High Tech Industry
Stieltjesweg 1
2628 CK Delft
+31 88 866 20 00

www.tno.nl
aart_willem.benschop@tno.nl
+31653575740

Date
24 October 2023
Our reference
TNO2023 M12017

P.O. Box 155, 2600 AD Delft

Dorel Netherlands
To the management of Dorel Juvenile

Korendijk 5
5704 RD HELMOND

Subject Statement on the possible health effects of the presence of naphthalene in the airbag warning label on a baby car seat

To the management of Dorel Juvenile,

Herewith you will receive our letter report concerning "Statement on the possible health effects of the presence of naphthalene in the airbag warning label on a baby car seat".

Sincerely,

Digitaal ondertekend door Aart Willem Benschop
op 2023-10-24 09:16:17

A.W. Benschop
MKB manager

Date
24 October 2023
Our reference
TNO2023 M12017

Statement on the possible health effects of the presence of naphthalene in the airbag warning label on a baby car seat

1. Introduction

At the request of Dorel Netherlands, Korendijk 5, 5704 RD Helmond, the Netherlands (further referred to as Dorel), TNO, Stieltjesweg 1, 2628 CK Delft, the Netherlands (further referred to as TNO) investigated the possible health effects of the presence of naphthalene in the airbag warning label on a baby car seat. According to Dorel, naphthalene (CASRN 91-20-3) was detected in a concentration of 3 mg/kg in the air bag warning label of one of the baby car seats tested, namely the Maxi-Cosi Pebble 360 Pro (further referred to as Pebble Pro), by the German Consumer Organization Stiftung Warentest (STIWA). The label is attached to the lining of the Pebble Pro and is, according to Dorel, 6 cm high and 12 cm wide (see picture below), and weighs 0.8 g. In view of the position of the label, babies may be exposed by inhalation to naphthalene that may be emitted from the label. Larger babies than the one in the picture may be exposed by oral intake when licking the label (if the naphthalene in the label would migrate out of it to saliva) or by dermal contact. Therefore, these three possible routes of exposure are evaluated in this assessment.

Baby in Pebble Pro
Photo copied from website "Made for Mums" (Review Maxi-Cosi-Pebble-Pro)

In order to gather information on the toxic potency of naphthalene, the websites of reputable national and international organizations in the area of toxicological hazard and risk assessment have been screened for relevant information. These organisations include, but are not limited to, the Dutch Institute for Public and the Environment (RIVM), the Dutch Health Council (Gezondheidsraad), the European Food Safety Authority (EFSA), the European Chemicals Agency (ECHA), the World health Organization (WHO), the International Agency for Research on Cancer (IARC), the US Environmental Protection Agency (EPA) and the US Agency for Toxic Substances and Disease Registry (ATSDR). For some specific subjects (e.g. evaporation rates), the on-line literature abstract and citation database SCOPUS was screened for relevant information.
The most recent toxicity report on naphthalene encountered which included health-based limit values, was published by the ATSDR in 2005 (ATSDR, 2005). This report was used as the main source of information for this risk assessment. Any other sources used are explicitly cited in the text, when applicable.

2. Background on naphthalene

Naphthalene is a white solid material that easily evaporates and is also the main ingredient of mothballs, and known as white tar or tar camphor. Its major commercial use is in the production of other chemicals used in the manufacture of PVC. The major consumer products containing naphthalene are mothballs or -crystals and toilet deodorant blocks. It has a characteristic, readily detectable "mothball" odour (Dutch Health Council, 2012) with an odour threshold (i.e. the lowest concentration in air a person can still smell) of 0.0075 to 0.42 mg/m^3 (WHO, 2010). It is poorly soluble in water (0.03 g/L),

but readily soluble in many organic solvents like alcohol, benzene and ether (Dutch Health Council, 2012). Its octanol-water partition coefficient (log K_{OW}) is 3.4 to 3.7 (EU, 2003).

3. Toxicological hazard assessment

3.1 Introduction

When possible and necessary the ATSDR derives health-based limit values for the chemicals it evaluates called Minimum Risk Levels (MRLs) for two routes of exposure (oral and respiratory) and three exposure durations (acute, intermediate and chronic). The ATSDR defines MRLs as levels of exposure to a specific chemical that are lower than those that may cause adverse health effects in the people most sensitive to the effects of the chemical concerned. It considers exposures from 1 to 14 days to be acute, exposures from 15 to 364 days to be intermediate and exposures from 365 days and more to be chronic. When derived, these will be used in the risk assessment of naphthalene. For the dermal route, the ATSDR has no established method to derive a MRL, nor does any other institute deriving legal limit values. TNO has made an approximation for naphthalene, based on the available data, to derive a health-based quantitative reference value that represents a safe exposure level.

3.2 Genotoxicity and carcinogenicity

In 2002, IARC concluded that there is sufficient evidence that naphthalene is carcinogenic in experimental animals, but that the available evidence is insufficient to draw a conclusion on the carcinogenicity of naphthalene in humans (IARC, 2002). The conclusion on experimental animals was based on a significantly increased number of female mice with lung tumours exposed via inhalation to 30 ppm (equivalent to 157 mg/m^3) of naphthalene for 6 hours per day, five days per week during a period of two years (IARC,2002). Concentrations of 52 mg/m^3 did not lead to an increased number of animals with lung tumours. In the same study, male mice did not develop lung tumours due to exposure to naphthalene. In a similar respiratory carcinogenicity study with rats, naphthalene did not induce lung tumours, but did produce nasal tumours even at the lowest concentration tested (52 mg/m^3). Carcinogenicity animal studies on oral exposure and on exposure via subcutaneous or intraperitoneal injection did not demonstrate carcinogenesis due to naphthalene exposure, although most of these studies had some short-comings (IARC, 2002). IARC also concluded that the carcinogenesis observed in the female mice occurred via a cytotoxic mechanism, which is a so-called threshold mechanism. This means that there are levels of exposure to naphthalene below which no cancer is induced, which is not the case for chemicals that are genotoxic (mutagenic) carcinogens.
In 2012, the Dutch Health Council has reviewed the mutagenicity and carcinogenicity of naphthalene, based on the IARC evaluation and new, mechanistic, evidence (Dutch Health Council, 2012). It concluded that the mode of carcinogenic action of naphthalene in rodents (rats and mice) is not relevant for humans, since humans lack the metabolic capacity to generate enough reactive metabolites to start the carcinogenic process. They also concluded that naphthalene is not genotoxic. Based on these data, the Dutch Health Council concludes that there is insufficient data to draw a conclusion on the carcinogenicity of naphthalene in humans, and that naphthalene is carcinogenic in animals.

In view of these evaluations, no health-based limit value can be derived for carcinogenic effects of naphthalene, since the only positive studies available concern tumours that are not relevant to humans. Furthermore, it should be noted that even if naphthalene is carcinogenic to humans (which cannot be proven or disproved based on the available evidence), most likely safe levels of exposure do exist for this kind of toxic effect since it is non-genotoxic.

3.3 Oral exposure

Based on case studies in humans that ingested naphthalene, sizable single doses of ingested naphthalene can cause anaemia. Not many quantitative data on the doses concerned are available, but they are presumably in the range of 100 mg/kg bw. After oral exposure also cataracts has been observed in humans, but there is no data available on the doses causing this effect. The ATSDR has derived an MRL for acute oral exposure of 0.6 mg/kg bw/day, based on a developmental toxicity study in rats in which some effects (lethargy, slow respiration, prone body posture) were observed in the dams on days 1 and 2 of the 10-day exposure. Based on the same study, ATSDR also set the MRL intermediate duration oral exposure to 0.6 mg/kg bw/day. These values will be used in the risk assessment. The ATSDR was not able to derive an MRL for chronic oral exposure.

3.4 Inhalation exposure

In humans, also inhalation exposure leads to anaemia or cataracts, but no dose levels associated with these effects could be identified. The ATSDR derived a chronic MRL for the respiratory route, based on the rodent carcinogenicity studies mentioned above, of 0.0007 ppm (equivalent to 0.0037 mg/m^3 or 3.7 µg/m^3). This value will be used in the risk assessment. The ATSDR was not able to derive MRLs for acute and intermediate respiratory exposure.

3.5 Dermal exposure

Not much information is available on the dermal toxicity of naphthalene. However, two case studies on infants wearing naphthalene treated diapers demonstrated (severe) symptoms of anaemia. This demonstrates that naphthalene may be absorbed from the skin into systemic circulation. Pure naphthalene is readily absorbed through the skin of rats: 48 h after dermal application of naphthalene approximately 80% of the applied dose was excreted via urine or exhaled air (Turkall et al., 1994). This means at least 80% of the dose was absorbed via the skin. As no mass balance is provided in this paper, a more exact value cannot be given. It should be noted the exposure was occluded, preventing evaporation of the naphthalene. When the dermal exposure site is not covered, dermal absorption would probably be much less in view of the volatile character of naphthalene. Absorption after oral intake is close to 100%. Since most likely dermal and oral exposure lead to comparable systemic effects (anaemia), and thus the internal, absorbed dose will determine toxicity, TNO proposes to use the oral MRLs of naphthalene of 0.6 mg/kg bw/day as dermal limit value, assuming dermal and oral to be equal. These are likely to be worst-case values as in reality dermal absorption is probably lower than oral absorption, meaning the real dermal limit values will be higher.

4. Exposure

Based on the assumption that the label weighs about 0.8 g, it will contain 2.4 µg of naphthalene. Pure naphthalene is very volatile and its evaporation rate to stationary ambient air is $1.7 \cdot 10^{-6}$ kg/m^2 s (equal to 0.17 µg/cm^2 s) (Tesconi et al., 1999). This means that 2.4 µg of pure naphthalene lodged on the label would disappear from it in matter of seconds. Since it was demonstrated to be present in the label, it must be tightly embedded in the material the label is made off. Exposure to naphthalene can occur only when it is either emitted to the air from the label or migrates to, e.g., the saliva of a baby licking the label or the moisture on the skin of baby in contact with the label. No data on emission rates or migration rates of naphthalene are available, but since it is likely to be tightly embedded in the label they will tend to be low. Furthermore, naphthalene is an apolar substance with a relatively high log K_{OW}, meaning it will not distribute easily into aqueous substances like saliva and skin moisture. Therefore, as a worst case estimate, it is assumed the emission rate will be 10% per day and that 10% of the

naphthalene in the label will migrate to saliva or skin moisture per day of contact. This means that ingestion of naphthalene will be at most 0.24 µg per day for a baby carried in a Pebble Pro, assuming all contaminated saliva will be ingested. This equals an oral exposure of 0.048 µg/kg bw/day for 5 kg baby. This is also the dermal exposure, assuming all naphthalene that has migrated to the skin moisture will be absorbed through the skin.
An emission rate of 10% naphthalene per day is equal to a rate of 0.01 µg/h. According to Hellweg et al. (2009), the indoor concentration of an emitted chemical can be calculated using the following formula:
$C_x = \frac{G_x}{V \times K_{ex}}$, in which:
C_x: concentration of substance x [µg/m^3]
G_x: emission rate of substance x [µg/h]
V: room volume [m^3]
k_{ex}: air exchange rate [h^{-1}]

In this case, the room volume is the volume of the car the baby is carried in. A small car has an interior volume of the passenger area of approx. 3 m^3 (according to a dealer website[1]). The air exchange rate of a stationary car without mechanic ventilation switched on and with windows closed is about 1 to 3 h^{-1} (Park et al., 1998). Taking the worst case air exchange rate of 1 h^{-1}, the concentration of naphthalene inside the car would be 0.0033 µg/m^3. This is a worst case estimate, since in a moving car, with the mechanical ventilation switched on, the air exchange rate would be much higher.
It should be noted that in these calculations the amount of naphthalene has been kept constant, which is a worst case approach, when on the other hand it is assumed naphthalene is emitted from or migrates from the label.

5. Risk assessment

In Table 1 the estimated exposure for the 3 routes is compared with their respective MRLs. The exposure values are divided by the MRL values to obtain the so-called Risk Index. When the risk index is greater than 1, adverse health effects as a result of exposure to naphthalene cannot be excluded. When the risk index is smaller than 1, no adverse health effects can be expected from the calculated exposure.

Table 1 Risk assessment of naphthalene exposure

Exposure route	Estimated exposure		MRL		Risk index
	Value	Unit	Type (unit)	Value	
Oral	0.048	µg/kg bw/day	Acute and intermediate (µg/kg bw/day)	600	0.00008
Dermal	0.048	µg/kg bw/day		600	0.00008
Respiratory	0.0033	µg/m^3	Chronic	3.7	0.0009

All risk indices are far below 1. Therefore, no adverse health effects are expected from exposure due to the presence of naphthalene in an amount of 3 mg/kg in an airbag warning label attached to the lining of a Pebble Pro baby seat.
Although no chronic MRL is available for the oral route of exposure, this is not a problem as the intermediate MRL covers exposures of up to 1 year and babies are not expected to be exposed much longer than one year, as they will outgrow their baby seat and also will not spend all their time lying in it. Furthermore, chronic health based limit values are usually at most only a factor 10 lower than intermediate (or subchronic) limit values, which in view of the low exposure will not lead to a Risk Index

[1] Differences Between Subcompact, Compact, Midsize, and Full-Size Cars - Buerkle Honda

higher than 1. Since intermediate and certainly acute limit values tend to be higher than chronic limit values, the chronic respiratory MRL also covers acute and intermediate exposures.
An uncertainty in this risk assessment is the possible carcinogenicity of naphthalene for humans. There are no adequate data to conclude whether or not it should be regarded as such. However naphthalene is not genotoxic, and will therefore have a safe threshold exposure. Furthermore, the estimated exposures are at such a low level, that only very portent genotoxic carcinogens would pose an unacceptable health risk. Therefore, based on all available evidence naphthalene is unlikely to constitute a carcinogenic risk in the present case.

6. Conclusion

No adverse health effects are expected from exposure due to the presence of naphthalene in an amount of 3 mg/kg in an airbag warning label attached to the lining of a Pebble Pro baby seat.

7. References

ATSDR, 2005. Toxicological profile for naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia, USA.

Dutch Health Council, 2012). Naphthalene. Evaluation of the carcinogenicity and genotoxicity. Health Council of the Netherlands, the Hague, the Netherlands. Publication no. 2012/30.
EU, 2003. European Union Risk Assessment Report NAPHTHALENE. CAS No: 91-20-3. EINECS No: 202-049-5. RISK ASSESSMENT. Office for Official Publications of the European Communities, Luxembourg, Luxembourg.

Hellweg et al., 2009. Integrating human indoor air pollutant exposure within life cycle impact assessment. Environ. Sci. Technol. 43, 1670–1679.

IARC, 2002. IARC monographs on the evaluation of carcinogenic risks to humans. Volume 82: Some traditional herbal medicines, some mycotoxins, naphthalene and styrene, page 367-436. International Agency for Research on Cancer, Geneva, Switzerland.

Park et al., 1998. Measurement of air exchange rate of stationary vehicles and estimation of in-vehicle exposure. Journal of Exposure Analysis and Environmental Epidemiology, 8 (1), pp. 65 – 78.
Tesconi et al., 1999. A practical method for the estimation of ambient vaporization rates of compounds. Chemosphere, Vol 38, No. 13, pp. 3193-3209.

Turkall et al., 1994. A Comparative Study of the Kinetics and Bioavailability of Pure and Soil-Adsorbed Naphthalene in Dermally Exposed Male Rats. Arch. Environ. Contam. Toxicol. 26, 504-509.
WHO, 2010. WHO Guidelines for Indoor Air Quality: Selected Pollutants. Chapter 4: Naphthalene. World Health Organization, Geneva, Switzerland.