

CONCENTRATIONS OF PHTHALATE ESTERS' FOUND IN HOMES OF HEALTHY AND ALLERGIC CHILDREN

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ABSTRACT

The incidence of asthma and allergy has increased throughout the developed world over the past 30-50 years, roughly the same time period that exposure to phthalates has increased. An ongoing study in Sweden, Damp Buildings and Health, showed associations between asthma and di(2-ethyl-hexyl)-phthalate concentration in dust and between eczema and rhinitis and butylbenzyl-phthalate. To further investigate the effect of the indoor environment on the prevalence of allergy and asthma among children, a case control study was conducted in 2004 in Bulgaria, including 184 children and in 2006 in Greenland in homes of 43 children. Dust samples were collected in the child's room, always above the floor. The analysis included six of the most commonly used phthalate esters: diethyl phthalate, dimethyl phthalate, dibutyl phthalate, butyl benzyl phthalate, di(2-ethylhexyl) phthalate and di-n-octyl phthalate. Phthalates in indoor dust could be found in all samples from Bulgarian and Greenlandic homes, however at different concentrations. The results from Bulgarian homes confirmed the findings from the Swedish study, showing higher mean concentrations of DEHP and BBzP in homes of cases in comparison to healthy children. For DEHP this difference reached significance.

KEYWORDS

Phthalates, Asthma, Allergy, Homes, Indoor environment

INTRODUCTION

In the developed parts of the world, people spend 90% or more of their life indoors. This fact implies that indoor air quality and chemicals present in the indoor environment are important factors for people's health.

One of the main sources for phthalate esters indoor is plasticized polyvinyl chloride (PVC) materials (Bornehag at al. 2005) (floor and wall covering materials), shower curtains, adhesives, synthetic leather, toys, cosmetics and very many other consumer products. Phthalates are constantly being emitted to the air and indoor dust since they are not chemically bound to the PVC structure.

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The presence of phthalates in indoor dust, in indoor and in outdoor air and in different types of food are quite well mapped. Human exposure to phthalates has mainly been studied by monitoring concentrations of metabolites in body fluids such as urine or blood (Becker et al. 2004). The results have shown that people are exposed to multiple phthalates and that children often are more exposed than adults (Koch et al. 2005).

Over the last few decades, asthma and allergies have increased all over the world (Asher et al. 2006). The causes of the increase in asthma and allergies and the causes of the differences between regions are not known. Genetic changes are not believed to be important as the time interval (30 - 50 years) for the increase in allergies is far too short. The cause should rather be due to environmental changes.

The home environment has changed considerably during the past 3-5 decades because of the introduction of new building technologies, as well as new building materials.

There is epidemiological evidence for associations between phthalates or plasticized products such as PVC and allergic symptoms in the airways (e.g. asthma), nose and skin. In the first phase of the Swedish "Dampness in Buildings and Health study" (DBH) study it was found that PVC as flooring material in combination with moisture problems in the floors was associated with e.g. asthma among children aged 1-6 years (Borhegag et al. 2002). Furthermore, in the second phase of the DBH-study a strong dose-response relationship was found between asthma and di(2-ethyl-hexyl)-phthalate (DEHP) concentration in indoor dust and between eczema and rhinitis and butyl-benzyl-phthalate (BBzP) (Bornehag et al. 2004). Presence of PVC surface materials was found to be associated with respiratory tract symptoms in studies in Norway (Jaakkola et al. 1999) and Finland (Jaakkola et al. 2000). Oie et al. 1997 elaborated possible mechanisms of respiratory effects by inhalation exposure and concluded that deposition of DEHP in the lungs may increase the risk of inflammation in the airways which is a characteristic feature of asthma.

In 2004 the ALLHOME study was initiated in Bulgaria and two years later, small study has been carried out in Greenland. The overall aim of the studies has been to map housing conditions regarding indoor environment, to compare the situation with those observed in the Swedish DBH study and to explore the role of indoor environmental exposures for allergies and asthma among small children. Both studies used the same design, protocols etc as the Swedish DBH-study. The main aim of the current paper has been to compare phthalate concentrations found in homes of healthy and allergic children in Bulgaria with two Scandinavian countries.

METHODS

The Bulgarian and the study in Greenland have been divided into two phases - the cross-sectional questionnaire study and the nested case-control study.

Selection of children

In the first phase baseline questionnaire on housing and health was sent to the parents. The questionnaire used in the first phase of the Swedish DBH study was used as a template and adapted to Bulgarian/Greenlandic conditions.

ALLHOME study in Bulgaria

During spring 2004 the questionnaire was sent to the parents of 12,982 children in two Bulgarian towns: Sofia and Burgas. Data for 4,479 children was collected, resulting in response rate of 34.5 %. Based on reported symptoms potential case and control children were selected. To be selected as a case the child

had to report at least two out of the following three symptoms "wheezing during the last 12 months"; "rhinitis during the last 12 months, when not having a cold", and "itching rash eczema in the last 12 months". In a follow up questionnaire, three month after the baseline questionnaire, they had to again report at least one of these three symptoms. Inclusion criteria for controls were absence of all of the three mentioned symptoms both at the baseline and the follow up questionnaire (Naydenov et al. 2006). Based on the selection criteria, 272 children (136 cases and 136 controls) were selected. In spite of a written consent given in the follow-up study, parents of 56 children refused their home to be inspected. Home investigations were therefore performed in 209 homes of 216 children since there were 7 pairs of siblings included. In twenty six of inspected homes inspectors were not allowed to perform dust sampling, thus dust samples from 183 homes of 190 children were taken and analyzed for the content of selected phthalates. From the 183 collected samples, three were destroyed in laboratory during the analyzing process; three samples were not coded by inspectors so it was not possible to find out where they collected. As a result, dust samples from 177 homes of 184 children, including 102 cases and 82 controls were used for the final analyses.

Study in Greenland

In May 2006 the baseline questionnaire was sent to families of 229 children in Sisimiut that is the second largest city in Greenland. The response rate was 24%. To be selected as a case the child had to report at least two out of three symptoms (wheezing, rhinitis, eczema) within the last 12 months or be diagnosed by doctor with asthma or rhinitis. Controls should never have any symptoms or diseases. Based on the selection criteria 18 controls and 19 cases were selected, however to enlarge to group, the inspections were additionally made in a group of 14 children that reported only one of the symptoms within the last 12 months. Therefore home investigations were performed in 34 homes of 51 children (Nors et al. 2007). The dust samples were taken in all homes. If siblings had separate rooms, one sample was collected in bedroom of each child. Altogether 40 samples from 51 children have been collected. Five children have been excluded because inspectors were not allowed to take samples in their homes. One child was excluded due to miscoding of the sample. One couple of siblings that shared bedroom but had different health status was also excluded. Thus, the total number of analyzed children was 43, including 21 cases and 22 controls.

Home investigations

The case-control study was conducted from December 2004 to March 2005 in Bulgaria and during August 2006 in Greenland. Inspections included general check-list, sensory and visual evaluation of the moisture related problems (dampness), collection of settled dust and at least 24-hour measurements of CO₂, relative humidity and air temperature. Parents were supposed to fill out a general questionnaire covering questions on the residence and family habits. The check-list filled out by the engineer was adopted from the one used in the Swedish DBH study. Further information can be obtained in (Naydenov et al. and Nors et al. 2007).

Dust samples

Sampling of settled dust for analyses of the content of phthalates was performed in the child's room, always above the floor level, e.g. over the door case, from the shelves and frames of paintings. A 1600 W vacuum cleaner equipped with dust collector and filter was used for the dust collection. The dust samples wrapped in an Aluminium folio and after that kept in a PE-bag with zip lock. Samples were frozen in the same day at -18°C. Later they were defrozen at room temperature and send to a

laboratory, where they were analyzed for content of 6 phthalates: dimethyl phthalate (DMP), diethyl phthalate (DEP), dibutyl phthalate (DBP), butyl benzyl phthalate (BBzP), di(2-ethylhexyl) phthalate (DEHP) and di-n-octyl phthalate (DnOP). The filters were not weighted before the sampling, however weighted prior to analysis; the dust was weighed at room temperature, which allowed relating the phthalate concentration to dust weight. Technique used for the analysis was gas chromatography/flame ionization detection (GC/FID). Further information can be obtained in (Kolarik et al.)

Statistical analysis

All analyses have been made on 184 children in the Bulgarian study and 43 children in the Greenlandic study. The concentrations of phthalates were not normally distributed and analyses of potential association between phthalates' concentration and health outcomes were made by using nonparametric Mann-Whitney U Test. Parametric tests including t-tests were used for analyses on log-transformed data. The concentrations are reported as medians, arithmetic means, and as geometric means with 95% confidence intervals (CI). The CI was calculated with a back-transform of mean $\log \pm 2 \times SE$. The analysis were considered as statistically significant when $p < 0.05$.

The studies were approved by the local ethical committees.

RESULTS

Characteristic of buildings

General information about children, families and housing conditions are summarized in Table 1. The main difference between Greenland and Bulgaria was in type of buildings. While in Greenland half of families lived in single-family or attached houses, in Bulgaria more than 90% lived in multi-family houses. Also type of wall and floor covering is different, specially the use of soft plastic carpets. In Greenland PVC in the child's room was reported only in 2 homes and linoleum in 1 home and the main type of floor covering was parquet. In Bulgaria, PVC and linoleum appears under a common name "balatum" that makes impossible to distinguish between them, however this "balatum" flooring was reported in the index child's room of more than 30% of children.

Concentrations of phthalates

Geometric mean phthalate concentrations with 95% confidence intervals, in milligram of phthalate per gram of dust, are shown in Table 2. Median and arithmetic mean phthalate concentrations, divided by case and control children, are presented in Table 3. Generally concentrations measured in dust samples of Bulgarian homes were order of magnitude higher than in Greenland, but in both countries all analyzed phthalates were found above the detection limits in most of the samples. In Bulgaria DBP and DEHP were found in all samples, in Greenland BBzP and DnOP were always present.

Associations between concentrations of phthalates in dust and health status of the children

In general there were no differences in the concentration of phthalates in dust between homes of cases and controls (Table 3). However, in Bulgaria DEHP was found in significantly higher concentrations in the homes of cases compared with controls. Furthermore, case children with parental reports of wheezing in the last 12 months, had significantly higher concentrations of DEHP compared to controls. The concentration of DEHP was also higher in homes of children with reported eczema in the last 12 months, but this difference didn't reach significance. In Greenland, a concentration of DEHP in dust was up to 10 times lower than in Bulgaria and such association to health was not found. In both countries the

concentration of BBzP was higher in homes of case children, but these differences were not significant. In Greenland significantly higher concentrations of DnOP were found in homes of case children compared to controls and the association was found between DnOP concentration and parental reported rhinitis in last 12 months. In Bulgaria, even though concentrations were higher, such association was not found.

In Bulgaria the association between inspectors' reported "balatum" in child's bedroom and case-status was observed and significance was reached for wheezing in last 12 months ($p=0.032$). However no association between phthalates concentration in dust and presence of "balatum" flooring was found. In Greenland due to insufficient number of homes with PVC flooring in child's room such analyses were not possible.

Table 1. Summary of characteristic of buildings, family habits and information about children from studies in Bulgaria and in Greenland

		Greenland		Bulgaria	
		No	%	No	%
building characteristic					
type of building	single-family house *	23	53.5	9	4.9
	multi-family house	20	46.5	170	92.4
year of construction	before 1960	4	9.3	8	4.3
	1961-2000	29	67.4	164	89.1
	after 2000	6	14.0	4	2.2
type of ventilation	natural without kitchen fan	7	16.3	100	54.3
	natural with kitchen fan	32	74.4	73	39.7
	mechanical	3	7.0		
type of heating	electric	5	11.6	35	19.0
	hot water	31	72.1	117	63.6
	other types	5	11.6	30	16.3
type of walls in child's room	paint	1	2.3	77	41.8
	wallpaper	1	2.3	62	33.7
	painted wallpaper	41	95.3	19	10.3
	other types			24	13.0
type of floor in child's room	linoleum **	1	2.3	63	34.2
	PVC **	2	4.7		
	parquet	33	76.7	46	25.0
	end to end carpet ***	3	7.0	35	19.0
	laminat	4	9.3	16	8.7
	stone			12	6.5
	other types			12	6.5
information about children and families					
age	0-2	13	30.2		
	2-6	15	34.9	149	81.0
	>6	15	34.9	35	19.0
gender	male	19	44.2	96	52.2
	female	24	55.8	88	47.8
allergy in family	yes	18	41.9	56	30.4
	no	25	58.1	127	69.0

* for Greenland it includes both single-family and attached houses

** "balatum" for Bulgaria

*** for Bulgaria additional 12 families who reported both carpet and "balatum" in child's room are included to "balatum" group

Table 2. Concentration of phthalates, in mg/g, in Bulgarian and Greenlandic homes expressed as geometric means with 95% CI.

phthalate	No ¹	geometric mean (95% CI)			
		Bulgaria		Greenland	
DMP	168	0.24 (0.20, 0.30)	28	0.03 (0.02, 0.04)	
DEP	181	0.33 (0.27, 0.40)	31	0.01 (0.01, 0.01)	
DBP	184	7.61 (6.37, 9.10)	42	0.79 (0.48, 1.30)	
BBzP	177	0.31 (0.27, 0.36)	43	0.06 (0.05, 0.08)	
DEHP	184	0.91 (0.75, 1.12)	41	0.13 (0.09, 0.21)	
DnOP	149	0.24 (0.20, 0.29)	43	0.02 (0.02, 0.03)	

Table 3. Mean and median concentrations of phthalates, in mg/g, in homes in Bulgaria and Greenland. Bold numbers shows significant difference in concentration found in homes of this group of cases compared to controls.

mean (median) concentrations of phthalates, mg/g										
Greenland										
	control		case		wheezing		rhinitis		eczema	
	No		No		No		No		No	
DMP	13	0.04 (0.03)	15	0.04 (0.02)	8	0.04 (0.02)	3	0.04 (0.03)	4	0.03 (0.03)
DEP	15	0.01 (0.01)	16	0.02 (0.01)	9	0.01 (0.01)	4	0.02 (0.02)	5	0.01 (0.01)
DBP	22	1.66 (1.19)	19	1.32 (1.12)	11	1.23 (0.83)	6	0.82 (0.67)	6	0.98 (0.87)
BBzP	22	0.07 (0.06)	21	0.14 (0.07)	11	0.09 (0.06)	6	0.08 (0.07)	6	0.08 (0.07)
DEHP	21	0.32 (0.20)	19	0.19 (0.14)	11	0.19 (0.13)	6	0.10 (0.10)	6	0.14 (0.10)
DnOP	22	0.025 (0.017)	21	0.034 (0.023)	11	0.04 (0.02)	6	0.041 (0.03)	6	0.03 (0.02)

Bulgaria										
	control		case		wheezing		rhinitis		eczema	
	No		No		No		No		No	
DMP	77	0.60 (0.30)	91	0.48 (0.24)	77	0.48 (0.23)	79	0.40 (0.23)	38	0.66 (0.29)
DEP	81	0.74 (0.36)	100	0.68 (0.32)	86	0.68 (0.31)	84	0.66 (0.30)	43	0.70 (0.35)
DBP	82	12.04 (9.87)	102	12.15 (9.61)	88	12.79 (11.17)	86	10.69 (8.63)	44	13.30 (9.61)
BBzP	77	0.45 (0.32)	100	0.53 (0.38)	87	0.53 (0.38)	84	0.49 (0.32)	43	0.60 (0.40)
DEHP	82	1.81 (0.86)	102	2.29 (1.24)	88	2.48 (1.75)	86	1.64 (1.03)	44	2.76 (0.93)
DnOP	67	0.38 (0.30)	82	0.41 (0.27)	70	0.41 (0.29)	68	0.41 (0.27)	36	0.37 (0.25)

DISCUSSION

The selection criteria, questionnaires and procedure in studies in Bulgaria and Greenland were adopted from the Swedish DBH study. Four out of six analyzed phthalates in the present studies were also measured in indoor dust in the DBH-study.

The concentrations of measured phthalates differ quite much between Greenland, Bulgaria and Sweden. Generally concentrations found in Greenland were much more in agreement with Swedish DBH and other studies compared to concentrations measured in Bulgaria. Results from Bulgaria are the only once from Eastern Europe and such differences compared to studies from Western and Northern Europe may suggest that use of plasticized products is more frequent in Eastern Europe or that the concentration of phthalates in final product is higher. Two phthalates, DBP and DEP, were found in concentrations up to 40 times higher in Bulgaria then in other countries (Table 4). In Greenland, the values of DBP were lower then in Bulgaria, but also higher compared to concentrations of other phthalates found there and compared to DBP concentrations found in other studies (Table 2, Table 4). Concentration of DEP found in Greenlandic homes were comparable with the one measured in Sweden (Bornehag et al. 2004), Germany (Fromme et al. 2004) and in US (Rudel et al 2003). DBP and DEP are used for example in soft toys and cosmetics; however, no information on type of toys and used cosmetics has been collected.

Much higher concentrations of DBP in Bulgaria and Greenland and DEP in Bulgaria may indicate strong sources of these phthalates. However, because concentration of DBP was much higher in both countries compared to all other known studies, hypothesis that the laboratory, where the samples from both studies were analyzed, had some problems with contaminations with DBP also should be considered.

Concentration of DMP was not measured in Swedish DBH study, but compared to the concentrations found in Berlin (Fromme et al. 2004), concentrations measured in Greenland were similar but the once measured in Bulgaria were more then 10 times higher.

Concentrations of DEHP in Bulgarian homes were more in agreement with the Swedish DBH and other studies then the concentrations measured in Greenland. Lower concentrations of DEHP in Greenlandic homes and much lower number of investigated homes could also explain lack of association to health effects found there as opposite to what was found in Sweden and Bulgaria. Due to small sample size we should also be careful with concluding on association between concentration of DnOP and parental reported rhinitis in last 12 months found in Greenland. However as DEHP and DnOP have similar application as plasticizers in floor coverings and toys and this possible relationship should be further investigated

Table 4. Measurements of the concentration of phthalates in dust in different countries. Table taken from Bornehag et al 2005.

Study	Country	No.	DEHP		BBzP		DnBP	
			50th ^a	95th ^a	50th ^a	95th ^a	50th ^a	95th ^a
present studies	Greenland	43	158	1277	62	545	1188 ^d	4409 ^d
	Bulgaria	184	988	7978	328	1565	9850 ^d	30784 ^d
Bornehag et al. 2004	Sweden	346	770	4069	135	599	150	568
Pohner et al. 1997	Germany	272	450	2000	-	-	-	-
Oie et al. 1997	Norway	38	640 ^b	-	110 ^b	-	100 ^b	-
Butte et al. 2001	Germany	286	740	2600	49	320	49	240
Becker et al. 2002	Germany	199	416	1190	15	207	42	160
Clausen et al. 2003	Denmark	23	858	2595	-	-	-	-
Rudel et al. 2003	USA	120	340	854 ^c	45	277 ^c	20	44 ^c
Kersten and Reich 2003	Germany	65	600	1600	19	230	47	180
Fromme et al. 2004	Germany	30	703	1540	30	218	56	130
Becker et al. 2004	Germany	252	515	1840	-	-	-	-

CONCLUSIONS

The main finding of these studies is that phthalates in indoor dust could be found in all samples from Bulgarian and Greenlandic homes, however at different concentrations. Another main finding is that DEHP found in similar concentrations in Bulgaria and Sweden was associated with wheezing among pre-school children.

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REFERENCES

1. Bornehag CG, Lundgren B, Weschler ChJ, Sigsgaard T, Hägerhed-Engman L, Sundell J. 2005. Phthalates in indoor dust and their association with building characteristics. *Environ Health Perspect* 113: 1399-1404.
2. Becker K, Seiwert M, Angerer J, Heger W, Koch HM, Nagorka R et al. 2004. DEHP metabolites in urine of children and DEHP in house dust. *Int J Hyg Environ Health* 207: 409-417.
3. Koch HM, Preuss R, Drexler H, Angerer J. 2005. Exposure of nursery school children and their parents and teachers to di-n-butylphthalate and butylbenzylphthalate. *Int Arch Occup Environ Health* 78: 223-229.
4. Asher MI, Montefort S, Bjorksten B, Lai ChKW, Strachan DP, Weiland SK et al. 2006. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC Phase One and Three repeat multicountry cross-sectional surveys. *Lancet* 368: 733-43.
5. Bornehag CG, Sundell J, Hägerhed L, Janson S and the DBH-study group. 2002. Dampness in buildings and health. Dampness at home as a risk factor for symptoms among 10851 Swedish children (DBH-step 1). In proceedings Indoor Air 2002, Monterey, USA: 431-436.
6. Bornehag CG, Sundell J, Weschler ChJ, Sigsgaard T, Lundgren B, Hasselgren M, Hägerhed-Engman L. 2004. The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study. *Environ Health Perspect* 112: 393-397.
7. Jaakkola JJ, Øie L, Nafstad P, Botten G, Samuelsen SO, Magnus P. 1999. Interior surface materials in the home and the development of bronchial obstruction in young children in Oslo, Norway. *Am J Public Health* 89: 188-192.
8. Jaakkola JJ, Verkasalo PK, Jaakkola N. 2000. Plastic wall materials in the home and respiratory health in young children. *Am J Public Health* 90: 797-799.
9. Øie L, Hersoug LG, Madsen JØ. 1997. Residential exposure to plasticizers and its possible role in the pathogenesis of asthma. *Environ Health Perspect* 105: 972-978.
10. Naydenov K, Melikov A, Markov D, Stankov P, Bornehag C-G, Sundell J. "A comparison between occupants' and inspectors' reports on home dampness and their associations with the health of children: the ALLHOME study". Submitted to *Building and Environment*.
11. Nors FE, Nielsen TB, Mortensen DK, Iversen A, Clausen G, Sundell J. "Indoor environment and building characteristics in homes of children with and without asthma and allergy in Sisimiut, Greenland". *Proceedings of Clima 2007*.
12. Kolarik B, Naydenov K, Larsson M, Bornehag CG, Sundell J. "The association between phthalates in dust and allergic diseases among Bulgarian children". Submitted to *Environ Health Perspect*.
13. Fromme H, Lahrz T, Piloty M, Gebhart H, Oddoy A, Ruden H. 2004. Occurrence of phthalates and musk fragrances in indoor air and dust from apartments and kindergartens in Berlin (Germany). *Indoor Air* 14: 188-195.
14. Rudel RA, Camann DE, Spengler JD, Korn LR, Brody JG. 2003. Phthalates, alkylophenols, pesticides, polybrominated diphenyl ethers, and other endocrine-disturbing compounds in indoor air and dust. *Toxicol Sci* 37: 4543-4553.