	Korea, <2007, serum
				40.4		[25]	US, adults, <2003, serum
178				2.22		[21]	Korea, <2007, serum
				34.4		[25]	US, adults, <2003, serum
179	present in human tissue[18]	estrogenic in vitro[18]					
180	indicator PCB	Not estrogenic in vitro[18]; not estrogenic in vitro, estrogen modulator in vitro[22]; estrogen modulator in vitro (gene, mitogen)[34]; estrogen modulator in vitro (mitogen) by estrogen depletion and ER, abstract: [28]. Not androgenic in vitro(gene), not anti-androgenic in vitro(gene) [34]		0.92	0.93	[32]	Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				2.16	1.63	[32]	Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum, UNITS ARE NG/ML WET WEIGHT
				20.9		[26]	Canadian women, <1994, breast milk (milk fat)
				23.8		[23]	Greece, 2002-4, breast milk
				28.42		[21]	Korea, <2007, serum

				44		[33]	pregnant women, Holland, 1988-2000, plasma
				61.26		[23]	Greece, 2002-4, serum
				140		in [24]	Swedish women, plasma
				269.2		[25]	US, adults, <2003, serum
					29	[27]	pregnant women, Sweden, 2000, plasma
					104.1	[24]	Belgium women, plasma
183		not estrogenic in vitro[18]		3.41		[21]	Korea, <2007, serum
				3.89		[26]	Canadian women, <1994, breast milk (milk fat)
				41.8		[25]	US, adults, <2003, serum
					8.8	[24]	Belgium women, plasma
185				0.28		[26]	Canadian women, <1994, breast milk (milk fat)
187		not estrogenic in vitro[18]; not estrogenic in vitro, estrogen modulator in vitro[22]		8.7		[26]	Canadian women, <1994, breast milk (milk fat)
				12.32		[21]	Korea, <2007, serum
				145.1		[25]	US, adults, <2003, serum
					18.9	[24]	Belgium women, plasma
189				0.35		[26]	Canadian women, <1994, breast milk (milk fat)
				0.39		[21]	Korea, <2007, serum
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.5		[23]	Greece, 2002-4, breast milk
	dioxin-like, mono-ortho PCB; tissue value back-calculated from TEQ/TEF			0.6		[23]	Greece, 2002-4, serum
				3.5		[25]	US, adults, <2003, serum
190				1.6		[21]	Korea, <2007, serum
191				0.36		[21]	Korea, <2007, serum
				0.63		[26]	Canadian women, <1994, breast milk (milk fat)
193				1.55		[21]	Korea, <2007, serum
				2.43		[26]	Canadian women, <1994, breast milk (milk fat)
194		not estrogenic in vitro, estrogen modulator in vitro[22]		3.76		[26]	Canadian women, <1994, breast milk (milk fat)
				5.21		[21]	Korea, <2007, serum
				80.1		[25]	US, adults, <2003, serum
					14.6	[24]	Belgium women, plasma
195				0.94		[21]	Korea, <2007, serum
				13		[25]	US, adults, <2003, serum

196				1.76		[21]	Korea, <2007, serum
	measured with 203			71.5		[25]	US, adults, <2003, serum
199		not estrogenic in vitro, estrogen modulator in vitro[22]			16	[24]	Belgium women, plasma
200				0.27		[21]	Korea, <2007, serum
201				5.02		[21]	Korea, <2007, serum
				5.04		[26]	Canadian women, <1994, breast milk (milk fat)
				87.9		[25]	US, adults, <2003, serum
202				1.31		[21]	Korea, <2007, serum
203				2.71		[21]	Korea, <2007, serum
		not estrogenic in vitro, estrogen modulator in vitro[22]		2.8		[26]	Canadian women, <1994, breast milk (milk fat)
	measured with 196			71.5		[25]	US, adults, <2003, serum
206				0.57		[26]	Canadian women, <1994, breast milk (milk fat)
				1.59		[21]	Korea, <2007, serum
				46.8		[25]	US, adults, <2003, serum
207				0.24		[21]	Korea, <2007, serum
208				0.45		[21]	Korea, <2007, serum
209		estrogenic in vitro[17]		0.38		[26]	Canadian women, <1994, breast milk (milk fat)
				1.09		[21]	Korea, <2007, serum
				27.4		[25]	US, adults, <2003, serum

PCB metabolites												
Metabolite			Endocrine effects	Human tissue levels								
Name	Abbrev.	related PCB#		Me	Me	Me	Me	Me	subjects, location, year, tissue	ref	Notes
Hydroxylated metabolites											
2-Chloro-4-biphenylol	4-OH-pcb1	1	Shows ER binding[19]								
4-Chloro-4'-biphenylol	4'-OH-pcb3	3	Shows ER binding[19]								
2',5'-Dichloro-2-hydroxybiphenyl	2'-OH-pcb9	9	estrogenic in vitro[17]								
2',5'-Dichloro-3-hydroxybiphenyl	3'-OH-pcb9	9	estrogenic in vitro[17]								
2',5'-Dichloro-4-hydroxybiphenyl	4'-OH-pcb9	9	estrogenic in vitro[17] Shows ER binding[19]								
3,5-Dichloro-2-hydroxybiphenyl	2-OH-pcb14	14	estrogenic in vitro[17]								
3,5-Dichloro-4-hydroxybiphenyl	4-OH-pcb14	14	estrogenic in vitro[17]								
2,2',5-Trichloro-4-hydroxybiphenyl	4-OH-pcb18	18	estrogenic in vitro[17]								
2',4',6'-Trichloro-4-hydroxybiphenyl	4'-OH-pcb30	30	estrogenic in vitro[17]								
2',3',4',5'-Tetrachloro-3-hydroxybiphenyl	3'-OH-pcb61	61	estrogenic in vitro[17]								
2,3,4,5-tetrachloro-4'-biphenylol	4'-OH-pcb61	61	Shows AR binding[20]								
2',3',4',5'-Tetrachloro-4-hydroxybiphenyl	4'-OH-pcb61	61	estrogenic in vitro[17] Shows ER binding[19]								
3,3',5,5'-tetrachloro-4,4'-biphenyldiol	4,4'-OH-pcb72	72	Shows AR binding[20] Shows ER binding[19]								
2',3',4',5,5'-Pentachloro-2-hydroxybiphenyl	6'-OH-pcb106	106	estrogenic in vitro[17]								
	4-OH-pcb107	107					1		Mothers, Sweden, 2000-2001, breast milk	[27]	includes 4'-OH-pcb108
	4-OH-pcb107	107					5		cord blood, Sweden, 2000-2001, plasma	[27]	includes 4'-OH-pcb108
	4-OH-pcb107	107					10		maternal plasma, Sweden, 2000-2001, plasma	[27]	includes 4'-OH-pcb108
	4-OH-pcb107	107				20	20		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	4-OH-pcb107	107				50	30		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-	[32]	

									2004; serum		
	4-OH-pcb107	107			58				Men, Sweden, 1991, plasma	[16]	
	4-OH-pcb107	107			290				Men, high fish diet; Latvia, 1993; plasma	[16]	
	4-OH-pcb107	107		10		60			pregnant women, Holland, 1988-2000, plasma	[33]	
	4-OH-pcb107	107						0.54	Women, median age 62; Sweden, 2000; serum	[35]	
	4´-OH-pcb120	120					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	4´-OH-pcb120	120					2		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4´-OH-pcb120	120					2		cord blood, Sweden, 2000-2001, plasma	[27]	
	4´-OH-pcb130	130					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	4´-OH-pcb130	130					3		cord blood, Sweden, 2000-2001, plasma	[27]	
	4´-OH-pcb130	130					4		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4'-OH-pcb130	130				10	3		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	4'-OH-pcb130	130				0	<3		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	3´-OH-pcb138	138					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	3´-OH-pcb138	138					9		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	3´-OH-pcb138	138					9		cord blood, Sweden, 2000-2001, plasma	[27]	
	3'-OH-pcb138	138				40	30		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	3'-OH-pcb138	138				80	70		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum.	[32]	
	3'-OH-pcb138	138			28				Men, Sweden, 1991, plasma	[16]	
	3'-OH-pcb138	138			74				Men, high fish diet; Latvia, 1993; plasma	[16]	
	3'-OH-pcb138	138		7		45			pregnant women, Holland, 1988-2000, plasma	[33]	
	4-OH-pcb146	146					0.2		Mothers, Sweden, 2000-2001, breast milk	[27]	
	4-OH-pcb146	146					21		cord blood, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb146	146					29		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb146	146				60	50		Pregnant women, Slovakia (70Km	[32]	

									from former PCB manuf. site), 2002-2004; serum		
	4-OH-pcb146	146				170	110		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	4-OH-pcb146	146			66				Men, Sweden, 1991, plasma	[16]	
	4-OH-pcb146	146			160				Men, high fish diet; Latvia, 1993; plasma	[16]	
	4-OH-pcb146	146		10		63			pregnant women, Holland, 1988-2000, plasma	[33]	
	4-OH-pcb146	146						0.68	Women, median age 62; Sweden, 2000; serum	[35]	
	3-OH-pcb153	153					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	3-OH-pcb153	153					5		cord blood, Sweden, 2000-2001, plasma	[27]	
	3-OH-pcb153	153					7		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	3-OH-pcb153	153				50	40		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	3-OH-pcb153	153				100	70		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	3-OH-pcb153	153			20				Men, Sweden, 1991, plasma	[16]	
	3-OH-pcb153	153			57				Men, high fish diet; Latvia, 1993; plasma	[16]	
	3-OH-pcb153	153		5		35			pregnant women, Holland, 1988-2000, plasma	[33]	
	4´-OH-pcb172	172					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	4´-OH-pcb172	172					4		cord blood, Sweden, 2000-2001, plasma	[27]	
	4´-OH-pcb172	172					5		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4'-OH-pcb172	172				30	20		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	4'-OH-pcb172	172				60	40		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	4'-OH-pcb172	172		2		15			pregnant women, Holland, 1988-2000, plasma	[33]	
	4´-OH-pcb178	178					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	4´-OH-pcb178	178					1		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4´-OH-pcb178	178					1		cord blood, Sweden, 2000-2001, plasma	[27]	
	3´-OH-pcb180	180					0.1		Mothers, Sweden, 2000-2001,	[27]	value <0.1 set to = 0.1

									breast milk		
	3´-OH-pcb180	180					1		cord blood, Sweden, 2000-2001, plasma	[27]	
	3´-OH-pcb180	180					2		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	3'-OH-pcb180	180				10	10		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	3'-OH-pcb180	180				30	20		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	3´-OH-pcb187	187					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	3´-OH-pcb187	187					2		cord blood, Sweden, 2000-2001, plasma	[27]	
	3´-OH-pcb187	187					3		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb187	187					0.4		Mothers, Sweden, 2000-2001, breast milk	[27]	
	4-OH-pcb187	187					24		cord blood, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb187	187					49		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb187	187				120	110		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	4-OH-pcb187	187				310	200		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
	4-OH-pcb187	187			68				Men, Sweden, 1991, plasma	[16]	
	4-OH-pcb187	187			120				Men, high fish diet; Latvia, 1993; plasma	[16]	
	4-OH-pcb187	187		20		22			pregnant women, Holland, 1988-2000, plasma	[33]	
	4-OH-pcb187	187						0.47	Women, median age 62; Sweden, 2000; serum	[35]	
	4-OH-pcb193	193					0.1		Mothers, Sweden, 2000-2001, breast milk	[27]	value <0.1 set to = 0.1
	4-OH-pcb193	193					2		maternal plasma, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb193	193					2		cord blood, Sweden, 2000-2001, plasma	[27]	
	4-OH-pcb193	193				10	10		Pregnant women, Slovakia (70Km from former PCB manuf. site), 2002-2004; serum	[32]	
	4-OH-pcb193	193				30	20		Pregnant women, Slovakia (close to former PCB manuf. site), 2002-2004; serum	[32]	
Methyl sulfone metabolites											
	3'-MeSO2-pcb49	49	not estrogenic, weak antiestrogen in vitro[31]								

	4'-MeSO2-pcb49	49	not estrogenic, antiestrogen in vitro[31]								
	3'-MeSO2-pcb101	101	not estrogenic, weak antiestrogen in vitro[31]								
	4'-MeSO2-pcb101	101	not estrogenic, antiestrogen in vitro[31]								
Other, related											
4-hydroxybiphenyl	4-hydroxybiphenyl	na	Shows AR binding[20]								

PCDDs						
Class/ Compound	**Endocrine activity**	**Food relevance**		**Human tissue levels**		
		Food type (e.g fish, veg. etc), level	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
PCDDs, data for class		Estimated dietary intake of dioxins and dioxin-like PCBs fell by around 50% from 1997 and 2001. Especially present in fat-containing foods (e.g. milk, meat (red meat > poultry), fish, eggs) Consumption estimated in 2001 was within the UK TDI (2pg WHO-TEQ/kg bw/day). Levels have not declined by the same amount in the following years UK, 2001 [36] **PCDFs & PCDDs** Cows milk (range): 0.12-0.25ng I-TEF /kg whole milk. UK, <1990 [37]		**7 PCDDs** Body burden (mean (95% CI)): 191 (167-217) pg/g lipid [38] *Placental levels; females, Taiwan, 2000-2001* **Data not tabulated:** *For 7 PCDDs and 10 PCDFs:* Human milk levels, Russia, 1998 [39]. Blood, lung, liver, bile, pancreas, spleen, kidney, mesentery fat; post-mortem samples, Japan, 2001-2002 [15]		
2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, 'dioxin')	Estrogen modulator in vivo [40], and in vitro [41,42], acting via the AhR [43,44]. Not estrogenic in vitro [45].	Salmon (range): 0.51-1.39 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.015 pg/g fw. Butter (consensus mean): 0.036 pg/g fw. Salmon (consensus mean): 0.077 pg/g fw. World-wide, 2000[30] 6% of TCDD content of milk carton paperboard had transferred into milk after 7 days refrigerated storage [37].		Serum (median): 4.9 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 0.15 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0.73 pg/g lipid; Greece, 2002-4, human milk[23]		
12378- PeCDD		Salmon (range): 0.8-4.16 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.021 pg/g fw. Butter (consensus mean): 0.072 pg/g fw. Salmon (consensus mean): 0.13 pg/g fw.[30]		Serum (median): 13.1 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 0.58 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 2.14 pg/g lipid; Greece, 2002-4, human milk[23]		
123478-HxCDD		Salmon (range): u.d.- 0.85 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.018 pg/g fw. Butter (consensus mean): 0.055 pg/g fw. Salmon (consensus mean): 0.032 pg/g fw.[30]		Serum (median): 10.8 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 2.7 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 1.1 pg/g lipid; Greece, 2002-4, human milk[23]		

123678- HxCDD		Salmon (range): u.d.-1.39 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.025 pg/g fw. Butter (consensus mean): 0.1 pg/g fw. Salmon (consensus mean): 0.062 pg/g fw. World-wide, 2000[30]	Serum (median): 42.7 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 10.7 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 5.3 pg/g lipid; Greece, 2002-4, human milk[23]
123789- HxCDD		Salmon (range): undetectable; UK, 1999 [29]. Chicken (consensus mean): 0.014 pg/g fw. Butter (consensus mean): 0.074 pg/g fw. Salmon (consensus mean): 0.032 pg/g fw. World-wide, 2000[30]	Serum (median): 8.5 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 4.8 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 1 pg/g lipid; Greece, 2002-4, human milk[23]
1234678- HpCDD		Salmon (range): undetectable; UK, 1999 [29]. Chicken (consensus mean): 0.12 pg/g fw. Butter (consensus mean): 0.22 pg/g fw. Salmon (consensus mean): 0.13 pg/g fw. World-wide, 2000[30]	Serum (median): 79.2 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 49 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 5 pg/g lipid; Greece, 2002-4, human milk[23]
OCDD		Salmon (range): 0.66-1.47 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.59 pg/g fw. Butter (consensus mean): 1.5 pg/g fw. Salmon (consensus mean): 1.3 pg/g fw. World-wide, 2000[30]	Serum (median): 743.8 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 300 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0 pg/g lipid; Greece, 2002-4, human milk[23]

PCDFs						
Class/ Compound	**Endocrine activity**	**Food relevance**		**Human tissue levels**		
		Food type (e.g fish, veg. etc), level	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
PCDFs, data for class				*10 PCDFs:* Body burden (mean (95% CI)): 30.6 (22.8-41.1) pg/g lipid [38] *Placental levels; females, Taiwan, 2000-2001*		
2,3,7,8-TCDF	Estrogen modulator in vitro, abstract only [46]	Salmon (range): 11.87-48.52 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.12 pg/g fw. Butter (consensus mean): 0.089 pg/g fw. Salmon (consensus mean): 1.1 pg/g fw. World-wide, 2000[30]		Serum (median): undetectable pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 0.1 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0.5 pg/g lipid; Greece, 2002-4, human milk[23]		
1,3,6,8-TCDF	Estrogen modulator in vitro, abstract only [46]					
12378-PeCDF		Salmon (range): 0.88-5.65 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.031 pg/g fw. Butter (consensus mean): 0.075 pg/g fw. Salmon (consensus mean): 0.17 pg/g fw. World-wide, 2000[30]		Serum (median): 3.1 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 0.2 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0.2 pg/g lipid; Greece, 2002-4, human milk[23]		
1,2,3,7,9-PeCDF	Estrogen modulator in vitro, abstract only [46]					
2,3,4,7,8-PeCDF	Estrogen modulator in vitro, abstract only [46]	Salmon (range): 3.75-13.95 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.066 pg/g fw. Butter (consensus mean): 0.12 pg/g fw. Salmon (consensus mean): 0.5 pg/g fw. World-wide, 2000[30]		Serum (median): 30.8 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 4.26 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 6.26 pg/g lipid; Greece, 2002-4, human milk[23]		
123478-HxCDF		Salmon (range): u.d.-0.68pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.033 pg/g fw. Butter (consensus mean): 0.083 pg/g fw. Salmon (consensus mean): 0.052 pg/g fw. World-wide, 2000[30]		Serum (median): 12.2 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 4.3 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 1.6 pg/g lipid; Greece, 2002-4, human milk[23]		
123678-HxCDF		Salmon (range): u.d.-0.78 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.021 pg/g fw. Butter (consensus mean): 0.082 pg/g fw. Salmon (consensus		Serum (median): 10.7 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 3.2 pg/g lipid; Greece, 2002-4, serum[23].		

		mean): 0.045 pg/g fw. World-wide, 2000[30]	Breast milk (mean): 1.6 pg/g lipid; Greece, 2002-4, human milk[23]
234678-HxCDF		Salmon (range): u.d.-1 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.018 pg/g fw. Butter (consensus mean): 0.077 pg/g fw. Salmon (consensus mean): 0.052 pg/g fw. World-wide, 2000[30]	Serum (median): 5.7 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 4.1 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0.7 pg/g lipid; Greece, 2002-4, human milk[23]
123789-HxCDF		Salmon (range): undetectable; UK, 1999 [29]. Chicken (consensus mean): 0.014 pg/g fw. Butter (consensus mean): 0.069 pg/g fw. Salmon (consensus mean): 0.045 pg/g fw. World-wide, 2000[30]	Serum (median): 2.3 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 1.3 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0.2 pg/g lipid; Greece, 2002-4, human milk[23]
1234678-HpCDF		Salmon (range): undetectable; UK, 1999 [29]. Chicken (consensus mean): 0.051 pg/g fw. Butter (consensus mean): 0.25 pg/g fw. Salmon (consensus mean): 0.15 pg/g fw. World-wide, 2000[30]	Serum (median): 11.6 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 30 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 1 pg/g lipid; Greece, 2002-4, human milk[23]
1234789-HpCDF		Salmon (range): undetectable; UK, 1999 [29]. Chicken (consensus mean): 0.009 pg/g fw. Butter (consensus mean): 0.1 pg/g fw. Salmon (consensus mean): 0.022 pg/g fw. World-wide, 2000[30]	Serum (median): 5.1 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 2 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0 pg/g lipid; Greece, 2002-4, human milk[23]
OCDF		Salmon (range): 0.66-1.47 pg/g lipid adjusted; UK, 1999 [29]. Chicken (consensus mean): 0.14 pg/g fw. Butter (consensus mean): 0.5 pg/g fw. Salmon (consensus mean): 0.15 pg/g fw. World-wide, 2000[30]	Serum (median): 14.9 pg/g lipid; Belgium women, 1999, serum[24]. Serum (mean): 0 pg/g lipid; Greece, 2002-4, serum[23]. Breast milk (mean): 0 pg/g lipid; Greece, 2002-4, human milk[23]

Phthalates

Phthalate esters are widely used as plasticizers to decrease the rigidity of certain polymers. Phthalates can leach from plastics and have been found to be ubiquitously distributed in the environment. Uses of phthalates, such as benzylbutylphthalate, as plasticizers include: floor tiles, cellulose plastics, polyvinyl acetates, polyurethanes, polysulfides, synthetic leathers, acrylic caulking, adhesive for medical devices, cosmetics, insecticide. Of particular relevance to food is the use of phthalates in regenerated cellulose films, paper and paperboard for the packaging of liquid, fatty and dry foods. Phthalates are reported to act as anti-androgens via effects on androgen synthesis, reviewed by [47].

Class/ Compound	**Endocrine activity**	**Food relevance**	**Human tissue levels**		
		Food type (e.g fish, veg. etc); level; geog. location, year	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Phthalates (data for class)		Food is a major exposure route for diiso-butyl, dibutyl, and di-2-ethylhexyl phthalates. Other routes are more important for dimethyl, diethyl, benzylbutyl, diisononyl, and diisodecyl phthalates, abstract only, [48].	10 urinary biomarkers of phthalates studied in 90 girls, USA, 2004-2005. 9 of the 10 markers were detectable in >94% of samples [49] Urinary levels of DEHP metabolites measured in 239 children aged 2-14 years; median daily intake was estimated using volume-based (7.8ug/kg bw/day) or creatinine-based (4.3ug/kg bw/day) models [50]. Retrospective study of primary and secondary metabolites of 5 phthalates (DnBP, DiBP, BBzP, DEHP, DiNP) in a total of 634 subjects (326F, 308M, age 20-29) from Germany from 1988 to 2003 (1988, 1989, 1991, 1993, 1996, 1998, 1999, 2001, 2003; >60 subjects per sampling year) [51]. Daily intakes were also estimated from the urinary metabolite levels.		
di-2-ethyl-hexyl phthalate ester (DEHP)	No ER binding, non-estrogenic in vitro or in vivo [52]; Shows ER binding, not estrogenic in vitro [53]	Food is major exposure route, abstract [48]	Estimated daily intake (median): 2.4ug/kg bw/d;, Germany, 2003 [51].		
di-n-butyl phthalate ester (DBP, DnBP)	Weak Shows ER binding, estrogenic in vitro but not in vivo [52]; Shows ER binding, estrogenic in vitro [53];	Food is major exposure route, abstract [48]	Serum: 72-359nM in [54] referred to WHO, 1997. Estimated daily intake (median): 1.9ug/kg bw/d;, Germany, 2003 [51].		

	estrogenic in vitro [129}		
Butyl-benzyl phthalate ester (BBP, BBzP)	weak Shows ER binding, estrogenic in vitro but not in vivo [52]; estrogenic in vitro [55]; Shows ER binding, estrogenic in vitro [53]; estrogenic in vitro [56]	Food is NOT major exposure route, abstract [48]	Estimated daily intake (median): 0.2ug/kg bw/d;, Germany, 2003 [51].
di-hexyl phthalate ester (DHP)	Shows weak ER binding, estrogenic in vitro but not in vivo [52]		
di-iso-heptyl phthalate ester	no ER binding, non-estrogenic in vitro and in vivo [52]		
di-n-octyl phthalate ester	no ER binding, non-estrogenic in vitro and in vivo [52]		
di-iso-nonyl phthalate ester (DiNP)	no ER binding, non-estrogenic in vitro and in vivo [52]; estrogenic in vitro [56]	Food is NOT major exposure route, abstract [48]	Estimated daily intake (median): 0.4ug/kg bw/d;, Germany, 2003 [51].
Di-iso-decyl phthalate ester	no ER binding, non-estrogenic in vitro and in vivo [52]	Food is NOT major exposure route, abstract [48]	
dis(2-ethylhexyl)adipate (DEHA)	Shows ER binding, not estrogenic in vitro [53]		
di-ethyl phthalate	estrogenic in vitro [56]	Food is NOT major exposure, abstract [48]route	
di-iso-butyl phthalate (DiBP)	estrogenic in vitro [56]	Food is major exposure route, abstract [48]	Estimated daily intake (median): 1.4ug/kg bw/d;, Germany, 2003 [51].
butyl cyclohexyl phthalate	estrogenic in vitro [56]		
di-phenyl phthalate	estrogenic in vitro [56]		
Iso-hexyl-benzyl phthalate	estrogenic in vitro [56]		
Di-tri-decyl phthalate	estrogenic in vitro [56]		

Bisphenol A & other phenols

Bisphenol A is used in the synthesis of polycarbonate plastics, and can leach from polycarbonate plastics if the polymerisation was incomplete or if the plastic is heated (for example when autoclaved for sterilisation) so that the polymer breaks down. Bisphenol A is used in packaging for food and drinks, and the presence of bisphenol A in food has been reported when the food was preserved by canning in polycarbonate-lined tin cans [57]. There is an *Opinion of the Scientific Committee on Food on Bisphenol A* from the European Commission (2002)[58].
Alkylphenols, including 4-nonylphenol and 4-octylphenol, are used as antioxidants and in the synthesis of detergents (alkylphenol polyethoxylates); exposure may occur through drinking water when, for example NP, leaches from PVC tubing used for milk processing and from plastics used in food packaging. Although alkylphenol polyethoxylates are not estrogenic themselves they may be degraded by sewage treatment into free, monoethoxylate and diethoxylate alkylphenols, with free phenols and alkylphenol diethoxylates being estrogenic and resulting in exposure through drinking water [55].
Phenylphenols. Although o-phenylphenol is a pesticide and so not included here, p and m- phenylphenol may have non-pesticide uses, for example p-phenylphenol is used in the rubber industry, with potential for food contact, and in resin manufacture.

Note: literature reports of bisphenol A concentrations are typically for total compound, however since bisphenol A undergoes conjugation in vivo, to glucuronide, this may be an over-estimate of the bioavailable amount.

Class/ Compound	**Endocrine activity**	**Food relevance**		**Human tissue levels**		
		Food type (e.g fish, veg. etc), level	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Bisphenol A (BPA), aka 4,4'-isopronylidenediphenol	estrogenic in vitro [59] and many since including: [17,57,60,61]; estrogenic in vivo, see many refs in [58]. Antiandrogenic in vitro [62], antiandrogenic in vitro [63], not androgenic in vitro [63]	Canned food (mean): 20ug/kg [58,64] Canned meat: 350-420ug/kg [58,64]	UK, 2000	Plasma (mean+/-SD): 4.4+/-3.9ng/ml *Pregnant women; Germany, 2000-2001* [65] Serum (mean +/-SD): 2.0+/-0.8ng/ml *Healthy premenopausal women; Japan, <2002* [66] Serum (mean+/-SEM): 0.64+/-0.1ng/ml *Normal women; Japan, <2002* [67] Serum (mean+/-SEM): 1.49+/-0.11 ng/ml *Normal men, Japan, <2002* [67] Serum (mean+/-SD): 2.5+/-1.5ng/ml *Normal premenopausal women; Japan, <2004* [68] Serum (mean +/-SEM): 0.7+/-0.09ng/ml *Normal women; Japan, <2004* [69]		
Bis(2-ethylhexyl)adipate (BEHA)	Shows ER binding and estrogenic in vitro (mitogen) [70].					

4-nonylphenol	estrogenic in vitro [60] [71] [72]; Shows ER binding and estrogenic in vitro (mitogen) [70].	estimated daily intake: <0.16mg [72]	Swiss	Plasma (range, n=3): 0.2-0.3ng/ml [73] Urine: undetectable, n=5, LOD 0.2ng/ml *Healthy volunteers, age 22-25yrs; Japan <2003.*
4-octylphenol	estrogenic in vitro [60]			
4-tert-octylphenol	Shows ER binding and estrogenic in vitro (mitogen) [70]; estrogenic in vitro [61,63], not androgenic in vitro, antiandrogenic in vitro[63]			Plasma (range, n=3): 0.1-0.2ng/ml [73] Urine: undetectable, n=5, LOD 0.02ng/ml *Healthy volunteers, age 22-25yrs; Japan <2003*
4-n-octylphenol	estrogenic in vitro [61]			
tert-butylphenol	estrogenic in vitro [61,71]			
4-ethylphenol	Shows ER binding and estrogenic in vitro (mitogen) [70].			
4-n-butylphenol	estrogenic in vitro [61]			
nonoxanol-9	estrogenic in vitro [71]			
4-t-butyl cyclohexanol	estrogenic in vitro [61]			
4-n-butyl chlorobenzene	estrogenic in vitro [61]			
4-t-butyl nitrobenzene	estrogenic in vitro [61]			
4-n-butyl aniline	estrogenic in vitro [61]			
p-phenylphenol	estrogenic in vitro [55,63]; Not androgenic in vitro[63], anti-androgenic in vitro [63]			
m-phenylphenol	estrogenic in vitro [55,63] Not androgenic in vitro[63], anti-androgenic in vitro [63]			
2,2’ biphenol	not estrogenic in vitro, not androgenic in vitro, weakly antiandrogenic in vitro [63]			
4,4’ biphenol	not estrogenic in vitro, not androgenic in vitro, weakly antiandrogenic in vitro [63]			
4-dihydroxybiphenyl (DHBP)	Shows ER binding and estrogenic in vitro (mitogen) [70].			
Polymerisers				
n-butylbenzene	Shows ER binding and estrogenic in vitro (mitogen) [70].			
Benzophenone	Shows ER binding and estrogenic in vitro (mitogen) [70].			
p-nitrotoluene	Shows ER binding and estrogenic in vitro (mitogen) [70].			

Antioxidants

Butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are phenolic antioxidants which are added to foods to prolong shelf life and to reduce nutrient loss. Because these substances are added to food they are potentially amongst the easiest chemicals to regulate should an endocrine-related concern be identified.

Class/ Compound	**Endocrine activity**	**Food relevance**		**Human tissue levels**		
		Food type (e.g fish, veg. etc), level	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
2-Tert-Butyl-4-hydroxyanisole (BHA); aka butylated hydroxyanisole	Estrogenic in vitro [17]. Not androgenic in vitro, antiandrogenic in vitro [74]; antiandrogenic in vitro [62]. Estrogen modulator, not antiandrogenic in vivo [75].	Maximum usage levels (FDA): 50ppm in dry breakfast cereals 1000ppm in active yeast approved as a food additive with regulatory limits of 100-200ppm for edible fat and oils inc. animal fats and vegetable oils (JECFA, 1996; WHO, 1999)		Adipose tissue: 0.01ppm, abstract: [76] *Canada, <1986*		
Butylated hydroxytoluene (BHT)	No ER binding[77]. Antiandrogenic in vitro, not androgenic in vitro [74]	"main *potential* sources of BHT": 'pastry, cakes and biscuits', 'chewing gums' and 'vegetable oils and margarines" , Italy, 2000[78]		Adipose tissue: 0.12ppm, abstract: [76] *Canada, <1986*		
Tert-butylhydroquinone						

Phytoestrogens

Phytoestrogens are chemicals with estrogenic properties but that, unlike the man-made 'xenoestrogens', occur naturally in plants, and thus in foods. Phytoestrogens are generally thought to be beneficial with anticancer and antiviral properties. The major groups of phytoestrogens are: isoflavones, which are particularly common in eastern diets (for example in soy and tofu); lignans, which are probably the most common phytoestrogens in the western diet; and coumestans, which includes coumestrol – one of the more estrogenic phytoestrogens. Other smaller groups include flavones, and mycoestrogens. Phytoestrogens may occur in various forms in foods (for example as glucosides) and may undergo metabolism both in the gastrointestinal tract prior to absorption (for example deconjugation to the aglycone, or demethylation) and in the body (for example sulphate conjugation). The estrogenicity of both the parent compound and the metabolites are of potential relevance, and in some cases the aglycone has been identified as the bioactive form, rather than the glucoside. Phytoestrogens may also exert effects by acting as tyrosine kinase inhibitors, by inhibiting DNA topoisomerase I and II or by acting as antioxidants.
Additional literature: Phytoestrogens have been reviewed as a possible alternative to HRT therapy, for example preparations of red clover sold as nutritional supplements [79]. A study of the effects of a mixture of phytoestrogens on uterine growth in prepubertal rats reported additive effects [54]. There is detailed information on phytoestrogens in a 'western' diet (Canada), abstract: [80]. Pharmacokinetics of daidzein and genistein after a food bolus [81]. Matsumara *et al.* compare eight phytoestrogens in various comparable assays, and discuss the likelihood of anti-estrogenic effects [82].
FSA: COT review of chemistry of phytoestrogens and analytical methods[83], Draft report from the COT Working Group on Phytoestrogens [84].

Class/ Compound	Endocrine activity	Food relevance		Human tissue levels		
		Food type (e.g fish, veg. etc), level	Geog. location, year	Tissue (plasma, lipid etc	Mean/ median levels	Subjects (gender, age, diet),Geog. location, year
Phytoestrogens (data for class)		Lignans typically found in broccoli and cauliflower, Isoflavonoids typically found in soy. Almost by definition, any phytoestrogen has the potential to be found in certain foods, however the concentration may vary and human exposure will vary greatly depending on diet. Further food level and estimated human intake information in [84]. Food levels of phytoestrogens and likely dietary sources, for women in US [85]. 10mg miso (probably due to genistein) or 10ml beer (probably due to 8-prenylnaringenin) were equivalent to 1pmol 17β-estradiol in the YES[86]		Plasma levels of phytoestrogens varied across Europe, with many subjects having undetectable (<0.4nM) levels: glycitein (80%), o-DMA (73%), equol (62%) Vegetarian/vegan subjects had levels 5-50 fold higher than subjects with a non-vegetarian diet. abstract: [87]. A mixture reported to be constructed based on human serum ratios was (ug/kg): coumestrol (0.001), genistein (30.8), naringenin (6.21), quercetin (3.86), catechin (4.63), epicatechin (16.55) [54].		
Coumestans						

Coumestrol (COM)	Shows ER binding [88]; estrogenic in vitro and in vivo [89]; shows ER binding and estrogenic in vitro (mitogen) [70]; shows ER binding, estrogenic in vitro (gene, mitogen)[82]. Shows no AR binding [20]	Found in alfalfa sprouts and various beans	
Isoflavones			
Genistein (GEN)	Estrogenic in vitro [60], estrogenic in vitro and in vivo[89]; Shows ER binding and estrogenic in vitro (mitogen) [70]; estrogenic in vitro (gene) [90]; binds ER, estrogenic in vitro (gene) [90]; sstrogen modulator in vitro against 17β-estradiol and pesticides [91]; shows ER binding and estrogenic in vitro (gene, mitogen)[82]. Shows AR binding [20,92].	Vegetables: 1-3 mg/100g Soy products: 20-1100 mg/100g Non soy legumes: 0-80 mg/100g *all reviewed in [89]* GEN is the most estrogenic component of red clover [90] Miso: 3.2-394 ug/g Tofu: 1.4-9 ug/g Soy sauce: 0.1-2.6 ug/ml [86]	*Plasma (mean(range)): 83.9 (9.2-303) nM [93]* Pregnant women, age 20-30; Japan, 1985 *Serum (mean): 7.1 nM [94]* Healthy women, aged 34-65; New York, 1985-91 *Plasma (median(10-90%range)) [95]:* On Western diet: 2.05(0-5.1) ng/ml On vegetarian diet: 12.1 (0-25.5) ng/ml On high soy diet: 74.6 (0-319) *Plasma (mean +/-SD), after 10wk high soy diet [96]:* 691 +/- 690 nM (EP), 806+/-1238 nM (NEP). Plasma levels for different populations and diets have been summarised: mean range 0.5-276 nM [89].
Biochanin A (GEN precursor)	Estrogenic in vitro and in vivo [89]; shows ER binding and estrogenic in vitro (gene) [90]; shows ER binding and estrogenic in vitro (mitogen) [70]. Shows AR binding [92]		

Daidzein (DAI)	Estrogenic in vitro and in vivo [89], shows ER binding, estrogenic in vitro (gene) [90]; Shows ER binding and estrogenic in vitro (mitogen) [70]; shows no ER binding and estrogenic in vitro (gene, mitogen)[82]. Shows AR binding [92]	Vegetables: 1-3 mg/100g Soy products: 20-900 mg/100g Non soy legumes: 0-10 mg/100g Fava beans: 100 mg/100g *all reviewed in [89]*	Plasma (mean(range)): 45.5 (2-243) nM [93] *Pregnant women, age 20-30; Japan, 1985* Serum (mean): 3.1 nM [94] *Healthy women, aged 34-65; New York, 1985-91* Plasma (mean(range)): 8.2 (1.2-36) ng/ml [97] *Men; UK, 1997* Prostatic fluid (mean(range)): 11.3 (u.d. – 62) ng/ml [97] *Men; UK, 1997* *Plasma (median(10-90%range)) [95]:* On Western diet: 3.2 (0-8.5) ng/ml On vegetarian diet: 12.7 (0.7-24.7) ng/ml On high soy diet: 30.4 (0-143) ng/ml *Plasma (mean +/-SD), after 10wk high soy diet [96]:* 369 +/- 456 nM (EP), 310 +/- 244 nM (NEP). Plasma levels for different populations and diets have been summarised: mean range 0.6-107 nM [89].
Formononetin (DAI precursor)	Estrogenic in vitro and in vivo [89]; binds ER, estrogenic in vitro (gene) [90]; Shows ER binding and estrogenic in vitro (mitogen) [70]. Shows AR binding [92]		

Equol (DAI metabolite)	Estrogenic in vitro and in vivo[89]; shows ER binding and estrogenic in vitro (mitogen) [70]; shows ER binding, estrogenic in vitro (gene, mitogen)[82]. Anti-androgenic in vivo (but by sequestering DHT and not by AR binding)[98]; shows AR binding[20]		Plasma (mean(range)): 71.1 (0.6-404) nM [93] *Pregnant women, age 20-30; Japan, 1985* Serum (mean): 0.53 nM [94] *Healthy women, aged 34-65; New York, 1985-91* Plasma (mean(range)): 0.57 (0.05-8.5) ng/ml [97] *Men; UK, 1997* Prostatic fluid (mean(range)): 0.5 (u.d. – 5.1) ng/ml [97] *Men; UK, 1997* *Plasma (median(10-90%range)) [95]:* On Western diet: 0.4 (0-2.1) ng/ml On vegetarian diet: 0.4 (0.1-0.6) ng/ml On high soy diet: 3.3 (0-33.3) ng/ml *Plasma (mean +/-SD), after 10wk high soy diet [96]:* 364 +/- 396 nM (EP), 2 +/- 7 nM (NEP). Not all humans produce equol from daidzein, only around 30% do so[81]. Plasma levels for different populations and diets have been summarised: mean range 0.1-5.5 nM [89].
Dihydrodaidzein (DAI metabolite)			
o-desmethylangolensin (DMA, a DAI metabolite)	Estrogenic in vitro and in vivo[89].		*Plasma (mean(range)): 31.2 (1.3-194) nM [93]* Pregnant women, age 20-30; Japan, 1985 *Serum (mean): 0.47 nM [94]* Healthy women, aged 34-65; New York, 1985-91 *Plasma (mean +/-SD), after 10wk high soy diet [96]:* 82 +/- 92 nM (EP), 100 +/- 99 nM (NEP). Plasma levels for different populations and diets have been summarised: mean range <0.1-3.3 nM [89].
Glycitein			*Plasma (mean +/-SD), after 10wk high soy diet [96]:* 0 +/- 0 nM (EP), 1.8 +/- 6.7 nM (NEP).

Lignans			
Enterolactone (ENL)	Estrogenic in vitro [89]; estrogen modulator in vivo (mice with MCF7 tumour) and in vitro (MCF7 production of VEGF) [99].	"Lignans" [89] fruit: 60-200 mg/100g vegetables: 100-400 mg/100g cereals: 100-700 mg/100g flaxseed: 68,000 mg/100g soy products: 900 mg/100g The plant lignans, Matairesinol and Secoisolariciresinol, are present in foods but are modified by gut microflora (to ENL and END), consequently humans	Plasma (mean(range)): 12.9 (0.5-58) nM [93] *Pregnant women, age 20-30; Japan, 1985* Plasma (mean(range)): 3.9 (0.05-12.3) ng/ml [97] *Men; UK, 1997* Prostatic fluid (mean(range)): 20.3 (u.d. – 156) ng/ml [97] *Men; UK, 1997* Serum (mean): 21.23 nM [94] *Healthy women, aged 34-65; New York, 1985-91* *Plasma (median(10-90%range)) [95]:* On Western diet: 4.6 (0.9-8.4) ng/ml On vegetarian diet: 75.4 (16.7-134) ng/ml On high soy diet: 6.2 (0-36.6) ng/ml Plasma levels for different populations and diets have been summarised: mean range **3.9-752 nM** [89].
Matairesinol (ENL precursor)			Plasma levels for different populations and diets have been summarised: **mean range 0.0-1.9 nM** [89].
Enterodiol (END)	Estrogen modulator in vivo (mice with MCF7 tumour) and in vitro (MCF7 production of VEGF) [99].		Plasma (mean(range)): 1.64 (0-9.6) nM [93] *Pregnant women, age 20-30; Japan, 1985* Prostatic fluid (mean(range)): 2.6 (u.d. – 10.4) ng/ml [97] *Men; UK, 1997* Serum (mean): 1.5 nM [94] *Healthy women, aged 34-65; New York, 1985-91* *Plasma (median(10-90%range)) [95]:* On Western diet: 0.4 (0-0.9) ng/ml On vegetarian diet: 5.1 (0-16) ng/ml On high soy diet: 1.7 (0-9.2) ng/ml Plasma levels for different populations and diets have been summarised: **mean range 0.4-65.6 nM** [89].
Secoisolariciresinol (END precursor)			
Mycoestrogens			
Ochratoxin A			

Zearalenone (ZEA)	Estrogenic in vitro [61], estrogenic in vitro [89]; estrogenic in vitro[100]. A metabolite (alpha-zearalanol) is estrogenic in vivo [89]; Four metabolites are Shows AR bindings [20].	Synthesised by moulds; ZEA and metabolites thereof are difficult to avoid in food products, namely cereal grains and derived foods. ZEA was detected in almost every one of 140 RAW maize samples, and was >100ug/kg in 42% of samples, abstract: [101]. Cleaning reduced concentrations of mycoestrogens, abstract doesn't state extent of reduction for ZEA.	
Others			
Naringenin (a flavanone)	Estrogenic in vitro [89]; Shows ER binding and estrogenic in vitro (mitogen) [70]; weakly estrogenic in vitro (gene), but not estrogenic in vitro (mitogen)[102]; estrogen modulator in vivo and in vitro (gene and mitogen) [102]. Shows slight AR binding [20]; not anti-androgenic in vitro (yeast or PC3(AR)2), abstract: [166}	occurs particularly in hops [83]	Plasma levels following 8ml/kg (subjects weighed 73+/-15Kg) of juice were 0.6+/-0.4uM (mean +/- SD, orange juice) and 6+/-5.4uM (grapefruit juice); levels at t0 were essentially zero[103].
8-prenylnaringenin	Shows ER binding and estrogenic in vitro (gene) [90,104] [105,106]; estrogenic in vivo[107]; shows ER binding, estrogenic in vitro (gene, mitogen)[82]. Anti-androgenic in one in vitro assay, not in another, abstract only [108]; not androgenic [105].	Most estrogenic component in hops [90], Human exposure may be from the metabolism of other phytochemicals into 8-PN rather than direct exposure to 8-PN in, e.g., beer [109]. Beer: 3 brands= 0.22, 0.52 and 4 ng/ml [86]	Peak serum levels following single oral doses were approx. 2.5ng/ml (50mg dose), 10ng/ml (250mg) and 34ng.ml (750mg dose)[110]. 8-PN itself has estrogenic metabolites (2 out of 12 metabolites, human liver microsomes)[111].
6-prenylnaringenin	Estrogenic in vitro (gene) [90,104,105]. Not androgenic [105].		
8-geranylnaringenin	Weakly estrogenic in vitro (YES); not androgenic[105]		

6,8-diprenylnaringenin	Weakly estrogenic in vitro (YES); not androgenic[105]		
Isoxanthohumol	Binds ER, estrogenic in vitro (gene) [90]; estrogenic in vitro (gene-ishikawa) but not in YES [104,105]. Not androgenic [105].	Present in 'strong ales' at up to 4mg/L.	May be metabolised to 8-prenylnaringen [109]
xanthohumol	Estrogenic in vitro (gene) [90]; not estrogenic in vitro (gene)[104,105] Not androgenic [105].		
6-(1,1-dimethylallyl)naringenin (6-DMA-N)	Anti-androgenic in vitro abstract: [108]		
Phloretin (PHL, a hydroxychalcone)	Estrogenic in vitro [89]; shows ER binding and estrogenic in vitro (mitogen) [70].		
Apigenin (APG, a flavone)	Estrogenic in vitro [89]; Shows ER binding and estrogenic in vitro (mitogen) [70].		
Kaempferol (KMP, flavonol)	Shows ER binding and estrogenic in vitro (mitogen) [70]; estrogenic in vitro [89].		
Quercetin (QUC, a flavonol)	Estrogenic in vitro [89]; Shows ER binding and estrogenic in vitro (mitogen) [70].		
Chalcone	Shows AR binding [20]		
4-hydroxychalcone	Shows AR binding [20]		
4-hydroxychalcone	Shows AR binding [20]		
flavone	Shows ER binding and estrogenic in vitro (mitogen) [70]. Shows AR binding [20]		
6-hydroxyflavone	Shows AR binding [20]		
flavanone	Shows AR binding [20]		
4-hydroxyflavanone	Shows AR binding [20]		
6-hydroxyflavanone	Shows AR binding [20]		

luteolin	Shows ER binding and estrogenic in vitro (mitogen) [70].		
Chrysin	Shows ER binding and estrogenic in vitro (mitogen) [70].		
Curcumin	Estrogen modulator in vitro against 17β-estradiol and pesticides [91]		
deoxymiroestrol	Shows ER binding, estrogenic in vitro (gene, mitogen)[82].		
miroestrol	Shows ER binding, estrogenic in vitro (gene, mitogen)[82]		
resveratrol	Shows no ER binding, estrogenic in vitro (gene), not estrogenic in vitro (mitogen)[82]	Occurs in grapes and wine	
Terpenoids			
Ferutinine	Estrogenic in vitro (gene) [112]	From the Umbelliferae family (examples include parsley and carrot), "has been used as a medicinal herb and/or spice"	
Tschimgine	Estrogenic in vitro (gene) [112]		
Tschimganidine	Estrogenic in vitro (gene) [112]		

Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are used as flame retardants in textile coatings and plastic. Belonging to the brominated flame retardants, PBDEs are like polychlorinated biphenyls very persistent in the environment and accumulate in humans and wildlife. Increasing levels in both, the environment and human tissues have been observed, thus recommending further studies on their toxicity. Besides the toxic effects that have been observed with PBDEs they are also under suspicion to be endocrine disruptors. The major exposure route of PBDEs for humans is via food, since they are accumulating in fish and meat. The PBDE congeners which are mainly detected in wildlife are BDE-47, BDE-99 and BDE-100.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet), Geog. location, year*
PBDEs in general		levels in food [113], lipid / wet weight: Spain, 2000 vegetables: - / 8 tubers: - / 7 ng/kg pulses: - / 11 ng/kg cereals: - / 36 ng/kg fruits: - / 6 ng/kg white fish: 2359 / 88 ng/kg shellfish: 3140 / 88 ng/kg tinned fish: 2117 / 260 ng/kg blue fish: 10839 / 1019 ng/kg pork / pork prod.: 597 / 172 ng/kg chicken: 247 / 10 ng/kg beef / beef prod.: 290 / 42 ng/kg lamb: 261 / 31 ng/kg eggs: 530 / 64 ng/kg dairy products: 677 / 48 ng/kg whole milk: 630 / 24 ng/kg semi skimmed milk: 618 / 10 ng/kg veg. oils/fats: 805 / 804 ng/kg margarine: 188 / 155 ng/kg estimated daily intake [113]: 51 ng/day, Sweden, 2001 40.8 ng/day, Sweden, 2002 44 ng/day, Canada, 2001 90.5 ng/day, UK, 2002 81.9–97.3 ng/day, Spain, 2000					

		levels in food [114], mean / median: US, 2006 fish: 1120 / 616 pg/g meat: 383 / 190 pg/g dairy products: 116 / 32.2 pg/g levels in food [115], median / range: Spain, 2003-05 oils: 119 / 14.8-2958 pg/g eggs: 73.5 / 12.8-557 pg/g dairy products: 66.1 / 3.24-1588 pg/g meats: 75.9 / 6.82-2518pg/g fish: 189 / 24-880 pg/g shellfish: 75.7 / 3.29-677 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 5.8-5.9 / 15-15 ng/kg/day	
Di-BDEs			
BDE-15	no ER-agonist in vitro [117]		
Tri-BDEs			
BDE-17		levels in food [115], median / range: Spain, 2003-05 oils: 0.83 / <0.29-33.8 pg/g eggs: <0.27 / - pg/g dairy products: <0.91 / - pg/g meats: <0.58 / - pg/g fish: 0.93 / <0.13-13.5 pg/g shellfish: 0.52 / <0.08-2.05 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.002-0.01 / 0.01-0.02 ng/kg/day	liver: 0.01 ng/g [118]; 1F, 4M, Sweden, 1994 adipose tissue: not detected [118]; 1F, 4M, Sweden, 1994 maternal blood: median: <0.01 ng/g, <0.01-0.03 ng/g [119]; 15F, Sweden, 2000/01 cord blood: median: <0.01 ng/g, <0.01-0.1 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: <0.01 ng/g, <0.01 ng/g, [119]; 15F, Sweden, 2000/01 serum: u.d., [120]; 91 F/M, Netherlands, 2004
BDE-28	weak ER-agonist in vitro [117]	levels in food [115], median / range: Spain, 2003-05 oils: 0.85 / <0.24-1.37 pg/g eggs: 0.27 / <0.17-1.25 pg/g dairy products: 0.8 / <0.02-6.12 pg/g meats: <0.66 / - pg/g fish: 2.04 / 0.28-52.2 pg/g shellfish: 1.63 / <0.1-4.54 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.02-0.03 / 0.05-0.06 ng/kg/day	adipose tissue: 0.05 ng/g (0–0.26 ng/g) [121]; 9F,11M, Belgium, 2000 liver: 0.05–0.09 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.05–0.15 ng/g, [118]; 1F, 4M, Sweden, 1994 maternal blood: median: 0.07 ng/g, <0.01-0.2 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.07 ng/g, <0.01-0.31 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.06 ng/g, 0.02-0.18 ng/g, [119]; 15F, Sweden, 2000/01 serum: 2 pg/g, [120]; 1 of 91 F/M, Netherlands, 2004
BDE-30	ER-agonist in vitro [117]		
BDE-32	weak ER-agonist in vitro [117]		
Tetra-BDEs			
BDE-47	weak ER-agonist	levels in food [115], median / range: Spain, 2003-05	adipose tissue: 1.45 ng/g (0.54–4.71 ng/g), [121];

	in vitro(and predominantly found in wildlife) [117], (in [122]) not in vitro (in [122]) AR-antagonist in vitro (and in vivo) [123]	oils: 21.6 / 6.65-55.3 pg/g eggs: 8.25 / 2.16-41.9 pg/g dairy products: 11.3 / 1.08-67.6 pg/g meats: 16.9 / 2.32-81.3 pg/g fish: 115 / 7.0-499 pg/g shellfish: 11.4 / 1.29-45.3 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.5-0.5 / 1.0-1.0 ng/kg/day	9F,11M, Belgium, 2000 adipose tissue: 1.36 ng/g lipid (0.2–5.8 ng/g), [124]; 3F, 10M Spain, 1998 liver: 1.5–4.9 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 1.7–4.0 ng/g, [118]; 1F, 4M, Sweden, 1994 foetal blood: median: 25 ng/g, 8.4-210 ng/g, [125]; 12, Indiana, 2001 maternal blood: median: 28 ng/g, 9.2-310 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.83 ng/g, 0.3-5.1 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.98 ng/g, 0.33-3.28 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 1.15 ng/g, 0.26-4.01 ng/g, [119]; 15F, Sweden, 2000/01 serum: 2.3-226 pg/g, [120]; 47 of 91 F/M, Netherlands, 2004
BDE-51	ER-agonist in vitro [117]		
BDE-66		levels in food [115], median / range: Spain, 2003-05 oils: 0.65 / <0.2-9.92 pg/g eggs: <0.24 / - pg/g dairy products: 0.67 / <0.02-10.8 pg/g meats: 0.71 / <0.1-12.6 pg/g fish: 2.37 / 0.23-23.9 pg/g shellfish: 0.4 / 0.04-5.22 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.04-0.04 / 0.08-0.08 ng/kg/day	liver: 0.03 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: not detected, [118]; 1F, 4M, Sweden, 1994 maternal blood: median: 0.02 ng/g, <0.01-0.14 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.01 ng/g, <0.01-0.11 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.02 ng/g, <0.01-0.07 ng/g, [119]; 15F, Sweden, 2000/01
BDE-71	weak ER-agonist in vitro [117]	Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: <0.001-0.01 / 0.002-0.02 ng/kg/day	
BDE-75	ER-agonist in vitro [117] not in vitro (in [122])		
BDE-77	no ER-agonist in vitro [117]	Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.002-0.01 / 0.003-0.02 ng/kg/day	
Penta-BDEs			
BDE-85	weak ER-agonist in vitro [117]	levels in food [115], median / range: Spain, 2003-05 oils: <1.83 / - pg/g eggs: <3.0 / - pg/g dairy products: 1.22 / <0.07-6.8 pg/g meats: 1.36 / <0.19-14.3 pg/g fish: 1.05 / <0.1-82 pg/g shellfish: <1.24 / -pg/g	liver: 0.03–0.16 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.02–0.07ng/g, [118]; 1F, 4M, Sweden, 1994 maternal blood: median: <0.01 ng/g, <0.01-0.07 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: <0.01 ng/g, <0.01-0.09 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.04 ng/g, <0.01-0.17 ng/g, [119];

		Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.03-0.02 / 0.03-0.04 ng/kg/day	15F, Sweden, 2000/01 serum: u.d., [120]; 91 F/M, Netherlands, 2004
BDE-99	weak ER-agonist in vitro (and predominantly found in wildlife) [117] no AR-antagonist in vitro (and in vivo) [123]	levels in food [115], median / range: Spain, 2003-05 oils: 13.9 / <1.08-54.5 pg/g eggs: 7.94 / <1.86-53.9 pg/g dairy products: 8.83 / 0.76-55.4 pg/g meats: 14.5 / <0.42-68.1 pg/g fish: 15.1 / 3.31-82 pg/g shellfish: 4.84 / 0.54-35 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.5-0.5 / 0.8-0.8 ng/kg/day	adipose tissue: 0.28 ng/g (0–1.61 ng/g), [121]; 9F,11M, Belgium, 2000 adipose tissue: 0.42 ng/g (<0.07–2.1 ng/g), [124]; 3F, 10M Spain, 1998 liver: 1.5–8.0 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.78–1.7 ng/g, [118]; 1F, 4M, Sweden, 1994 fatal blood: median: 7.1 ng/g, 2.2–54 ng/g, [125]; 12, Indiana, 2001 maternal blood: median: 5.7 ng/g, 2.4–68 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.19 ng/g, <0.01-1.43 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.07 ng/g, <0.01-0.85 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.21 ng/g, 0.07-2.2 ng/g, [119]; 15F, Sweden, 2000/01 serum: 3.6-401, [120]; 23 of 91 F/M, Netherlands, 2004
BDE-100	ER-agonist in vitro (and predominantly found in wildlife) [117] not in vitro (in [122]) AR-antagonist in vitro (and in vivo) [123]	levels in food [115], median / range: Spain, 2003-05 oils: 4.12 / <0.32-19.5 pg/g eggs: <1.35 / - pg/g dairy products: 2 / <0.11-12.5 pg/g meats: 1.98 / <0.2-21.5 pg/g fish: 21.4 / 4.91-155 pg/g shellfish: 0.85 / 0.17-11.2 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.08-0.08 / 0.2-0.2 ng/kg/day	adipose tissue: 0.48 ng/g (0.17–1.5 ng/g), [121]; 9F,11M, Belgium, 2000 adipose tissue: 0.51 ng/g (0.15–1.4 ng/g), [124]; 3F, 10M Spain, 1998 liver: 0.24–0.71 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.15–0.57 ng/g, [118]; 1F, 4M, Sweden, 1994 foetal blood: median: 4.1 ng/g, 1.8–91 ng/g, [125]; 12, Indiana, 2001 maternal blood: median:4.2 ng/g, 1.9–110 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.17 ng/g, <0.01-0.52 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.07 ng/g, <0.01-0.27 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.14 ng/g, <0.01-0.69 ng/g, [119]; 15F, Sweden, 2000/01 serum: 2.4-132 pg/g, [120]; 21 of 91 F/M, Netherlands, 2004
BDE-119	ER-agonist in vitro [117]	Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.003-0.01 / 0.007-0.02 ng/kg/day	
Hexa-BDEs			
BDE-138	no ER-agonist in vitro [117]	Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.005-0.02 / 0.01-0.03 ng/kg/day	

BDE-153	ER-antagonist in vitro [117] ER-antagonist in vitro [117] no AR-antagonist in vitro (and in vivo) [123]	levels in food [115], median / range: Spain, 2003-05 oils: 5.38 / <0.63-15.9 pg/g eggs: 6.91 / <0.5-15.67 pg/g dairy products: 1.66 / 0.1-20.7 pg/g meats: 4.96 / <0.15-35.1pg/g fish: 5 / 0.16-19.7 pg/g shellfish: 1.24 / <0.12-4.86 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.1-0.1 / 0.2-0.2 ng/kg/day	adipose tissue: 2.49 ng/g, 1.42–4.72 ng/g, [121]; 9F,11M, Belgium, 2000 adipose tissue: 1.83 ng/g, (0.67–4.2 ng/g), [124]; 3F, 10M Spain, 1998 liver: 0.44–4.3 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.57–1.4 ng/g, [118]; 1F, 4M, Sweden, 1994 foetal blood: median: 4.4 ng/g, 1.0–120 ng/g, [125]; 12, Indiana, 2001 maternal blood: median: 2.9 ng/g, 1.0–83 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.56 ng/g, 0.27-1.03 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.17 ng/g, <0.01-0.32 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.32 ng/g, 0.03-1.16 ng/g, [119]; 15F, Sweden, 2000/01 serum: 1.9-253 pg/g, [120]; 76 of 91 F/M, Netherlands, 2004
BDE-154	no AR-antagonist in vitro (and in vivo) [123]	levels in food [115], median / range: Spain, 2003-05 oils: 1.82 / <0.54-10.7 pg/g eggs: 0.37 / <0.24-2.46 pg/g dairy products: 0.64 / <0.04-5.92 pg/g meats: 0.77 / <0.09-7.14 pg/g fish: 4.84 / <0.05-42.3 pg/g shellfish: 1.14 / <0.1-6.61 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.03-0.04 / 0.06-0.07 ng/kg/day	liver: 0.01–0.29 ng/g, [118]; 1F, 4M, Sweden, 1994 adipose tissue: 0.04–0.09 ng/g, [118]; 1F, 4M, Sweden, 1994 foetal blood: median: 0.7 ng/g, 0.2–7.2 ng/g, [125]; 12, Indiana, 2001 maternal blood: median: 0.3 ng/g, 0.0–6.1 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.04 ng/g, <0.01-0.16 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: <0.01 ng/g, <0.01-0.17 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.02 ng/g, <0.01-0.14 ng/g, [119]; 15F, Sweden, 2000/01 serum: 1.2-46 pg/g, [120]; 19 of 91 F/M, Netherlands, 2004
BDE-166	ER-antagonist in vitro [117]		
Hepta-BDEs			
BDE-183		levels in food [115], median / range: Spain, 2003-05 oils: 0.97 / <0.05-160 pg/g eggs: 1.91 / 0.31-14.3 pg/g dairy products: 1.29 / 0.08-42.7 pg/g meats: 1.06 / <0.01-236 pg/g fish: 0.75 / <0.02-1.58 pg/g shellfish: 0.63 / 0.1-76.6 pg/g Dietary intakes from whole diet (adults) [116]: U.K.,2003 average/high level: 0.03-0.03 / 0.06-0.06 ng/kg/day	foetal blood: median: 0 ng/g, 0.0–4.8 ng/g, [125]; 12, Indiana, 2001 maternal blood: median: 0 ng/g, 0.0–2.7 ng/g, [125]; 12F, Indiana, 2001 maternal blood: median: 0.06 ng/g, 0.01-0.44 ng/g, [119]; 15F, Sweden, 2000/01 cord blood: median: 0.01 ng/g, <0.01-0.1 ng/g, [119]; 15F, Sweden, 2000/01 breast milk: median: 0.01 ng/g, <0.01-0.14 ng/g, [119];

			15F, Sweden, 2000/01 serum: 2.2-308 pg/g, [120]; 10 of 91 F/M, Netherlands, 2004
BDE-190	ER-antagonist in vitro [117]		
BDE-209		Dietary intakes from whole diet [116]: U.K., 2003 average/high level: 4.5-4.5 / 13-13 ng/kg/day	serum: 151-1944 pg/g, [120]; 11 of 91 F/M, Netherlands, 2004
HO-PBDEs			
T_2-like HO-BDE	ER-agonist in vitro [117]		
T_3-like HO-BDE	ER-agonist in vitro [117]		
T_4-like HO-BDE	no ER-agonist in vitro [117]		

Perfluorinated chemicals (PFCs)

Perfluorinated chemicals (PFCs) are widely used in surfactants, as refrigerants, for surface protection (e.g. carpets, textiles), lubricants and in paper treatment (e.g. for food packages). PFOS is an end-stage metabolite of PFCs which are produced with perlfuorooctanesulfonylfluoride (POSF) as precursor and is also used in as surfactant in fire fighting foams, cleaners and floor polish. PFOS and PFOA are the most prevalently found PFCs in the environment and human tissues. Although only little is known of the major pathways of human exposure to PFCs as well as their potential endocrine activity, their stability and bioaccumulation suggest, that they might be taken up via the food chain and should thus be included in further testing.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet), Geog. location, year*
Perfluoroalkyl acids (PFAAs)							
Perfluorooctane sulfonate (PFOS)	no ER-agonist in vitro [126]	Dietary intake (adults) [127]: U.K., 2004 average: 0.01 ± 0.003 – 0.1 ± 0.03 μg/kg/day high level: 0.03 ± 0.01 – 0.2 ± 0.04 μg/kg/day			plasma: median: 22.3 μg/l, 6.2-130.7 μg/l, [128]; 54F, 51M, Germany, 2003/04 serum: mean/median/range: 4.4 / 3.5 / <1-8 ng/ml, [129]; 8F, Italy, 2001 serum: mean/median/range: 4.3 / 4.2 / <1-10.3 ng/m, [129]; 42M, Italy, 2001 serum: mean/median/range: 33.3 / 33.8 / 16-60 ng/ml, [129]; 15F, Poland, 2003 serum: mean/median/range: 55.4 / 40.9 / 21-116 ng/ml, [129]; 10M, Poland, 2003 serum: mean/median/range: 11.1 / 10.4 / 4.9-19 ng/ml, [129]; 4F, Belgium, 1998, 2000 serum: mean/median/range: 16.8 / 17.6 / 4.5-27 ng/ml, [129]; 16M, Belgium, 1998, 2000 plasma: mean/median/range: 11.8 / 10.9 / 2.5-30.7 μg/l, [130]; 168F, Germany 2005 plasma: mean/median/range: 15 / 13.7 / 2.1-55.0 μg/l, [130]; 188M, Germany 2005 plasma: mean/median: 33.4 / 29.0 ng/ml, [131]; 17 F/M, Sweden, 1997, 2000 plasma: mean/median: 14.2 / 12.9 ng/ml, [131]; 13 F/M, UK, 2003 maternal serum: mean/median: 20.7/ 18.7/ 8.2-48 ng/ml,[132]; 12 F, Sweden, 2004 milk: mean/median: 0.201 / 0.166 / 0.06-0.47 ng/ml, [132];		

			12 F, Sweden, 2004 serum: mean/median/range: 21.3 / 20.8 / 17.7-29.5ng/ml,[133]; 40 pools of 3802 samples, Australia, 2002/03 maternal serum: 0.1-1.3 ng/g [134]; 38 of 42 F, Netherlands, 2005 cord blood serum: 0.1-0.2 ng/g [134]; 7 of 27 S, Netherlands, 2005 Half-life in serum: 5.4 years (Olsen et al., in [128])
Perfluorooctanoate (PFOA)	no ER-agonist in vitro [126]	Dietary intake (adults) [127]: U.K., 2004 average: 0.001 ± <0.001 – 0.07 ± 0.01 μg/kg/day high level: 0.003 ± 0.002 – 0.1 ± 0.03 μg/kg/day	plasma: median: 6.8 μg/l, 1.7-39.3 μg/l, [128]; 54F, 51M, Germany, 2003/04 serum: mean/median/range: <3 / <3 / <3 ng/ml, [129]; 8F, Italy, 2001 serum: mean/median/range: <3 / <3 / <3 ng/m, [129]; 42M, Italy, 2001 serum: mean/median/range: 21.9 / 23.2 / 9.7-34 ng/ml, [129]; 15F, Poland, 2003 serum: mean/median/range: 20.5 / 18.4 / 11-40 ng/ml, [129]; 10M, Poland, 2003 serum: mean/median/range: 4.1 / 2.4 / <1-7.6 ng/ml, [129]; 4F Belgium, 1998, 2000 serum: mean/median/range: 5.0 / 4.3 / 1.1-13 ng/ml, [129]; 16M, Belgium, 1998, 2000 plasma: mean/median/range: 5.2 / 4.8 / 1.5-16.2 μg/l, [130]; 168F, Germany 2005 plasma: mean/median/range: 6.0 / 5.7 / 0.5-19.1 μg/l, [130]; 188M, Germany 2005 maternal serum: mean/median: 3.8 / 3.8 / 2.4-5.3 ng/ml, [132]; 12 F, Sweden, 2004 milk: mean/median: NA / NA / <0.209-0.492 ng/ml, [132]; 12 F, Sweden, 2004 serum: mean/median/range: 7.6 / 7.6 / 5.0-9.9 ng/ml, [133]; 40 pools of 3802 samples, Australia, 2002/03 maternal serum: 0.2-4.2 ng/g [134]; 39 of 42 F, Netherlands, 2005 cord blood serum: 0.6-2.3 ng/g [134]; 16 of 27 S, Netherlands, 2005 Half-life in serum: 3.8 years (Olsen et al., in [128])
Perfluorohexane sulfonate (PFHxS)			serum: mean/median/range: 1.3 / 1.3 / <1-1.4 ng/ml, [129]; 8F, Italy, 2001 serum: mean/median/range: 1.7 / 1.7 / <1-2.1 ng/m, [129];

			42M, Italy, 2001 serum: mean/median/range: 1.3 / 1.2 / 0.5-2.6 ng/ml, [129]; 15F, Poland, 2003 serum: mean/median/range: 1.3 / 1.2 / <0.4-1.8 ng/ml, [129]; 10M, Poland, 2003 serum: mean/median/range: <1 / <1 / <1 ng/ml, [129]; 4F Belgium, 1998, 2000 serum: mean/median/range: 1.3 / 1.2 / <1-1.4 ng/ml, [129]; 16M, Belgium, 1998, 2000 maternal serum: mean/median: 4.7 / 4.0 / 1.8-11.8 ng/ml, [132]; 12 F, Sweden, 2004 milk: mean/median: 0.085 / 0.070 / 0.031-0.172 ng/ml, [132]; 12 F, Sweden, 2004 serum: mean/median/range: 7.2 / 6.2 / 2.7-19.0 ng/ml, [133]; 40 pools of 3802 samples, Australia, 2002/03
Perfluorooctane sulphonamide (PFOSA)			serum: mean/median/range: 1.7 / 1.7 / <1.3-1.7 ng/ml, [129]; 8F, Italy, 2001 serum: mean/median/range: 1.8 / 1.6 / <1.3-2.3 ng/m, [129]; 42M, Italy, 2001 serum: mean/median/range: 2.3 / 1.6 / 0.4-7.7 ng/ml, [129]; 15F, Poland, 2003 serum: mean/median/range: 1.7 / 1.0 / <0.4-4.4 ng/ml, [129]; 10M, Poland, 2003 serum: mean/median/range: <3 / <3 / <3 ng/ml, [129]; 4F Belgium, 1998, 2000 serum: mean/median/range: <3 / <3 / <3 ng/ml, [129]; 16M, Belgium, 1998, 2000 maternal serum:mean/median: 0.24/0.19/<0.1-0.49 ng/ml,[132]; 12 F, Sweden, 2004 milk: mean/median: 0.013 / 0.010 / <0.007-0.030 ng/ml, [132]; 12 F, Sweden, 2004 serum: mean/median/range: 0.81 / 0.71 / 0.36-2.4 ng/ml, [133]; 40 pools of 3802 samples, Australia, 2002/03
Fluorotelomer Alcohols (FTOHs)			
6:2 FTOH	ER-agonist in vitro[126], [135]		
8:2 FTOH	ER-agonist in vitro[126], [135]		

Parabens

Parabens are used in food, cosmetics and pharmaceuticals for their antimicrobial activity. The parabens most widely used in food industry are methyl- and propylparaben. Their use increased 30 fold from 1960 to 1970. Parabens were detected breast milk, cord blood, in human breast cancer tissue and urine.
A variety of studies showed, that parabens can act as endocrine disrupters and some were shown to be (anti-) estrogenic and (anti-) androgenic in vitro as well as in vivo. Their activity was shown to increase with length or branching of the alkyl chain.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Parabens in general	estrogenic activity increases with chain length	estimated consumption (in 3 days) [136]: Cake: 96 mg Piecrust: 164 mg Doughnuts / sweet-rolls: 82 mg Syrup: 91 mg Pickles: 6 mg Jelly / jams: 27 mg total daily consumption[136]: 76 mg/day Generally found in: processed vegetables, baked goods, fats and oils, seasonings, sugar substitutes, coffee extracts, fruit juices, pickles, sauces, soft drinks, frozen dairy products. Concentrations: 450–2000 ppm daily consumption [137]: infants: 1 – 16 mg/kg >2 years / adults: 4 – 6 mg/kg					
Methylparaben (MP)	ER-agonist in vitro [138], [139], [135] in vitro, not in vivo [137] binds ER, not in vitro [140] ER-binding [141] AR-antagonist in vitro [142] not in vitro [143]	daily intake [136]: average: 222 mg, LSRO / FASEB maximum: 347 mg, LSRO / FASEB			Human breast cancer tissue: Mean: 12.8 ng/g, [144]; 20F, UK, (2004) Urine: in 99 % of samples, median: 43.9 ng/ml, [145]; 100 F/M, US, 2003-05		
Ethylparaben (EP)	ER-agonist				Human breast cancer tissue: Mean: 2.0 ng/g, [144];		

	in vitro [138], [139], [135] in vitro, not in vivo [137] binds ER, not in vitro [140] ER-binding [141] AR-antagonist in vitro [143]		20F, UK, (2004) Urine: in 58 % of samples (no conc.), [145]; 100 F/M, US, 2003-05
n-Propylparaben (PP)	ER-agonist in vitro [138], [139], [135] in vitro, not in vivo [137] in vivo [146] binds ER, in vitro [140] ER-binding [141] AR-antagonist in vitro [142], [143]	daily intake [136]: average: 238 mg LSRO / FASEB maximum: 381 mg LSRO / FASEB	Human breast cancer tissue: Mean: 2.6 ng/g, [144]; 20F, UK, (2004) Urine: in 96 % of samples, median: 9.1 ng/ml, [145]; 100 F/M, US, 2003-05
Isopropylparaben	ER-agonist in vitro [139] binds ER, in vitro [140] AR-antagonist in vitro [143]		
n-Butylparaben (BP)	ER-agonist in vitro [138], [139], [135] in vitro, in vivo [137] binds ER, in vitro [140] ER-binding [141] AR-antagonist in vitro [142], [143]		Human breast cancer tissue: Mean: 2.3 ng/g, [144]; 20F, UK, (2004) Urine: in 69 % of samples, (no conc.), [145]; 100 F/M, US, 2003-05
Isobutylparaben	ER-agonist in vitro [139] in vitro, in vivo [147] binds ER, in vitro [140] AR-antagonist in vitro [143]		Human breast cancer tissue: Mean: 0.9 ng/g, [144]; 20F, UK, (2004)
Amylparaben	ER-agonist binds ER, in vitro [140]		
Hexylparaben	ER-agonist binds ER, in vitro [140]		
Heptylparaben	ER-binding [141]		
Dodecylparaben	ER-agonist binds ER, in vitro [140]		
Ethylhexylparaben	ER-agonist binds ER, in vitro [140] ER-binding [141]		
Benzylparaben	ER-agonist in vitro, in vivo [148] binds ER, in vitro [140]		Human breast cancer tissue: Mean: 0.0 ng/g, [144]; 20F, UK, (2004) Urine: in 39 % of samples, (no conc.), [145];

	ER-binding [141]		100 F/M, US, 2003-05
p-hydroxybenzoic acid (major paraben metabolite)	ER-agonist in vitro [149]		

Polycyclic musks (PCMs)

Synthetic musk compounds are used in many personal care products, cosmetics, cleansing agents and detergents include nitro, polycyclic and makrocyclic. Due to the known toxicity of nitro musks, they have been largely replaced by PCMs with 70 % of musks produced being PCMs. Their lipophily and stability leads to their enrichment in the environment where they can be detected in most compartments and aquatic fauna as well as in human adipose tissue and mother's milk. Several of the PCMs were shown to be endocrine disruptors, including estrogenicity and antiandrogenicity in in vivo and in vitro studies. Although they only exhibited weak estrogenic responses, their contribution in the mixture of compounds that are present in the environment and in food might not be negligible.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
HHCB Galaxolide / Abbalide / Pearlide	ER-agonist in vitro, not in vivo [150] not in vitro [151] weakly in vitro [152] ER-antagonist in vitro [152] (SERM) in vitro, in vivo [153], [154] AR-antagonist in vitro [154]	farmed trout [155]: 5 μg/kg fresh weight, in 98 % 1.2 μg/kg fresh weight, in 60 % daily intake in [150]: 0.6 μg/kg (Ford, 1999)		Denmark 1999 2003/04	adipose tissue: 28–189 μg/kg fat, [156]; 8F, 6M Germany, 1993-95 breast milk: 16–108 μg/kg fat, [156]; 5F, Germany, 1993-95 breast milk: median/mean: 147 / 179 / 38–422 μg/kg fat, [155]; 10F, Denmark, 1999 breast milk: median/mean: 62 / 73 / u.d.–281 μg/kg fat, [157]; 52of53F, Switzerland 1998/99 adipose tissue: 12-171 ng/g lipid, [158]; 15F, Switzerland 1983/84, 1994 serum levels: median: 420 / u.d.-4100 ng/l [159]; 55F, 45M, higher in female, Austria adipose tissue: median/mean: 149 / 178 / 12-789 ng/g fat,[160]; 37F, 12M, in 100 %, US (NY) 2003/04 serum: 0.2-9.2 ng/g, [120]; 91 of 91 F/M, Netherlands, 2004 maternal serum: 0.15-3.2 ng/g [134]; 38 of 42 F, Netherlands, 2005 cord blood serum: 0.11-1.6 ng/g [134]; 26 of 27 S, Netherlands, 2005		
ADBI Celestolide / Crysolide	AR-antagonist weak in vitro [154]				adipose tissue: u.d. / low, [156]; 8F, 6M, Germany, 1993-95 breast milk: u.d. / low, [156]; 5F, Germany, 1993-95 breast milk: median/mean: 5.98 / 7.78 /u.d.–11.2 μg/kg fat,[155]; 10F, Denmark, 1999 breast milk: median/mean: u.d. / u.d. / u.d. μg/kg fat, [157]; 53F, Switzerland 1998/99 adipose tissue: 0.12-3.5 ng/g lipid, [158];		

			15F, Switzerland 1983/84, 1994 serum levels: u.d., [159]; 55F, 45M, Austria serum: 0.05 ng/g, [120]; 1 of 91 F/M, Netherlands, 2004 maternal serum: 0.09-0.34 ng/g [134]; 4 of 42 F, Netherlands, 2005 cord blood serum: 0.07-0.26 ng/g [134]; 6 of 27 S, Netherlands, 2005
AHDI (AHMI) Phantolide	ERβ-antagonist in vitro [154] AR-antagonist in vitro [154]		adipose tissue: u.d. / low, [156]; 8F, 6M, Germany, 1993-95 breast milk: u.d. / low, [156]; 5F, Germany, 1993-95 breast milk: median/mean: u.d. / 8.03 /u.d.–9.94 μg/kg fat, [155]; 10F, Denmark, 1999 breast milk: median/mean: u.d. / u.d. / u.d. μg/kg fat, [157]; 53F, Switzerland 1998/99 serum levels: < 100 ng/l (only in 1 subject), [159]; serum levels: median: <LOD / <LOD-800 ng/l, [159]; 55F, 45M, higher in female, Austria
ATII Traeseloid			adipose tissue: u.d. / low, [156]; 8F, 6M, Germany, 1993-95 breast milk: u.d. / low, [156]; 5F, Germany, 1993-95 breast milk: median/mean: u.d. / - / u.d.–2.58 μg/kg fat, [155]; 10F, Denmark, 1999 breast milk: median/mean: 74 / 74 / u.d.-74 μg/kg fat, [157]; 1of53F, Switzerland 1998/99 serum levels: <100 ng/l (only in 2 subjects), [159]; 55F, 45M, higher in female, Austria serum: 0.1-11 ng/g, [120]; 4 of 91 F/M, Netherlands, 2004 maternal serum: u.d. [134]; 42 F, Netherlands, 2005 cord blood serum: u.d. [134]; 27 S, Netherlands, 2005
DPMI Cashmeran			adipose tissue: - , [156]; 8F, 6M, Germany, 1993-95 breast milk: - , [156]; 5F, Germany, 1993-95 breast milk: median/mean: u.d. / u.d. / u.d. μg/kg fat, [157]; 53F, Switzerland 1998/99 serum levels: u.d., [159]; 55F, 45M, Austria serum: 8.0 ng/g, [120]; 1 of 91 F/M, Netherlands, 2004 maternal serum: u.d. [134]; 42 F, Netherlands, 2005 cord blood serum: u.d. [134]; 27 S, Netherlands, 2005
AHTN Tonalide / Fixolide	ER-agonist in vitro, not in vivo [150] in vitro [151] weakly in vitro [152] ER-antagonist	farmed trout [155]: Denmark 1.2 μg/kg fresh weight, in 98 % 1999 <0.2μg/kg fresh weight, in 34 % 2003/04 daily intake in [150]: 1.6 μg/kg (Ford, 1999)	adipose tissue: 8–33 μg/kg fat, [156]; 8F, 6M, Germany, 1993-95 breast milk: 11–58 μg/kg fat, [156]; 5F, Germany, 1993-95 breast milk: median/mean: 17.5/ 19.5/ 5.58–37.9μg/kg fat,[155];

	in vitro [152] (SERM) in vitro, in vivo [153], [154] AR-antagonist in vitro [154]		10F, Denmark, 1999 breast milk: median/mean: 31 / 44 / u.d.–136 μg/kg fat, [157]; 53F, Switzerland 1998/99 adipose tissue: 1-23 ng/g lipid, [158]; 15F, Switzerland 1983/84, 1994 serum levels: median: <LOD / <LOD-800 ng/l, [159]; 55F, 45M, higher in female, Austria adipose tissue: median/mean: 37.4 / 42 / <8-34 ng/g fat,[160]; 37F, 12M, in 86 %, US (NY) 2003/04 serum: 0.1-11 ng/g, [120]; 88 of 91 F/M, Netherlands, 2004 maternal serum: 0.06-0.49 ng/g [134]; 18 of 42 F, Netherlands, 2005 cord blood serum: 0.1-1.5 ng/g [134]; 16 of 27 S, Netherlands, 2005
ATTN (AETT) Versalide	ERβ-antagonist in vitro [154] AR-antagonist in vitro [154]		adipose tissue: u.d. / low, [156]; 8F, 6M, Germany, 1993-95 breast milk: u.d. / low, [156]; 5F, Germany, 1993-95 breast milk: median/mean: u.d. / u.d. / u.d. μg/kg fat, [157]; 53F, Switzerland 1998/99

UV-filters

UV-filters comprise different groups of chemicals which are employed in a broad spectrum of use. They are used in sun screens and product protection in cosmetics as well as in plastics, folia, fabrics and washing powder. UV-filters are high production volume substances and due to their lipophilic nature tend to accumulate in the food chain. They are found in environment where they were detected not only in, in effluents from sewage treatment plants, but also in lakes and fish. Not much is known so far about their half-life or tissue levels. However, in addition to rising production volumes of UV-filters and their known accumulation in the food chain, some of them were also found to act as endocrine disruptors. The endocrine activities found included (anti-) estrogenicity as well as (anti-) androgenicity, which were shown in both, in vitro and in vivo assays.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc)*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Miscellaneous							
4-methylbenzylidene camphor (4-MBC)	ER(β)-agonist in vitro, in vivo [161], [162], [163] in vitro [164], [165], [154] in vitro, in vivo, ERβ [166] in vivo [167], [146] in vitro, not in vivo [168] ER-antagonist in vitro [169], [163] AR-antagonist in vitro [169], [154] not in vitro [164]	fish: 44-166 ng/g fat, [170] Switzerland, 3 lakes fish: up to 1800 ng/g fat, [171] Switzerland, different rivers			human systemic exposure [164]: 0.23 mg/kg body weight serum after exposure: up to 20 ng/ml, [172]; 17F, 15M Denmark, (2004)		
3-Benzylidene camphor (3-BC)	ER(β)-agonist in vitro [164], [169], [154] in vitro, in vivo, ERβ [166] ER-antagonist in vitro [169] AR-antagonist in vitro [169], [154] not, in vitro [164]						
Octyl methoxy cinnamate (OMC / EHMC)	ER-agonist in vitro, in vivo [161] in vitro [164], [165], [154] in vitro, not in vivo [168] in vivo [146] ER-antagonist in vitro [169] AR-agonist in vitro [169]	drinking water: 0.45 μg/l (1/15), [173] US 2001/02 fish: 64 ng/g fat, [170] Switzerland, 3 lakes			human breast milk: up to 445 ng/g lipid, ([174]in[175]); 6F, Germany serum after exposure: up to 20 ng/ml, [172]; 17F, 15M Denmark, (2004)		

	AR-antagonist in vitro [169] not, in vitro [164]		
Isopentyl-4-methoxy cinnamate (IMC)	ER-antagonist in vitro [169] AR-agonist in vitro [169] AR-antagonist in vitro [169]		
butyl methoxy dibenzoyl methane (B-MDM)	ER-agonist not in vitro, not in vivo [161] not in vitro [164] weakly, in vitro [154] in vitro, not in vivo [168] AR-antagonist not in vitro [164] weakly, in vitro [154]		
Octocrylene (OC)	ER-agonist in vitro [169] AR-agonist in vitro [169] AR-antagonist in vitro [169]	fish: 25 ng/g fat, [170] Switzerland, 3 lakes fish: up to 2400 ng/g fat, [171] Switzerland, different rivers	
Benzophenone derivates			
Benzophenone-1 (BP-1)	ER-agonist in vitro [164], [165], [169] AR-antagonist in vitro [169]	drinking water: 0.25 μg/l (1/15), [173] US 2001/02	
Benzophenone-2 (BP-2)	ER-agonist in vitro [164], [169] ER-antagonist in vitro [169] AR-antagonist in vitro [169]		
Benzophenone-3 (BP-3)	ER-agonist in vitro, in vivo [161] in vitro [164], [165], [169], [154] in vitro, not in vivo [168] ER-antagonist in vitro [169] AR-antagonist in vitro [164], [169], [154], [176]	fish: 99-123 ng/g fat, [170] Switzerland, 3 lakes	human breast milk: up to 445 ng/g lipid, ([174]in[175]); 6F, Germany serum after exposure: up to 300 ng/ml, [172]; 17F, 15M Denmark, (2004) urine after exposure: 260 ng/ml, [177]; 1S, USA, 1998
Benzophenone-4 (BP-4)	ER-agonist in vitro [169] ER-antagonist in vitro [169] AR-antagonist in vitro [169] not, in vitro [164]		
Benzophenone-6 (BP-6)			
Benzophenone-8 (BP-8)			

Benzophenone-12 (BP-12)			
4-Hydroxy benzophenone (4HB; metabolite)	ER-agonist in vitro [169] AR-antagonist in vitro [169]		
4,4'-Dihydroxy benzophenone (4DHB)	ER-agonist in vitro [169] ER-binding [141] AR-antagonist in vitro [169]		
p-Aminobenzoates			
4-aminobenzoic acid (PABA)	ER-antagonist in vitro [169] AR-antagonist in vitro [169]		
Octyl dimethyl-p-aminobenzoic acid (OD-PABA)	ER-agonist in vitro, not in vivo [161], [168] in vitro [164], [154] ER-antagonist in vitro [169] AR-antagonist not in vitro [164]		
Ethyl-4-amino benzoate (Et-PABA)	ER-agonist in vitro, in vivo [169]		
Ethoxylated ethyl 4-aminobenzoate (PEG25-PABA)	ER-antagonist in vitro [169]		
Salicylates			
Homosalate (HMS)	ER-agonist in vitro, not in vivo [161] in vitro [164], [154], [169] in vitro, not in vivo [168] ER-antagonist in vitro [169] AR-agonist in vitro [169] AR-antagonist in vitro [164], [169], [154],[176]		
Benzyl salicylate (BS)	ER-agonist in vitro [169] ER-antagonist in vitro [169] AR-antagonist in vitro [169]		
Phenyl salicylate (PS)	ER-agonist in vitro [169] ER-antagonist in vitro [169] AR-antagonist in vitro [169]		
Octyl salicylate (OS)	ER-antagonist in vitro [169] AR-agonist in vitro [169] AR-antagonist in vitro [169]		

Metals

Food contamination with metals occurs either through environmental contamination, like contamination of soil which leads to accumulation in plants or the metals enter the food chain via feeds which contain toxic metals. Contamination can also happen during handling and processing of food via the processing equipment and storage and packaging containers. Metals have now also been found to be able to act as endocrine disruptors. The metals which are able to interfere with oestrogen action are thus a class of inorganic xenoestrogens which were termed metalloestrogens [178]. It was found that organometal compounds but also inorganic anions and cations possess endocrine activity and some of the metals have a known physiological role while for others no function is known.

Class/ Compound	**Endocrine activity**	**Food relevance**			**Human tissue levels**		
		Food type (e.g. fish, veg. etc)	*Level (M/g)*	*Geog. location, year*	*Tissue (plasma, lipid etc*	*Mean/ median levels*	*Subjects (gender, age, diet),Geog. location, year*
Cadmium (Cd)	*ER-agonist* in vitro, ER-binding [179] not in vitro [180] in vitro [181], [182] in vivo [183], + rev. in[184] *AR-agonist* in vitro, in vivo[185] *AR-binding* [186], [187] Effects might be tissue dependent! [188]	Food is the most important source of human exposure to Cadmium (and smoking) [189] Cadmium has no known physiological function Dietary intakes (in [190]): 10 μg/day Spain, 1990-91 to 30 μg/day Greece, (1994) 1/3 via animal products (e.g. high levels in shellfish, kidneys), rest from plants Dietary intake [191]: mean: 13.8 μg/day Canada, (1987) median: 11.9 μg/day Canada, (1987) Dietary intakes [192]: 11.17 μg/day CanaryIslands,(2006) from 0.19 μg/day Germany, 2002 to 143.42 μg/day Greenland, 2000 Levels in food [192]: Canary Islands, (2006) fish: 87.98 ± 45.3 μg/kg Viscera: 22.73 ± 10.92 μg/kg Red meat: 14.2 ± 1.85 μg/kg Vegetables: 13.62 ± 1.87 μg/kg Dairy products: 0.42 ± 0.7 μg/kg Levels in food [193]: U.K., 2000 Bread: 15 μg/kg Meat products: 7 μg/kg Fish: 13 μg/kg Oils and fat: 1-2 μg/kg			Human breast cancer tissue: mean: 20.4±17.5 μg/g, [195]; 43F Control tissue: mean: 31.7 ± 39.4 μg/g, [195]; 32F Finland 1985 / 86 no significant difference, positive correlation with smoking levels in breast tissue are high compared to other tissues. Cadmium is weakly excreted with breast milk [195]. Blood: mean: 0.85 ng/ml, [196]; 220F Follicular fluid: mean: 0.34 ng/ml, [196]; 220S Czech Republic, (2001) Placenta: mean: 18.02 ng/g, [197]; 688F, Czech Republic, 1992 Biological half-life: 15 – 30 years [188] 10 – 40 years [189] (due to accumulation in blood, kidney, liver, placenta, testis, ovaries) Acts toxic on testes [198]		

		Vegetables: 9-14 μg/kg Milk: 0.07-0.1 μg/kg Dairy products: 1-2 μg/kg Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 0.28 / <0.04-3.64 mg/kg Honey: 0.04 / <0.04-0.04 mg/kg Root vegetables: 0.04 / <0.04-0.06 mg/kg Nuts: 0.06 / <0.04-0.15 mg/kg Deer & pheasant: 0.04 / <0.04-0.04 mg/kg Sweets: 0.04 / <0.04-0.04 mg/kg Dried fruit: 0.04 / <0.04-0.04 mg/kg	
Mercury (Hg) Inorganic-Hg Methyl-Hg Ethyl-Hg	*ER-agonist* in vitro [199] *AR-binding* [186]	Primary human exposure via food (fish consumption), (+ exposure to Hg from amalgam fillings and vaccines) [200], [189] Dietary intakes (as in [190]): 0.7μg/day Netherlands,1984-86 to 13.5 μg/day Belgium, (1983) dependent on level of pollution in the local environment elemental, inorganic and organic forms, all forms are present in food Levels in food [193]: U.K., 2000 Bread: 0.5-0.6 μg/kg Meat products: 0.8-0.9 μg/kg Fish: 71 μg/kg Oils and fat: 0-0.1 μg/kg Vegetables: 0-0.2 μg/kg Milk: 0-0.1 μg/kg Dairy products: 0-0.5 μg/kg	Placenta: I-Hg: median/max: 1.3 / 6.7μg/kg, [201]; Me-HG: median/max: 1.8 / 6.2 μg/kg, [201]; 119F, Sweden (2002) Maternal blood: I-Hg: median/max: 0.32 / 1.9 μg/kg, [201]; Me-HG: median/max: 0.73 / 2.8 μg/kg, [201]; 119F, Sweden (2002) Cord blood: I-Hg: median/max: 0.34 / 1.1 μg/kg, [201]; Me-HG: median/max: 1.4 / 4.8 μg/kg, [201]; 119F, Sweden (2002) approximate half-life in the body [200]: I-Hg: 40 days; Me-Hg: 70 days; E-Hg: 20 days Can interfere with spermatogenesis [198]
Arsenic (As) Arsenite	*ER-agonist* in vitro [202]	Primary human exposure through drinking water and food [202], [189]; high levels of organic arsenic in seafood [190] Levels in food [203]: Canada, 1985-88 all samples: mean/median: 73.2 / 5.1 / < 0.1-4830 ng/g fish: 1662 ng/g meat and poultry: 24.3 ng/g bakery goods, cereals: 24.5 ng/g fats and oils: 19.0 ng/g vegetables: 7 ng/g Levels in food [204]: West Bengal, 2 regions, (2003)	

		total (mean): 60.3 and 102 μg/kg vegetables: 20.9 and 21.2 μg/kg cereals, bakery goods: 130 and 179 μg/kg spices: 133 and 202 μg/kg drinking water: 107 μg/l Levels in food [193]: U.K., 2000 Bread: 9 μg/kg Meat products: 10 μg/kg Fish: 3400 μg/kg Oils and fat: 16 μg/kg Vegetables: 2-7 μg/kg Milk: 2 μg/kg Dairy products: 6 μg/kg Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 0.12 / <0.13-0.222 mg/kg Honey: 0.13 / <0.13-0.16 mg/kg Root vegetables: 0.13 / <0.13-0.17 mg/kg Nuts: 0.39 / <0.13-0.84 mg/kg Deer & pheasant: 0.18 / <0.13-0.33 mg/kg Sweets: 0.14 / <0.13-0.22 mg/kg Dried fruit: 0.15 / <0.13-0.30 mg/kg Dietary intakes (in [190]): 38 to 286 μg/day (France, Belgium, Spain, Netherlands, UK, 1984-99, levels depending on seafood consumption) Dietary intake [191]: mean 16.7 μg/day Canada, (1987) median 9.79 μg/day Canada, (1987) Daily dietary intake (in [204]): Canada: 59.2 μg; US: 38.6 μg; Japan: 160 – 280 μg; UK: 89 μg; Austria: 27 μg; New Zealand: 55 μg	
Lead (Pb)	*ER-agonist* in vitro [199], [182] *AR-binding* [186]	Human exposure via food and air [189] Dietary intakes [190]: 16 μg/day Spain, 1981 to 280 μg/day Italy, (1996) Dietary intake [191]: mean: 53.8 μg/day Canada, (1987) median: 42.7 μg/day Canada, (1987) Levels in food [193]: U.K., 2000 Bread: 7 μg/kg Meat products: 6 μg/kg Fish: 14-15 μg/kg Oils and fat: 3-4 μg/kg	Has an effect on hormone levels [198] blood: mean, children/adults: 3.5 / 3.7 μg/dl [205]; European countries, including: Denmark, France, Germany, Greece, Israel, Sweden, 1997-2000 blood: mean, exposed/nonexposed: 39.5/30.6μg/l [206]; 400 children, France, 1995/97 blood : mean, men/women: 74 / 49 μg/l [207]; 300F, 301M, France, (2001) blood: mean/median: 9.5 / 8.5 μg/dl [208];

		Vegetables: 11 μg/kg Milk: 1 μg/kg Dairy products: 1-2 μg/kg Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 0.06 / <0.05-0.42 mg/kg Honey: 0.06 / <0.05-0.28 mg/kg Root vegetables: 0.05 / <0.05-0.28 mg/kg Nuts: 0.16 / <0.05-0.5 mg/kg Deer & pheasant: 0.23 / <0.05-1.63 mg/kg Sweets: 0.09 / <0.05-0.41 mg/kg Dried fruit: 0.06 / <0.05-0.2 mg/kg	430F, Mexiko, 1994/95 bone (tibial): mean/median: 10.2 / 9.8 μg/g [208]; 430F, Mexiko, 1994/95 bone (patellar): mean/median: 15.2 / 14.6 μg/g [208]; 430F, Mexiko, 1994/95
Selenium (Se) (Selenite)	*ER-agonist* in vitro [209], [182]	Selenium is an essential micronutrient. Human exposure primarily through cereals, grains and vegetables [209] Counterbalances Cadmium induced toxicity [195] and might have a protective role against Hg poisoning [201] Levels in food [204]: West Bengal, 2 regions, (2003) total (mean): 90.9 and 109 μg/kg vegetables: 3.1 and 5.6 μg/kg cereals, bakery goods: 149 and 116 μg/kg spices: 495 and 365 μg/kg drinking water: 0.38 μg/l Levels in food [193]: U.K., 2000 Bread: 60 μg/kg Meat products: 100 μg/kg Fish: 320 μg/kg Oils and fat: 1-11 μg/kg Vegetables: 5-15 μg/kg Milk: 12 μg/kg Dairy products: 19-21 μg/kg	
Iron (Fe)	*AR-binding* [186]	Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 5.5 / <1.5-29.7 mg/kg Honey: 1.6 / <1.5-2.7 mg/kg Root vegetables: 7.1 / <1.5-103.1 mg/kg Nuts: 28.2 / 6.2-52.4 mg/kg Deer & pheasant: 21.5 / 9.6-31.2 mg/kg Sweets: 28.2 / <1.5-144.4 mg/kg Dried fruit: 15.9 / 7.6-56.1 mg/kg	
Zinc (Zn)	*AR-binding* [186], [187]	Counterbalances Cadmium induced toxicity [195] Daily dietary intake (in [204]):	Placenta: mean: 54.6 μg/g, [197]; 688F, Czech Republic, 1992

		different areas: 5-22 mg; USA: 10-15 mg; Finland: 16 mg; Daily dietary intake [210]: 6.7-11 mg; Germany, (1991) Levels in food [204]: West Bengal, 2 regions, (2003) total (mean): 12.7 and 12.5 mg/kg vegetables: 5.33 and 5 mg/kg cereals, bakery goods: 19.4 and 15 mg/kg spices: 42.1 and 28.4 mg/kg drinking water: 51.8 μg/l Levels in food [193]: U.K., 2000 Bread: 8.2 mg/kg Meat products: 26 mg/kg Fish: 8.3 mg/kg Oils and fat: 0.38 mg/kg Vegetables: 2.4-3.5 mg/kg Milk: 4.8 mg/kg Dairy products: 11 mg/kg Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 6.4 / <2.2-49.1 mg/kg Honey: 2.2 / <2.2-3.3 mg/kg Root vegetables: 3.3 / <2.2-14.6 mg/kg Nuts: 28.0 / 4.0-58.6 mg/kg Deer & pheasant: 17.3 / 6.2-44.5 mg/kg Sweets: 4.7 / <2.2-21.6 mg/kg Dried fruit: 4.1 / <2.2-32.6 mg/kg	
Copper (Cu)	*ER-agonist* in vitro [199] Zink-replacement on ER inhibits DNA binding [211] *AR-binding* [186]	Daily dietary intake (in [204]): Netherlands: 1200-1400 μg; USA: 2-4 mg; Daily dietary intake [210]: 540-920 μg; Germany, (1991) Levels in food [204]: West Bengal, 2 regions, (2003) total (mean): 3.33 and 3.55 mg/kg vegetables: 1.59 and 1.58 mg/kg cereals, bakery goods: 5.53 and 3.95 mg/kg spices: 8.66 and 8.08 mg/kg drinking water: 1.95 μg/l Levels in food [193]: U.K., 2000 Bread: 1.4 mg/kg Meat products: 1.6 mg/kg Fish: 1.1 mg/kg Oils and fat: 0.11 mg/kg Vegetables: 0.88-0.96 mg/kg Milk: 0.06 mg/kg	Alters testosterone, LH, FSH secretion [198]

		Dairy products: 0.52 mg/kg Levels in food [194]; (mean/range): U.K., 2007 Mushrooms: 2.2 / <0.3-21.7 mg/kg Honey: 0.3 / <0.3-0.6 mg/kg Root vegetables: 2.0 / <0.3-139.2 mg/kg Nuts: 8.4 / 1.1-13.8 mg/kg Deer & pheasant: 1.2 / 0.5-2.0 mg/kg Sweets: 1.4 / <0.3-5.1 mg/kg Dried fruit: 6.5 / 2.2-68.4 mg/kg	
Nickel (Ni)	*ER-agonist* in vitro [199] Zink-replacement on ER inhibits DNA binding [211]	Daily dietary intake (in [204]): different areas 100-300 μg; Daily dietary intake [210]: 111-256 μg; Germany, (1991) Levels in food [204]: West Bengal, 2 regions, (2003) total (mean): 0.59 and 0.74 mg/kg vegetables: 0.36 and 0.16 mg/kg cereals, bakery goods: 0.87 and 0.72 mg/kg spices: 1.33 and 2.26 mg/kg drinking water: 9.58 μg/l Levels in food [193]: U.K., 2000 Bread: 53 μg/kg Meat products: 66 μg/kg Fish: 65 μg/kg Oils and fat: 26-27 μg/kg Vegetables: 44-83 μg/kg Milk: 8 μg/kg Dairy products: 41 μg/kg	
Cobalt (Co)	*ER-agonist* in vitro [199] *AR-binding* [186]		
Tin (Sn) (Organotin: Tributyltin – TBT Dibutyltin – DBT Monobutyltin – MBT)	*ER-agonist* in vitro [199], [182] no ERα-binding [212] *AR-binding* [212]	Levels in food [193]: U.K., 2000 Bread: 6 μg/kg Meat products: 130 μg/kg Fish: 28 μg/kg Oils and fat: 4-5 μg/kg Vegetables: 0.9-8 μg/kg Milk: 0.8-0.9 μg/kg Dairy products: 34 μg/kg	serum: TBT: 0.1 ng/g, [120]; 3 of 91 F/M, Netherlands, 2004 DBT: u.d., [120]; 91 F/M, Netherlands, 2004 MBT: 0.1 ng/g, [120]; 3 of 91 F/M, Netherlands, 2004
Chromium (Cr)	*ER-agonist* in vitro [199], [182]	Levels in food [193]: U.K., 2000 Bread: 31 μg/kg	

		Meat products: 84 μg/kg Fish: 110 μg/kg Oils and fat: 100-110 μg/kg Vegetables: 8-16 μg/kg Milk: 5 μg/kg Dairy products: 26 μg/kg	
Vanadium (V) Vanadate	*ER-agonist* in vitro [199]		
Calcium (Ca)	*AR-binding* [187]		
Magnesium (Mg)	*AR-binding* [187]		
Lithium (Li)	*ER-agonist* in vitro [182]		
Antimony (Sb)	*ER-agonist* in vitro [182]		
Barium (Ba)	*ER-agonist* in vitro [182]		

Notes to Table:

Estrogenic *in vitro*: estrogen agonist, e.g. in ER-CALUX, MCF7 or similar assay; this is more than simply binding the receptor, and means there was activation/agonism as well

(gene), indicates estrogenicity measured as a change in gene expression, e.g ER-CALUX
(mitogen), indicates estrogenicity measured as increased proliferation of estrogen-sensitive cell line, usually MCF7
(…+Luc) indicates assay that incorporates a luciferase reporter gene

Estrogen modulator: describes reduction in estrogen effect on co-application; includes ER antagonists if the mode of action was not **proven** to be ER antagonism
ER antagonist: reduces effect of estrogen, has no agonist activity alone, antagonism of ER was demonstrated (for example binding of ER with no agonism?).

LOD: limit of detection
u.d.: undetectable in assay
fw: fresh weight
EP: subject was an 'equol producer', based on urinary production >1umol/24hr after 10wk high soy diet.
NEP: subject was a 'non-equol producer', based on urinary production <1umol/24hr after 10wk high soy diet.

Literature Cited

1. **Bennion BJ, Cosman M, Lightstone FC, Knize MG, Montgomery JL, Bennett LM, Felton JS, Kulp KS. 2005. PhIP carcinogenicity in breast cancer: computational and experimental evidence for competitive interactions with human estrogen receptor. *Chem Res Toxicol* 18:1528-1536.**
   Ref Type: Journal

2. **Van de Wiele T, Vanhaecke L, Boeckaert C, Peru K, Headley J, Verstraete W, Siciliano S. 2005. Human colon microbiota transform polycyclic aromatic hydrocarbons to estrogenic metabolites. *Environ Health Perspect* 113:6-10.**
   Ref Type: Journal

3. **Lauber SN, Ali S, Gooderham NJ. 2004. The cooked food derived carcinogen 2-amino-1-methyl-6-phenylimidazo[4,5-b] pyridine is a potent oestrogen: a mechanistic basis for its tissue-specific carcinogenicity. *Carcinogenesis* 25:2509-2517.**
   Ref Type: Journal

4. **Kataoka H, Nishioka S, Kobayashi M, Hanaoka T, Tsugane S. 2002. Analysis of mutagenic heterocyclic amines in cooked food samples by gas chromatography with nitrogen-phosphorus detector. *Bull Environ Contam Toxicol* 69:682-689.**
   Ref Type: Journal

5. **Sugimura T, Wakabayashi K, Nakagama H, Nagao M. 2004. Heterocyclic amines: Mutagens/carcinogens produced during cooking of meat and fish. *Cancer Sci* 95:290-299.**
   Ref Type: Journal

6. **Felton JS, Knize MG, Salmon CP, Malfatti MA, Kulp KS. 2002. Human exposure to heterocyclic amine food mutagens/carcinogens: relevance to breast cancer. *Environ Mol Mutagen* 39:112-118.**
   Ref Type: Journal

7. **Ushiyama H, Wakabayashi K, Hirose M, Itoh H, Sugimura T, Nagao M. 1991. Presence of carcinogenic heterocyclic amines in urine of healthy volunteers eating normal diet, but not of inpatients receiving parenteral alimentation. *Carcinogenesis* 12:1417-1422.**
   Ref Type: Journal

8. **DeBruin LS, Martos PA, Josephy PD. 2001. Detection of PhIP (2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine) in the milk of healthy women. *Chem Res Toxicol* 14:1523-1528.**
   Ref Type: Journal

9. **Tsai KS, Yang RS, Liu SH. 2004. Benzo[a]pyrene regulates osteoblast proliferation through an estrogen receptor-related cyclooxygenase-2 pathway. *Chem Res Toxicol* 17:679-684.**
   Ref Type: Journal

10. **Vinggaard AM, Hnida C, Larsen JC. 2000. Environmental polycyclic aromatic hydrocarbons affect androgen receptor activation in vitro. *Toxicology* 145:173-183.**
    Ref Type: Journal

11. **Arcaro KF, O'Keefe PW, Yang Y, Clayton W, Gierthy JF. 1999. Antiestrogenicity of environmental polycyclic aromatic hydrocarbons in human breast cancer cells. *Toxicology* 133:115-127.**
    Ref Type: Journal

12. **Zanieri L, Galvan P, Checchini L, Cincinelli A, Lepri L, Donzelli GP, Del BM. 2007. Polycyclic aromatic hydrocarbons (PAHs) in human milk from Italian women: influence of cigarette smoking and residential area. *Chemosphere* 67:1265-1274.**
    Ref Type: Journal

13. **Villeneuve DL, Khim JS, Kannan K, Giesy JP. 2002. Relative potencies of individual polycyclic aromatic hydrocarbons to induce dioxinlike and estrogenic responses in three cell lines. *Environ Toxicol* 17:128-137.**
    Ref Type: Journal

14. **ATSDR. Toxicological profile for polychlorinated biphenyls (PCBs). ATSDR November 2000.**
    Ref Type: Report

15. **Iida T, Todaka T, Hirakawa H, Hori T, Tobiishi K, Matsueda T, Watanabe S, Yamada T. 2007. Concentration and distribution of dioxins and related compounds in human tissues. *Chemosphere* 67:S263-S271.**
    Ref Type: Journal

16. **Sjodin A, Hagmar L, Klasson-Wehler E, Bjork J, Bergman A. 2000. Influence of the consumption of fatty Baltic Sea fish on plasma levels of halogenated environmental contaminants in Latvian and Swedish men. *Environ Health Perspect* 108:1035-1041.**
    Ref Type: Journal

17. **Soto AM, Sonnenschein C, Chung KL, Fernandez MF, Olea N, Serrano FO. 1995. The E-SCREEN assay as a tool to identify estrogens: an update on estrogenic environmental pollutants. *Environ Health Perspect* 103 Suppl 7:113-122.**
    Ref Type: Journal

18. **DeCastro BR, Korrick SA, Spengler JD, Soto AM. 2006. Estrogenic activity of polychlorinated biphenyls present in human tissue and the environment. *Environ Sci Technol* 40:2819-2825.**
    Ref Type: Journal

19. **Blair RM, Fang H, Branham WS, Hass BS, Dial SL, Moland CL, Tong W, Shi L, Perkins R, Sheehan DM. 2000. The estrogen receptor relative binding affinities of 188 natural and xenochemicals: structural diversity of ligands. *Toxicol Sci* 54:138-153.**
    Ref Type: Journal

20. **Fang H, Tong W, Branham WS, Moland CL, Dial SL, Hong H, Xie Q, Perkins R, Owens W, Sheehan DM. 2003. Study of 202 natural, synthetic, and environmental chemicals for binding to the androgen receptor. *Chem Res Toxicol* 16:1338-1358.**
    Ref Type: Journal

21. **Park H, Lee SJ, Kang JH, Chang YS. 2007. Congener-specific approach to human PCB concentrations by serum analysis. *Chemosphere* .**
    Ref Type: Journal

22. **Pliskova M, Vondracek J, Canton RF, Nera J, Kocan A, Petrik J, Trnovec T, Sanderson T, van den BM, Machala M. 2005. Impact of polychlorinated biphenyls contamination on estrogenic activity in human male serum. *Environ Health Perspect* 113:1277-1284.**
Ref Type: Journal

23. **Costopoulou D, Vassiliadou I, Papadopoulos A, Makropoulos V, Leondiadis L. 2006. Levels of dioxins, furans and PCBs in human serum and milk of people living in Greece. *Chemosphere* 65:1462-1469.**
Ref Type: Journal

24. **Koppen G, Covaci A, Van CR, Schepens P, Winneke G, Nelen V, van LN, Vlietinck R, Schoeters G. 2002. Persistent organochlorine pollutants in human serum of 50-65 years old women in the Flanders Environmental and Health Study (FLEHS). Part 1: Concentrations and regional differences. *Chemosphere* 48:811-825.**
Ref Type: Journal

25. **Orloff KG, Dearwent S, Metcalf S, Kathman S, Turner W. 2003. Human Exposure to Polychlorinated Biphenyls in a Residential Community. *Archives of Environmental Contamination and Toxicology* 44:125-131.**
Ref Type: Journal

26. **Newsome WH, Davies D, Doucet J. 1995. PCB and organochlorine pesticides in Canadian human milk -- 1992. *Chemosphere* 30:2143-2153.**
Ref Type: Journal

27. **Guvenius DM, Aronsson A, Ekman-Ordeberg G, Bergman A, Noren K. 2003. Human prenatal and postnatal exposure to polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorobiphenylols, and pentachlorophenol. *Environ Health Perspect* 111:1235-1241.**
Ref Type: Journal

28. **Oh SM, Ryu BT, Lee SK, Chung KH. 2007. Antiestrogenic potentials of ortho-PCB congeners by single or complex exposure. *Arch Pharm Res* 30:199-209.**
Ref Type: Journal

29. **Jacobs M, Ferrario J, Byrne C. 2002. Investigation of polychlorinated dibenzo-p-dioxins, dibenzo-p-furans and selected coplanar biphenyls in Scottish farmed Atlantic salmon (Salmo salar). *Chemosphere* 47:183-191.**
Ref Type: Journal

30. **Lindstrom G, Haug LS, Nicolaysen T, Dybing E. 2002. Comparability of world-wide analytical data of PCDDs, PCDFs and non-ortho PCBs in samples of chicken, butter and salmon. *Chemosphere* 47:139-146.**
Ref Type: Journal

31. **Letcher RJ, Lemmen JG, van der BB, Brouwer A, Bergman A, Giesy JP, van den BM. 2002. In vitro antiestrogenic effects of aryl methyl sulfone metabolites of polychlorinated biphenyls and 2,2-bis(4-chlorophenyl)-1,1-dichloroethene on 17beta-estradiol-induced gene expression in several bioassay systems. *Toxicol Sci* 69:362-372.**
Ref Type: Journal

32. **Park JS, Linderholm L, Charles MJ, Athanasiadou M, Petrik J, Kocan A, Drobna B, Trnovec T, Bergman A, Hertz-Picciotto I. 2007. Polychlorinated biphenyls and their hydroxylated metabolites (OH-PCBS) in pregnant women from eastern Slovakia. *Environ Health Perspect* 115:20-27.**
Ref Type: Journal

33. **Soechitram SD, Athanasiadou M, Hovander L, Bergman A, Sauer PJ. 2004. Fetal exposure to PCBs and their hydroxylated metabolites in a Dutch cohort. *Environ Health Perspect* 112:1208-1212.**
Ref Type: Journal

34. **Bonefeld-Jorgensen EC, Andersen HR, Rasmussen TH, Vinggaard AM. 2001. Effect of highly bioaccumulated polychlorinated biphenyl congeners on estrogen and androgen receptor activity. *Toxicology* 158:141-153.**
Ref Type: Journal

35. **Weiss J, Wallin E, Axmon A, Jonsson BAG, Akesson H, Janak K, Hagmar L, Bergman A. 2006. Hydroxy-PCBs, PBDEs, and HBCDDs in Serum from an Elderly Population of Swedish Fishermen's Wives and Associations with Bone Density. *Environ Sci Technol* 40:6282-6289.**
Ref Type: Journal

36. **FSA. Dioxins and dioxin-like PCBs in the UK diet: 2001 total diet study samples. FSIS 38/03.**
Ref Type: Report

37. **Startin JR, Rose M, Wright C, Parker I, Gilbert J. 1990. Surveillance of British foods for PCDDs and PCDFs. *Chemosphere* 20:793-798.**
Ref Type: Journal

38. **Wang SL, Chang YC, Chao HR, Li CM, Li LA, Lin LY, Papke O. 2006. Body burdens of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls and their relations to estrogen metabolism in pregnant women. *Environ Health Perspect* 114:740-745.**
Ref Type: Journal

39. **Schecter A, Piskac AL, Grosheva EI, Matorova NI, Ryan JJ, Furst P, Papke, Adibi J, Pavuk M, Silver A, Ghaffar S. 2002. Levels of dioxins and dibenzofurans in breast milk of women residing in two cities in the Irkutsk Region of Russian Siberia compared with American levels. *Chemosphere* 47:157-164.**
Ref Type: Journal

40. **Safe S, Astroff B, Harris M, Zacharewski T, Dickerson R, Romkes M, Biegel L. 1991. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) and related compounds as antioestrogens: characterization and mechanism of action. *Pharmacol Toxicol* 69:400-409.**
Ref Type: Journal

41. **Nodland KI, Wormke M, Safe S. 1997. Inhibition of Estrogen-Induced Activity by 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) in the MCF-7 Human Breast Cancer and Other Cell Lines Transfected with Vitellogenin A2 Gene Promoter Constructs1. *Archives of Biochemistry and Biophysics* 338:67-72.**
Ref Type: Journal

42. **Legler J, van den Brink CE, Brouwer A, Murk AJ, van der Saag PT, Vethaak AD, van der Burg B. 1999. Development of a stably transfected**

estrogen receptor-mediated luciferase reporter gene assay in the human T47D breast cancer cell line. *Toxicol Sci* 48:55-66.
Ref Type: Journal

43. White TE, Gasiewicz TA. 1993. The human estrogen receptor structural gene contains a DNA sequence that binds activated mouse and human Ah receptors: a possible mechanism of estrogen receptor regulation by 2,3,7,8-tetrachlorodibenzo-p-dioxin. *Biochem Biophys Res Commun* 193:956-962.
Ref Type: Journal

44. Zacharewski TR, Bondy KL, McDonell P, Wu ZF. 1994. Antiestrogenic Effect of 2,3,7,8-Tetrachlorodibenzo-p-dioxin on 17{beta}-Estradiol-induced pS2 Expression. *Cancer Res* 54:2707-2713.
Ref Type: Journal

45. Bredhult C, Backlin BM, Olovsson M. 2007. Effects of some endocrine disruptors on the proliferation and viability of human endometrial endothelial cells in vitro. *Reproductive Toxicology* 23:550-559.
Ref Type: Journal

46. Krishnan V, Safe S. 1993. Polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (PCDDs), and dibenzofurans (PCDFs) as antiestrogens in MCF-7 human breast cancer cells: quantitative structure-activity relationships. *Toxicol Appl Pharmacol* 120:55-61.
Ref Type: Journal

47. Fisher JS. 2004. Environmental anti-androgens and male reproductive health: focus on phthalates and testicular dysgenesis syndrome. *Reproduction* 127:305-315.
Ref Type: Journal

48. Wormuth M, Scheringer M, Vollenweider M, Hungerbuhler K. 2006. What Are the Sources of Exposure to Eight Frequently Used Phthalic Acid Esters in Europeans? *Risk Analysis* 26:803-824.
Ref Type: Journal

49. Wolff MS, Teitelbaum SL, Windham G, Pinney SM, Britton JA, Chelimo C, Godbold J, Biro F, Kushi LH, Pfeiffer CM, Calafat AM. 2007. Pilot study of urinary biomarkers of phytoestrogens, phthalates, and phenols in girls. *Environ Health Perspect* 115:116-121.
Ref Type: Journal

50. Wittassek M, Heger W, Koch HM, Becker K, Angerer J, Kolossa-Gehring M. 2007. Daily intake of di(2-ethylhexyl)phthalate (DEHP) by German children -- A comparison of two estimation models based on urinary DEHP metabolite levels. *Int J Hyg Environ Health* 210:35-42.
Ref Type: Journal

51. Wittassek M, Wiesmuller GA, Koch HM, Eckard R, Dobler L, Muller J, Angerer J, Schluter C. 2007. Internal phthalate exposure over the last two decades - A retrospective human biomonitoring study. *Int J Hyg Environ Health* 210:319-333.
Ref Type: Journal

52. Zacharewski TR, Meek MD, Clemons JH, Wu ZF, Fielden MR, Matthews JB. 1998. Examination of the in vitro and in vivo estrogenic activities of eight commercial phthalate esters. *Toxicol Sci* 46:282-293.
Ref Type: Journal

53. Jobling S, Reynolds T, White R, Parker MG, Sumpter JP. 1995. A variety of environmentally persistent chemicals, including some phthalate plasticizers, are weakly estrogenic. *Environ Health Perspect* 103:582-587.
Ref Type: Journal

54. van Meeuwen JA, van den BM, Sanderson JT, Verhoef A, Piersma AH. 2007. Estrogenic effects of mixtures of phyto- and synthetic chemicals on uterine growth of prepubertal rats. *Toxicol Lett* 170:165-176.
Ref Type: Journal

55. Sonnenschein C, Soto AM. 1998. An updated review of environmental estrogen and androgen mimics and antagonists. *J Steroid Biochem Mol Biol* 65:143-150.
Ref Type: Journal

56. Harris CA, Henttu P, Parker MG, Sumpter JP. 1997. The estrogenic activity of phthalate esters in vitro. *Environ Health Perspect* 105:802-811.
Ref Type: Journal

57. Brotons JA, Olea-Serrano MF, Villalobos M, Pedraza V, Olea N. 1995. Xenoestrogens released from lacquer coatings in food cans. *Environ Health Perspect* 103:608-612.
Ref Type: Journal

58. SCF/CS/PM/3936 final. Opinion of the Scientific Committee on Food on Bisphenol A. European Commission.
Ref Type: Report

59. Krishnan AV, Stathis P, Permuth SF, Tokes L, Feldman D. 1993. Bisphenol-A: an estrogenic substance is released from polycarbonate flasks during autoclaving. *Endocrinology* 132:2279-2286.
Ref Type: Journal

60. Ranhotra HS, Teng CT. 2005. Assessing the estrogenicity of environmental chemicals with a stably transfected lactoferrin gene promoter reporter in HeLa cells. *Environmental Toxicology and Pharmacology* 20:42-47.
Ref Type: Journal

61. Olsen CM, Meussen-Elholm ETM, Hongslo JK, Stenersen J, Tollefsen KE. 2005. Estrogenic effects of environmental chemicals: An interspecies comparison. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology* 141:267-274.
Ref Type: Journal

62. Roy P, Salminen H, Koskimies P, Simola J, Smeds A, Saukko P, Huhtaniemi IT. 2004. Screening of some anti-androgenic endocrine disruptors using a recombinant cell-based in vitro bioassay. *J Steroid Biochem Mol Biol* 88:157-166.
Ref Type: Journal

63. Paris F, Balaguer P, Terouanne B, Servant N, Lacoste C, Cravedi JP, Nicolas JC, Sultan C. 2002. Phenylphenols, biphenols, bisphenol-A and 4-tert-octylphenol exhibit alpha and beta estrogen activities and antiandrogen activity in reporter cell lines. *Mol Cell Endocrinol* 193:43-49.
Ref Type: Journal

64. Goodson A, Summerfield W, Cooper I. 2002. Survey of bisphenol A and bisphenol F in canned foods. *Food Addit Contam* 19:796-802.
Ref Type: Journal

65. Schonfelder G, Wittfoht W, Hopp H, Talsness CE, Paul M, Chahoud I. 2002. Parent bisphenol A accumulation in the human maternal-fetal-placental unit. *Environ Health Perspect* 110:A703-A707.
Ref Type: Journal

66. Ikezuki Y, Tsutsumi O, Takai Y, Kamei Y, Taketani Y. 2002. Determination of bisphenol A concentrations in human biological fluids reveals significant early prenatal exposure. *Hum Reprod* 17:2839-2841.
Ref Type: Journal

67. Takeuchi T, Tsutsumi O. 2002. Serum bisphenol a concentrations showed gender differences, possibly linked to androgen levels. *Biochem Biophys Res Commun* 291:76-78.
Ref Type: Journal

68. Hiroi H, Tsutsumi O, Takeuchi T, Momoeda M, Ikezuki Y, Okamura A, Yokota H, Taketani Y. 2004. Differences in serum bisphenol a concentrations in premenopausal normal women and women with endometrial hyperplasia. *Endocr J* 51:595-600.
Ref Type: Journal

69. Takeuchi T, Tsutsumi O, Ikezuki Y, Takai Y, Taketani Y. 2004. Positive relationship between androgen and the endocrine disruptor, bisphenol A, in normal women and women with ovarian dysfunction. *Endocr J* 51:165-169.
Ref Type: Journal

70. Han DH, Denison MS, Tachibana H, Yamada K. 2002. Relationship between estrogen receptor-binding and estrogenic activities of environmental estrogens and suppression by flavonoids. *Biosci Biotechnol Biochem* 66:1479-1487.
Ref Type: Journal

71. Shaw I, McCully S. 2002. A review of the potential impact of dietary endocrine disruptors on the consumer. *International Journal of Food Science and Technology* 37:471-476.
Ref Type: Journal

72. Muller S, Schmid P, Schlatter C. 1998. Evaluation of the estrogenic potency of nonylphenol in non-occupationally exposed humans. *Environmental Toxicology and Pharmacology* 6:27-33.
Ref Type: Journal

73. Kawaguchi M, Inoue K, Sakui N, Ito R, Izumi S, Makino T, Okanouchi N, Nakazawa H. 2004. Stir bar sorptive extraction and thermal desorption-gas chromatography-mass spectrometry for the measurement of 4-nonylphenol and 4-tert-octylphenol in human biological samples. *J Chromatogr B Analyt Technol Biomed Life Sci* 799:119-125.
Ref Type: Journal

74. Schrader TJ, Cooke GM. 2000. Examination of selected food additives and organochlorine food contaminants for androgenic activity in vitro. *Toxicol Sci* 53:278-288.
Ref Type: Journal

75. Kang HG, Jeong SH, Cho JH, Kim DG, Park JM, Cho MH. 2005. Evaluation of estrogenic and androgenic activity of butylated hydroxyanisole in immature female and castrated rats. *Toxicology* 213:147-156.
Ref Type: Journal

76. Conacher HB, Iverson F, Lau PY, Page BD. 1986. Levels of BHA and BHT in human and animal adipose tissue: interspecies extrapolation. *Food Chem Toxicol* 24:1159-1162.
Ref Type: Journal

77. Inoue K, Okumura H, Higuchi T, Oka H, Yoshimura Y, Nakazawa H. 2002. Characterization of estrogenic compounds in medical polyvinyl chloride tubing by gas chromatography-mass spectrometry and estrogen receptor binding assay. *Clin Chim Acta* 325:157-163.
Ref Type: Journal

78. Leclercq C, Arcella D, Turrini A. 2000. Estimates of the theoretical maximum daily intake of erythorbic acid, gallates, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) in Italy: a stepwise approach. *Food Chem Toxicol* 38:1075-1084.
Ref Type: Journal

79. Beck V, Rohr U, Jungbauer A. 2005. Phytoestrogens derived from red clover: an alternative to estrogen replacement therapy? *J Steroid Biochem Mol Biol* 94:499-518.
Ref Type: Journal

80. Thompson LU, Boucher BA, Liu Z, Cotterchio M, Kreiger N. 2006. Phytoestrogen content of foods consumed in Canada, including isoflavones, lignans, and coumestan. *Nutr Cancer* 54:184-201.
Ref Type: Journal

81. Cassidy A, Brown JE, Hawdon A, Faughnan MS, King LJ, Millward J, Zimmer-Nechemias L, Wolfe B, Setchell KD. 2006. Factors affecting the bioavailability of soy isoflavones in humans after ingestion of physiologically relevant levels from different soy foods. *J Nutr* 136:45-51.
Ref Type: Journal

82. Matsumura A, Ghosh A, Pope GS, Darbre PD. 2005. Comparative study of oestrogenic properties of eight phytoestrogens in MCF7 human breast cancer cells. *The Journal of Steroid Biochemistry and Molecular Biology* 94:431-443.
Ref Type: Journal

83. COT working group on phytoestogens. Chemistry of phytoestrogens and overview of analytical methodology. PEG/2000/06.
Ref Type: Report

84. COT. Working group on phytoestrogens (draft report).
Ref Type: Report

85. Horn-Ross PL, Barnes S, Lee M, Coward L, Mandel JE, Koo J, John EM, Smith M. 2000. Assessing phytoestrogen exposure in epidemiologic studies: development of a database (United States). *Cancer Causes Control* 11:289-298.
Ref Type: Journal

86. Takamura-Enya T, Ishihara J, Tahara S, Goto S, Totsuka Y, Sugimura T, Wakabayashi K. 2003.

Analysis of estrogenic activity of foodstuffs and cigarette smoke condensates using a yeast estrogen screening method. *Food and Chemical Toxicology* 41:543-550.
Ref Type: Journal

87. Peeters PH, Slimani N, van der Schouw YT, Grace PB, Navarro C, Tjonneland A, Olsen A, Clavel-Chapelon F, Touillaud M, Boutron-Ruault MC, Jenab M, Kaaks R, Linseisen J, Trichopoulou A, Trichopoulos D, Dilis V, Boeing H, Weikert C, Overvad K, Pala V, Palli D, Panico S, Tumino R, Vineis P, Bueno-de-Mesquita HB, van Gils CH, Skeie G, Jakszyn P, Hallmans G, Berglund G, Key TJ, Travis R, Riboli E, Bingham SA. 2007. Variations in plasma phytoestrogen concentrations in European adults. *J Nutr* 137:1294-1300.
Ref Type: Journal

88. Kuiper GG, Carlsson B, Grandien K, Enmark E, Haggblad J, Nilsson S, Gustafsson JA. 1997. Comparison of the ligand binding specificity and transcript tissue distribution of estrogen receptors alpha and beta. *Endocrinology* 138:863-870.
Ref Type: Journal

89. Whitten PL, Patisaul HB. 2001. Cross-species and interassay comparisons of phytoestrogen action. *Environ Health Perspect* 109 Suppl 1:5-20.
Ref Type: Journal

90. Overk CR, Yao P, Chadwick LR, Nikolic D, Sun Y, Cuendet MA, Deng Y, Hedayat AS, Pauli GF, Farnsworth NR, vanBreemen RB, Bolton JL. 2005. Comparison of the in Vitro Estrogenic Activities of Compounds from Hops (Humulus lupulus) and Red Clover (Trifolium pratense). *J Agric Food Chem* 53:6246-6253.
Ref Type: Journal

91. Verma SP, Salamone E, Goldin B. 1997. Curcumin and genistein, plant natural products, show synergistic inhibitory effects on the growth of human breast cancer MCF-7 cells induced by estrogenic pesticides. *Biochem Biophys Res Commun* 233:692-696.
Ref Type: Journal

92. Beck V, Unterrieder E, Krenn L, Kubelka W, Jungbauer A. 2003. Comparison of hormonal activity (estrogen, androgen and progestin) of standardized plant extracts for large scale use in hormone replacement therapy. *The Journal of Steroid Biochemistry and Molecular Biology* 84:259-268.
Ref Type: Journal

93. Adlercreutz H, Yamada T, Wahala K, Watanabe S. 1999. Maternal and neonatal phytoestrogens in Japanese women during birth. *Am J Obstet Gynecol* 180:737-743.
Ref Type: Journal

94. Zeleniuch-Jacquotte A, Adlercreutz H, Akhmedkhanov A, Toniolo P. 1998. Reliability of serum measurements of lignans and isoflavonoid phytoestrogens over a two-year period. *Cancer Epidemiol Biomarkers Prev* 7:885-889.
Ref Type: Journal

95. Safford B, Dickens A, Halleron N, Briggs D, Carthew P, Baker V. 2003. A model to estimate the oestrogen receptor mediated effects from exposure to soy isoflavones in food. *Regul Toxicol Pharmacol* 38:196-209.
Ref Type: Journal

96. Wiseman H, Casey K, Bowey EA, Duffy R, Davies M, Rowland IR, Lloyd AS, Murray A, Thompson R, Clarke DB. 2004. Influence of 10 wk of soy consumption on plasma concentrations and excretion of isoflavonoids and on gut microflora metabolism in healthy adults. *Am J Clin Nutr* 80:692-699.
Ref Type: Journal

97. Morton MS, Chan PS, Cheng C, Blacklock N, Matos-Ferreira A, branches-Monteiro L, Correia R, Lloyd S, Griffiths K. 1997. Lignans and isoflavonoids in plasma and prostatic fluid in men: samples from Portugal, Hong Kong, and the United Kingdom. *Prostate* 32:122-128.
Ref Type: Journal

98. Lund TD, Munson DJ, Haldy ME, Setchell KD, Lephart ED, Handa RJ. 2004. Equol is a novel anti-androgen that inhibits prostate growth and hormone feedback. *Biol Reprod* 70:1188-1195.
Ref Type: Journal

99. Bergman Jungestrom M, Thompson LU, Dabrosin C. 2007. Flaxseed and Its Lignans Inhibit Estradiol-Induced Growth, Angiogenesis, and Secretion of Vascular Endothelial Growth Factor in Human Breast Cancer Xenografts In vivo. *Clin Cancer Res* 13:1061-1067.
Ref Type: Journal

100. Le GR, Pakdel F. 2001. Assessment of oestrogenic potency of chemicals used as growth promoter by in-vitro methods. *Hum Reprod* 16:1030-1036.
Ref Type: Journal

101. Scudamore KA, Patel S. 2000. Survey for aflatoxins, ochratoxin A, zearalenone and fumonisins in maize imported into the United Kingdom. *Food Addit Contam* 17:407-416.
Ref Type: Journal

102. Ruh MF, Zacharewski T, Connor K, Howell J, Chen I, Safe S. 1995. Naringenin: a weakly estrogenic bioflavonoid that exhibits antiestrogenic activity. *Biochem Pharmacol* 50:1485-1493.
Ref Type: Journal

103. Erlund I, Meririnne E, Alfthan G, Aro A. 2001. Plasma Kinetics and Urinary Excretion of the Flavanones Naringenin and Hesperetin in Humans after Ingestion of Orange Juice and Grapefruit Juice. *J Nutr* 131:235-241.
Ref Type: Journal

104. Milligan SR, Kalita JC, Heyerick A, Rong H, De Cooman L, De Keukeleire D. 1999. Identification of a Potent Phytoestrogen in Hops (Humulus lupulus L.) and Beer. *J Clin Endocrinol Metab* 84:2249.
Ref Type: Journal

105. Milligan SR, Kalita JC, Pocock V, Van De Kauter V, Stevens JF, Deinzer ML, Rong H, De Keukeleire D. 2000. The Endocrine Activities of 8-Prenylnaringenin and Related Hop (Humulus lupulus L.) Flavonoids. *J Clin Endocrinol Metab* 85:4912-4915.
Ref Type: Journal

106. Milligan S, Kalita J, Pocock V, Heyerick A, De Cooman L, Rong H, De Keukeleire D. 2002. Oestrogenic activity of the hop phyto-oestrogen, 8-prenylnaringenin. *Reproduction* 123:235-242.
Ref Type: Journal

107. Schaefer O, Humpel M, Fritzemeier KH, Bohlmann R, Schleuning WD. 2003. 8-Prenyl naringenin is a potent ER[alpha] selective phytoestrogen present in hops and beer. *The Journal of Steroid Biochemistry and Molecular Biology* 84:359-360.
Ref Type: Journal

108. Zierau O, Morrissey C, Watson RW, Schwab P, Kolba S, Metz P, Vollmer G. 2003. Antiandrogenic activity of the phytoestrogens naringenin, 6-(1,1-dimethylallyl)naringenin and 8-prenylnaringenin. *Planta Med* 69:856-858.
Ref Type: Journal

109. Possemiers S, Heyerick A, Robbens V, DeKeukeleire D, Verstraete W. 2005. Activation of Proestrogens from Hops (Humulus lupulus L.) by Intestinal Microbiota; Conversion of Isoxanthohumol into 8-Prenylnaringenin. *J Agric Food Chem* 53:6281-6288.
Ref Type: Journal

110. Rad M, Humpel M, Schaefer O, Schoemaker RC, Schleuning WD, Cohen AF, Burggraaf J. 2006. Pharmacokinetics and systemic endocrine effects of the phyto-oestrogen 8-prenylnaringenin after single oral doses to postmenopausal women. *British Journal of Clinical Pharmacology* 62:288-296.
Ref Type: Journal

111. Zierau O, Hauswald S, Schwab P, Metz P, Vollmer G. 2004. Two major metabolites of 8-prenylnaringenin are estrogenic in vitro. *The Journal of Steroid Biochemistry and Molecular Biology* 92:107-110.
Ref Type: Journal

112. Ikeda K, Arao Y, Otsuka H, Nomoto S, Horiguchi H, Kato S, Kayama F. 2002. Terpenoids found in the umbelliferae family act as agonists/antagonists for ER(alpha) and ERbeta: differential transcription activity between ferutinine-liganded ER(alpha) and ERbeta. *Biochem Biophys Res Commun* 291:354-360.
Ref Type: Journal

113. Bocio A, Llobet JM, Domingo JL, Corbella J, Teixido A, Casas C. 2003. Polybrominated diphenyl ethers (PBDEs) in foodstuffs: human exposure through the diet. *J Agric Food Chem* 51:3191-3195.
Ref Type: Journal

114. Schecter A, Papke O, Harris TR, Tung KC, Musumba A, Olson J, Birnbaum L. 2006. Polybrominated diphenyl ether (PBDE) levels in an expanded market basket survey of U.S. food and estimated PBDE dietary intake by age and sex. *Environ Health Perspect* 114:1515-1520.
Ref Type: Journal

115. Gomara B, Herrero L, Gonzalez MJ. 2006. Survey of polybrominated diphenyl ether levels in Spanish commercial foodstuffs. *Environ Sci Technol* 40:7541-7547.
Ref Type: Journal

116. Food Standards Agency. Brominated chemicals: UK dietary intakes. Food survey information sheet 10/06.
Ref Type: Report

117. Meerts IA, Letcher RJ, Hoving S, Marsh G, Bergman A, Lemmen JG, van der BB, Brouwer A. 2001. In vitro estrogenicity of polybrominated diphenyl ethers, hydroxylated PDBEs, and polybrominated bisphenol A compounds. *Environ Health Perspect* 109:399-407.
Ref Type: Journal

118. Meironyte GD, Bergman A, Noren K. 2001. Polybrominated diphenyl ethers in Swedish human liver and adipose tissue. *Arch Environ Contam Toxicol* 40:564-570.
Ref Type: Journal

119. Guvenius DM, Aronsson A, Ekman-Ordeberg G, Bergman A, Noren K. 2003. Human prenatal and postnatal exposure to polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorobiphenylols, and pentachlorophenol. *Environ Health Perspect* 111:1235-1241.
Ref Type: Journal

120. Peters RJB. Man-Made Chemicals in Human Blood. TNO-report R 2004/493.
Ref Type: Report

121. Covaci A, de BJ, Ryan JJ, Voorspoels S, Schepens P. 2002. Distribution of organobrominated and organochlorinated contaminants in Belgian human adipose tissue. *Environ Res* 88:210-218.
Ref Type: Journal

122. Legler J, Brouwer A. 2003. Are brominated flame retardants endocrine disruptors? *Environ Int* 29:879-885.
Ref Type: Journal

123. Stoker TE, Cooper RL, Lambright CS, Wilson VS, Furr J, Gray LE. 2005. In vivo and in vitro anti-androgenic effects of DE-71, a commercial polybrominated diphenyl ether (PBDE) mixture. *Toxicol Appl Pharmacol* 207:78-88.
Ref Type: Journal

124. Meneses M, Wingfors H, Schuhmacher M, Domingo JL, Lindstrom G, van BB. 1999. Polybrominated diphenyl ethers detected in human adipose tissue from Spain. *Chemosphere* 39:2271-2278.
Ref Type: Journal

125. Mazdai A, Dodder NG, Abernathy MP, Hites RA, Bigsby RM. 2003. Polybrominated diphenyl ethers in maternal and fetal blood samples. *Environ Health Perspect* 111:1249-1252.
Ref Type: Journal

126. Maras M, Vanparys C, Muylle F, Robbens J, Berger U, Barber JL, Blust R, De CW. 2006. Estrogen-like properties of fluorotelomer alcohols as revealed by mcf-7 breast cancer cell proliferation. *Environ Health Perspect* 114:100-105.
Ref Type: Journal

127. Food Standards Agency. Fluorinated chemicals: UK dietary intakes. Food survey information sheet 11/06.
Ref Type: Report

128. Midasch O, Schettgen T, Angerer J. 2006. Pilot study on the perfluorooctanesulfonate and perfluorooctanoate exposure of the German general population. *Int J Hyg Environ Health* 209:489-496.
Ref Type: Journal

129. Kannan K, Corsolini S, Falandysz J, Fillmann G, Kumar KS, Loganathan BG, Mohd MA, Olivero J, Van WN, Yang JH, Aldoust KM. 2004. Perfluorooctanesulfonate and related fluorochemicals in human blood from several countries. *Environ Sci Technol* 38:4489-4495.
Ref Type: Journal

130. Fromme H, Midasch O, Twardella D, Angerer J, Boehmer S, Liebl B. 2007. Occurrence of perfluorinated substances in an adult German population in southern Bavaria. *Int Arch Occup Environ Health* 80:313-319.
Ref Type: Journal

131. Karrman A, Langlois I, Bavel BV, Lindstrom G, Oehme M. 2007. Identification and pattern of perfluorooctane sulfonate (PFOS) isomers in human serum and plasma. *Environ Int* .
Ref Type: Journal

132. Karrman A, Ericson I, van BB, Darnerud PO, Aune M, Glynn A, Lignell S, Lindstrom G. 2007. Exposure of perfluorinated chemicals through lactation: levels of matched human milk and serum and a temporal trend, 1996-2004, in Sweden. *Environ Health Perspect* 115:226-230.
Ref Type: Journal

133. Karrman A, Mueller JF, van BB, Harden F, Toms LM, Lindstrom G. 2006. Levels of 12 perfluorinated chemicals in pooled australian serum, collected 2002-2003, in relation to age, gender, and region. *Environ Sci Technol* 40:3742-3748.
Ref Type: Journal

134. Peters RJB. Man-Made Chemicals in Maternal and Cord Blood. TNO-report B&O-A R2005/129.
Ref Type: Report

135. Vanparys C, Maras M, Lenjou M, Robbens J, Van Bockstaele D, Blust R, De Coen W. 2006. Flow cytometric cell cycle analysis allows for rapid screening of estrogenicity in MCF-7 breast cancer cells. *Toxicology in Vitro* 20:1238-1248.
Ref Type: Journal

136. Soni MG, Carabin IG, Burdock GA. 2005. Safety assessment of esters of p-hydroxybenzoic acid (parabens). *Food Chem Toxicol* 43:985-1015.
Ref Type: Journal

137. Routledge EJ, Parker J, Odum J, Ashby J, Sumpter JP. 1998. Some alkyl hydroxy benzoate preservatives (parabens) are estrogenic. *Toxicol Appl Pharmacol* 153:12-19.
Ref Type: Journal

138. Byford JR, Shaw LE, Drew MG, Pope GS, Sauer MJ, Darbre PD. 2002. Oestrogenic activity of parabens in MCF7 human breast cancer cells. *J Steroid Biochem Mol Biol* 80:49-60.
Ref Type: Journal

139. Okubo T, Yokoyama Y, Kano K, Kano I. 2001. ER-dependent estrogenic activity of parabens assessed by proliferation of human breast cancer MCF-7 cells and expression of ERalpha and PR. *Food Chem Toxicol* 39:1225-1232.
Ref Type: Journal

140. Morohoshi K, Yamamoto H, Kamata R, Shiraishi F, Koda T, Morita M. 2005. Estrogenic activity of 37 components of commercial sunscreen lotions evaluated by in vitro assays. *Toxicol In Vitro* 19:457-469.
Ref Type: Journal

141. Blair RM, Fang H, Branham WS, Hass BS, Dial SL, Moland CL, Tong W, Shi L, Perkins R, Sheehan DM. 2000. The estrogen receptor relative binding affinities of 188 natural and xenochemicals: structural diversity of ligands. *Toxicol Sci* 54:138-153.
Ref Type: Journal

142. Chen J, Ahn KC, Gee NA, Gee SJ, Hammock BD, Lasley BL. 2007. Antiandrogenic properties of parabens and other phenolic containing small molecules in personal care products. *Toxicol Appl Pharmacol* .
Ref Type: Journal

143. Satoh K, Nonaka R, Ohyama K, Nagai F. 2005. Androgenic and antiandrogenic effects of alkylphenols and parabens assessed using the reporter gene assay with stably transfected CHO-K1 cells (AR-EcoScreen System). *Journal of Health Science* 51:557-568.
Ref Type: Journal

144. Darbre PD, Aljarrah A, Miller WR, Coldham NG, Sauer MJ, Pope GS. 2004. Concentrations of parabens in human breast tumours. *J Appl Toxicol* 24:5-13.
Ref Type: Journal

145. Ye X, Bishop AM, Reidy JA, Needham LL, Calafat AM. 2006. Parabens as urinary biomarkers of exposure in humans. *Environ Health Perspect* 114:1843-1846.
Ref Type: Journal

146. Inui M, Adachi T, Takenaka S, Inui H, Nakazawa M, Ueda M, Watanabe H, Mori C, Iguchi T, Miyatake K. 2003. Effect of UV screens and preservatives on vitellogenin and choriogenin production in male medaka (Oryzias latipes). *Toxicology* 194:43-50.
Ref Type: Journal

147. Darbre PD, Byford JR, Shaw LE, Horton RA, Pope GS, Sauer MJ. 2002. Oestrogenic activity of isobutylparaben in vitro and in vivo. *J Appl Toxicol* 22:219-226.
Ref Type: Journal

148. Darbre PD, Byford JR, Shaw LE, Hall S, Coldham NG, Pope GS, Sauer MJ. 2003. Oestrogenic activity of benzylparaben. *J Appl Toxicol* 23:43-51.
Ref Type: Journal

149. Pugazhendhi D, Pope GS, Darbre PD. 2005. Oestrogenic activity of p-hydroxybenzoic acid (common metabolite of paraben esters) and methylparaben in human breast cancer cell lines. *J Appl Toxicol* 25:301-309.
Ref Type: Journal

150. Seinen W, Lemmen JG, Pieters RH, Verbruggen EM, van der BB. 1999. AHTN and HHCB show weak estrogenic--but no uterotrophic activity. *Toxicol Lett* 111:161-168.
Ref Type: Journal

151. **Bitsch N, Dudas C, Korner W, Failing K, Biselli S, Rimkus G, Brunn H. 2002. Estrogenic activity of musk fragrances detected by the E-screen assay using human mcf-7 cells. *Arch Environ Contam Toxicol* 43:257-264.**
Ref Type: Journal

152. **Schreurs RH, Quaedackers ME, Seinen W, van der BB. 2002. Transcriptional activation of estrogen receptor ERalpha and ERbeta by polycyclic musks is cell type dependent. *Toxicol Appl Pharmacol* 183:1-9.**
Ref Type: Journal

153. **Schreurs RH, Legler J, rtola-Garicano E, Sinnige TL, Lanser PH, Seinen W, van der BB. 2004. In vitro and in vivo antiestrogenic effects of polycyclic musks in zebrafish. *Environ Sci Technol* 38:997-1002.**
Ref Type: Journal

154. **Schreurs RH, Sonneveld E, Jansen JH, Seinen W, van der BB. 2005. Interaction of polycyclic musks and UV filters with the estrogen receptor (ER), androgen receptor (AR), and progesterone receptor (PR) in reporter gene bioassays. *Toxicol Sci* 83:264-272.**
Ref Type: Journal

155. **Duedahl-Olesen L, Cederberg T, Pedersen KH, Hojgard A. 2005. Synthetic musk fragrances in trout from Danish fish farms and human milk. *Chemosphere* 61:422-431.**
Ref Type: Journal

156. **Rimkus GG, Wolf M. 1996. Polycyclic musk fragrances in human adipose tissue and human milk. *Chemosphere* 33:2033-2043.**
Ref Type: Journal

157. **Zehringer M. 2001. Use of laminar cup liners for the preparation of fatty samples for pesticide analysis. *Food Addit Contam* 18:859-865.**
Ref Type: Journal

158. **Muller S, Schmid P, Schlatter C. 1996. Occurrence of nitro and non-nitro benzenoid musk compounds in human adipose tissue. *Chemosphere* 33:17-28.**
Ref Type: Journal

159. **Hutter HP, Wallner P, Moshammer H, Hartl W, Sattelberger R, Lorbeer G, Kundi M. 2005. Blood concentrations of polycyclic musks in healthy young adults. *Chemosphere* 59:487-492.**
Ref Type: Journal

160. **Kannan K, Reiner JL, Yun SH, Perrotta EE, Tao L, Johnson-Restrepo B, Rodan BD. 2005. Polycyclic musk compounds in higher trophic level aquatic organisms and humans from the United States. *Chemosphere* 61:693-700.**
Ref Type: Journal

161. **Schlumpf M, Cotton B, Conscience M, Haller V, Steinmann B, Lichtensteiger W. 2001. In vitro and in vivo estrogenicity of UV screens. *Environ Health Perspect* 109:239-244.**
Ref Type: Journal

162. **Tinwell H, Lefevre PA, Moffat GJ, Burns A, Odum J, Spurway TD, Orphanides G, Ashby J. 2002. Confirmation of uterotrophic activity of 3-(4-methylbenzylidine)camphor in the immature rat. *Environ Health Perspect* 110:533-536.**
Ref Type: Journal

163. **Mueller SO, Kling M, Arifin FP, Mecky A, Duranti E, Shields-Botella J, Delansorne R, Broschard T, Kramer PJ. 2003. Activation of estrogen receptor alpha and ERbeta by 4-methylbenzylidene-camphor in human and rat cells: comparison with phyto- and xenoestrogens. *Toxicol Lett* 142:89-101.**
Ref Type: Journal

164. **Schlumpf M, Schmid P, Durrer S, Conscience M, Maerkel K, Henseler M, Gruetter M, Herzog I, Reolon S, Ceccatelli R, Faass O, Stutz E, Jarry H, Wuttke W, Lichtensteiger W. 2004. Endocrine activity and developmental toxicity of cosmetic UV filters--an update. *Toxicology* 205:113-122.**
Ref Type: Journal

165. **Heneweer M, Muusse M, van den BM, Sanderson JT. 2005. Additive estrogenic effects of mixtures of frequently used UV filters on pS2-gene transcription in MCF-7 cells. *Toxicol Appl Pharmacol* 208:170-177.**
Ref Type: Journal

166. **Schlumpf M, Jarry H, Wuttke W, Ma R, Lichtensteiger W. 2004. Estrogenic activity and estrogen receptor beta binding of the UV filter 3-benzylidene camphor. Comparison with 4-methylbenzylidene camphor. *Toxicology* 199:109-120.**
Ref Type: Journal

167. **Durrer S, Maerkel K, Schlumpf M, Lichtensteiger W. 2005. Estrogen target gene regulation and coactivator expression in rat uterus after developmental exposure to the ultraviolet filter 4-methylbenzylidene camphor. *Endocrinology* 146:2130-2139.**
Ref Type: Journal

168. **Schreurs R, Lanser P, Seinen W, van der BB. 2002. Estrogenic activity of UV filters determined by an in vitro reporter gene assay and an in vivo transgenic zebrafish assay. *Arch Toxicol* 76:257-261.**
Ref Type: Journal

169. **Kunz PY, Fent K. 2006. Multiple hormonal activities of UV filters and comparison of in vivo and in vitro estrogenic activity of ethyl-4-aminobenzoate in fish. *Aquat Toxicol* 79:305-324.**
Ref Type: Journal

170. **Balmer ME, Buser HR, Muller MD, Poiger T. 2005. Occurrence of some organic UV filters in wastewater, in surface waters, and in fish from Swiss Lakes. *Environ Sci Technol* 39:953-962.**
Ref Type: Journal

171. **Buser HR, Balmer ME, Schmid P, Kohler M. 2006. Occurrence of UV filters 4-methylbenzylidene camphor and octocrylene in fish from various Swiss rivers with inputs from wastewater treatment plants. *Environ Sci Technol* 40:1427-1431.**
Ref Type: Journal

172. **Janjua NR, Mogensen B, Andersson AM, Petersen JH, Henriksen M, Skakkebaek NE, Wulf HC. 2004. Systemic Absorption of the Sunscreens Benzophenone-3, Octyl-Methoxycinnamate, and 3-(4-Methyl-Benzylidene) Camphor After Whole-Body Topical Application and Reproductive Hormone Levels in Humans. *J Investig Dermatol***

123:57-61.
Ref Type: Journal

173. Loraine GA, Pettigrove ME. 2006. Seasonal variations in concentrations of pharmaceuticals and personal care products in drinking water and reclaimed wastewater in southern California. *Environ Sci Technol* 40:687-695.
Ref Type: Journal

174. Hany J, Nagel R. 1995. Detection of Sunscreen Agents in Human Breast-Milk. *Deutsche Lebensmittel-Rundschau* 91:341-345.
Ref Type: Journal

175. Kunz PY, Fent K. 2006. Estrogenic activity of UV filter mixtures. *Toxicol Appl Pharmacol* 217:86-99.
Ref Type: Journal

176. Ma R, Cotton B, Lichtensteiger W, Schlumpf M. 2003. UV filters with antagonistic action at androgen receptors in the MDA-kb2 cell transcriptional-activation assay. *Toxicol Sci* 74:43-50.
Ref Type: Journal

177. Felix T, Hall BJ, Brodbelt S. 1998. Determination of benzophenone-3 and metabolites in water and human urine by solid-phase microextraction and quadrupole ion trap GC-MS. *Analytica Chimica Acta* 371:195-203.
Ref Type: Journal

178. Safe S. 2003. Cadmium's disguise dupes the estrogen receptor. *Nat Med* 9:1000-1001.
Ref Type: Journal

179. Stoica A, Katzenellenbogen BS, Martin MB. 2000. Activation of estrogen receptor-alpha by the heavy metal cadmium. *Mol Endocrinol* 14:545-553.
Ref Type: Journal

180. Silva E, Lopez-Espinosa MJ, Molina-Molina JM, Fernandez M, Olea N, Kortenkamp A. 2006. Lack of activity of cadmium in in vitro estrogenicity assays. *Toxicol Appl Pharmacol* 216:20-28.
Ref Type: Journal

181. Garcia-Morales P, Saceda M, Kenney N, Kim N, Salomon DS, Gottardis MM, Solomon HB, Sholler PF, Jordan VC, Martin MB. 1994. Effect of cadmium on estrogen receptor levels and estrogen-induced responses in human breast cancer cells. *J Biol Chem* 269:16896-16901.
Ref Type: Journal

182. Choe SY, Kim SJ, Kim HG, Lee JH, Choi Y, Lee H, Kim Y. 2003. Evaluation of estrogenicity of major heavy metals. *Sci Total Environ* 312:15-21.
Ref Type: Journal

183. Johnson MD, Kenney N, Stoica A, Hilakivi-Clarke L, Singh B, Chepko G, Clarke R, Sholler PF, Lirio AA, Foss C, Reiter R, Trock B, Paik S, Martin MB. 2003. Cadmium mimics the in vivo effects of estrogen in the uterus and mammary gland. *Nat Med* 9:1081-1084.
Ref Type: Journal

184. Darbre PD. 2006. Metalloestrogens: an emerging class of inorganic xenoestrogens with potential to add to the oestrogenic burden of the human breast. *J Appl Toxicol* 26:191-197.
Ref Type: Journal

185. Martin MB, Voeller HJ, Gelmann EP, Lu J, Stoica EG, Hebert EJ, Reiter R, Singh B, Danielsen M, Pentecost E, Stoica A. 2002. Role of cadmium in the regulation of AR gene expression and activity. *Endocrinology* 143:263-275.
Ref Type: Journal

186. Donovan MP, Schein LG, Thomas JA. 1980. Inhibition of androgen-receptor interaction in mouse prostate gland cytosol by divalent metal ions. *Mol Pharmacol* 17:156-162.
Ref Type: Journal

187. Wilson EM. 1985. Interconversion of androgen receptor forms by divalent cations and 8 S androgen receptor-promoting factor. Effects of Zn2+, Cd2+, Ca2+, and Mg2+. *J Biol Chem* 260:8683-8689.
Ref Type: Journal

188. Henson MC, Chedrese PJ. 2004. Endocrine disruption by cadmium, a common environmental toxicant with paradoxical effects on reproduction. *Exp Biol Med (Maywood)* 229:383-392.
Ref Type: Journal

189. Jarup L. 2003. Hazards of heavy metal contamination. *Br Med Bull* 68:167-182.
Ref Type: Journal

190. Nasreddine L, Parent-Massin D. 2002. Food contamination by metals and pesticides in the European Union. Should we worry? *Toxicol Lett* 127:29-41.
Ref Type: Journal

191. Dabeka RW, McKenzie AD, Lacroix GM. 1987. Dietary intakes of lead, cadmium, arsenic and fluoride by Canadian adults: a 24-hour duplicate diet study. *Food Addit Contam* 4:89-101.
Ref Type: Journal

192. Rubio C, Hardisson A, Reguera JI, Revert C, Lafuente MA, Gonzalez-Iglesias T. 2006. Cadmium dietary intake in the Canary Islands, Spain. *Environ Res* 100:123-129.
Ref Type: Journal

193. Food Standards Agency. 2000 Total Diet Study of 12 elements - aluminium, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, tin and zinc. Food survey information sheet 48/04.
Ref Type: Report

194. Food Standards Agency. Metals in a variety of food. Food survey information sheet 01/07.
Ref Type: Report

195. Antila E, Mussalo-Rauhamaa H, Kantola M, Atroshi F, Westermarck T. 1996. Association of cadmium with human breast cancer. *Sci Total Environ* 186:251-256.
Ref Type: Journal

196. Fiala J, Hruba D, Crha I, Rezl P, Totusek J. 2001. Is environmental cadmium a serious hazard to Czech population? *Int J Occup Med Environ Health* 14:185-188.
Ref Type: Journal

197. Fiala J, Hruba D, Rezl P. 1998. Cadmium and zinc concentrations in human placentas. *Cent Eur J Public Health* 6:241-248.
Ref Type: Journal

198. Queiroz EK, Waissmann W. 2006. Occupational exposure and effects on the male reproductive system. *Cad Saude Publica* 22:485-493.
Ref Type: Journal

199. Martin MB, Reiter R, Pham T, Avellanet YR, Camara J, Lahm M, Pentecost E, Pratap K, Gilmore BA, Divekar S, Dagata RS, Bull JL, Stoica A. 2003. Estrogen-like activity of metals in MCF-7 breast cancer cells. *Endocrinology* 144:2425-2436.
Ref Type: Journal

200. Clarkson TW, Magos L, Myers GJ. 2003. The toxicology of mercury--current exposures and clinical manifestations. *N Engl J Med* 349:1731-1737.
Ref Type: Journal

201. Ask K, Akesson A, Berglund M, Vahter M. 2002. Inorganic mercury and methylmercury in placentas of Swedish women. *Environ Health Perspect* 110:523-526.
Ref Type: Journal

202. Stoica A, Pentecost E, Martin MB. 2000. Effects of arsenite on estrogen receptor-alpha expression and activity in MCF-7 breast cancer cells. *Endocrinology* 141:3595-3602.
Ref Type: Journal

203. Dabeka RW, McKenzie AD, Lacroix GM, Cleroux C, Bowe S, Graham RA, Conacher HB, Verdier P. 1993. Survey of arsenic in total diet food composites and estimation of the dietary intake of arsenic by Canadian adults and children. *J AOAC Int* 76:14-25.
Ref Type: Journal

204. Roychowdhury T, Tokunaga H, Ando M. 2003. Survey of arsenic and other heavy metals in food composites and drinking water and estimation of dietary intake by the villagers from an arsenic-affected area of West Bengal, India. *Sci Total Environ* 308:15-35.
Ref Type: Journal

205. Fewtrell LJ, Pruss-Ustun A, Landrigan P, yuso-Mateos JL. 2004. Estimating the global burden of disease of mild mental retardation and cardiovascular diseases from environmental lead exposure. *Environmental Research* 94:120-133.
Ref Type: Journal

206. Leroyer A, Nisse C, Hemon D, Gruchociak A, Salomez JL, Haguenoer JM. 2000. Environmental lead exposure in a population of children in northern France: factors affecting lead burden. *Am J Ind Med* 38:281-289.
Ref Type: Journal

207. Leroyer A, Hemon D, Nisse C, Bazerques J, Salomez JL, Haguenoer JM. 2001. Environmental exposure to lead in a population of adults living in northern France: lead burden levels and their determinants. *Sci Total Environ* 267:87-99.
Ref Type: Journal

208. Brown MJ, Hu H, Gonzales-Cossio T, Peterson KE, Sanin LH, Kageyama MdL, Palazuelos E, Aro A, Schnaas L, Hernandez-Avila M. 2000. Determinants of bone and blood lead concentrations in the early postpartum period. *Occup Environ Med* 57:535-541.
Ref Type: Journal

209. Stoica A, Pentecost E, Martin MB. 2000. Effects of selenite on estrogen receptor-alpha expression and activity in MCF-7 breast cancer cells. *J Cell Biochem* 79:282-292.
Ref Type: Journal

210. Anke M, Groppel B, Krause U, Arnhold W, Langer M. 1991. Trace element intake (zinc, manganese, copper, molybdenum, iodine and nickel) of humans in Thuringia and Brandenburg of the Fed. Rep. of Germany. *J Trace Elem Electrolytes Health Dis* 5:69-74.
Ref Type: Journal

211. Predki PF, Sarkar B. 1992. Effect of replacement of "zinc finger" zinc on estrogen receptor DNA interactions. *J Biol Chem* 267:5842-5846.
Ref Type: Journal

212. Satoh K, Nagai F, Aoki N. 2001. Several environmental pollutants have binding affinities for both androgen receptor and estrogen receptor alpha. *Journal of Health Science* 47:495-501.
Ref Type: Journal