

Man and his waste



*Bio-aerosol exposure and
respiratory health effects
in waste management*



Inge M. Wouters



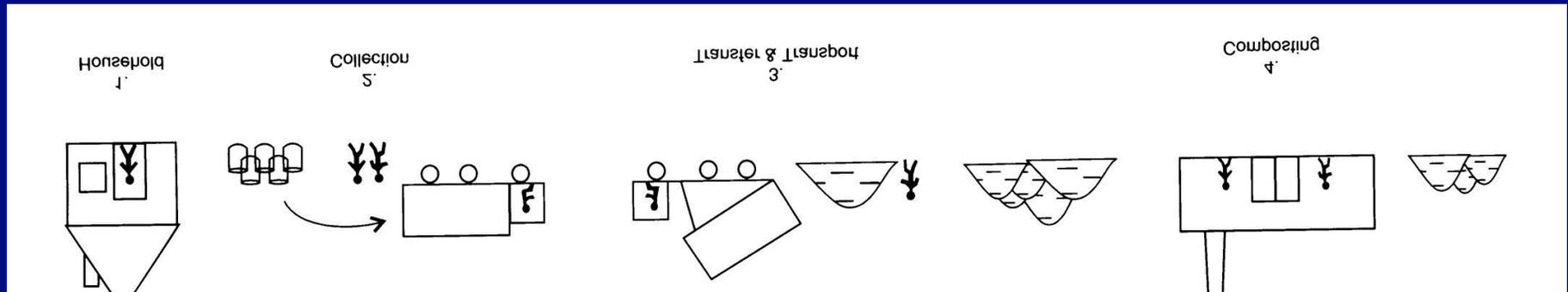
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The waste industry

- **Pre-industrial:**
re-use and recycling
- **Post-industrial:**
increased volume
waste management systems (collection and landfill, incineration)



- **Mid 90's:**
rapid development of the (organic waste)recycling industry



Occupational Health Risk

Op 10 augustus 1995, nu dus drie-en-een-half jaar geleden, stond het volgende bericht op pagina 3 van NRC Handelsblad:

Grote zorg over gebruik biobak bij fractie van VVD - Den Haag, 10 aug. De VVD-fractie in de Tweede Kamer maakt zich grote zorgen over de gezondheidsrisico's van het gebruik van zogeheten biobakken, de afvalbakken voor

groente-, fruit- en tuinafval. De kamerleden Te Veldhuis en Kamp hebben ministers De Boer (milieu) en Borst (volksgezondheid) gisteren een lijst met vragen gestuurd. De kamerleden

wijzen daarbij onder meer op een onderzoek van het Centraal Bureau voor de Schimmelcultuur in Baarn waaruit blijkt dat in broeierige bakken 'zelfs de vorming van kankerverwekkende stoffen niet mag worden uitgesloten'. Einde bericht.

Mid 90's:

Poulsen et al. concluded that waste management resulted in new and poorly described health risks mainly due to exposure to bio-aerosols



Bioaerosols: Definition

- Synonymous with “*biological agents*” and “*organic dust*”
- *Airborne and settled particulate matter or aerosols of microbial, plant or animal origin*

E.g. **bacteria**, **fungi**, viruses, HMW allergens, **endotoxins**, **mycotoxins**, **peptidoglycans**, $\beta(1,3)$ -**glucans**, **fungal volatile organic components**, **pollens**, etc etc



Major bio-aerosol related diseases

- **Infectious diseases**
living and pathogenic viruses, bacteria fungi
airway or systemic, like gastro-intestinal infections
- **Respiratory diseases**
host's inflammatory reaction due to inhaled microbial
agents (both allergic and non-allergic)
- **Neoplastic diseases**
specific carcinogenic microbial toxins



Objectives

- Bio-aerosol exposure in the total waste management chain
- Health effects in key-populations
(symptoms questionnaire, airway inflammatory responses by nasal lavage, serology, BHR)
- Dose-response relationships



Domestic waste
Household produced

Industrial waste
Industrial processes

Sub-fractions

Organic waste

Residual waste

Mixed waste or Organic/residual waste

Green waste

Biomass

Household

Handling

I. Collection

II. Transfer & Transport

III. Domestic composting and/or Incineration or landfill

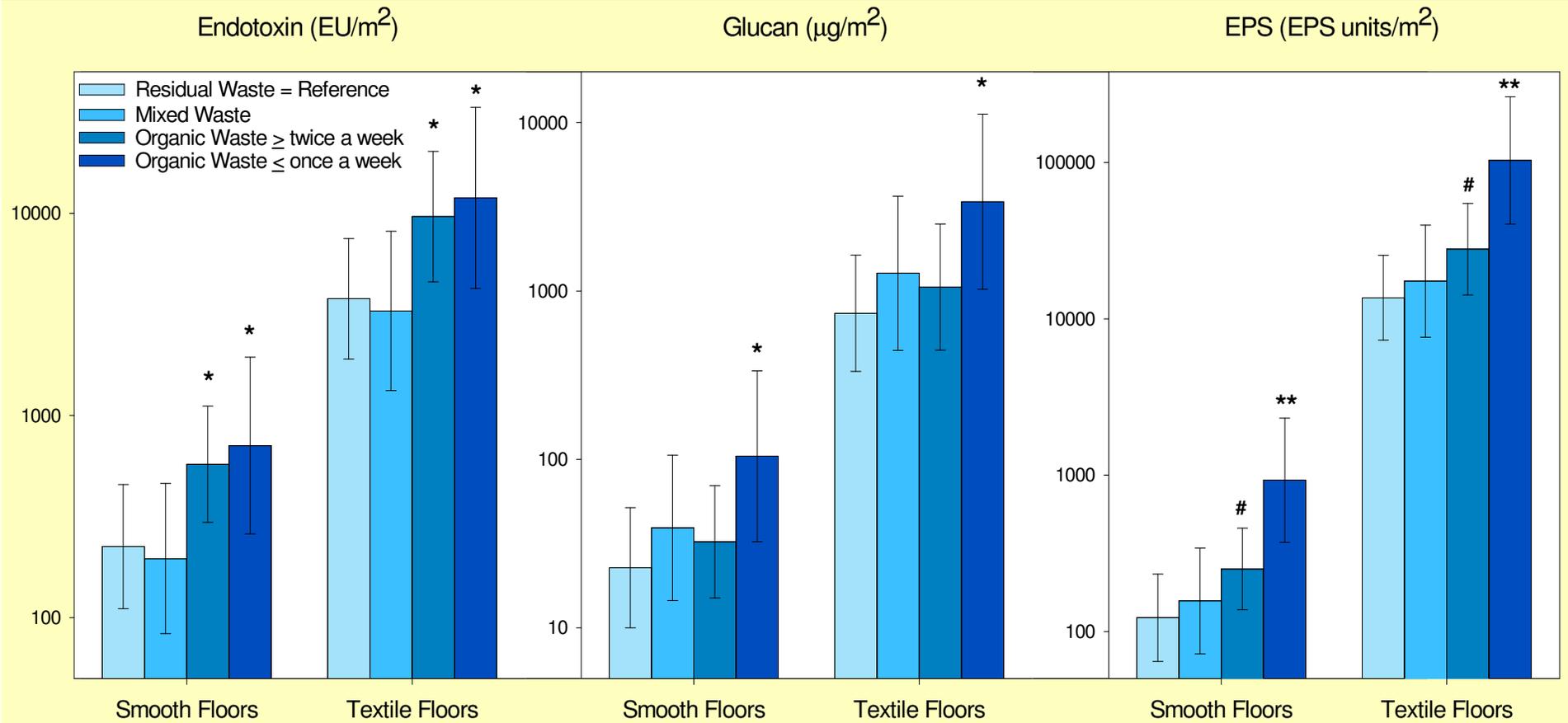
IV. Green composting

V. Biofuel power plant



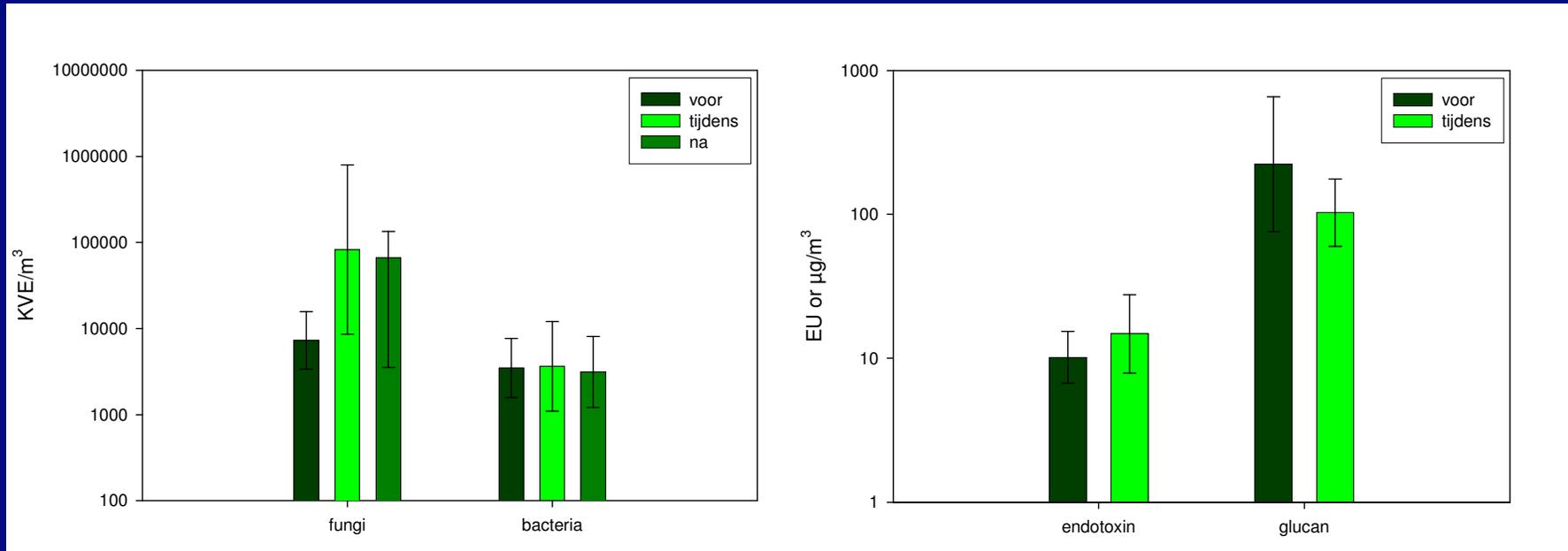


Bio-aerosols in living rooms





Bioaerosol release



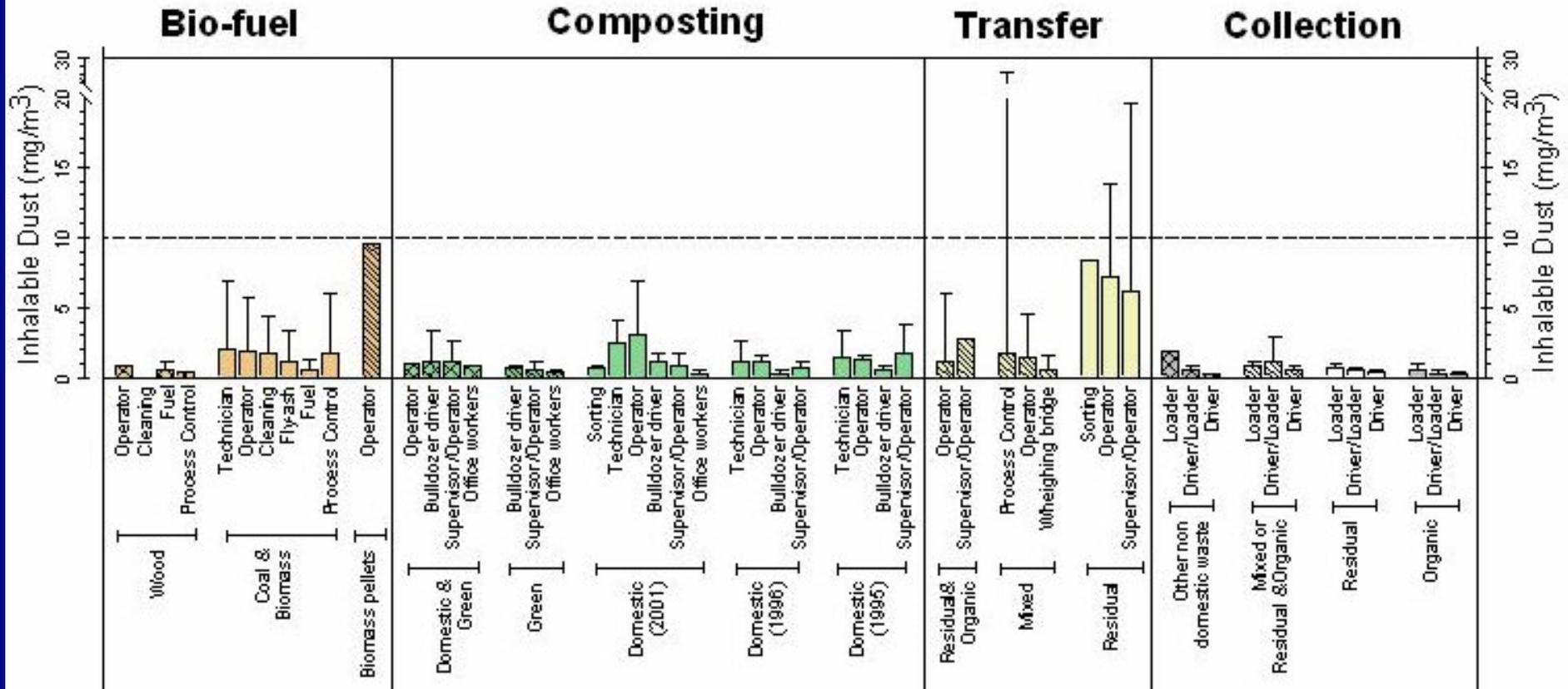


Methods Occupational Exposure Studies

- **Inhalable dust** by personal monitoring
- **Bio-aerosol exposure:**
 - Endotoxin – marker of (gram-) bacteria
 - Glucan – marker of fungi
 - EPS-Pen/Asp – marker of fungi



Inhalable Dust Levels (mg/m³)



>10 mg: 6%
>4 mg: 14%

1%
7%

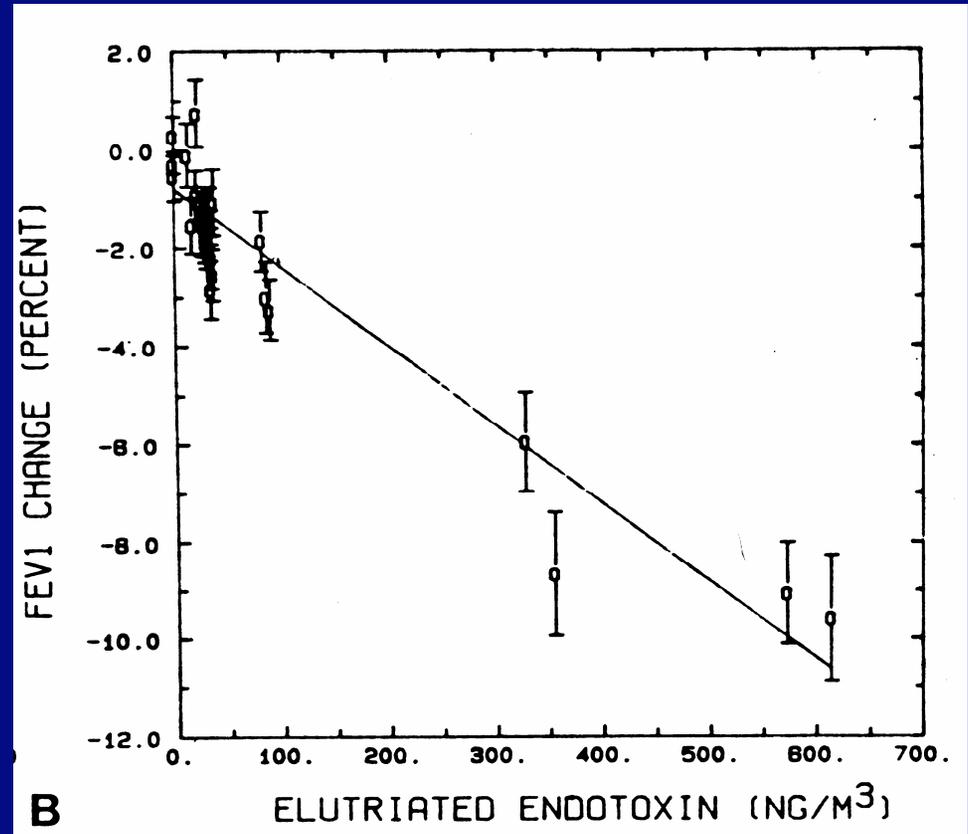
n.a.
n.a.

<1%
<1%



Occupational Exposure Limits for endotoxin

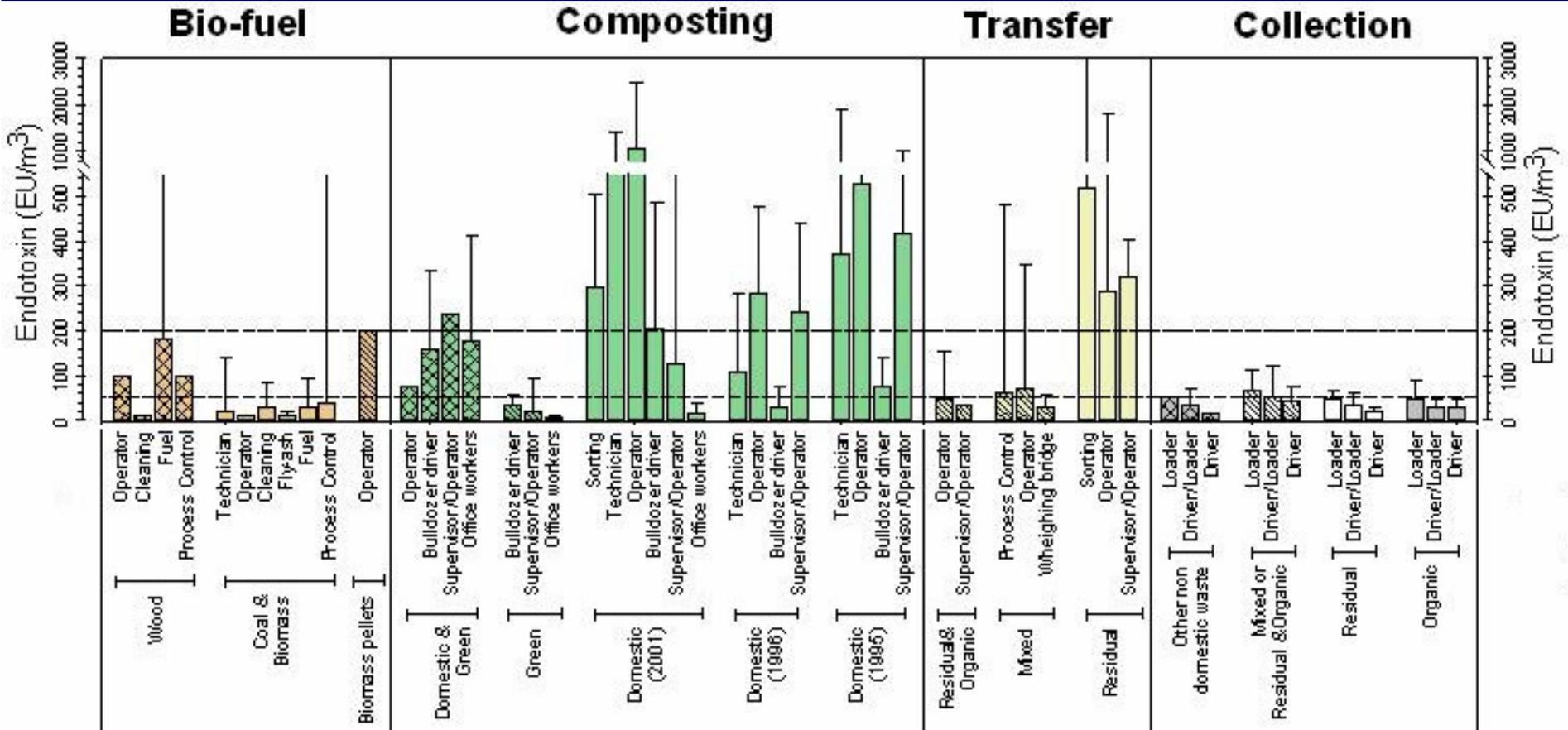
- Observational studies on acute respiratory effects suggest LOELs/NOELs **below 100 EU/m³** (Milton 1994, 1995; Zock 1998)
- Dutch recommended **health based OEL** is set at **50 EU/m³** based on a challenge study with cotton dust (LOEL \approx **90 EU/ m³**) (DECOS 1998)
- Dutch **legal limit** is set at **200 EU/m³**; effective from Januari 2003



(Castellan 1987)



Inhalable Endotoxin Levels (EU/m³)



>50 EU:	40%	100%	25%	85%	n.a.	45%
>200 EU:	14%	33%	5%	45%	n.a.	10%

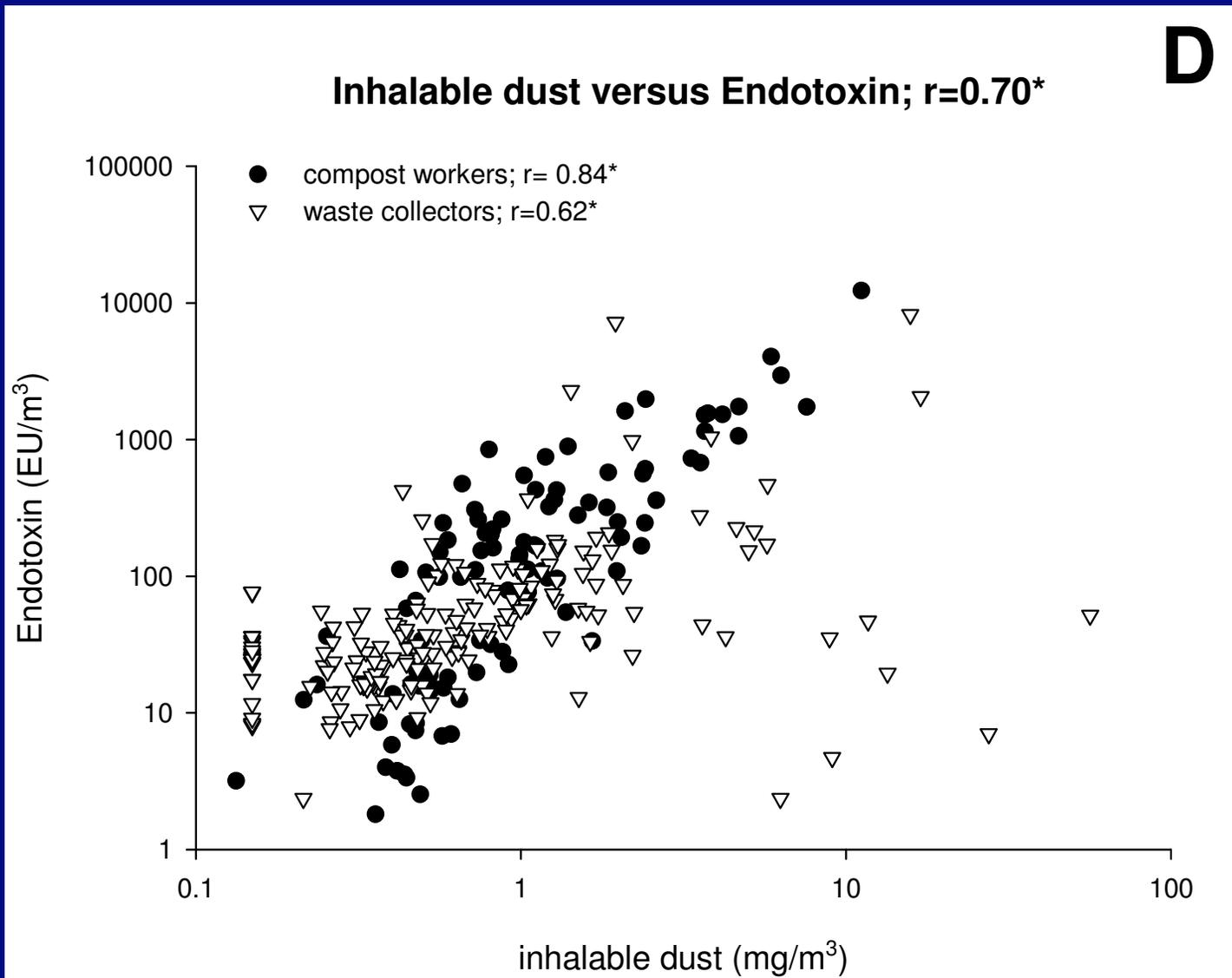


Exposure variance

	Inhalable dust		Endotoxin		Glucan	
	within	between	within	between	within	between
Study A: Domestic waste collectors						
Worker only	0.49	0.33	1.05	0.17	1.55	0.09
Plant	0.48	0.27	1.02	0.10	1.49	0.01
Type of waste + task	0.47	0.27	0.96	0.18	1.55	0.08
Study D: Domestic organic & green waste composting						
Worker only	0.45	0.42	1.23	2.72	0.53	1.64
Plant	0.44	0.31	1.12	1.34	0.53	1.11
Type of waste + Task	0.43	0.14	1.16	0.81	0.55	0.97
Study E: Use of biomass in power production						
Worker only	1.42	0.51	1.32	1.94	1.85	0.82
Plant no	1.27	0.14	1.43	1.19	2.32	ne ¹
Task	1.54	0.29	1.31	2.08	1.80	0.93
Type of material (wood or coal)	1.27	0.43	1.41	1.71	1.75	0.95



Correlation dust and endotoxin





Levels in various occupational environments

	EU/m ³	reference
Grain processing	12-285	Smid et al., 1992
Water sewage treatment	300	Melbostadt et al., 1994
Pig farmers	920	Preller et al., 1995
Chicken farmers	1.300-10.000	Thelin et al., 1984
Garbage handling	8-25	Sigsgaard et al., 1994
Potato processing	10-40.000	Zock et al., 1995
Fiber glass production	10-3900	Milton et al., 1996



Respiratory Symptoms in Compost Workers

	General		Composting population			
	Population		Overall		Domestic	
	%	PR	%	PR (CI)	%	PR (CI)
Lower respiratory tract last 12 mo						
Wheezing	24	1	22	1.0 (0.7-1.4)	25	1.1 (0.7-1.8)
Wheezing with SOB ^a	16	1	9	0.7 (0.4-1.2)	12	0.9 (0.4-1.8)
Wheezing without a cold	13	1	10	0.8 (0.5-1.3)	12	0.9 (0.4-1.9)
Woken up due to chest tightness	12	1	6	0.7 (0.4-1.3)	10	1.2 (0.6-2.6)
SOB in rest	8	1	12	1.8 (1.1-3.0)*	17	2.6 (1.4-5.0)**
Exercise induced SOB	21	1	30	1.7 (1.2-2.3)**	33	1.8 (1.2-2.8)**
Woken due to SOB	6	1	5	1.0 (0.5-2.0)	6	1.2 (0.4-3.2)
Woken due to cough	32	1	14	0.6 (0.4-0.9)**	20	0.8 (0.5-1.4)
Cough symptoms^b						
Daily cough	16	1	29	1.8 (1.3-2.5)***	36	2.2 (1.4-3.4)***
Daily cough up phlegm	10	1	20	1.9 (1.3-2.9)**	26	2.6 (1.5-4.3)***
Dyspnea						
Dyspnea going one flight of stairs	19	1	19	1.3 (0.9-2.0)	23	1.7 (1.0-2.9) *
Dyspnea versus contemporaries	3	1	6	2.5 (1.2-5.5)*	10	4.8 (2.0-11.8) ***

* p<0.05, ** p<0.01, *** p<0.01 compared to general population

^a SOB, Shortness of breath

^b Daily for at least part of the year



	Green		Domestic		Domestic&green	
	%	PR	%	PR	%	PR

Respiratory symptoms:

Cough	20.7	1.0	38.6	1.9 *	57.1	2.8 *
Cough up phlegm	18.3	1.0	31.4	1.7#	38.5	2.1
Wheezing	6.1	1.0	17.1	2.8 *	14.3	2.3
Shortness of breath (SOB)	11.0	1.0	25.7	2.3 *	35.7	3.3 *
SOB & wheezing	4.9	1.0	20.0	4.1 *	14.3	2.9
Chest tightness	11.0	1.0	27.1	2.5*	21.4	2.0

Irritation symptoms:

Stuffed nose	31.7	1.0	38.6	1.2	35.7	1.1
Runny nose	20.7	1.0	32.9	1.6	35.7	1.7
Sneezing	32.9	1.0	30.0	0.9	53.9	1.6

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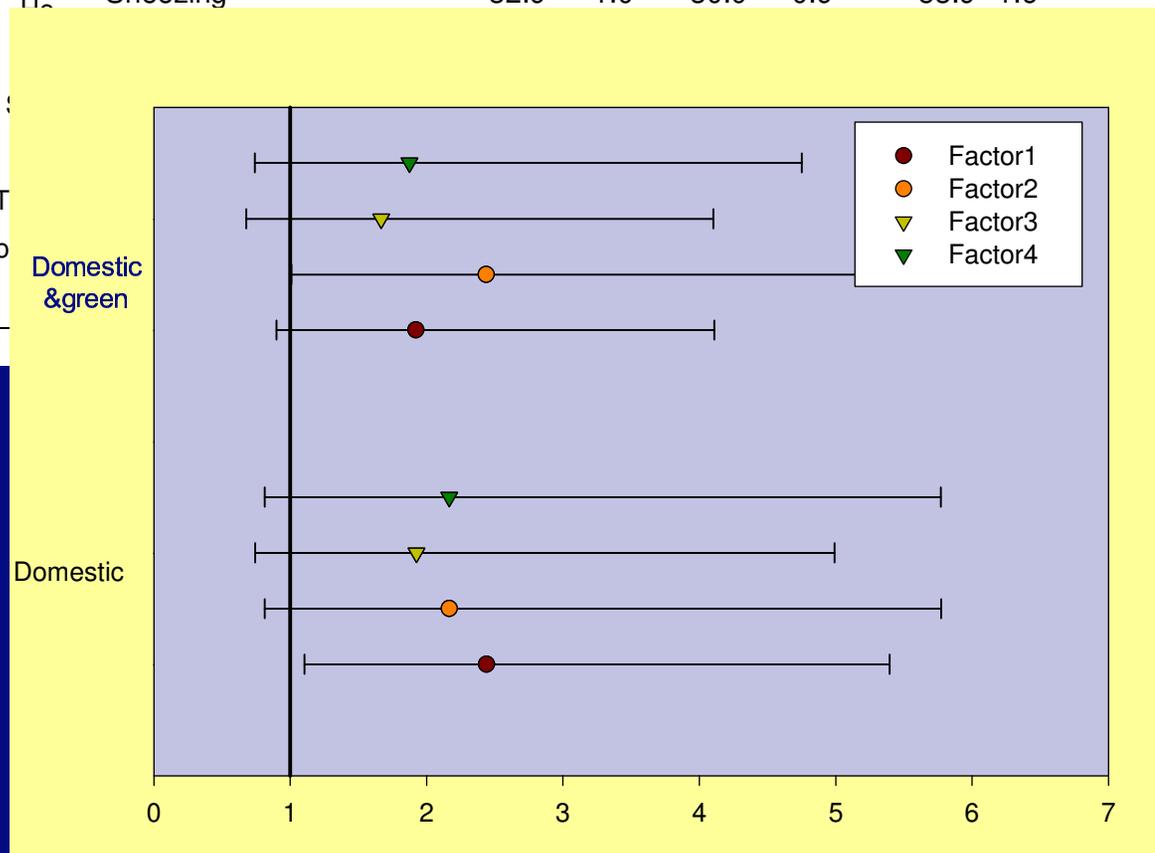
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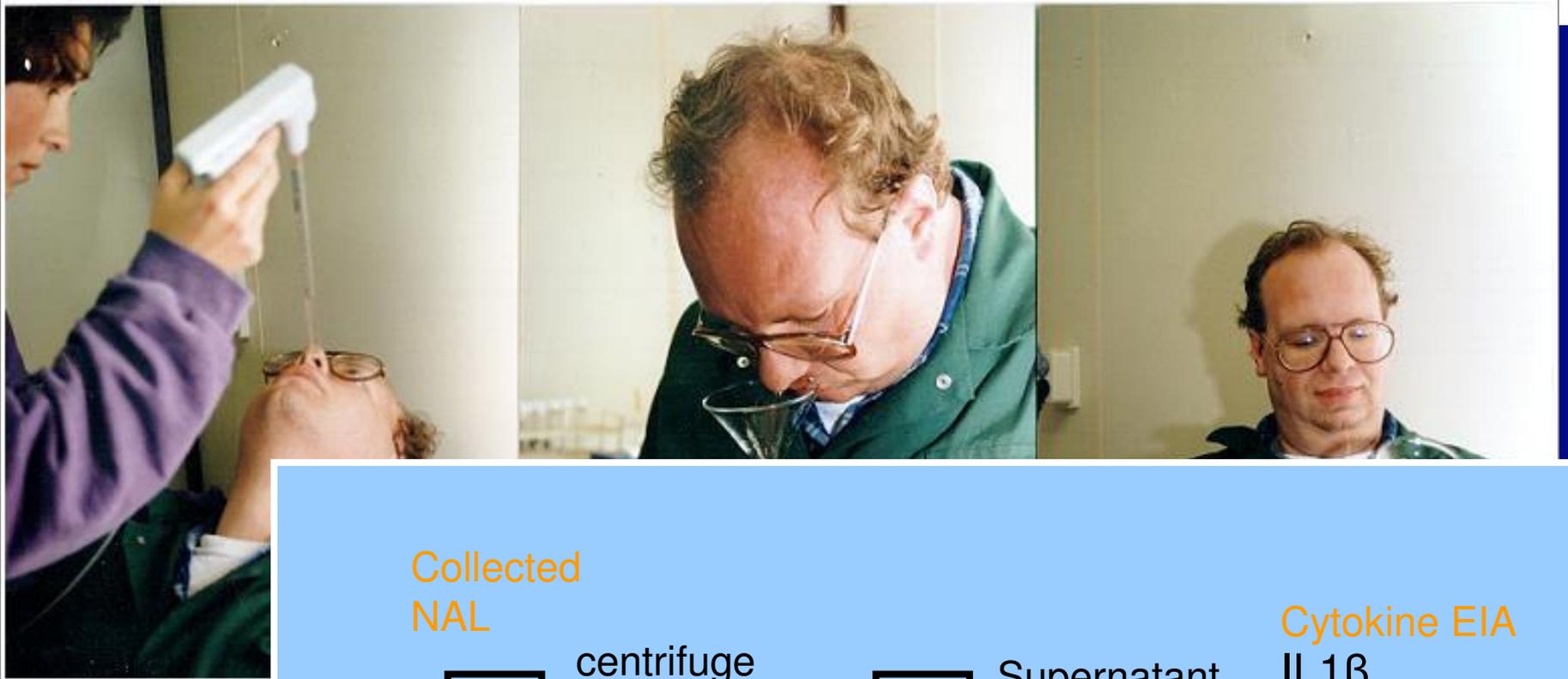




Symptoms and exposure

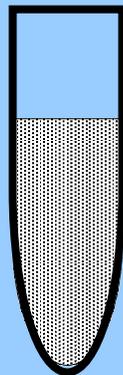
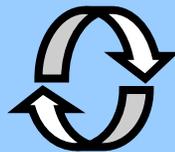
		'neurological & nose'	'respiratory & eyes and throat'	'flu-like & gastro-intestinal'	'irritation of skin'
Dust		1.0	1.0	1.0	1.0
	>0.60 -	1.94 (0.80-4.72)	1.42 (0.51-3.90)	1.34 (0.52-3.45)	0.85 (0.25-2.94)
	> 1.03 -	0.75 (0.19-2.91)	2.64 (0.94-7.41) [#]	1.76 (0.62-5.01)	2.11 (0.64-6.91)
	> 1.77	3.08 (1.19-7.95) [*]	3.27 (1.19-9.00) [*]	2.24 (0.81-6.18)	3.14 (1.03-9.59) [*]
Endo		1.0	1.0	1.0	1.0
	> 23 -	1.52 (0.57-4.09)	0.99 (0.30-3.24)	1.19 (0.42-3.38)	0.47 (0.09-2.45)
	> 81 -	1.42 (0.52-3.92)	2.28 (0.84-6.17)	1.78 (0.68-4.67)	1.99 (0.65-6.08)
	> 284	3.06 (1.22-7.66) [*]	3.56 (1.35-9.38) [*]	2.12 (0.79-5.68)	2.96 (0.99-8.84) [#]
Glucan		1.0	1.0	1.0	1.0
	> 50 -	1.84 (0.72-4.69)	2.22 (0.77-6.40)	1.75 (0.63-4.85)	2.80 (0.82-9.55)
	> 200	1.61 (0.80-3.27)	2.97 (1.42-6.25) [*]	1.72 (0.82-3.61)	3.20 (1.28-8.02) [*]
	>0.92 -	0.50 (0.15-1.66)	2.15 (0.95-4.87) [#]	1.49 (0.62-3.56)	2.30 (0.83-6.32)
	> 2.14	2.04 (1.00-4.19) [*]	2.67 (1.21-5.88) [*]	1.90 (0.83-4.36)	3.42 (1.35-8.65) [*]

Nasal Lavage & Serology



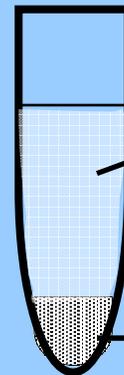
Collected
NAL

centrifuge



Supernatant

-20 °C



Cytokine EIA

IL1 β

IL6

IL8

TNF α

Count

Total cell

Differential cell

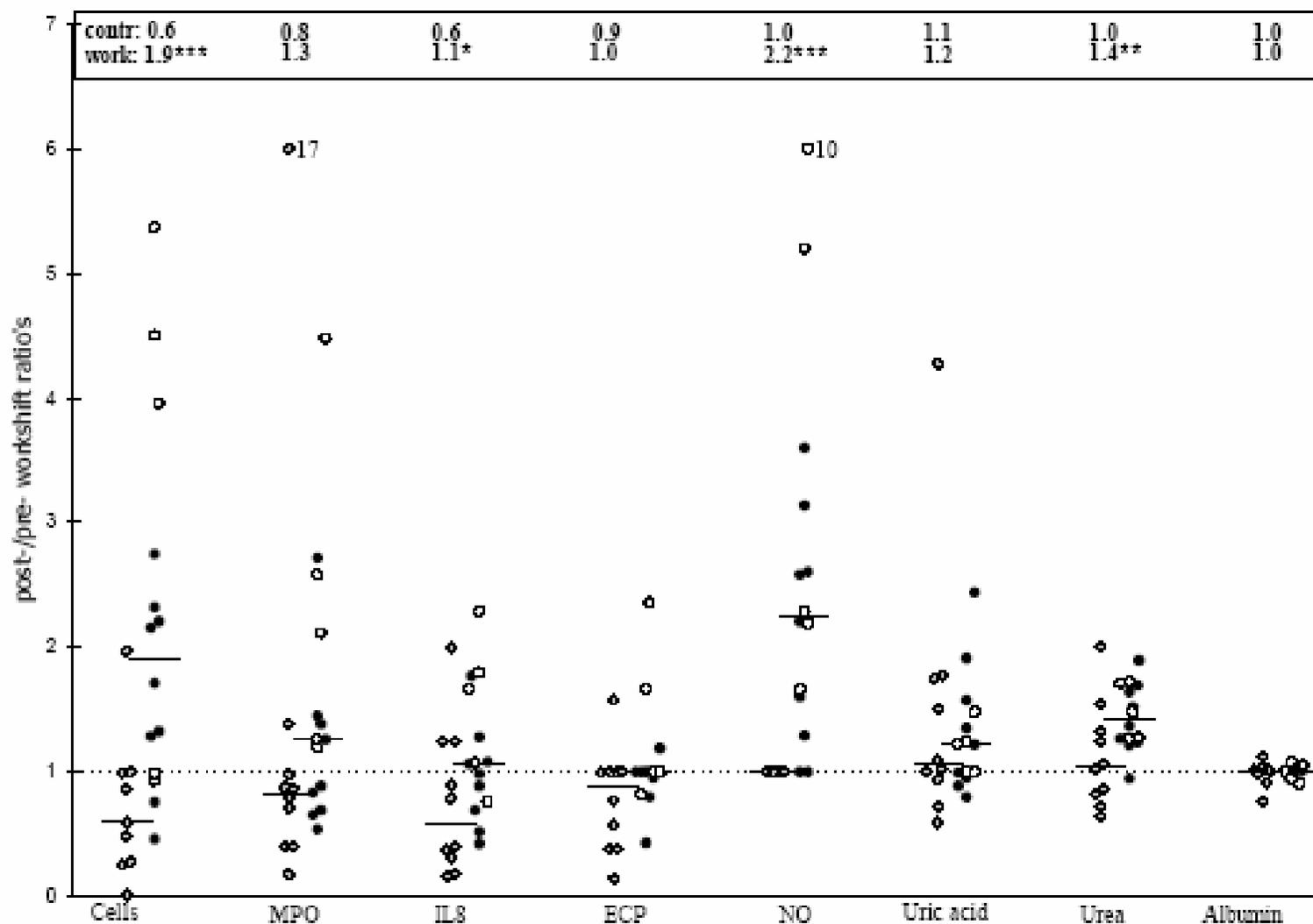


Differential Counts & Serology

- **NAL major cell type:**
neutrophils and epithelial cells
- **Serology:**
IgG titers against *A. fumigatus*, *Aspergillus-4*,
Penicillium-4, *Cladosporium-3*, *M. faeni* and *T. vulgaris* **similar** for waste collectors and controls
- Rarely positive IgE** tests against molds in waste collectors (2%) and compost workers

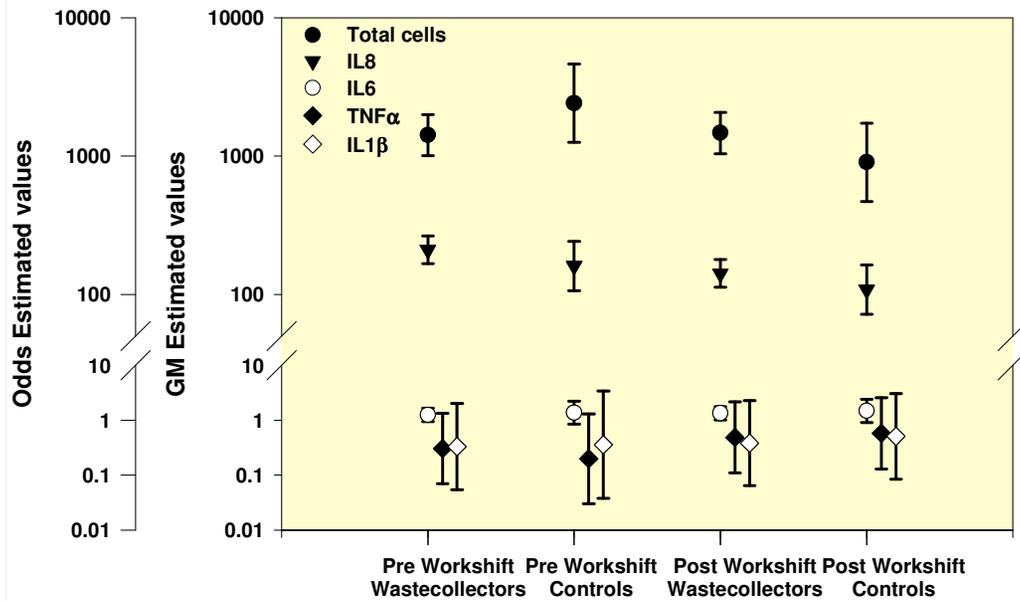


Compost workers: NAL over shift-ratio increased



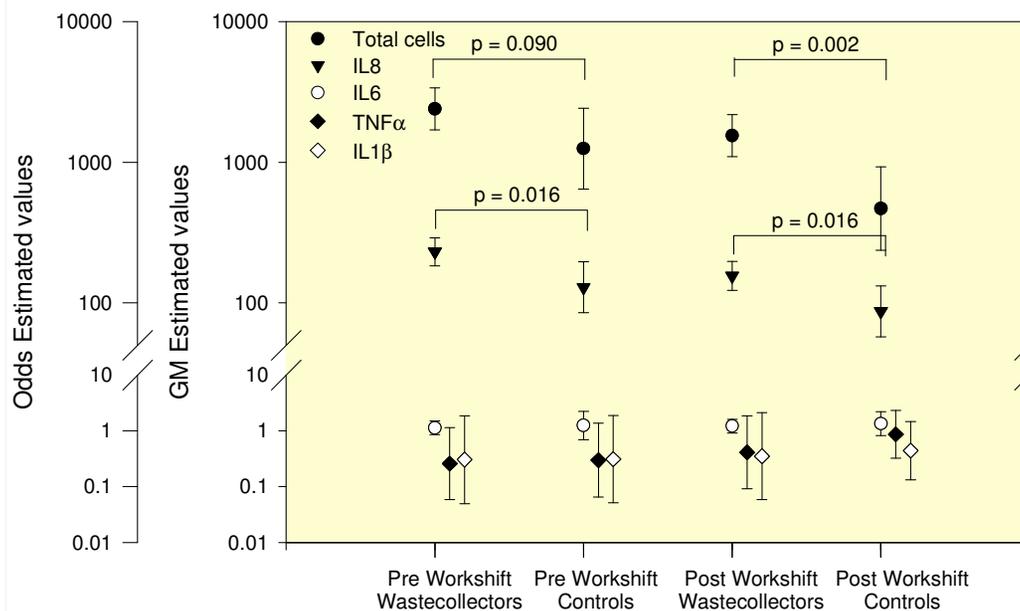
Waste collectors

Begin Week



Begin week:
no significant differences

End Week



End week:
Pre- and post increased
Ratio increased



In summary: NAL studies in waste recycling industry

	Exposure		Reaction in NAL	
	Endotoxin (EU/m ³)	Glucan (μg/m ³)	Acute	Sub-Chronic
1	75 – 527	0.54 – 4.85	1.4 – 3.2	1.1 – 4.8
2	29 – 285	0.36 – 4.44	1.2 – 2.3	-
3	27 – 53	0.87 – 1.46	1.4 – 1.6	1.3



Association NAL and Respiratory Symptoms (waste collectors – post shift)

	Cells	IL8
Cough	1.80 #	2.52 **
Cough with phlegm	2.00 #	2.36 *
Wheezing chest	1.33	4.28 *
Dyspnea	0.80	2.44
Shortness of Breath	3.00	2.75
Chest tightness	2.00	1.83
Stuffed nose	1.22	1.71 *
Runny nose	1.50 #	1.59 *
Itchy nose/sneeze	1.47	1.15
Throat irritation	2.33 #	2.14 #



Conclusions Waste Studies

- Bio-aerosol exposure levels **above OEL**
- Waste collectors and compost workers showed increased **respiratory and systemic symptoms**
- Acute and delayed **upper airway inflammation** compared to controls, which is non-immune mediated and most likely related to bio-aerosol exposure and symptoms
- Considerable **inter-individual variability** in exposure-response relationships



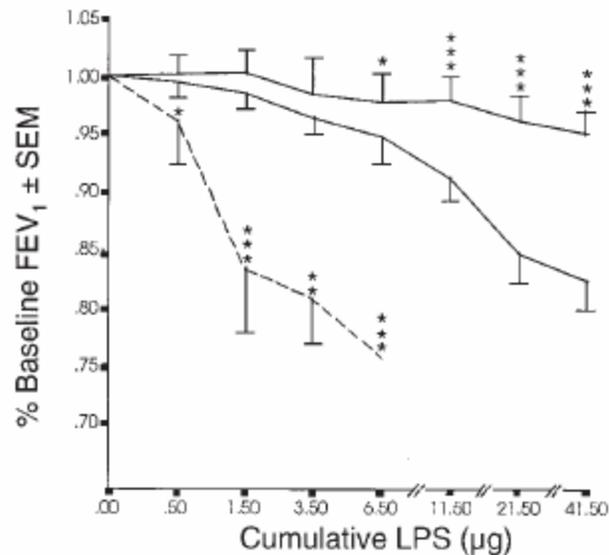
However,

- Implications unknown?
- Accelerated lung-function decline?
- Dose-response relationships differ between persons



Individual Responsiveness

Inter-individual variance workers and experimental studies



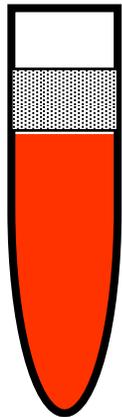
- Subjects with BHR and/or asthma are more sensitive to develop symptoms (Michel 1989, 1992, 1997)
- Relationship between chronic respiratory symptoms and endotoxin exposure is steeper in atopic pig farmers (Preller, Eur J Resp Dis 1997)
- Variable airway responses to LPS in non-atopic, non-asthmatic subjects (Kline, 1999)

Relates to individual responsiveness in inflammatory responses?



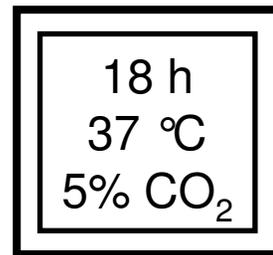
Principle Whole Blood Assay

0.9 ml EDTA blood
+ 0.1 ml stimulant



vortex
briefly

Incubate
overnight



vortex
briefly
& centrifuge

Supernatant
-20 °C

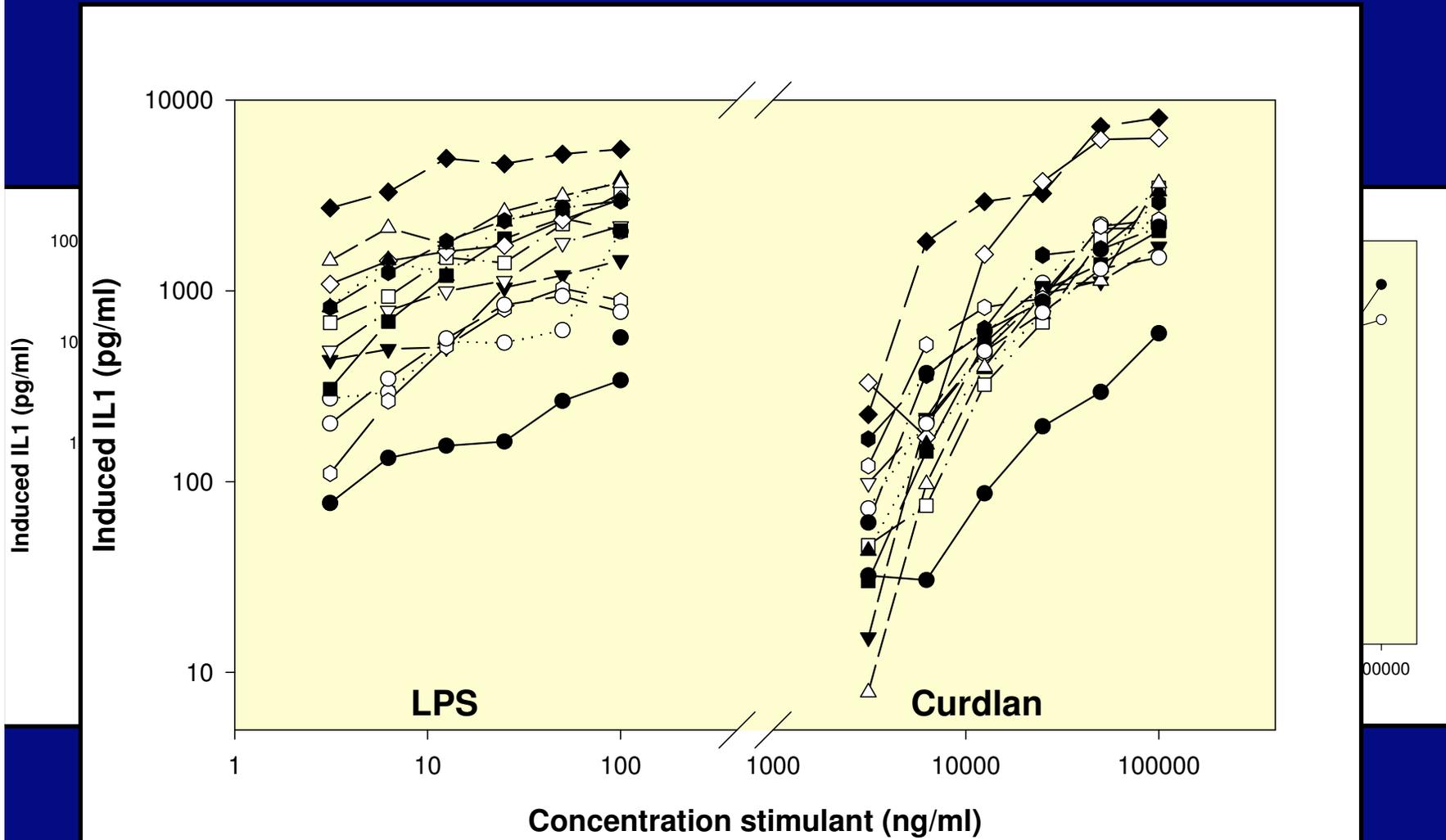


Cytokine
EIA

IL1 β
IL6
IL8
TNF α



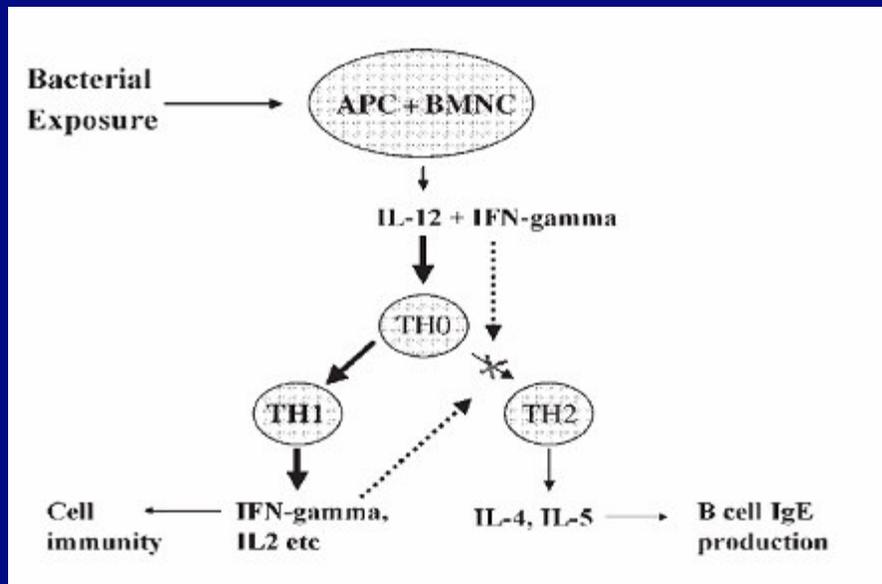
Dose-Response Curves





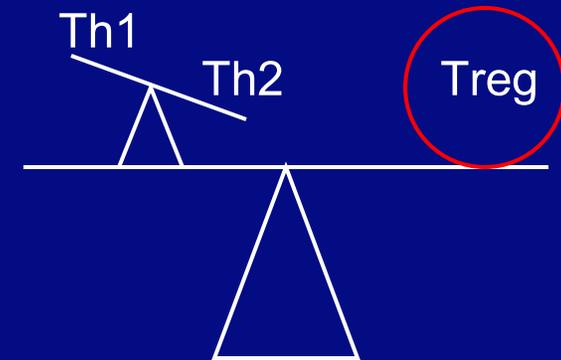
Hygiene hypothesis/Protective effects

Exposure to endotoxins or other microbes might protect from the development of atopy or asthma in children or adolescents



Th1/Th2 balance

Douwes, 2002



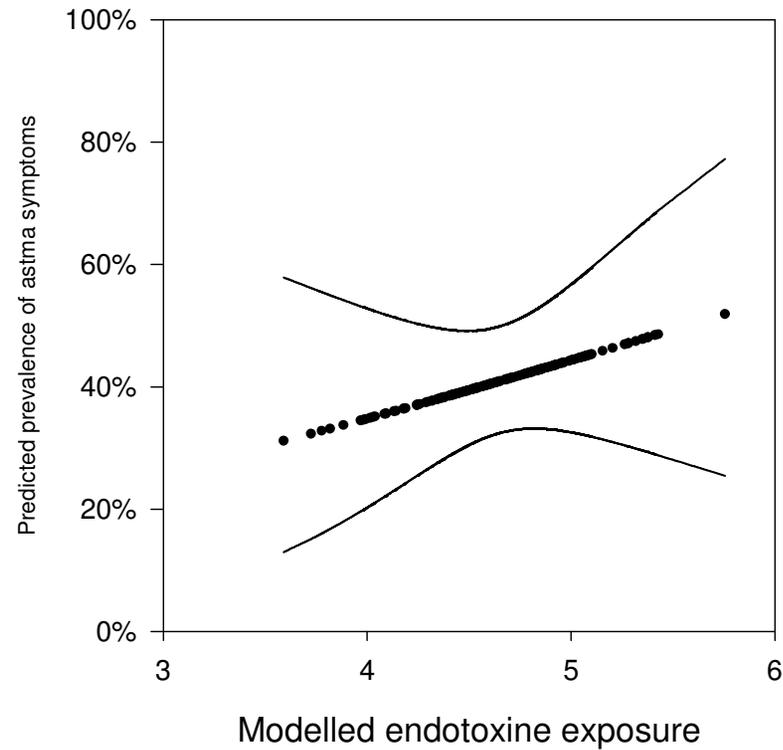
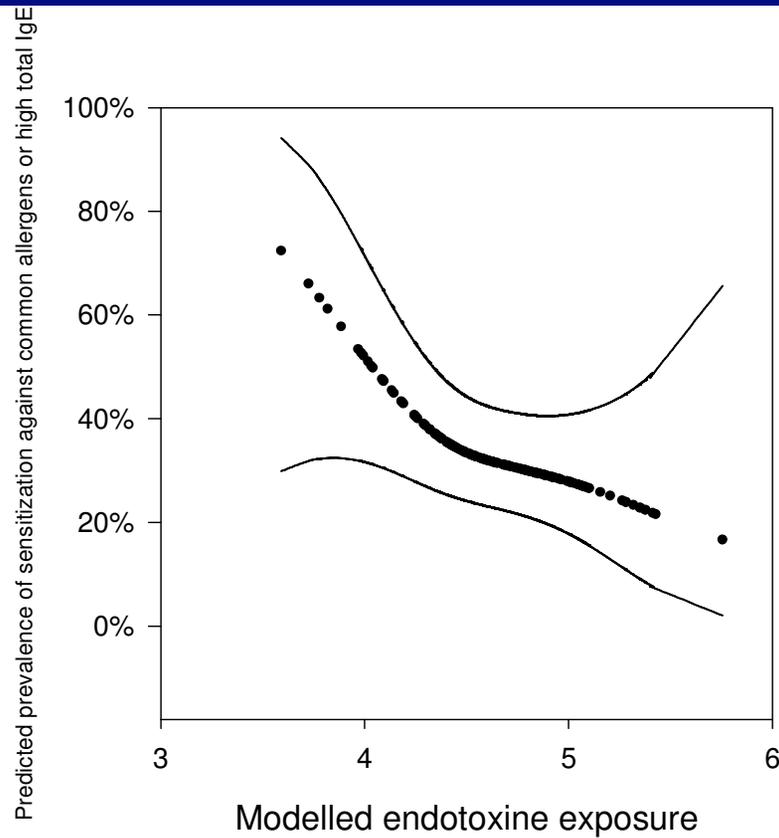
Tregulatory

Umetsu 2003



Protective effects in adults?

Portengen et al., JACI 2005



Future Research

- Long-term health effects
- Inter-individual variability
- Protective effects



Universiteit Utrecht

Onderzoek naar blootstelling aan
Microbiële agentia
en
Gezondheidseffecten in de
Agrarische industrie

OMEGA