National Institute for Public Health
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FRONT OFFICE FOOD AND PRODUCT SAFETY

Risk Assessment of asbestos in toy sand

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Nederlandstalige samenvatting: Risicobeoordeling van asbest in speelzand

Aanleiding vraagstelling
Op 4 februari publiceerde het AD een artikel over het voorkomen van asbest in speelzand. Naar aanleiding van berichten uit Australië over asbest in speelzand heeft het AD zelf onderzoek laten uitvoeren. In 6 van de 12 onderzochte monsters speelzand zijn losse vezels van grijze (tremoliet) asbest aangetroffen, in gehaltes tussen 0,1 en 5%.

De NVWA heeft besloten om zelf onderzoek uit te voeren naar asbest in speelzand op de Nederlandse markt. Deze monsters zijn onderzocht door een extern laboratorium. Ter referentie zijn ook andere soorten zand, zoals zandbakzand, meegenomen in het onderzoek. Asbest kan als vervuiling in zand aanwezig zijn. Het mag niet aanwezig zijn in speelzand boven de 0,1% of als de vervuiling leidt tot een gezondheidsrisico voor kinderen. De vraag is dus in hoeverre er sprake is van een gezondheidsrisico voor spelende kinderen. Deze vraag wil de NVWA graag beantwoord zien voor onderbouwing van een eventuele terugroepactie. Daarnaast wil de NVWA ook de consumenten graag voorlichten over de mogelijke gezondheidsrisico's.

Vragen van de NVWA die zijn beantwoord:
1. Wat zijn relevante blootstellingsroutes voor kinderen aan asbestvezels in speelzand?
2. Wat is de geschatte blootstelling aan asbestvezels voor kinderen wanneer zij spelen met speelzand?
    a. Is hierbij nog onderscheid te maken in leeftijdscategorieën?
    b. Is er onderscheid in de verschillende typen speelzand?
    c. Hoe verhoudt dit zich tot andere soorten zand, zoals zandbakzand?
3. Wat is het gezondheidsrisico voor kinderen wanneer zij spelen met speelzand?

Beantwoording van de vragen
Voor de risicoschatting is een vergelijking gemaakt tussen de blootstelling van kinderen aan asbestvezels uit speelzand met de gezondheidskundige grenswaarden die zijn afgeleid door de Gezondheidsraad. Dit zijn het Maximaal Toelaatbaar Risico (MTR) van 300 vezels/m^3 en het Verwaarloosbaar Risico (VR) van 3 vezels/m^3. Beide grenswaarden zijn afgeleid voor inademing van amfibole (naaldvormige) asbestvezels en gemiddeld over de hele levensduur. De MTR staat voor een risico van 1:10 000 op het krijgen van asbestkanker en wordt doorgaans gebruikt als de referentiewaarde om te bepalen of maatregelen om de blootstelling te verlagen noodzakelijk zijn. De huidige achtergrondconcentratie van asbest in de buitenlucht in Nederland ligt gemiddeld rond de 35 vezels/m^3 met een spreiding van <30–81 vezels/m^3 en is dus hoger dan het VR.

De blootstelling aan asbest bij het gebruik van de verschillende speelzandproducten is zo realistisch mogelijk *worst-case*[1] geschat. Hierbij is er onder andere vanuit gegaan dat kinderen gedurende 7 jaar (zandbakzand) of 13 jaar regelmatig aan besmette producten zijn blootgesteld, zowel op scholen en opvanglocaties als thuis. Deze blootstelling op alle blootstellingsmomenten is opgeteld en gemiddeld over een levensduur van 75 jaar, om te kunnen vergelijken met de referentiewaarden.

De producten zijn ingedeeld in vijf categorieën die verschillen in mate van kleverigheid en in de manier waarop ermee gespeeld wordt.

- Los decoratiezand. Dit is vaak gekleurd, los zand dat onder andere wordt gebruikt om op kleurplaten te plakken of flesjes mee te vullen. In 26 van deze producten zijn asbestvezels gevonden. Doordat dit zand droog is, zal relatief veel van dit asbest vrijkomen. Dit leidt bij frequent spelen gedurende 13 jaar met deze producten tot een geschatte levensgemiddelde blootstelling van 3,4 vezels/m^3. Deze waarde ligt ruim onder de MTR wat aangeeft dat het risico acceptabel is. Er zijn vier producten in deze categorie waarbij de geschatte blootstelling boven de MTR zou komen, als een kind gedurende 13 jaar regelmatig alleen met deze producten speelt. Dit zijn de producten waarbij de asbestconcentratie boven de 0,1% ligt. Voor deze producten is in deze hypothetische worst-case scenario's het risico onacceptabel.
- Half-klevend kinetisch zand. Aan dit zand zijn andere stoffen toegevoegd om het steviger te maken en te zorgen dat het niet uitdroogt, maar het valt nog wel uit elkaar als je het oppakt. In twee van deze producten is asbest aangetroffen. Als een kind vaak speelt met deze producten, komt de levensgemiddelde blootstelling rond de 2,9 vezels/m^3. Dit betekent dat het risico verwaarloosbaar is.
- Sterk klevend kinetisch zand. Dit is erg stug en plakkerig kinetisch zand dat bedoeld is om te kneden en sculpturen te maken. Ook aan dit zand zijn stoffen toegevoegd. In geen van de producten in deze groep is asbest aangetroffen. Voor deze productgroep wordt geen risico verwacht.
- Speeltjes gevuld met zand. Dit zijn zakjes, fidget-toys of blokken met zand erin. In 7 van deze producten is asbest aangetroffen. In principe is niet de bedoeling dat dit zand vrijkomt, waardoor ook de blootstelling aan asbest laag is. Er is vanuit gegaan dat een kind gedurende 13 jaar elk jaar een keer wordt blootgesteld door een speeltje dat kapot gaat. Dit leidt tot een levensgemiddelde blootstelling van 0,012 vezels/m^3, wat ruim onder het verwaarloosbaar risico ligt.
- Zandbakzand. Er is rekening mee gehouden dat zandbakzand zowel binnen als buiten gebruikt kan worden in de zandbak en/of op speeltafels. Er is asbest

[1] Een worst-case scenario is een veronderstelling waarbij je uitgaat van het slechtst mogelijke scenario. Je kiest dan voor de hoogste of meest risicovolle waarde die in de praktijk kan voorkomen. Dit doe je om er zeker van te zijn dat je niemand onderschat of onbeschermd laat bij het beoordelen van risico's.

aangetroffen in 5 voorverpakte zakken zandbakzand. Als een kind vaak speelt met zandbakzand, komt de levensgemiddelde blootstelling rond de 0,54 vezels/m^3. Dit ligt onder het verwaarloosbaar risico.

De onzekerheid in de blootstellingschatting is erg groot. Dit komt doordat er geen gemeten waarden zijn voor de hoeveelheid asbest die werkelijk vrij komt, hoe dit zich precies gedraagt in de ruimte, hoe vaak kinderen spelen met deze producten en hoeveel jaar ze ermee spelen. Daarnaast kunnen we alleen iets zeggen over de producten die bemonsterd zijn, wat een steekproef is van alle producten die op de markt zijn. Vanwege de grote onzekerheid is bij het berekenen van de blootstelling gekozen voor een worst-case scenario waarvan aangenomen wordt dat het kan voorkomen (‘realistisch worst-case’).

De blootstelling van kinderen die spelen met de verschillende soorten speelzand valt ruim onder de grenswaarde voor een toelaatbaar risico en ligt op of onder de waarde die hoort bij een verwaarloosbaar risico. Dit komt doordat in de meeste producten het asbestgehalte erg laag is en er dus in het algemeen geen reden tot zorg is.

Er zijn vier producten met los decoratief zand met een duidelijk hoger asbestgehalte dan de andere producten. In een worst-case scenario waarbij kinderen jaren achtereen alleen met deze producten zouden spelen, kunnen deze vier producten tot een onacceptabel risico leiden. In de praktijk zal dit vrijwel zeker niet voorkomen. Er wordt aanbevolen aan fabrikanten, importeurs, inspectie en overheid om maatregelen te treffen om asbestvervuiling van speelzand in de toekomst zoveel mogelijk te voorkomen.

Background to request
On 4 February the AD newspaper published an article on the presence of asbestos in toy sand. Following reports from Australia about asbestos in toy sand, AD commissioned its own measurements. They found tremolite asbestos fibres in 6 out of 12 samples, in concentrations of 0.1–5 w/w%.

NVWA has decided to conduct its own investigation to asbestos in toy sand on the Dutch market. These samples have been analysed by an external laboratory (SGS Search). Other types of sand, such as sandbox sand, have also been included in the investigation for reference purposes. It is prohibited to have asbestos in toy sand at levels either above 0.1% or at a level that leads to a health risk of children. The question is whether there is a health concern for children that have played with contaminated sand. NVWA would like to see this question answered to substantiate a potential recall. Next to that, NVWA also wants to use the answer to inform consumers about possible health risks.

The external laboratory has been asked to conduct the following analysis:
- Amount of asbestos in the sand
- Identification of the asbestos fibres
- Number of respirable fibres per kg product

Questions by the NVWA
1. What are the relevant routes of exposure for children exposed to asbestos fibres in toy sand?
2. What is the estimated exposure to asbestos fibres of children playing with toy sand?
    a. Is it possible to make a difference in age groups?
    b. Is there a difference between types of toy sand?
    c. How does this compare to other types of sand, such as sandbox sand?
3. What is the health risk for children when they play with toy sand?

Elements that should be taken into account in the risk assessment are exposure routes, exposure to asbestos fibres, age, and health risk.

Conclusion

It should be noted that there is no safe exposure to asbestos. The risk to develop an asbestos-related health effect depends on the level of exposure. For this reason, contamination of toy sand with asbestos fibres is undesirable and should be prevented as much as possible.

We conclude that the risk of asbestos-related diseases from playing with toy sands lies at or below the negligible risk level. The asbestos exposure from most products is very low and does not pose a concern. However, there are four loose decorative sand products with notably higher levels of contamination compared to the other products. It is important to prevent further exposure to these products as in a hypothetical worst-case scenario where a child is always playing with one of these products they may lead to an unacceptably high risk.

1) *What are the relevant routes of exposure for children exposed to asbestos fibres in toy sand?*

The most relevant route of asbestos exposure is inhalation of airborne fibres. No notable increase in risk is expected from oral intake of contaminated sand.

2) *What is the estimated exposure to asbestos fibres of children playing with toy sand?*

The exposure is calculated for four types of toy sand products: loose decorative sand, semi-cohesive (kinetic) sand, toys filled with sand, and sandbox sand. No asbestos was found in the fifth type of toy sand, cohesive kinetic sand products. The outcome of the exposure assessment using the geometric mean concentration of each product group is given in Table 5 and summarised in the Table below (in fibres/m^3):

	Loose decorative sand	Semi-cohesive sand	Sand-filled toys	Sandbox sand	MTR	VR
Lifetime exposure	3.4	2.9	0.012	0.54	300	3

A second, hypothetical worst case exposure assessment using the maximum concentration of each product group revealed a lifetime exposure above the MTR for loose decorative sand. We have subsequently calculated the asbestos exposures for each individual product in this group that tested positive on asbestos. These lifetime exposures range from 0.075 to 840 fibres/m^3. Four out of 26 asbestos-containing loose decorative sand products lead to a calculated exposure above the MTR.

a. *Is it possible to make a difference in age groups?*

There is no known difference between age groups in sensitivity for health effects due to asbestos. It is expected that the exposure will differ between age groups due to differences in play behaviour, duration, and frequency. However, specific information on these aspects is very limited. Moreover, the most important factor for the risk is the lifetime exposure.

b. *Is there a difference between types of toy sand?*

There are clear differences between types of toy sand and the level of contamination, release of fibres and behavioural parameters. The highest exposure is expected from loose decorative sand, as this group includes the products with the highest level of both asbestos contamination and release. Exposure from other product groups was considerably lower. The concentrations found cover a very wide range with a 80 000 fold difference between the lowest and the highest concentration.

c. *How does this compare to other types of sand, such as sandbox sand?*

The asbestos concentrations in sandbox sand were generally lower than in other products. It is expected children play in sandboxes with larger amounts of sand and this activity is limited to a younger age (0-7 years).

3) *What is the health risk for children when they play with toy sand?*

The risk from asbestos in semi-cohesive sand and toys filled with sand can be considered negligible. An important factor that reduces the risk of these products is that the release of fibres is limited by the physical properties of the products. Sandbox sand has a higher release of fibres, but this sand contained lower concentrations of fibres. As a result, also the risk from playing with sandbox sand is negligible as well.

The exposure to fibres from loose decorative sand is estimated to be the highest of all product groups as this group included the products with the highest level of both asbestos contamination and release of fibres. During frequent play with various products from this group the lifetime exposure still lies below the limit value for an acceptable risk.

There are four loose decorative sand products with notably higher levels of asbestos contamination. For these products the lifetime-averaged exposure lies above the MTR if a child would play with only these products for 13 years, 92 times a year. It is highly unlikely that this will happen in reality. As in this worst-case scenario the use of these four products can lead to lifetime exposure exceeding the MTR, further exposure to these products should be prevented as they may result in an unacceptable risk.

It should be noted that there is a large degree of uncertainty in this assessment. At the moment there are no measurements of the actual release of asbestos fibres, their movement through the air, and the frequency of play with these products. Furthermore, this assessment only applies to the products that have been sampled. Because of the high uncertainty, realistic worst-case estimates were made based on the limited information available. In reality, it is likely that the exposure time of a child to these products is much shorter.

It is advised that producers/importers, market authorities and regulators take action to prevent contamination of toy sands with asbestos in the future.

Introduction

Asbestos has been found in sand products that are marketed as children's toys. The question is whether these fibres pose a health risk when children play with these products. To answer this question, a risk assessment is performed for children playing with toy sand products.

The products were categorised in five groups with different exposure scenarios:

- Loose sand for decorative play – sand that flows freely and is not sticky. Used to make sand paintings, fill bottles, patterns on light tables e.g.
- Semi-cohesive kinetic sand – sand with additives to make it stick together, but still falls apart.
- Cohesive kinetic sand – sand with additives to the extent that it has become clay-like and does not fall apart.
- Sandbox sand – sand meant to be used in sandboxes.
- Sand in small bags, fidget toys – sand contained in a textile bag or plastic figure, not meant to come free.

The risk assessment is performed for all product groups selected by the NVWA that tested positive for asbestos by the external laboratory (consolidated data received 11 March 2026, updated 18 March 2026). We first describe the results of the laboratory analyses, then the health based reference values for asbestos fibres, the exposure scenarios, followed by the risk assessment. Finally, the variability and uncertainties in the risk assessment, and recommendations are discussed.

In this risk assessment the approach of the earlier performed risk assessment for asbestos containing make-up products for children is used as starting point (RIVM, 2018a and b), because it is anticipated that the current risk assessment has many similarities regarding the exposure profile, the extrapolation to lifelong exposure and subsequent risk characterisation.

Laboratory analyses

The NVWA selected a wide range of products for analysis of which 106 products were analysed at the time of writing. The number of samples that tested positive for asbestos was 26/45 (58%) for loose sand, 2/15 (13%) for semi-cohesive sand, 0/20 (0%) for cohesive sand, 5/16 (31%) for sandbox sand, and 7/10 (70%) for sand in small toys.

The product characteristics and outcome of the analysis of the products that tested positive for asbestos are presented in Table 1.

At first, a qualitative/semi-quantitative assessment of asbestos in the products was performed with Scanning Electron Microscopy (SEM)/EDX conform NEN5896 (2003). These results are displayed in the row 'Asbestos (w/w% product)'. This method gives a rough estimation of the amount of asbestos in bulk materials, based on an estimated comparison with a reference material, but does not include a precise fibre count. As a consequence, these values are much higher than the actual concentrations and should not be used to determine the asbestos content of the sand. The outcome of this method was used to select products for further analysis.

Secondly, positive samples were also used in a quantitative determination of asbestos fibres, which has been performed with SEM conform VDI3866 Blatt 5 – Appendix B. Based on the SEM analyses it is possible to determine the asbestos content, by making an estimation of the mass of the fibres based on their number and dimensions. These values are used in the risk assessment (column 'Asbestos estimated (est.) mass fraction (w/w%)').

In this risk assessment, we assume that the sampled batches are representative of all batches of the product. This means that we assume that products bought in the past contain the same concentrations and that children may have been exposed to products with these concentrations for many years.

Table 1. Overview of products with a positive test on the presences of asbestos using SEM/EDX. Data as received from NVWA, last updated 18 March 2026. Asbestos (w/w% of product) is estimated according to NEN 5896, information on type of fibre is added. Asbestos estimated (est.) mass fraction (w/w%) is determined according to VDI 3866 Blatt 5 Appendix B

Product nr	**Type**	**Weight (g)**	**Asbestos (estimate w/w% of product) - NEN 5896**	**Asbestos est. mass fraction (w/w%) - VDI 3866 Blatt 5**
2	Sand in small bag, fidget toy	200*	0.1–2 Tre	8.624×10^{-5}
6	Loose sand for decorative play	200*	0.1–2 Chr, 0.1–2 Ant, 0.1–2 Tre	1.392×10^{-3}
8	Loose sand for decorative play	500*	0.1–2 Chr, 2–5 Tre	2.402×10^{-1}
13	Loose sand for decorative play	400*	0.1–2 Tre	2.020×10^{-3}
16	Loose sand for decorative play	200*	0.1–2 Tre	3.518×10^{-3}
18	Loose sand for decorative play	750	0.1–2 Chr, 2–5 Tre	4.199×10^{-1}
19	Loose sand for decorative play	400*	0.1–2 Tre	4.104×10^{-4}
20	Loose sand for decorative play	500	0.1–2 Tre	3.917×10^{-4}
21	Loose sand for decorative play	200*	0.1–2 Tre	6.957×10^{-5}
23	Sand in small bag, fidget toy	200*	0.1–2 Tre	1.374×10^{-3}
25	Loose sand for decorative play	200*	0.1–2 Chr, 0.1–2 Tre	2.927×10^{-3}
29	Loose sand for decorative play	400*	0.1–2 Chr, 0.1–2 Tre	2.204×10^{-3}
32	Loose sand for decorative play	750	0.1–2 Chr, 0.1–2 Tre	3.653×10^{-3}
33	Loose sand for decorative play	750	0.1–2 Chr, 0.1–2 Tre	1.394×10^{-4}
34	Loose sand for decorative play	600	0.1–2 Tre	1.709×10^{-3}
37	Loose sand for decorative play	360	0.1–2 Chr, 0.1–2 Ant	5.518×10^{-3}
38	Loose sand for decorative play	500*	0.1–2 Chr, 0.1–2 Tre	2.962×10^{-4}
52	Sandbox sand	25 000	0.1–2 Act	1.338×10^{-5}
56	Sandbox sand	15 000	0.1–2 Tre	1.066×10^{-5}
57	Loose sand for decorative play	1 000*	0.1–2 Chr, 0.1–2 Tre	4.865×10^{-3}
58	Loose sand for light table	5 000	0.1–2 Tre	4.507×10^{-5}
61	Sandbox sand	25 000	0.1–2 Act	8.607×10^{-6}
67	Loose sand for decorative play	400*	0.1–2 Chr, 0.1–2 Tre	4.848×10^{-4}

69	Loose sand for decorative play	700	0.1–2 Chr, 0.1–2 Tre	1.056×10^{-4}
81	Loose sand for decorative play	630	0.1–2 Tre	1.136×10^{-4}
88	Loose sand for decorative play	630	0.1–2 Tre	1.729×10^{-3}
89	Loose sand for decorative play	700*	0.1–2 Chr, 2–5 Tre	3.324×10^{-1}
91	Loose sand for decorative play	750	0.1–2 Tre	3.813×10^{-4}
95	Loose sand for decorative play	40	0.1–2 Tre	3.780×10^{-5}
96	Loose sand for decorative play	400*	0.1–2 Chr, 0.1–2 Tre	4.277×10^{-3}
99	Sand in small bag, fidget toy	250	0.1–2 Tre	5.017×10^{-6}
100	Sandbox sand, same as nr 52	25 000	0.1–2 Act, 0.1–2 Ant, 0.1–2 Tre	1.154×10^{-3}
137	Semi-cohesive kinetic sand	200*	0.1–2 Tre	4.529×10^{-4}
140	Semi-cohesive kinetic sand	1 000*	0.1–2 Chr, 0.1–2 Ant, 2–5 Tre	1.119×10^{-2}
151	Sandbox sand	25 000*	0.1–2 Act, 0.1–2 Ant	1.057×10^{-5}
165	Loose sand for decorative play	250*	0.1–2 Chr, 2–5 Tre	2.297×10^{-1}
171	Sand in small bag, fidget toy	320	0.1–2 Tre	1.459×10^{-4}
172	Sand in small bag, fidget toy	250*	2–5 Tre	3.067×10^{-1}
174	Sand in small bag, fidget toy	250*	0.1–2 Tre	2.420×10^{-3}
175	Sand in small bag, fidget toy	250*	0.1–2 Chr, 2–5 Tre	1.505×10^{-1}

* Weight of product has been estimated.

Chr = chrysotile, Act = actinolite, Ant = anthophyllite, Tre = tremolite.

Toxicology

Asbestos can cause various types of cancer including mesothelioma (cancer of the thin layer covering the lungs and other organs), lung cancer, and cancer in the larynx and ovaries. In addition, a positive association has been observed with cancer in the throat, stomach, and colon. The International Agency for Research on Cancer (IARC) further states that all forms of asbestos are proven human carcinogens (Group 1) (IARC, 2012).

The hazardous properties of asbestos are caused by asbestos fibres being small enough to penetrate deep into the lungs. Because asbestos fibres are very inert, the fibres remain intact and accumulate in the tissue. This can lead to prolonged inflammatory response, fibrosis and eventually tumour formation. There is usually a delay of several decades between the initial exposure to asbestos and the occurrence of cancer. (Gezondheidsraad, 2010).

A distinction is made between two types of asbestos: spiral-shaped serpentines (chrysotile: white asbestos) and needle-shaped amphiboles (including crocidolite (blue asbestos), amosite (brown asbestos), tremolite, actinolite and anthophyllite). The fibres of these two types of asbestos differ in size and flexibility. For lung cancer, chrysotile and amphiboles have the same carcinogenic potential. For mesothelioma, the carcinogenic potential of amphiboles is 50 times higher than that of chrysotile (Gezondheidsraad, 2010).

The assessment of the health risks for users of the products only includes the exposure by inhalation. The extent of the risk is mainly determined by the type of asbestos, the presence of respirable asbestos fibres in a product, the concentration of asbestos fibres in the air and the duration of exposure. The estimate of the concentration of respirable asbestos fibres in the air is a crucial part of the assessment of health risks.

In the Netherlands, two limit values are available for this risk assessment: the MTR (maximum allowable risk) and the VR (negligible risk). At the level of the MTR value, the additional cancer risk is 1 case per 10 000 life-time exposed individuals. The VR is not officially used as limit value in policy making, as this level is too low to be practically usable. The VR was defined as MTR/100 (thus 1 case per 1 000 000 life-time exposed individuals). MTR and VR are policy-level risk levels for exposure of the general population. In 2010, the Health Council of the Netherlands made recommendations for an update of the MTR and VR values of asbestos (see Table 2, Gezondheidsraad, 2010). The MTR and VR values for asbestos are applicable to lifetime exposure (75 years) of the general population, and are expressed in fibres per m^3 measured by TEM (Transmission Electron Microscopy). The values are based on the endpoints of mesothelioma and lung cancer together (Gezondheidsraad, 2010). SEM (the method used by SGS) is generally considered equal to TEM in reliability and precision, so no conversion has to be used to correct for a difference in method.

Table 2. MTR- and VR-values derived by the Health Council of the Netherlands for asbestos (Gezondheidsraad, 2010)

	Proposed MTR and VR values		
	Chrysotile (fibres/m^3)	Mixed exposure to chrysotile and up to 20% amphibole (fibres/m^3)	100% amphibole (fibres/m^3)
MTR	2 800	1 300	300
VR	28	13	3

These values were also used in the risk assessment for asbestos in children's make-up in 2018. In the meantime, the Health Council of the Netherlands released a statement that a revision of the values with new information would not lead to a meaningfully different outcome and that the values are still applicable (Gezondheidsraad, 2019).

Both chrysotile and amphibole fibres were found in toy sands. It is not known what the exact distributions is of both fibre types. As amphibole types of asbestos (tremolite, actinolite and anthophyllite), were found frequently and this is the most harmful type of asbestos, the MTR and VR for 100% amphibole fibres are used in the risk assessment (300 fibres/m^3 (MTR), 3 fibres/m^3 (VR)).

Exposure

Exposure scenarios
Exposure of children to asbestos-contaminated toy sand will primarily take place at childcare centers (including daycare and out-of-school care), in primary school, at home, and in outdoor sandboxes. The inhalation exposure depends on the concentration of fibres in the product, the release rate during play, the distribution of the fibres in the air,

and the time children are in the vicinity of the product during and after its use. As these parameters differ between the product groups and locations, the exposure is calculated separately for each combination of product group and location that we expect under realistic worst-case use. To assess the total risk from each product group, we will also calculate the sum of exposures to one product group from all locations. None of the products in the group cohesive kinetic sand tested positive for asbestos, thus these products are excluded from further consideration.

Not every product group is expected to be used at every location. Inside homes, we expect the use of loose decorative sand, semi-cohesive kinetic sand, and sand-filled toys, but no use of sandboxes. In schools and childcare centres, sandbox sand may be used indoors, for example in indoor sandboxes or on a sand table. Loose decorative sand and semi-cohesive kinetic sand are also expected to be offered to children at schools and childcare centres, whereas sand-filled toys are not typically available (expert judgement). Outside, only sandboxes are expected to be a relevant exposure scenario. Though products intended for indoor use may also be used outside, we conservatively assume their use is exclusively indoors as this would lead to higher exposure. For an overview of the product–location combinations included in this assessment, refer to the exposure parameters in Table 4 below; combinations not considered here are marked as not applicable (N/A).

For the exposure modelling, we make a distinction between release events and exposure events. Release events are the events when the sand releases asbestos fibres into the air. For most products, this happens every time when children play with them. The sand-filled toys, however, are not expected to release fibres during normal play, but only when they break. Exposure occurs during the release event, but exposure may be prolonged or can also occur later. If release happens indoors, part of the fibres can remain in the air after the release event has finished. Exposure will then continue, and may occur repeatedly if the same room is visited again, for as long as some asbestos is still in the air. For outdoor release, a locally increased concentration of asbestos is to be expected, but the fibres are expected to dissipate quickly after playing has ended. Repeated exposure from a play event in the past is therefore not expected to occur outside.

During an indoor release event, the asbestos fibres are released into the air locally, but will spread to other parts of the room. The exposure of the child playing with the sand and the exposure of others in the room during the release event depends on how fast the fibres spread. A slower spread means that the near-field concentration around the playing children will be higher than the far-field concentration experienced by others in the room, whereas a faster spread will lead to more equal air concentrations.

Cherrie (1999) has studied the distribution of respirable dust emitted in rooms with various sizes and ventilation rates. For the room volumes used in this risk assessment (see Table 4) and for air change rates typical of homes and schools (up to 1 air change per hour), he found nearly equal concentrations through the entire room, regardless of the distance to the source. The exposure of children to asbestos is therefore mainly determined by the air concentrations in rooms where contaminated toy sand is used and by how much time they spend in these rooms, rather than solely by the time each child themself plays with toy sand. We therefore do not separately model near-field and far-field exposure, and choose our exposure parameters to represent playing activities per location instead of per child.

Based on the above considerations, we constructed and parametrised exposure models for the different products and locations. First, we describe the model conceptually using equations. This is followed by the derivation of parameter values.

Exposure model
In the context of cancer risk assessment, the Health Council of the Netherlands defines lifelong exposure of the general population as exposure that lasts 24 hours per day, 7 days per week, and 52 weeks per year, for a lifetime of 75 years. These parameters defining 'lifelong exposure' are presented in Table 3.

Table 3. Parameters defining 'lifelong exposure' for the general population.

Parameter	**Value**	**Reference**
Hours of exposure per day $f_{\mathrm{h/d}}$	24	Health Council of the Netherlands (2012)
Days of exposure per year $f_{\mathrm{d/yr}}$	364	52 weeks per year × 7 days per week (Health Council of the Netherlands, 2012)
Lifetime t_{life} (years)	75	Health Council of the Netherlands (2012)

To be able to compare exposure with the lifetime guidance values MTR and VR, we built an exposure model to estimate the exposure to airborne asbestos fibres from all release events during childhood, which is subsequently averaged over a lifetime.

The exposure is calculated in three steps that are briefly introduced in the bullets and will be further explained in the text below:

- First, the concentration of asbestos fibres in the air during the release event is calculated.
- Then, the exposure event concentration is calculated by taking into account the decrease of the air concentration over time combined with the exposed time. In the equations below this concentration is c_{event}.
- All exposure events that follow one release event are combined to derive the lifetime-averaged exposure from one release event. This is L_{event}. We average over the entire lifetime, not just over the childhood, because the MTR and VR are defined as lifelong average concentrations.
- Finally, the expected number of release events during childhood is taken into account to arrive at the exposure from all release events during childhood averaged over a lifetime. This is L_{all}.

<u>Exposure equations</u>
The number of released fibres is related to the mass fraction of fibres in the sand f_{fibre} (as measured according to VDI3866 Blatt 5) and the amount of sand used M_{sand}. The release of fibres from agitated sand is expressed here as 'release coefficient' C_{release} in number of fibres in air per mg fibres in sand. For indoor exposure, we model the asbestos concentration during the release event c_{event} (concentration in the room during or right after playing with toy sand) by distributing the released number of fibres over the entire room with volume V_{room}, which results in the equation

$$c_{\mathrm{event}} = \frac{f_{\mathrm{fibre}} \times C_{\mathrm{release}} \times M_{\mathrm{sand}}}{V_{\mathrm{room}}} \quad \text{(indoors)}$$

After the playing activity has stopped, the concentration in the room air slowly diminishes through a combination of ventilation of airborne fibres and cleaning of settled fibres. We describe the decrease in air concentration using an exponential removal rate Q, that can be thought of as an effective 'ventilation' rate measured in air changes per time. This is set at 560 air changes per year, which corresponds to a removal of 99% of the asbestos fibres from the air in 72 hours. See the section on exposure parameters for further explanation and derivation of the parameter.

The contribution of a single release event to the lifetime-averaged room concentration is then calculated by averaging the diminishing event concentration $c_{\mathrm{event}} \times \exp(-Q \times t)$ over the lifetime t_{life}. Additionally, we must take into account that a child spends only a fraction of their time f_{room} in the room where the asbestos-contaminated play sand has been used. Assuming that the time interval between release and re-entry into the room is

effectively randomised when considering all the release and exposure events in childhood, the fraction of exposure is the same as the fraction of time spent in the room.

We note that the decrease of the concentration over time is taken into account by the removal rate Q. The peak in concentrations in the first days after release is averaged out over a lifetime. The fraction of time in the room f_{room} must therefore be understood as a yearly-average time spent in a room where the sand has been used, not exclusively as the fraction of time spent during the first 72 hours after release.

The contribution of a single release event to the lifetime-averaged asbestos exposure, including a factor $1/f_{\mathrm{h/d}}$ to account for the units, is then

$$L_{\mathrm{event}} = \frac{f_{\mathrm{room}}}{f_{\mathrm{h/d}}} \times \frac{c_{\mathrm{event}}}{t_{\mathrm{life}}} \int_0^{t_{\mathrm{life}}} \exp(-Q \times t)\,\mathrm{d}t \approx \frac{f_{\mathrm{room}}}{f_{\mathrm{h/d}}} \times \frac{c_{\mathrm{event}}}{t_{\mathrm{life}}} \int_0^{\infty} \exp(-Q \times t)\,\mathrm{d}t = \frac{f_{\mathrm{room}} \times c_{\mathrm{event}}}{f_{\mathrm{h/d}} \times Q \times t_{\mathrm{life}}} \quad \text{(indoors)}$$

The lifetime-averaged exposure from all events L_{all} is then determined by multiplying the contribution of a single event with the number of release events during childhood. The number of events is determined by the release frequency F_{release} and the number of years in childhood during which exposure occurs, t_{exp}. This results in

$$L_{\mathrm{all}} = L_{\mathrm{event}} \times F_{\mathrm{release}} \times t_{\mathrm{exp}} \quad \text{(indoors)}$$

For the outdoor scenarios, the calculations are similar, but slightly different. Instead of the air volume in a room, we use the volume of the near field V_{NF}:

$$c_{\mathrm{event}} = \frac{f_{\mathrm{fibre}} \times C_{\mathrm{release}} \times M_{\mathrm{sand}}}{V_{\mathrm{NF}}} \quad \text{(outdoors)}$$

Furthermore, we assume that after play has ended the asbestos will be quickly dissipated in the outdoor air. Therefore, the contribution to the lifetime-averaged air concentration from one release event is calculated by scaling with the time spent playing t_{play} relative to the lifetime, including the relevant conversion factors for the units:

$$L_{\mathrm{event}} = \frac{c_{\mathrm{event}} \times t_{\mathrm{play}}}{f_{\mathrm{h/d}} \times f_{\mathrm{d/yr}} \times t_{\mathrm{life}}} \quad \text{(outdoors)}$$

With the frequency of release F_{release} and the number of years during which the child plays with the sand t_{exp}, the lifetime-averaged cumulate exposure is then

$$L_{\mathrm{all}} = L_{\mathrm{event}} \times F_{\mathrm{release}} \times t_{\mathrm{exp}} \quad \text{(outdoors)}$$

The values of the parameters introduced above can differ between types of toy sand and between locations. Below we describe how we derived these parameter values. An overview of the parameters and their values is given in Table 4.

Table 4. Product- and location-dependent exposure parameters.

Parameter	Product group	Home	School and childcare	Outside	Reference
Fibre mass fraction in sand f_{fibre} (mg fibres/kg sand)	Loose decorative sand	Geometric mean: 17.05 Maximum: 4 199			See Table 1
	Semi-cohesive sand	Geometric mean: 22.51 Maximum: 111.9			
	Sand-filled toys	Geometric mean: 13.83 Maximum: 1 505			
	Sandbox	Geometric mean: 0.272 3 Maximum: 11.54			
Release coefficient C_{release} (fibres in air/mg fibres in sand)	Loose decorative sand	1 290			See text below, based on Tromp et al. (2002)
	Semi-cohesive sand	129			
	Sand-filled toys	1 290			
	Sandbox	1 290			
Amount of sand M_{sand} (kg)	Loose decorative sand	0.5	3	N/A	Expert judgment (see text below)
	Semi-cohesive sand	1	1	N/A	
	Sand-filled toys	0.25	N/A	N/A	
	Sandbox	N/A	10	10	
Room volume V_{room} / near-field volume V_{NF} (m^3)		58	100	100	te Biesebeek et al. (2014), expert judgment based on Arbeidscatalogus -VO and Cherrie (1999) (see text below)
Removal rate Q (air changes per year)		560	560	N/A	Expert judgment (see text below)
Fraction of time in the room f_{room} (h per day yearly average)		12	5.5	N/A	Expert judgment (see text below)
Time in the outdoor sandbox t_{play} (h)		N/A	N/A	2	OECD (2025)
Frequency of release F_{release} (per year)	Loose decorative sand	52	40	N/A	Expert judgment (see text below)
	Semi-cohesive sand	104	1 000	N/A	
	Sand-filled toys	1	N/A	N/A	
	Sandbox	N/A	200	365	

Exposure duration t_{exp} (years)	Loose decorative sand	13	13	N/A	Expert judgment (see text below)
	Semi-cohesive sand	13	13	N/A	
	Sand-filled toys	13	N/A	N/A	
	Sandbox	N/A	7	7	

N/A: not applicable.

Exposure parameters

Asbestos fibre concentrations

Of the two measurement methods, only VDI3866 Blatt 5 provides a precise and quantitative determination of respirable asbestos fibre concentrations. We therefore use only these measurements in the exposure model. We convert these concentrations from w/w% to mg fibres/kg sand to match the units of the other parameters.

For each product group, we calculate the exposure with two different asbestos fibre concentrations: the geometric mean[2] of the measured concentrations in the group, and the maximum of the measured concentrations in the group. The geometric mean concentration represents a typical concentration of a product within a group, and is expected to be the most representative value as lifetime exposure will be to different products. The maximum concentration is used to screen for individual products that can lead to exposure above the MTR, in a hypothetical scenario where a child is always playing with this same product. If we find that the maximum concentration of a product group leads to exposure above the MTR, we additionally calculate exposures for every product in that group, to be able to identify all products that can lead to exposure above the MTR.

We note that none of the products in the group cohesive kinetic sand tested positive for asbestos, thus no exposure is calculated for these products.

The choice of using the maximum concentration for the entire exposure calculation represents a very conservative scenario where the same highly contaminated product is used for the entire childhood, or that the product is replaced by an equally contaminated one. Such a scenario also implies the assumption that the repeated release of fibres does not lead to a significant decrease in the concentration of fibres in the sand. This is a reasonable assumption for most exposure scenarios considered here. Based on the fibre counts and fibre weights in the raw data from SGS Search, and the release coefficients adopted below, over 10 000 release events are required to deplete the sand of asbestos fibres.

The geometric mean concentrations represent a more realistic exposure level. If products are replaced during childhood, it is unlikely that every purchased toy sand product contains the highest concentration of asbestos. On the other hand, replacement of products ensures that the fibre concentration of the products will not significantly decrease even in the most intensive release scenarios.

Amount of sand, frequency of release, and duration of exposure

The amount of sand used during play was derived by expert judgment based on a reasonably worst-case estimation of the amount of product that might be agitated during play in one room. It was taken into account that a group of children may be playing with

[2] The geometric mean is determined by multiplying all values and taking the *n*th root of the outcome (in which *n* is the number of values). For example, the geometric mean of 2, 8, and 32 is $(2 \times 8 \times 32)^{(1/3)} = 8$.

the product at the same time, both at home and in schools and childcare centres. This was the reason to choose relatively large amounts.

Out of the 26 products of loose sand that tested positive, 25 are loose sand for decorative play and one is specifically marketed for use with a light table. We use the same exposure scenario for both, as we think the use amounts and frequencies are similar between the two activities. Furthermore, the same kind of sand is used for both types of loose sand products, therefore any of these products can be used for either activity, regardless of the use for which the product was marketed.

Based on a worst-case estimate of 100 g loose decorative sand per child, we estimate up to 500 g of loose decorative sand being used at home, and 3 kg of loose decorative sand for an entire group of children at school or in a childcare centre. Loose decorative sand, once mixed with several colours or glued to a sand painting, cannot be reused. We therefore estimate that the frequency of play and therefore of release events is less frequent than for the other products, and set it to once a week at home and also once a week at school or in childcare centres. For exposure at schools and in childcare centres, we assume 40 weeks of exposure per year instead of 52. Some children may be exposed more weeks per year as they attend childcare centres during the school holidays. However, the assumption that exposure happens every school week is likely an overestimation for most children, therefore we judge 40 weeks per year to be sufficiently conservative. We assume 13 years of exposure to this product group, considering that exposure may start at very young age even though the product is intended for older children, and that exposure events occur until the end of primary school.

For semi-cohesive sand, we judged that this product group is more likely to be used by smaller groups of children at a time, but with multiple groups sequentially during the day, similar to clay and toy slime. Based on the product weights in Table 1, we consider 1 kg to be a conservative amount. Use frequency data are available for Korean children playing with children's clay and with toy slime from the Children risk and exposure assessment methodology (CREAM) study, made available through the OECD Database on Children's Exposure Factors (OECD, 2025). Though the Korean database mentions different frequencies for different age groups and sexes, we consider that the differences in toy material and between countries is too large to warrant the same level of precision in our assessment. For use at home, we therefore take for the release frequency the highest reported 75th percentile[3] of the use frequencies, which is twice per week, or 104 times per year. During the early years of school and childcare, we conservatively assume up to 10 uses per weekday, or 2 000 uses per year assuming 40 weeks of school and childcare per year, as this would allow all children to play each day with the sand in small groups. However, we expect the frequency of playing events at schools and childcare centres to decrease significantly for children in the older age groups. We therefore assume an average of 1 000 uses per year when averaged out over 13 years of exposure. This exposure period is based on the same reasoning as for loose decorative sand.

For sand-filled toys, we consider that several toys per child may break during their childhood. Considering a household with several children and 13 years of exposure, we therefore conservatively assume one toy a year will break. Based on the product weights in Table 1, we assume a product amount of 250 g.

Finally, the OECD database (OECD, 2025) also includes time per day children spend playing on sand, based on US EPA data. This playing on sand is a wider concept than just playing in a sandbox. However, lacking a better alternative, we conservatively set our time spent playing in outdoor sandboxes f_{play} to their worst-case value of 2 hours per

[3] It is common practice to use the 75th percentile (or 25th percentile, for reciprocal parameters) in a realistic worst-case exposure assessment. Though it is desirable to cover a high percentile (e.g. the 95th) in the final exposure estimate, using that same high percentile for every exposure factor will lead to a much more worst-case result due to the stacking of worst-case approximations.

day, every (school) day. For this product group we limit the exposure duration to 7 years, being approximately the age at which children move from the lower half of primary school to the upper half. This moment is often accompanied with a move to a different schoolyard without a sandbox.

Release coefficient (release of fibres from contaminated sand)

We derive the release coefficient C_{release} from the study by Tromp (2002). In this study, asbestos soft board was used as a source material, containing approximately 70% asbestos, of which 20 percentage points are chrysotile and 50 percentage points are the amphibole amosite. Respirable asbestos fibres made up approximately 3% the board's mass (0.5 percentage points chrysotile, 2.5 percentage points amosite). The board was crushed and mixed with sand in different proportions. Approximately 4.5 kg of the asbestos-containing sand was placed on a 50- by 30-cm tray inside a fume hood with a volume of approximately 2 m^3. In some of the experiments, water was added to the sand mixture at 5% or 10% by weight. A fan was positioned to blow at the tray of sand to study the influence of air velocity as a proxy for activity level: 0–2 m/s with the fan off (light activity), 2.5–3.5 m/s, and 3–4 m/s (heavy activity). The highest fan setting caused a great amount of agitation; dust clouds were formed and 540 to 980 g of sand was displaced out of the tray, which is 12 to 22% of the total. For the medium activity, there was a loss of 60 to 230 g, or 1.3 to 5.1%. At the one measurement with light activity, 20 g loss, or 0.44%, was reported.

We base ourselves on the experiments with the highest asbestos concentration of 70 mg/kg (corresponding to a fibre concentration of 3 mg/kg) in the sand and dry conditions, because this is the only concentration for which the fibre concentration in air could be reliably measured. The release of fibres is expected to scale linearly with the concentration in sand, therefore the relative release will be valid for other concentrations as well. The dry sand is considered to be comparable to the loose play sand. In view of the relative sand losses, we consider the highest fan settings as a conservative proxy for relatively rough playing with sand. Under these conditions, Tromp (2002) measured 10 600, 8 730, and 6 830 fibres/m^3 at 1.5 m above the tray, which averages to 8 720 fibres/m^3. We therefore derive a release coefficient

$$C_{\text{release}} = \frac{8\,720 \text{ fibres in air / m}^3 \text{ air} \times 2 \text{ m}^3 \text{ air}}{3 \text{ mg fibres in sand / kg sand} \times 4.5 \text{ kg sand}} \quad \text{(loose sand)}$$

$$\approx 1\,290 \text{ fibres in air / mg fibres in sand}$$

When water is added, Tromp (2002) shows that fibre concentrations in the air drop by a factor of 10 for every 5% of additional moisture. As 5% of moisture corresponds to damp soil and 10% to very wet soil, we consider these two moisture contents as proxies for semi-cohesive toy sand and cohesive toy sand, respectively. Therefore, these two types of toy sands are estimated to have the same release coefficients as moist and wet sand, respectively:

$$C_{\text{release}} \approx \begin{cases} 129 \text{ fibres in air / mg fibres in sand} & \text{(semi-cohesive sand)} \\ 12.9 \text{ fibres in air / mg fibres in sand} & \text{(cohesive sand)} \end{cases}$$

The Tromp (2002) data were also used for the outdoor scenario. Studies conducted outdoors included elements such as heavy machinery and materials that contained larger, non-respirable fragments of asbestos, and lacked information on mass fraction of respirable fibres, thus requiring extrapolation steps to represent a sandbox scenario. It is considered that the extrapolation from the indoor scenario is less uncertain, which is supported by the study by Swartjes and Tromp (2008). Hence it was concluded that the Tromp (2002) study provides the most appropriate estimation for release of fibres as the study material represents toy sand the best and differences between in- and outdoor setting were considered to be acceptable.

Room volumes

The room volume depends on the location of the scenario. For use at home, we use the default value for a Dutch living room V_{room} = 58 m^3, taken from the ConsExpo General Fact Sheet (te Biesebeek et al., 2014). For schools and childcare centres, the Arbeidscatalogus-VO (Labour Catalogue Secondary Education) specifies a minimum of 2 m^2 usable floor space per pupil to ensure a safe class room.[4] Assuming a 2.5 m ceiling height and at least 20 children, the class room has to be at least 100 m^3, so we assume V_{room} = 100 m^3 as a realistic worst case.

For the outdoor scenarios, we use a conservative near-field volume of V_{NF} = 100 m^3. This is based on the work of Cherrie (1999): rooms of 100 m^3 with typical ventilation rates show little difference between near-field and far-field concentrations, but at the next higher room volume of 300 m^3 a noticeable difference starts to appear. The near-field volume therefore appears to be somewhere between 100 and 300 m^3 in size.

Removal rate of asbestos fibres from a room

After emission of asbestos has ceased, the fibres are slowly eliminated from the air by both ventilation and settling. Sahmel et al. (2015) have studied the removal rate of chrysotile asbestos fibres under very still conditions, and conclude that 99% of the toxicologically relevant fibres are eliminated from the air after 20–80 minutes by a combination of ventilation to outdoor air and settling to the floor. This result is in stark contrast with removal times of 48 to 72 hours in real-life contexts that are mentioned by various organisations offering testing, removal, and legal services.[5,6,7,8,9] The difference is thought to lie in the air movements that occur under normal (i.e. not very still) conditions, that can prevent asbestos fibres from settling. Furthermore, fibres that do settle can be resuspended by activity in the room, which can cause additional low-level exposure at far longer timescales, until the room is cleaned using adequate means for asbestos removal. To our knowledge, no studies are available with settling and resuspension timescales of asbestos under realistic use of a home or school. Given the lack of data, we make a conservative assumption of an exponential removal model with a removal rate of Q = 560 air changes per year, which corresponds to a removal of 99% of the asbestos fibres from the air in 72 hours.

There are not enough data to quantify different assumptions for homes versus schools and daycare centres, though it is to be expected that the frequency and method of cleaning has an impact on the removal rate. In schools, the cleaning protocol involves daily wet cleaning of all surfaces, which would remove many of the settled fibres. Vacuum cleaning, on the other hand, will likely resuspend many fibres.

In this model, the decrease in the air concentration is relatively slow but continuous, whereas in reality the air concentration is expected to drop faster but can also increase periodically upon resuspension. As the hazard of asbestos is chronic, the time at which exposure happens is not important.

Duration of time indoors

For the indoor scenarios, we make conservative assumptions based on expert judgement for the fraction of time spent in the room where playing with toy sand occurs. For the home, we assume a yearly average f_{room} = 12 hours per day are spent in the living room. For schools and childcare centres, we assume that on a school day 10 hours are spent in classrooms. This is therefore a very conservative scenario with prolonged before- and

[4] https://www.arbocatalogus-vo.nl/lokalen/theorielokaal-algemene-eisen/
[5] https://milehighenvironmentalinc.com/environmental-blog/how-long-does-asbestos-stay-in-the-air/
[6] https://www.asbestosremovalpro.com/blog/how-long-does-asbestos-stay-in-the-air/
[7] https://www.asbestosclaims.law/asbestos-blog/how-long-can-asbestos-stay-airborne/
[8] https://www.oracleasbestos.com/blog/how-long-does-asbestos-stay-airborne/
[9] https://www.airpf.com/how-long-does-asbestos-stay-in-the-air/

after-school care in addition to school or daycare. With 200 school days per year, this scenario corresponds to a yearly average f_{room} = 5.5 hours per day.

Exposure calculation
With the above values and equations, the concentrations during the release event and the lifetime-averaged concentrations are calculated for the different toys and locations, using both the geometric mean and maximum concentrations, and shown in Table 5. For each type of product, the lifetime-averaged exposures from all release events are also summed from all locations to arrive at a total lifetime exposure per product type. The scenario 'cohesive sand' was not included, as no products within this category tested positive for asbestos fibres.

For the product group of loose decorative sand, the calculated exposure using the maximum concentration exceeds the MTR of 300 fibres/m^3 (see section Risk assessment). We have therefore calculated the lifetime-averaged exposure from all release events at all locations for each of the loose decorative sand products individually in addition to the geometric mean and maximum values used above. The resulting calculated exposures are provided in Table 6.

Table 5. Exposure estimates for different types of sand and different locations (fibres/m^3)

	Location	**GM/ Max**	**Loose decorative sand**	**Semi-cohesive sand**	**Cohesive sand**	**Sand-filled toys**	**Sandbox sand**
Exposure during the release event, c_{event}	Home	GM	190	50	—	77	N/A
		Max	47 000	250	—	17 000	N/A
	Schools and childcare centres	GM	660	29	—	N/A	35
		Max	160 000	140	—	N/A	1 500
	Outdoors	GM	N/A	N/A	—	N/A	35
		Max	N/A	N/A	—	N/A	1 500
Lifetime-averaged exposure due to one release event, L_{event}	Home	GM	0.002 3	0.000 60	—	0.000 92	N/A
		Max	0.56	0.003 0	—	0.10	N/A
	Schools and childcare centres	GM	0.003 6	0.000 16	—	N/A	0.000 19
		Max	0.89	0.000 79	—	N/A	0.008 1
	Outdoors	GM	N/A	N/A	—	N/A	0.000 11
		Max	N/A	N/A	—	N/A	0.004 5
Lifetime-averaged exposure from all release events, L_{all}	Home	GM	1.5	0.81	—	0.012	N/A
		Max	380	4.0	—	1.3	N/A
	Schools and childcare centres	GM	1.9	2.1	—	N/A	0.27
		Max	460	10	—	N/A	11
	Outdoors	GM	N/A	N/A	—	N/A	0.27
		Max	N/A	N/A	—	N/A	12
	All locations (total)	GM	3.4	2.9	—	0.012	0.54
		Max	840	14	—	1.3	23

Values are rounded to two significant digits.

GM/Max: based on geometric mean or maximum of concentrations, respectively.

N/A: not applicable.

—: no exposure calculated because no asbestos was detected.

Table 6. Estimated exposure to asbestos for each of the products containing loose decorative sand that tested positive for asbestos.

Product nr	Asbestos est. mass fraction (w/w%) - VDI 3866 Blatt 5	Lifetime-averaged exposure from all release events, L_{all}, total of all locations (fibres/m^3)
6	1.392×10^{-3}	2.8
8	2.402×10^{-1}	480
13	2.020×10^{-3}	4.0
16	3.518×10^{-3}	7.0
18	4.199×10^{-1}	840
19	4.104×10^{-4}	0.82
20	3.917×10^{-4}	0.78
21	6.957×10^{-5}	0.14
25	2.927×10^{-3}	5.8
29	2.204×10^{-3}	4.4
32	3.653×10^{-3}	7.3
33	1.394×10^{-4}	0.28
34	1.709×10^{-3}	3.4
37	5.518×10^{-3}	11
38	2.962×10^{-4}	0.59
57	4.865×10^{-3}	9.7
58	4.507×10^{-5}	0.090
67	4.848×10^{-4}	0.97
69	1.056×10^{-4}	0.21
81	1.136×10^{-4}	0.23
88	1.729×10^{-3}	3.4
89	3.324×10^{-1}	660
91	3.813×10^{-4}	0.76
95	3.780×10^{-5}	0.075
96	4.277×10^{-3}	8.5
165	2.297×10^{-1}	460

Exposure values are rounded to two significant digits.

Risk assessment

The risk of inhalation of the asbestos fibres from toy sand is highly dependent on the amount of fibres that are released during play, which varies widely between products, and the total time children are exposed to fibres in the air. The estimated air concentration during product use is calculated for the products with the highest levels of contamination and the geometric mean of each product group. Secondly the contribution of a single exposure event to the lifetime exposure is given. Finally, the lifetime average exposure from all release events is calculated, which is the total exposure to asbestos fibres from repeated play with sand divided over the entire lifespan (see Exposure section).

In the risk assessment the lifetime-averaged exposure from all release events of asbestos from each group of toy sands for children are compared to the MTR and VR. The risk of cancer due to life-time asbestos exposure at the level of the MTR is 1 in 10 000, and at the VR 1 in 1 000 000 (see section Toxicology). As the majority of the fibres detected were tremolite asbestos (amphibole asbestos), the exposure estimates of asbestos fibres are compared to the MTR value for amphibole asbestos fibres of 300 fibres/m^3 and the VR value of 3 fibres/m^3.

The outcome of the exposure calculations and the MTR and VR are summarised in Table 7. For each scenario, both the calculations with the geometric mean concentrations and with the maximum concentrations are provided. The exposure estimates during the playing event include the highest estimated exposure encountered at any given location. The contribution of a single event to the lifetime-averaged exposure is also provided, again using highest estimated value at any location. The total lifetime exposure is calculated by combining the exposures at home, at school/daycare/out-of-school care, and in outdoor sandboxes for each of the product groups separately. The exposure assessment already includes such high frequencies of use per type of toy sand that it does not seem realistic to sum the exposure for all toy sand types.

Table 7. Exposure estimates for asbestos from toy sand, compared to the MTR and VR for amphibole asbestos fibres (fibres/m³)

	GM/ Max	**Loose decorative sand**	**Semi-cohesive sand**	**Cohesive sand**	**Sand-filled toys**	**Sandbox sand**	**MTR**	**VR**
Exposure during the release event, c_{event}, maximum of all locations	GM	660	50	—	77	35	N/A	N/A
	Max	160 000	250	—	17 000	1 500		
Lifetime-averaged exposure due to one release event, L_{event}, maximum of all locations	GM	0.003 6	0.000 60	—	0.000 92	0.000 19	300	3
	Max	0.89	0.003 0	—	0.20	0.010		
Lifetime-averaged exposure from all release events, L_{all}, total of all locations	GM	3.4	2.9	—	0.012	0.54	300	3
	Max	840	14	—	2.6	23		

Values are rounded to two significant digits.
GM/Max: based on geometric mean or maximum of concentrations, respectively.
N/A: not applicable – MTR and VR are lifetime-averaged guidance values.
—: no exposure calculated because no asbestos was detected.

Risk assessment per product group

Loose decorative sand

Loose decorative sand in this context is decorative sand used for example for sand painting or to fill flasks. This is often (but not always) coloured sand that flows freely. As this is dry sand, the release of fibres is relatively high. In 26 of these 43 products asbestos was found (60%). If a child would play frequently over 13 years with the

product with the geometric mean concentration, the lifetime-averaged exposure from all release events at all locations is 3.4 fibres/m^3, which is below the MTR and almost at the level of the VR. However, the same frequent exposure to only the product with the highest concentration would result in a lifetime-averaged exposure of 840 fibres/m^3. This value lies above both the VR and the MTR.

As the calculation using the highest concentration exceeded the MTR, the lifetime averaged exposure for all release events at all locations has also been calculated for every individual loose sand product (Table 6).

There are four loose decorative sand products with notably higher exposure levels than the others, which lead to estimated exposure levels above the MTR. Incidentally, these are the products that contain asbestos above 0.1%. This means that for these four products there is a concern.

Semi-cohesive sand

These are relatively loose kinetic sand products in which other substances have been added to the sand to make it more attractive to knead and sculpt with. The release of asbestos fibres from semi-cohesive sand is expected to be limited due to the stickiness of the sand. In two of these products asbestos was detected. The lifetime-averaged exposure estimate for the geometric mean of these products resulted in an exposure of 2.9 fibres/m^3. The lifetime exposure to only the product with the highest concentration is estimated at 14 fibres/m^3. This means that the lifetime exposure is always well below the MTR of 300 fibres/m^3 for amphibole fibres and most likely at or below the negligible risk level.

Cohesive kinetic sand

No asbestos was determined in the 19 cohesive kinetic sand samples tested. Based on the current measurements, there is no health risk from asbestos fibres from any of the sampled products.

Sand-filled toys

These are small bags, fidget toys and in one case blocks filled with loose sand. Asbestos has been found in seven of these products. The exposure to asbestos fibres from sand filled toys is expected to be limited to cases of incidental rupture of the toys. It is assumed that a child will be exposed once a year for 13 years, with an estimated event exposure of 8 400 fibres/m^3. The lifetime-averaged exposure from all release events is 0.012 fibres/m^3 for the geometric mean of the products and 2.6 fibres/m^3 for the product with the highest concentration, which is below the MTR and the VR. As this is incidental exposure with a short duration and with a relatively small amount of sand, the asbestos contamination found in these toys is expected to result in a negligible risk.

Sandbox sand

Sandboxes are mostly used outdoors, but sometimes also inside in childcare centres. The amount of sand used in sandboxes is larger than other forms of toy sand. Asbestos fibres were found in five pre-packaged bags of sandbox sand. The concentrations of asbestos fibres were low compared to other products. It was conservatively assumed children play daily for two hours during 7 years with asbestos-contaminated sand. The estimated event exposure is 1 500 fibres/m^3. The lifetime exposure of 0.54 fibres/m^3 at the geometric mean and 23 fibres/m^3 for the product with the highest concentration. This indicates that in nearly all situations, the risk will be negligible as it is well below the VR. Even if children play very often with products with the highest concentration the risk is still below the MTR, but not below the VR, indicating an acceptable but not negligible risk.

Sources of variability and uncertainties

In the risk assessment various assumptions had to be made as there are no or very limited data available for many relevant exposure parameters. In addition, the measurements, fibre analysis and hazard data have their own uncertainties. Table 8 provides an overview of key sources of variability and uncertainty in the assessment.

Table 8. Qualitative assessment of the uncertainty and variability in the risk assessment

Variable Name	**Description**	**Risk may actually be higher (↑) or lower (↓)**
Hazard assessment		
Child sensitivity	There are no child-specific data for the risk of asbestos exposure. It is assumed that the mechanism of toxicity is the same as for adults. However, due to the long latency period of asbestos cancer, exposure at an early age may increase the risk.	↑
Exposure route	Only inhalation exposure was included, as this is known to be the route that poses the highest risk for asbestos fibres. However, oral and dermal exposure also occur. The additional risk of these routes is expected to be much lower than from inhalation.	↑
Type of asbestos	As most fibres were amphibole asbestos and this is the most hazardous form, the reference values for 100% amphibole fibres were used, leading to an overestimation of the risk.	↓
Fibre analysis		
Limited fibre characterisation	The fibre dimensions (length, diameter, aspect ratio) have not been taken into account.	↑↓
Variability of contamination	Asbestos is usually not homogeneously distributed through a material, resulting in over- or underestimation of contamination when determined with a single measurement. Furthermore, contamination may differ between batches of the same product.	↑↓
Exposure assessment		
Product selection	A sample has been taken of products that are currently available in the Netherlands, either in physical stores or web shops. It is unknown to what extent this sample is representative for all toy sand products.	↑↓
Amount of sand	The amount of sand used in play in each event was estimated high to account for multiple children playing at the same time. This may be lower in reality.	↓
Fibre release during play, including humidity/stickiness	There are no measurement data for the release of asbestos fibres from toy sands under play conditions. This releasing factor has been estimated based on simulation experiments by TNO on asbestos release from sand.	↓
Room volume and duration of stay in contaminated rooms	For the home scenario, it was assumed that the playing takes place in the living room. If instead a child plays in their bedroom, higher concentrations of asbestos in the air are	↑↓

	expected due to the smaller room volume. This would result in higher exposure. In this situation, children may be exposure for longer times as they would also be exposed during their sleep. However, the part of the day spent in contaminated rooms is already chosen conservatively in the considered scenario.	
Exposure duration and frequency: playtime per day and total number of days played	There is very limited data on play behaviour. Data have been used from play with clay and slime (toys). Moreover, there is a high variation between children in how often and long they play with toy sand. We have assumed long exposure durations as children may not only be exposed as a result of their own play, but also from play by older or younger siblings.	↓
Addition (cumulative) of play on different locations	A complicating factor is that children might play with toy sands either at home, in schools and in day/after-school care. A worst-case estimation has been made, by summing up the estimated exposure during playing over one day, also including exposure through other children playing in the same room.	↓
Combined release of fibres in a group situation	In schools and daycares, the fibre concentration in the air depends on the play of all children in the room. This has been estimated, as there is no data available.	⇅
Aggregate exposure	Aggregate exposure to asbestos from playing with multiple sand types was not considered.	↑
Distribution of fibres in the air and removal from the area	This is highly dependent on air movement, ventilation, and cleaning. Assumptions made are worst-case.	↓

Additional considerations and recommendations

Although it does not give a measure for the actual risk, it should be noted that asbestos fibres are also present in the air when there are no specific sources known. In the nineteen-eighties the background exposure reached its peak of over 3000 fibres/m^3 due to the use of asbestos in buildings and car brake pads. In recent measurements by TNO the average background concentration was 35 fibres/m^3, with a distribution of <30–81 fibres/m^3 (Tromp & Spaan, 2018, in Dutch).

An important source of uncertainty is that there are no measurement data for the release of asbestos fibres from toy sand under play conditions. The only way to address this knowledge gap is by measuring air concentrations of asbestos fibres from contaminated materials under conditions that simulate play behaviour. The results of such a study could verify and refine the outcome of the exposure assessment.

The risk assessment includes only products that were sampled, which is a subset of the toy sand products on the market. In the group of loose decorative sand products, there was a very large difference between products in the level of asbestos contamination. Four products had concentrations at a level where an unacceptable risk may occur when the product is frequently used for a long period of time.

It is advised that follow-up actions are taken by producers/importers, market authorities and regulators to identify asbestos contaminated toy sands in an earlier stage and prevent their entry on the market in the future.

This risk assessment only considered the risk of children playing with contaminated sand. The occupational risk of workers, such as teachers, nursery personnel and professional cleaners is also highly relevant due to their play, presence and activities. This is addressed in a separate risk assessment.

Answer to questions and conclusion

It should be noted that there is no safe exposure to asbestos. The risk to develop an asbestos-related condition depends on the level of exposure. For this reason, contamination of toy sand with asbestos fibres is undesirable and should be prevented as much as possible.

We conclude that the risk of asbestos-related diseases from playing with toy sands lies at or below the negligible risk level. The asbestos exposure from most products is very low and does not pose a concern. However, there are four loose decorative sand products with notably higher levels of contamination compared to the other products. It is important to prevent further exposure to these products as in a hypothetical worst-case scenario where a child is always playing with one of these products they may lead to an unacceptably high risk. It is also advised that producers/importers, market authorities and regulators take action to prevent contamination of toy sands with asbestos in the future.

1. *What are the relevant routes of exposure for children exposed to asbestos fibres in toy sand?*

The most relevant route of asbestos exposure is inhalation of airborne fibres. No notable increase in risk is expected from oral intake of contaminated sand.

2. *What is the estimated exposure to asbestos fibres of children playing with toy sand?*

The exposure is calculated for four types of toy sand products: loose decorative sand, semi-cohesive (kinetic) sand, toys filled with sand, and sandbox sand. No asbestos was found in the fifth type of toy sand, cohesive kinetic sand products. The outcome of the exposure assessment using the geometric mean and maximum concentration of each product group is given in Table 5.

A second hypothetical exposure assessment using the maximum concentration of each product group revealed a lifetime exposure above the MTR for loose decorative sand. We have subsequently calculated the asbestos exposures for each individual product in this group that tested positive on asbestos. These lifetime exposures range from 0.075 to 840 fibres/m3. Four out of 26 asbestos-containing loose decorative sand products lead to a calculated exposure above the MTR.

a. *Is it possible to make a difference in age groups?*

There is no known difference between age groups in sensitivity for health effects due to asbestos. It is expected that the exposure will differ between age groups due to differences in play behaviour, duration, and frequency. However, specific information on these aspects is very limited. Moreover, the most important factor for the risk is the lifetime exposure.

b. *Is there a difference between types of toy sand?*

There are clear differences between types of toy sand and the level of contamination, release of fibres and behavioural parameters. The highest exposure is expected from loose decorative sand, as this group includes the products with the highest level of both asbestos contamination and release. Exposure from other product groups was considerably lower. The concentrations found cover a very wide range with a 80 000 fold difference between the lowest and the highest concentration.

c. *How does this compare to other types of sand, such as sandbox sand?*

The asbestos concentrations in sandbox sand were generally lower than in other products. It is expected children play in sandboxes with larger amounts of sand and this activity is limited to a younger age (0-7 years).

3. *What is the health risk for children when they play with toy sand?*

The risk from asbestos in semi-cohesive sand and toys filled with sand can be considered negligible. An important factor that reduces the risk of these products is that the release of fibres is limited by the physical properties of the products. Sandbox sand has a higher release of fibres, but this sand contained lower levels of fibres. As a result, also the risk from playing with sandbox sand is negligible as well.

The exposure to fibres from loose decorative sand is estimated to be the highest of all product groups as this group included the products with the highest level of both asbestos contamination and release of fibres. During frequent play with various products from this group the lifetime exposure still lies below the limit value for an acceptable risk. There are four loose decorative sand products with notably higher levels of asbestos contamination. For these products the lifetime-averaged exposure lies above the MTR if a child would play with only these products for 13 years, 92 times a year. It is highly unlikely that this will happen in reality. As in this worst-case scenario the use of these four products can lead to lifetime exposure exceeding the MTR, further exposure to these products should be prevented as they may result in an unacceptable risk.

It should be noted that there is a large degree of uncertainty in this assessment. At the moment there are no measurements of the actual release of asbestos fibres, their movement through the air, and the frequency of play with these products. Furthermore, this assessment only applies to the products that have been sampled. Because of the high uncertainty, realistic worst-case estimates were made based on the limited information available. In reality, it is likely that the exposure time of a child to these products is much shorter.

It is advised that producers/importers, market authorities and regulators take action to prevent contamination of toy sands with asbestos in the future.

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