HAZARDOUS SUBSTANCE REDUCTION THROUGH PHASE OUT OF OLD ARTICLES AND MATERIALS IN PRE-SCHOOLS

CALCULATIONS OF ACTUAL REDUCTION IN STOCKHOLM, SWEDEN

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Pictures courtesy of the Chemical Centre, Anne Lagerqvist, Maria Pettersson, Katarina Johansson and Maria Arwidsson.

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1. INTRODUCTION

One of the sub-objectives in the Stockholm Environment Programme 2016-2019 is to reduce the amount of substances hazardous to health in pre-school environments. In the Chemical Action Plan for the City of Stockholm, a number of actions are defined in the work towards a non-toxic Stockholm. Both the Environment Programme and the Chemical Action Plan have been adopted by the Stockholm City council, and the various municipal units are obliged to follow them.

Furthermore, the City of Stockholm is coordinating the Interreg Baltic Sea Region Project NonHazCity (*Innovative management solutions for minimising emissions of hazardous substances from urban areas in the Baltic Sea Region)*. The project aims to show how municipalities can reduce emissions of hazardous substances (HS) and other pollutants from small scale emitters in urban areas.

Many old resting mattresses and toys in Stockholm's pre-schools have been replaced in recent years due to the high risk of content of hazardous substances.[1] These actions are described in the guidance document for a chemical smart pre-school developed by the Chemical Centre at the Environment and Health Administration in the City of Stockholm, as one part of the work according to the Chemical Action Plan. To estimate the amount of hazardous substances phased out by replacement of toys and mattresses is one means of follow up on the actions taken.

Pre-school children in Stockholm are of the age one to six. In Sweden, there is a national curriculum already for the smallest children, although not being exhaustive at that age, this is the reason that the institutions where many children spend their day are not called day-care centres, nurseries or kindergartens. Due to this, the term pre-school is used throughout this report.

This report describes the effects of the efforts to reduce the occurrence of hazardous substances by discarding articles and materials with risk of containing HS in the pre-schools of Stockholm municipality. The calculations on hazardous substance reduction presented here are based on the findings in the NonHazCity project, where the Chemical Centre sent around 200 articles and materials for analysis. The articles and materials were both new and old, collected from pre-schools and purchased from the procured suppliers.[1]

The City of Stockholm assigned Trossa AB, in collaboration with EnviroPlanning AB, to calculate the amounts of phthalate plasticizers, organophosphorous flame retardants and chlorinated paraffins removed from pre-schools due to the replacement of mattresses and toys. Furthermore, the content of new articles was also taken into account, mainly due to risk of PFAS presence.

2. BACKGROUND

2.1. Hazardous chemicals in products in children's everyday lives

Children are exposed to hazardous chemicals in different ways. Exposure can occur via direct ingestion when eating fruit containing pesticide residues or persistent chemicals present in the animal food chain. Furthermore, mouthing of toys and other items, ingestion of dust containing hazardous substances, as well as skin contact with finger paint and accidental eye contact with detergents might also contribute to the overall exposure. Another exposure route is inhalation of hazardous substances present in dust, perfumes or cleaning products with spray bottles. Moreover, phthalates might be inhaled when evaporating from plastic products such as toys or flooring.[2]

[1] Pettersson, Oldén and Lagerqvist. Hazardous substances in articles and materials. City of Stockholm 2018. The report is present at the NonHazCity website www.nonhazcity.eu

[2] Van Engelen, Park, Janssen, Oomen, Brandon, Bouma, Sips, Van Raaij. Chemicals in Toys A general methodology for assessment of chemical safety of toys with a focus on elements. RIVM report 2008.

Various studies measuring the chemical content in air and dust show, for example, that phthalates and other plasticizers, flame retardants and organic solvents may be released from products in pre-schools and homes.[3, 4, 5] Furthermore, hazardous substances such as the ones mentioned in this report are frequently detected in human blood samples, mothers milk and other matrices. [6]

Many different items, such as clothes, shoes, toys, furniture, electronic equipment and other household items surround children. Compared to food and cosmetics, where the contents are listed on the packaging, it is very difficult to find information about the chemicals in a mattress or a doll. There is always the option of carrying out a chemical analysis of the product, but this is expensive and requires knowledge about which chemicals to look for. Avoiding all hazardous chemicals found in different products and articles is impossible and more stringent legislation is needed.

[3] Larsson and Berglund Utvärdering av barns exponering för kemikalier i förskolan. Institure of environmnetal Medicine, Karolinska Institutet 2016.

[4] Langer, Bibi, Egelrud, de Wit and Sellström. Kemikaliesmarta åtgärder i förskola – Kemikaliebelastning i förskolans innemiljö –förskolan Hovet. IVL Rapport B229. 2017.

[5] Björklund. Brominated flame retardants and perfluoroalkyl acids in Swedish indoor microenvironments Implications for human exposure. Doctoral thesis in Applied Environmental Science, Stockholm University. 2011.

[6] www.livsmedelsverket.se/om-oss/samarbeten/project/undersokning-av-miljofororeningar-i-modersmjolk-och-blod

2.2. Legislative framework – a short overview

2.2.1. General legislation on chemicals in articles through REACH

The European chemicals legislation, regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulates the use of chemicals within production in the EU. While imported items are not subject to the all these rules, some apply for all items sold on the European market, whether or not produced outside EU. There are specific bans and regulations on content of certain chemicals in articles in the restriction list (Appendix XVII) while the authorisation list (Appendix XIV) gives specific HS a sunset date when use should cease, and authorisation for use is needed. Furthermore, substances with the following hazard properties may be identified as substances of very high concern (SVHC) under REACH (Article 59), and are then listed on the candidate list for inclusion in the legislation:

- Substances meeting the criteria for classification as carcinogenic, mutagenic or toxic for reproduction (CMR) category 1A or 1B in accordance with regulation 2008/1272/EC on Classification, Labelling and Packaging (CLP).
- Substances which are persistent, bioaccumulative and toxic (PBT), or very persistent and very bioaccumulative (vPvB) according to REACH Annex XIII.
- Substances on a case-by-case basis that cause an equivalent level of concern as CMR or PBT/vPvB substances.

For substances of very high concern, the manufacturer must provide information about a content above 0,1 percent as well as instructions for safe use if the articles are sold business to businesses. Consumers may obtain the same information within 45 days on request. Many of the chemicals, which were analysed in the project on which this report is based, are present on the candidate list of SVHC.

To date (June 2018), 191 of the 21.551[7] chemicals registered under REACH have been identified as SVHC, there may also be undetected cases as many of the registered chemicals only have a limited data set of their environmental and health properties. The European Chemicals Agency has a roadmap aiming at identifying all relevant SVHC until 2020.[8] The NGO ChemSec has identified 913 hazardous chemicals as fulfilling the criteria for SVHCs in their SIN List database.[9] The number of chemicals in use globally is estimated to be at least somewhere around 100.000 different substances.[10]

Even though the manufacturers are obliged, through REACH, to inform clients about the content of candidate list substances in articles, projects investigating compliance show that many manufacturers and suppliers are not aware of these obligations. Consequently, information is not distributed in the supply chain as detailed and efficiently as required.

For other chemicals than SVHC, manufacturers are under no obligation to provide information about content in articles. Moreover, there is no system where the information follows the product through its life cycle. This also creates difficulties in the recycling industry, such as for plastics, where the different additives are not known but still have an impact on the quality of the recycled material. For example, PVC products such as flooring or cables often comprise around 20% of plasticizers[11], vinyl

[7] www.echa.europa.eu

[8] https://echa.europa.eu/svhc-roadmap-to-2020-implementation

[9] http://chemsec.org/sin-list/

[10] Government Accountability Office. Toxic substances: EPA has increased efforts to assess and control chemicals but could strengthen its approach. Washington, DC: GAO; 2013. And www.echa.europa.eu

[11] A survey of phthalates in articles in Sweden. PM 2/14. The Swedish Chemicals Agency 2014.

gloves have been found to contain 45 % [12] and gym balls up to 79% of phthalates, respectively.[13] Many phthalates are already under legislative measures aiming at reduction of exposure for humans and environment to these hazardous substances. Thus, if such PVC articles as mentioned above are recycled, the recycled material will be contaminated by regulated phthalates.

2.2.2. Legislation on toys

Unlike many other everyday items with which children come into contact, the chemical content in toys is strictly regulated through the Toy Safety Directive (2009/48/EC).

European legislation on toys was first introduced in 1988. Already then, limits were set for eight different metals, e. g. chromium, lead, mercury. Also, for toys categorized as chemical products, such as chemical experiment sets and plastic moulding sets, limits of some hazardous elements were introduced by standardization. In the current Toy Safety Directive, which came into force through national legislation in EU countries in 2011, restrictions on chemicals were tightened and in force from 2013. Briefly, the main changes were:

- Substances meeting the criteria for classification as carcinogenic, mutagenic or toxic for reproduction (CMR) are prohibited in the accessible parts of toys.
- Restriction of a total of 19 elements, including the previously mentioned eight metals together with, for example, boron and cobalt in accessible toy parts.
- 55 allergenic fragrances are regulated. However, some of them may be used in certain toys provided that they are indicated on the label and comply with additional requirements, specific for fragrances.

For all these chemicals, low limits are set, often with the classification and labelling reporting limits for chemical mixtures in mind. There are also later additions to TSD for specific substances, e.g. organophosphorous flame retardants (TCEP, TDCP and TCPP), bisphenol A and formamide. Although comprehensive, some of the regulations in TSD only apply to toys intended for children under 36 months of age since smaller children have a higher risk of putting items in their mouth. This is a drawback since children older than three years also do that and the fact that children under three come into contact with a wide variety of toys, which might not all be intended for them by the supplier. In order to not have to follow the more stringent regulation, the manufacturer can indicate that the toy is not for use by children under the age of three.

[12] https://www.testfakta.se/sites/default/files/_BINARY_92277.pdf

[13] https://www.kemi.se/global/pm/2014/pm-2-14-ftalater.pdf

TSD does not specify how compliance with the safety requirements should be documented. The technical details for this are instead developed by the European standardisation organisations, CEN and CENELEC. The European Commission gives mandates (request for standardisation) to the standardisation organisations to develop standards for different issues. When the current Toy Safety Directive came into force, a mandate was given to CEN to revise standards for toys in accordance with the new directive. These standards set the framework within which the suppliers and producers of toys should work.

2.2.3. Legislation on other articles children use

For most other articles children come into contact with, the legislation is not as elaborated as for toys, concerning chemical content. These articles could be mattresses, clothes and baby strollers. Some areas of articles, for example food contact materials and electronics have their own designated legislation similar to TSD.

The general Product Safety Directive states that only safe products are to be sold. Despite this, the presence of harmful chemicals is not explicitly regulated for most articles. Also, one of the most notified risks in the commission's rapid alert system for dangerous products is chemical risks. About a quarter of the alerts in the system each year involve chemical risks which are not in accordance with legislation.[14] This indicates scope for improvement regarding legislation on chemical content of articles, including enforcement, in general and not only for specific products groups.

Chemicals in articles can also be specifically regulated through restriction in Annex XVII in REACH. Compared to article group specific regulations, such as the Toy Safety Directive, regulation through REACH is done on a case-by-case basis. Some examples can be the phthalates DEHP, DBP, BBP and polycyclic aromatic hydrocarbons (PAHs) in childcare articles, which are regulated in Annex XVII. Considering the restrictions for the above mentioned phthalates it is worth noting that mattresses are included in the definition of childcare articles used here.[15]

2.3. Description of analysed substance groups

This report covers calculations on the presence of phthalate plasticizers, organophosphorous flame retardants, chlorinated paraffins and highly fluorinated substances (PFAS). While all the substances are calculated for in mattresses, for toys the focus was on phthalate plasticizers and chlorinated paraffins due to differences in material composition. For information on analysed substances within each group described below, please see the report on analyses. [16]

2.3.1. Phthalates

Phthalates are plasticizers present in different types of plastic material, most commonly as additives in polyvinyl chloride (PVC) where the content can reach up to around 70%. 15 phthalates are at present identified as SVHC due to their classification as toxic for reproduction according to CLP. This also reflects the criteria in the Toy Safety Directive, absence from those 15 phthalates as well as three unclassified phthalates present on the REACH restriction list due to the precautionary principle, is thus the lowest standard used among European toy retailers nowadays. Alternative plasticizers (non-phthalate plasticizers) were also tested for in some of the items, these are at present not subject to any regulation.

[14] European Commission. 2017 results of the EU Rapid Alert System for dangerous non-food products.

[15] REACH Annex XVII, item 51.

[16] Pettersson, Oldén and Lagerqvist. Hazardous substances in articles and materials. City of Stockholm 2018.

2.3.2. Organophosphorous flame reatardants

Organophosphorous flame retardants are used in furniture foam and textiles. This substance group also contains substances with other functions, for example pesticides and plasticizers. Some of these substances have been found to be causative agents in cancer development as well as eliciting harm to the nervous system, including brain development. Hence, a few of these substances are regulated via REACH while others are restricted in the Toy Safety Directive. Organophosphorous substances can also be chlorinated or brominated, in this case they are halogenated flame retardants.

2.3.3. Chlorinated paraffins

Chlorinated paraffins (CP) are substances which occur in soft plastic or foam material, as flame retardants and secondary plasticizers, in the latter case often together with a phthalate as primary plasticiser. Short chain chlorinated paraffins (SCCP) are regulated through the EU Regulation on Persistent Organic Pollutants (POPs regulation) and in the Stockholm Convention on POPs, SCCP are also present on the REACH SVHC list. Medium chain chlorinated paraffins (MCCP) are not regulated yet but they are classified as harmful to the nursing child and very toxic for aquatic organisms. Long chain chlorinated paraffins (LCCP) are neither regulated, nor classified. All three types were analysed.

2.3.4. Highly fluorinated substances (PFAS)

Highly fluorinated substances (PFAS) are used as surface coatings on textiles, in kitchen utensils and lubricants of different kinds (the two latter uses were not analysed in this study). Many of these substances are highly persistent and bioaccumulative and are thus prone to have effects on health and environment, which is also indicated by many scientific studies. Some of these substances are regulated (for example PFOS and PFOA), but not the fluorotelomer alcohols (FTOH).

3. METHOD

Using the results from previous chemical analyses on old and new mattresses and toys mentioned above, chemical content in these article groups was identified and used to calculate the quantities of different substances that has been phased out through discarding of old material. Furthermore, the input data comprised statistics of purchase for the last years in public pre-schools as well as weights of the mattresses and toys. The Chemical Centre also give support to the private pre-schools within the city, but statistics from these actors is harder to retrieve and is not part of this report. A detailed description of the background data used is presented below.

The method of substance flow analysis and source tracking implemented elsewhere in the NonHazCity project was used to approximate on numbers and content of the old articles. [17] A mean value and worst case value was identified for each parameter. The worst case value was based on the highest amount of HS detected in any mattress or toy, respectively, as well as the highest measured weight and the highest estimated number of items. This means that the worst case is most probably not the actual case for the whole city, but can be of local importance since the pre-schools often had many mattresses and toys of the same kind, bought at the same time. This means that one pre-school might have only "worst case mattresses" while for others it might vary slightly around the mean value. The worst case serve as an illustration as to how bad it could be, but should be taken as just that, and not the actual presence of HS.

3.1. Mattresses

For mattress purchases, statistics were available for the years 2015-2018. In the previous project, mentioned above, a number of old and new mattresses (both covers and core) were sent for chemical analysis to determine the content of some of the commonly used phthalates, organo-phosphorous flame retardants and chlorinated paraffins.[18] Brominated flame retardants (PBDE, PBB, HBCDD etc, here excluding brominated organophosphates) were also tested for, but none were detected. Some mattresses were also tested for highly fluorinated substances (PFAS).[18] Using the results from the previous study[19], calculations were made on the quantities of phthalates, chlorinated paraffins and flame retardants that the city has phased out by replacing old mattresses.

[17] Jonsson, A., Fridén, U., Thuresson, K.and Sörme, L.(2008).Substance flow analysis of organic pollutants in Stockholm.Water, Air and Soil Pollution: Focus 8:433-443. And: Jens Gercken et al. (2018) Hazardous substance occurrence in Baltic sea pilot municiplaitites: Major output from the tracking and ranking for prioritisation of sources in NonHazCity project. The report is present at the NonHazCity website www.nonhazcity.eu

[18] Detected phthalates: DIBP, DBP, BBP, DEHP, DNOP, DINP, DIDP and DHP. Detected phospho-organic flame retardants: TCEP, TCPP, TPP, TDCPP and TIBP. Detected chlorinated paraffins: SCCP and MCCP. Detected PFAS: FTOH and FTA. For details of analysed substances see: Pettersson, Oldén and Lagerqvist. Hazardous substances in articles and materials. City of Stockholm 2018.

[19] Pettersson, Oldén and Lagerqvist. Hazardous substances in articles and materials. City of Stockholm 2018.

3.1.1. Background analytical data

The content of phthalates, chlorinated paraffins and organophosphorous flame retardants were collected for all samples. Averages for covers and cores from old mattresses were calculated and the worst-case analytical values for both covers and cores were identified.

The new mattress covers were free from the analysed phthalates and chlorinated paraffins, apart from one nursing-table mattress which contained 2 600 mg/kg (0,26%) DEHP and 6700 mg/kg (0,67%) SCCP. The phthalate value is above the 0,1%-limit in REACH annex XVII and the SCCP level is above the 0,15% limit in the POPs directive, hence, the mattress was withdrawn from the market when the content of the regulated phthalate was detected. This report focuses on resting mattresses, statistics for nursing table mattresses are not included, due to this, the mattress described here was not included in the calculations. Resting mattresses were defined as those used by the children to take a nap at the pre-school during daytime, and are the scope of this report.

The corresponding new cores occasionally contained very small amounts of organophosphorous flame retardants, apart from one type of resting mattress that contained amounts as high as 82 200 mg/kg (8,2%). This mattress was rapidly removed from the market and the composition updated in new versions produced. Furthermore, it was bought very infrequently, probably only by one single pre-school in Stockholm. Due to these facts, this mattress was not considered in the mean value for new mattresses. The averages and worst-case values for mattress covers are shown in Table 1 while the values for mattress foam cores are presented in Table 2.

*Table 1. Summary background analytical data regarding **mattress covers**.*

Subject	Phthalate plasticizers (mg/kg)	Phosphor organic flame retardants (mg/kg)
Old mattress covers – average	154 000	Not analysed
Old mattress covers - worst case	345 000	Not analysed
New mattress covers – average	0	Not analysed
New mattress covers - worst case	0	Not analysed

*Table 2. Summary background analytical data regarding **mattress foam cores**.*

Subject	Phthalate plasticizers (mg/kg)	Phosphor organic flame retardants (mg/kg)
Old mattress cores – average	32 600	10 500
Old mattress cores - worst case	115 000	61 300
New mattress cores - average	Not Analysed	8 *
New mattress cores - worst case	Not analysed	82 200

* The worst-case resting mattress is not included in average since it was rapidly removed from the market and the city has bought very few of these. The average value is at contamination level and is not considered actively added.

Regarding the analytical data for chlorinated paraffins, which can function as both plasticizers and flame retardants, presence was only detected in the covers of four old mattress and in the cover of one new mattress, i.e. the nursing table mattress that is not included in the calculations due to the delimitation to resting mattresses, mentioned above.

In new mattresses, the covers are mostly made of polyurethane coated fabrics instead of PVC and some of them were analysed for highly fluorinated substances (PFAS) which may be used for such materials to achieve increased water repellent properties. Of these materials, PFAS (i. e. 8:2 FTOH, 10:2 FTOH and 8:2 FTA) was found in two of the three mattresses purchased from the suppliers. One was the cover to the worst-case foam core noted above and the cover for the other one was adjusted to a material which was subsequently analysed and is now free from PFAS. The averages and worst-case values regarding chlorinated paraffins and PFAS are shown in Table 3.

Table 3. Summary background analytical data.

Subject	Chlorinated paraffins (mg/kg)	PFAS (µg/kg)
Old mattress covers – average	144	0 (only one analysed)
Old mattress covers - worst case	2 100	0
New mattress covers – average	0	0*
New mattress covers - worst case	0	510

*The worst case is not included in the average since the mattress which was bought the most did not contain PFAS, another was adjusted and the third was bought very seldom. It would thus be misguiding to have an average including the two latter.

3.1.2. Number of mattresses

Data for estimation of the number of mattresses that have been replaced was acquired in two ways:

1. From the city districts

   Information was requested from all 14 city districts, and nine submitted their approximations of how many mattresses had been replaced in 2015-2017. We estimated that each of the five districts that did not submit information replaced 500 mattresses, which was the lowest amount reported by any of the other districts. For our analysis, the total number of mattresses replaced was ca 9600.

2. From the suppliers

   Information from the suppliers (Lekolar, ABA skol, Form&Miljö and Tysta leksaker) showed that the number of mattresses sold to the city in 2016-2017 (Lekolar and Form&Miljö) or 2015-2017 (ABA-skol and Tysta leksaker) was ca 7900.

The statistics from the suppliers is lower than the numbers received from the city districts. A plausible reason is that pre-schools do not always have complete knowledge concerning when mattresses were replaced. Some may have been replaced earlier, and some pre-schools have replaced mattresses for sheepskin or sleeping pads. Others allow children to sleep in their strollers.

Another uncertainty is that statistics from the suppliers varied from 2015-2017 and 2016-2017. Furthermore, the city districts which did not submit statistics might have replaced some mattresses in 2018, hence the timeframe used is 2015-2018. The number of mattresses used in the calculations to show the amounts of phthalate plasticizers, chlorinated paraffins and flame retardants was the average of the numbers yield from city districts and suppliers, 8750 pieces, see Table 4.

Table 4. Estimation of the number of mattresses.

Description of value	Number
Mattress – based in information from 9 city districts which answered with exact numbers	7100
Mattress – based in information from city districts, together with estimations for the remaining 5 districts	9 600
Mattress – based in information from suppliers	7 900
Average number of mattresses	(7 900 + 9 600) / 2 = 8 750

For calculation of the worst-case number for new mattresses, the resting mattress which contained high levels of organophosphorous flame retardants was chosen as 40 pieces actually were bought by the city. Assuming that the percentage of this type of mattress is the same among the "unknown" mattresses, i.e. the 2 500 pc. assumed for the districts which did not supply statistics gives the following approximation: 100 x 40 / 7 100 = 0,56% are of that type of mattress, which in turn gives 0,56% x 2 500 = 14. Thus, the worst-case number of mattress containing organophosphorous flame retardants is estimated at 40 + 14 = 54 pieces bought in total. It is unlikely that many more have bought this mattress since it is not recommended in the tips for purchase provided by the Chemicals Centre. [20] Regarding the worst-case number for PFAS, there are more mattresses that have been sold to the pre-schools. The 40 mattresses above still contain PFAS, and 1290 mattresses of another kind that contained PFAS (but were later adjusted) were sold during 2015 and 2016. The percentage of the known mattresses will be 100 x 1 330 / 7 100 = 18,7%. Similar to the calculation above, this gives 18,7% of 2500 = 470. The worst-case number of mattresses containing PFAS, is thus estimated to 1330 + 470 =1 800 pieces.

These worst-case numbers were not added to the average since this would give a misguidance indicating that all new mattresses contained these chemicals, intentionally added at functional levels. Moreover, most of these discrepancies were adjusted by the retailers/producers of the mattresses during the course of the project.

3.1.3. Number of resting children

According to statistics from the Swedish National Agency for Education (*Skolverket*), 67% of children aged 1-5 attended a public pre-school in 2017. This number varies only very slightly between different-sized cities and urban vs. rural area. Therefore, we assume that 67% also applies for Stockholm.

According to the City of Stockholm, there were 59 500 children of this age in Stockholm, and 67% of this figure is approximately 40 000. Most children begin pre-school around the age of 1.5, and normally have a daily rest until they are around 3 years. Assuming that they attend pre-school until they are aged 5.5, the 40 000 children can be divided into eight age groups with 5 000 children in each. It is assumed that the three youngest age groups rest daily, i.e. children aged 1.5-2, 2-2.5 and 2.5-3. This means that 3 x 5000 = 15 000 children presumably rest, and most do that on a mattress.

According to statistics from the city districts and suppliers, the public pre-schools have replaced 9 600 respectively 7 900 old mattresses for new ones in 2015-17. Some might have replaced their mattresses before or after that, but as a first estimation this suggests that there still could be around 5 000 old mattresses in pre-schools, even though some of these children probably have other good sleeping arrangements, for example outside in their strollers, and might not need new mattresses.

[20] Please see www.stockholm.se/kemikaliesmartforskola for more details

3.1.4. Estimation of weights

In order to calculate the amounts of phased out chemicals, input data of weights of covers and foam cores were needed. Hence, some of the old covers and cores were weighed. Due to the fact that these mattresses were quite small, a weight span for old mattresses was estimated based on information from the suppliers of new mattresses as well as experiences from inventories at other pre-schools than the ones donating material for the analyses. As we do not have actual numbers of various kinds of old mattresses, calculations were based on both an estimated average and worst case value of weight for both cover and foam core, using the experiences described above.

Table 5. Weights of old mattresses

Description of value	Covers (kg)	Foam cores (kg)
Actual weights for two old, quite small mattresses	0.55 / 1.04	1 / 1.2
Estimated weight of old mattresses in general	0,5-1,5	1-4
Estimated average weights	**1**	**2.5**
Estimated worst-case weights	**1.5**	**4**

For new mattresses, calculations were based on an average determined from the information about weights from the suppliers. The new mattresses are in general lighter than the old ones and mainly come in two sizes; three small ones with sizes of 110-117 x 53-55 cm and one larger with a size of 140 x 55 cm. The thicknesses vary slightly. 56% of the mattresses are of the smaller type, and 44% were the larger type. This gives average weights displayed in table 6.

Table 6. Weights of new mattresses

Description of value	Number	Covers (kg)	Foam cores (kg)
Small mattresses, average	4420	0.36	0.77
Large mattresses, average	3490	0.51	1.53
Average weight of small and large mattresses	-	**0.43**	**1.15**
Worst-case weights	-	**0.51**	**1.5**

3.2. Toy animals and figures

As mentioned above, a number of old and new toy animals and figures made from plastic were sent for chemical analysis, within the NonHazCity project, to determine the content of a number of phthalate plasticizers, alternative plasticizers as well as chlorinated paraffins.[21] Using the results from this previous study, the amount of HS that the city has managed to phase out by active replacement of toy figures was calculated. A delimitation was made for animal and human figures, thus, dolls, balls and larger toys were not included. The assumption made in this report is that the number of new toys bought (both plastic, rubber, textile and wooden) equals the number of old and discarded plastic toys.

In total, 90% of the old PVC toys tested contained phthalates at varying levels while new toys at most contained trace amount under the 0,1% legislative level. A mean value of phthalate content was calculated for all old plastic toys, 69 700 mg/kg (7%). Furthermore, the results showed that the highest total of restricted phthalates was 419 000 mg/kg in a toy lizard, approximately 42% of the toy. This value was used as the worst case.

For chlorinated paraffins, only three out of 23 old toys (13%) contained SCCP or MCCP at levels up to 6 700 mg/kg (0,7%, SCCP) and 29 400 mg/kg (2,9%, MCCP). None of the new toys contained chlorinated paraffins. The approximation that 13% of all phased out toys contained chlorinated paraffins was made from that result, and the sum of SCCP and MCCP, 36 000 mg/kg (3,6%) was used for the worst case calculations while the average was 13 000 mg/kg (1,3%, the sum of all CP content of the three toys containing CP, divided by three). The reason that the values for SCCP and MCCP were used as a sum was that in all toys where chlorinated paraffins were detected, both types were found. Long chained chlorinated paraffins, on the other hand, were not detected in any sample.

3.2.1 Sales statistics and weight of toys

An assumption was made that the old toys were replaced by the same number of new toys. In practice there might have been more toys that were thrown away, but at the same time a number of toys has been bought for newly built pre-schools. Some old plastic toys may also have been replaced by new wooden, rubber or textile toys or not replaced at all. While the amount of wooden, rubber and textile toys were assessed, the latter have not been taken into account since it is very hard to estimate how many toys that were not replaced at all. Although, for the worst case value, it was assumed that the double amount of old toys were phased out since many of the pre-schools started to phase out toys as one of the first activities already in 2014 and statistics are not available until 2017. Thus, a lot of toys might already been phased out prior to the start of the statistics.

[21] Pettersson, Oldén and Lagerqvist. Hazardous substances in articles and materials. City of Stockholm 2018.

Table 7. Number of toys of different materials

Description of value	Number bought 2017
Plastic toys (PVC)	4110
Rubber Toys (TPR)	936
Rubber toys (Latex)	77
Textile toys (polyester)	98
Wooden toys	991
Total	6212

From the city's purchasing system, statistics for all bought toy items in the city districts were collected for a twelve-month period February 1st 2017 – February 1st 2018. From the website of the contracted supplier Lekolar, information about the article number, the number of different toys in a package as well as the material of the different toys was collected. This was done to make sure that only plastic, rubber, textile and wooden animals and figures were taken into account. The total number of PVC-plastic animals and figures bought by the city districts in 2017 was 4110, and the corresponding number for wooden toys 991, 1013 rubber toys (TPR and Latex) and 98 textile toys were also bought, giving a total of ca 6210 (Table 7).

The average weight of new plastic figures was 31 grams (average of 17 new figures) and the worst case 134 grams. The old figures on the other hand had an average weight of 65 grams per piece (average of 8 old figures collected from pre-schools) with the worst case being 137 grams. In general, old PVC figures were heavier than new ones of the same size indicating a difference in the material composition. In contrast, new rubber figures (TPR) were heavier than new PVC figures.

Since 35% of the purchases are known to be made outside the city's purchasing system, for the toys and creative materials supplier, the numbers of figures were increased with the corresponding 35%, assuming that the deviation is the same for all toy categories. This yields a number of 9560 toys in total per year, which will be used for further calculations, together with a multiplication by four to get the amount of figures for the four year time period (2014-2017), 38200. To illustrate the fact that many pre-schools probably started phasing out toys already 2014-15, from which years there are no city-wide statistics, an assumption was made that the number of phased out toys might actually be the double, 76500, and this number was used for the worst case calculations.

4. RESULTS

4.1. Mattresses

The values extracted from the previous work and the estimations made, described under section 3 (Method) were the basis for the calculations of the total amounts of phthalate plasticizers, chlorinated paraffins and orgaonphoshorous flame retardants removed from the pre-schools. Phthalate plasticizers and organophosphorous flame retardants were found in most of the old mattresses and a few of the new ones, but in general at lower levels in the latter. Chlorinated paraffins were only found in four old resting mattress covers.

Tables 8 and 9 show the amount of phased out phthalate plasticizers, chlorinated paraffins and organophosphorous flame retardants in old covers and cores respectively as well as the content in the newly purchased ones. All numbers are the total for the four years between 2015-18.

*Table 8. Summary of amounts of phthalates and chlorinated paraffins in mattress **covers**.*

Description of value	Weight/ mattress (g)	Number of mattresses	Total amount of phthalate plasticizers (kg)	Total amount of chlorinated paraffins (kg)
Old - average	1 000	8 750	1 350	1,3
Old - worst case	1 500	8 750	4 500	27
New - average	430	8 750	0	0
New - worst case	510	54	0	0

*Table 9. Summary of amounts of phthalates and flame retardants in mattress **foam cores**.*

Description of value	Weight/ mattress (g)	Number of mattresses	Total amount of phthalate plasticizers (kg)	Total amount of phosphor organic flame retardants (kg)
Old - average	2 500	8 750	713	229
Old - worst case	4 000	8 750	4 000	2 140
New - average	1 150	8 750	0*	0,1**
New - worst case	1 500	54	0	6,7

*Phthalate plasticizers were only analysed in one new mattress foam core.

**The worst-case mattress is not included in average since it was rapidly removed from the market and the city bought very few of these.

In table 10, the detected amounts of PFAS in covers are shown. PFAS was analysed for in the three new mattress cover types and one old cover and was found in the cover of two of the new mattresses, but not in the one which was most frequently purchased. These types of substances are used in surface treatment of textiles but not in the foam cores, hence, PFAS was only analysed for in the mattress covers.

*Table 10. Summary of estimated amounts of PFAS in **covers.***

Description of value	Weight/ mattress (g)	Number of mattresses	Total amount of PFAS (g)
Old mattress – average	1 000	8 750	0 (only one analysed)
Old mattress - worst case	1 500	8 750	0
New mattress - average	430	6950*	0
New mattress - worst case	510	1800**	0,47

*One of the three types of mattresses bought did not contain PFAS and was the one most frequently purchased. 6950 pieces including the estimation for the city units which did not answer.
**This is the actual number bought of PFAS-containing mattresses together with an approximation for the city units which did not respond.

Considerable amounts of hazardous substances have been phased out from the public pre-schools in Stockholm, illustrated in Table 11, where total content in old, phased out, mattresses is presented. This can be compared to the small amounts in Table 12 where the total amounts in the new mattresses are presented. What has been added, in some cases of the new cover materials, is PFAS. While the amount is small, it is merely monomers from a polymerisation process that are measured with the methods used. Furthermore, these substances have been found to give measurable effects already at low concentrations as well as being very bioaccumulative and persistent, as opposed to phthalates, for example.

*Table 11. Total amounts of analysed hazardous substances **in old mattresses**.*

Whole mattresses (cover and foam core)	Total amount of phthalate plasticizers (kg)	Total amount of phosphor organic flame retardants (kg)	Total amount of chlorinated paraffins (kg)	Total amount of PFAS (g)
Old – average	**2 100**	**230**	1,3	0*
Old - worst case	**8 550**	**2 140**	27	0

* Only one old cover was analysed since the old mattress covers were mainly made from PVC.

*Table 12. Total amounts of analysed hazardous substances **in new mattresses,** after update of material content for some of the sampled mattresses.*

Whole mattresses (cover and foam core)	Total amount of phthalate plasticizers kg)	Total amount of phosphor organic flame retardants (kg)	Total amount of chlorinated paraffins (kg)	Total amount of PFAS (g)
New – average	0	0,1	0	0
New - worst case*	0	0,1	0	0,0075

* In the worst case, the mattresses which were updated are not included since the content of the material composition was changed and the HS removed, except for the mattress containing both organophosphorus flame retardants and PFAS, this one still contains PFAS, and the content of this mattress is used for the worst case. The other mattress which contained PFAS had higher levels originally but is now free from such, hence the difference in the number for PFAS in this table compared to Table 10, above. The amounts of organophosphorus flame retardants can be assumed to be the same since these levels were considered to be contamination from the production process.

4.2. Toys

With the assumptions and analytical data described in section 3.2, it was possible to calculate the maximum and average amount of phthalates that has been phased out from the city districts when replacing plastic animals and figures. Although some larger old figures were found, older figures were in general heavier than new ones also when being of the same size.

Table 13. Numbers of toys and amount of phased out phthalates during four years.

Description of value	Weight (g)	Number of toys over four years	Amount of phthalate plasticizer (%)	Total amount of phthalate plasticizers (kg)
Old - average	65	38200	7	175
Old - worst case	137	76400	42	4400
New – average	25	38200	0	0
New - worst case	60	38200	0,01*	0,2*

*This amount is below functional levels and is probably an unintended addition or contamination, for this reason, it is not included in the mean.

If using the average amount (7%) in the tested old toys, 175 kg of phthalates has been phased out during four years, equaling ca 44 kg per year, see Table 13. If all replaced plastic animals and figures had contained as much restricted phthalates as the lizard with the highest content (42%) 1050 kg of phthalates has been phased out from the city districts in Stockholm over four years, equaling ca 260 kg per year. If instead assuming that the amount of toys approximated for four years is an underestimation and that the actual number is the double according to the facts described in the methods section, above, 2100 kg of phthalates would have been phased out (still using the average weight, 65 gram). Using the highest weight measured for old toys (137g) would then yield a reduction of 4400 kg of phthalates over four years. Almost all new toys were free from the analyzed substances while some contained trace levels of phthalates, below 0,1%.

Table 14. Numbers of toys and amount of phased out chlorinated paraffins during four years.

Description of value	Weight (g)	13% of the number of toys over four years	Amount of chlorinated paraffins (%)	Total amount of chlorinated paraffins (kg)
Old - average	65	4970	1,3	4
Old - worst case	137	9940	3,6	50
New – average	25	4970	0	0
New - worst case	60	4970	0	0

For chlorinated paraffins an assumption was made that 13% of the replaced toys may have contained these chemicals as 3 out of 23 tested old toys (13%) contained chlorinated paraffins. If using the average concentration of 13 000 mg/kg (1,3%) in the calculations, 4 kg of chlorinated paraffins has been phased out by replacing the toys with new ones over four years (1 kg per year), see Table 14. If instead assuming that all of the replaced toys contained the average concentration of chlorinated paraffins, 32 kg of chlorinated paraffins has been phased out. Using the worst case scenario, with 3,6% content, and assuming 13% occurrence, 50 kg of chlorinated paraffins would have been phased out. Although unlikely, if 100% of the old toys weighed 137g and contained 3,6% chlorinated paraffins, 380 kg would have been phased out, as a worst case.

5. CONCLUSIONS

5.1. Risk reduction

By replacement of old mattresses for newer ones, large amounts of phthalate plasticizers and organophosphorous flame retardants have been removed from the public pre-schools in Stockholm. Only one of the new resting mattresses available from the suppliers contained a substantial amount of organophosphorous flame retardants. Due to the analyses made by the Chemicals Centre, a large order of that mattress was withdrawn. Further on, in new mattress covers, PFAS may be used to achieve desirable water repellency properties. Some PFAS were found in two out of three analysed new mattress covers. One of the mattresses containing PFAS was the same mattress that contained the large amount of organophosphorous flame retardants. The foam core composition was updated and the flame retardants were removed from the production, although, it still contains PFAS in the cover. For the other mattress with detected PFAS content, the supplier decided to change the cover material to a type that is free of PFAS.

The consequences for health and environment of phthalate exposure are now known to the degree that several of them are legally restricted in various ways. DEHP and several other phthalates has a harmonized classification for reproductive toxicity. Phthalates have been shown to be present in dust, which is one exposure source for smaller children. The presence in the dust originate from presence in articles and material in the indoor environment, and by removing those sources, the amount in the dust can be reduced.[22] This is of course dependent on the type of flooring material present[23]. Removing a few plastic toys from a room with PVC-flooring might not make that big of a difference for the levels of plasticizers present in the dust while the intake from mouthing will decrease.

[22] Kristin Larsson– Thesis for doctoral degree (Ph.D.) Karolinska Institutet, 2018: Characterizing Chemical Exposure – Focus on Children´s Environment, and, Giovanoulis et. al., Reduction of harmful chemicals in Swedish preschool dust, manuscript in preparation, 2018.

[23]Huan Shu et.al. PVC Flooring at Home and Uptake of Phthalates in Pregnant Women, Indoor air, 2018.

Highly fluorinated substances also have several documented effects. One such substance, PFOS, has a harmonized classification including several hazards; specific toxicity to the liver, carcinogenicity and reproductive toxicity, but less is known about the effective levels in humans. Another of those substances, PFOA, is found at levels of ng/mL in children's blood samples and these substances are extremely persistent and bioaccumulative and will not be excreted readily.[24] FTOH, which was the type of PFAS found in the analyses providing the basis for this report, are not regulated at present but some of them are known to degrade into other, possibly classified, types of PFAS.

It is a challenge to determine which type of chemical that is worst in terms of effects on humans after exposure; phthalates or PFAS. But, the replacement of mattresses have the benefit that large amounts of phthalates which are toxic for reproduction have been phased out while most of the new mattresses are also free from PFAS. The content of FTOH was phased out from one mattress as late as 2017, which means that some of the newly bought mattresses of that kind might contain those substances. The levels of free FTOH found are low compared to the levels of phthalates to such an extent which indicates that the substitution was still favorable, even though PFAS are more persistent than phthalates. Although, the total content of FTOH is higher in the material than the results indicate since they are added to make a polymerized surface, and only free monomers are measured with the method used. This opens up for extended analyses of total fluorine content in materials in future projects, to achieve a more detailed picture.

When replacing the old toy figures with new, also new plasticizers have entered into the children's environment. By making the same kind of worst case calculations, it can be estimated that, if new plastic and toy animals and figures contain the highest level found of DINCH, DEHT or ATBC, for every 50 kg of restricted phthalates replaced, either 33 kg of DINCH, 32 kg of DEHT or 19 kg of ATBC, was introduced. Neither DINCH, DEHT or ATBC has a harmonized classification according to ECHA. There has been data indicating that DINCH could have endocrine disruptive properties, but these have been deemed as not relevant to humans.[25] If so, the conclusion is that the replacement of old toys containing restricted plasticizers has not resulted in presence of chemicals exposing the children to new risks.

5.2. Discussion

Measures to reduce phthalate plasticizers and organophosphorous flame retardants in the children´s environment by replacing old mattresses with newer ones seem to have been a good prioritisation, as considerable amounts of these hazardous substances have been removed

A mean value of 2100 kg or a worst case scenario of 8 550 kg of restricted phthalate plasticizers has been removed when the mattresses were replaced with new ones over four years. For organophosphorous flame retardants the corresponding figures were 230 kg or 2140 kg. Moreover, between 1,3 to 27 kg of chlorinated paraffins have been phased out due to the replacement of mattresses.

[24] Kerstin Winkens et. al. Early life exposure to per- and polyfluoroalkyl substances (PFASs): A critical review, Emerging Contaminants, 2017.

[25] Swetox 2016. Alternativa mjukgörare i sjukvårdsmiljö.

Although the PFAS measured is a remnant from a polymerisation process, which means that the fluorinated content of the material is higher than the measured values, it is still probably much lower than the average phthalate content in the old mattresses. After the analyses, PFAS was removed from one of the commonly bought mattresses which means that the majority of the mattresses the city purchases, if the statistics continue to be similar to the ones received for this report, are now free of PFAS.

For the plastic animals and figures, the amount of phased out chemicals was smaller, in one year 44 kg of phthalate plasticizers has been removed on average and 1 kg of chlorinated paraffins. For four years, the corresponding numbers are 175 kg of phthalate plasticizers and 4 kg of chlorinated paraffins. The corresponding worst case values were 4400 kg and 50 kg, respectively. Even if these values are smaller than for mattresses, the replacement of old toys is still important as all these figures are of a size that small children may put in their mouth and chew on. Different additives in the plastic material, such as phthalates may then migrate to the child's saliva and cause exposure.

All these calculations have some uncertainties, which are larger for toys than mattresses due to the assumptions of the number of replaced toys, but the calculations illustrate the magnitudes, even if the numbers will never be exact. Another factor for the toys is that they might have been the first product group the pre-schools discarded, this means that the toys might have been replaced already 2014-2015, before the the e-purchasing system was implemented from which the 2017/2018 year's statistics was retrieved. This was taken into consideration by calculating a worst case scenario with the double amount of toys. For future replacement of different products in pre-schools similar calculations could be made as a basis for decision on what substitution measures are to be prioritized.

To conclude, this report illustrates that the efforts made to reduce HS presence in the everyday environment of children in pre-schools had effect since several tonnes of hazardous substances were removed from the indoor environment of the public pre-schools of Stockholm.

ABOUT THE PROJECT

The project “Innovative Management Solutions for Minimizing emissions of hazardous substances from urban areas in the Baltic Sea Region” (NonHazCity) is financed by the European regional development fund within the Interreg Baltic Sea Region program, from March 2016 to February 2019. The project involves 18 partners from Sweden, Finland, Estonia, Latvia, Lithuania, Poland and Germany and 23 associated partners.

NonHazCity wants to demonstrate possibilities of municipalities and WWTPs to reduce emissions of priority hazardous substances (HS) from small scale emitters in urban areas that cannot be reached by traditional enforcement techniques. Substances of concern will be identified and prioritised, sources tracked and ranked, individual HS Source Maps and Chemicals Action Plans developed by each partner municipality.

Municipal entities will implement own substance reduction measures at their premises. Private small scale businesses will pilot substitution actions and improve their assortment. Inhabitants will be shown their HS emission share and test the use of less HS in every-days household management to help to protect the Baltic Sea environment but also their own health.

If you are interested to follow the project this newsletter will be produced about twice a year. It is also possible to read about activities at the project website www.nonhazcity.eu and at partner websites.

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