DTC
DANSK TOKSIKOLOGI CENTER

Evaluation of FuranFlex/FuranFix

Inner lining material for chimneys

Background

The Swedish certifying body SWEDCERT has requested DTC to carry out a toxicological evaluation of the product FuranFlex/FuranFix which is to be used as inner lining in chimneys.

FuranFlex/FuranFix is marketed by the company Isokern (Sweden).

In order for SWEDCERT to issue a type approval for the product, Isokern must substantiate that FuranFlex/FuranFix does not emit hazardous chemical substances, etc. in undesirable high concentrations when used.

According to building regulation 6:73[55] of Boverket* (Sweden) emission of flue gases should be reduced to a minimum. Flue gases should be lead through chimneys/flues sufficiently tall to prevent flue gas around or inside the building (through ventilating shafts or open windows) and prevent flue gas from being led to the nearest buildings.

To carry out the evaluation DTC received information on the chemical composition of FuranFlex/FuranFix from the producer Kompozitor (Hungary). Furthermore, DTC received additional information from Isokern and SWEDCERT to carry out a worst-case assessment.

SWEDCERT has requested DTC two assess two situations: Used with chimneys, where the temperature can reach up to 450°C at the source of the heat, and a chimney fire where temperatures may exceed 1000°C.

Worst-case assessment

Assumption:

1. Minimum room size = 10 m^2. Floor-to-ceiling height = 2.5 m => V_{room} = 25 m^3.
2. Chimney height = Floor-to-ceiling height*safety factor = 2.5 m*2 = 5 m.
3. $Diameter_{FuranFlex/FuranFix}$ = 150 mm (according to information from SWEDCERT) => weight of product = 5 m*1400 g/m = 7000 g.
4. Approx. 1% of the compounds vaporising at approx. 450°C/1000°C enters the room, e.g. through leaks, open windows, fireplaces, etc. The remainder is given off to the surroundings.
5. Organic compounds decompose to CO, NO_2 and SO_2. At 450°C approx. 10% of the compounds is assumed to vaporise without any decomposition.

For detailed calculations please refer to the enclosure. The different concentrations appear from the below table.

*The Swedish National Board of Housing, Building and Planning

Table

Substance	Indoor concentration (450°C) [ppm]	Outdoor concentration (450°C) [ppm]	Indoor concentration (1000°C) [ppm]	Outdoor concentration (1000°C) [ppm]	TCLo: Lowest observed tox. dose	Limit values [ppm]
Carbon monoxide (CO)	88.1	218	822	2035	Inh-man TCLo: 650 ppm/45 min	25
Nitrogen dioxide (NO_2)	11.1	27.4	11.1	27.4	Inh-hmn TCLo: 90 ppm/40 min	5.6
Sulphur dioxide (SO_2)	1.87	4.65	1.87	4.65	Inh-hmn TCLo: 12 ppm/1H	1.3
Carbon black	-	-	-	-	-	-
Aniline black	0.01	0.03	-	-	-	-
p-Toluene sulphonic acid	0.37	0.91	-	-	-	-
Hexamethylenetetramine	0.45	1.12	-	-	Inh-rat TCLo: 61 ppm/6H/13W-I	-
Phenol-formaldehyde resin	-	-	-	-	-	-
Furan resin	-	-	-	-	-	-
Carbamide	0.90	2.22	-	-	Inh-rat TCLo: 61 ppm/6H/13W-I	-
Bisphenol-A	0.41	1.01	-	-	Inh-rat TCLo: 31 ppm/17W-I	-
Polyethylene	-	-	-	-	-	-
Polyethylene terephthalate fibres	-	-	-	-	-	-

The concentrations in the table are given with 3 significant figures.

Discussion

Indoor concentration (450°C):

In information retrievals DTC has searched for TCLo: Lowest observed toxicological concentration.

TCLo values for p-toluene sulphonic acid and aniline black were not found in the available literature. The calculated concentrations in a 25 m^3 room are 0.01 ppm for aniline black and 0.37 ppm for p-toluene sulphonic acid, respectively. These very low concentrations does not cause any health concerns.

TCLo values for CO, NO_x, SO_2, hexamethylenetetramine, carbamide, and bisphenol-A are above the values that could be found in the room (factor 6.5-135).

Our partial conclusion is that the contribution of toxic compounds (1%) from FuranFlex/FuranFix at 450°C to a room with a volume of 25 m^3 does not result in substance concentrations which cause any health concerns.

Outdoor concentrations (450°C):

If compared with indoor concentrations, the calculated outdoor concentrations are approx 2.5 times higher for all compounds. Very quickly (i.e. within a few seconds) these concentrations will be further attenuated with a factor 100-1000 which means that none of the values causes any health concerns.

Indoor concentration (1000°C => chimney fire):

The concentration of CO is approx. 9.3 times higher compared with the concentration at 450°C. This concentration is approx. 1.3 times higher that the lowest observed toxicological concentration. Rooms must have ventilation of minimum 0.35 l/s/m^2 according to SWEDCERT and the Swedish standards. This means that ventilation in a 10 m^2 room is 0.21 m^3/min (height = 2.5 m).

Using a formula for "washing out " it is possible to calculate the CO concentration at a given time.

$$C=C_0*e^{-kt}$$

As the TCLo value for CO was 650 pm/45 min it is relevant to calculate the CO concentration in the room after 45 minutes. Thus we get:

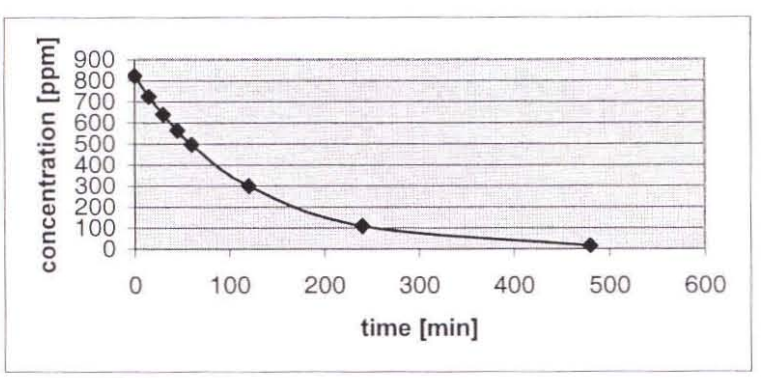
$$C_{CO,\ t=45}=822*e^{-k*45}$$

We can find k by assuming k=v/V=(0.21 m^3/min)/25 m^3 = 0.0084 min^{-1}. Thus we have:

$$C_{CO,\ t=45}=4110*e^{-0.0084*45} = \underline{563\ ppm}.$$

This value is lower than the TCLo and consequently not of any health concern. The value 563 ppm is the concentration in the room after exactly 45 minutes. The average from t=0 to t=45 gives a higher CO concentration. Furthermore, it is assumed that chimney soot will contribute with a CO dose.

The following graph of the CO concentration (ppm) in the room as a function of the time is obtained through the formula for "washing out ".



As the graph indicates the concentration will fall rapidly in the beginning. The half-life $t_{1/2}$ can be calculated through the following equation:

$$t_{1/2}=(\ln 2)/k$$

which gives a half-life of 0.693/0.0084 = <u>82.5 min</u>.

The other compounds (NO_2 and SO_2) are found in the same concentrations as for 450°C/indoors (see comments above).

Enclosure

Worst Case assessment (at 450°C):

Assumption:

1. Minimum room size = 10 m^2. Floor-to-ceiling height = 2.5 m => V_{room} = 25 m^3.
2. Chimney height = Floor-to-ceiling height*safety factor = 2.5 m*2 = 5 m.
3. Diameter = 150 mm (according to information from SWEDCERT) => weight of product = 5 m*1400 g/m = 7000 g.
4. Approx. 1% of the compounds vaporising at approx. 450°C enters the room, e.g. through leaks, open windows, fireplaces, etc. The remainder is given off to the surroundings and is thinned approx. 1000 times before being inhaled.
5. Organic compounds decompose to CO, NO_2, SO_2. Only approx. 10% of the compounds is assumed to vaporise without any decomposition.

At 450°C (the further away from the chimney the lower the temperature) DTC assesses, that the following compounds decompose/vaporise:

Aniline black, p-toluene sulphonic acid, hexamethylenetetramine, carbamide, bisphenol-A, polyethylene and polyethylene terephthalate fibres.

Aniline black occurs with 0.11% in the material. Approx. 0.056% CO may be generated; approx. 0.015% NO_2 and 10% (= 0.011%) remain as aniline black.

p-Toluene sulphonic acid occurs with 0.94 % in the material. Approx. 0.460% CO may be generated; 0.179% SO_2 and 10% (=0.094 %) remain as p-toluene sulphonic acid.

Hexamethylenetetramine occurs with 0.94 % in the material. Approx. 0.470% CO may be generated; 0.376% NO_2 and 10% (=0.094%) remain as hexamethylenetetramine.

Carbamide occurs with 0.80 % in the material. Approx. 0.160% CO may be generated; 0.376% NO_2 and 10% (=0.080%) remain as carbamide.

Bisphenol-A occurs with 1.39 % in the material. Approx. 1.098% CO may be generated, and 10% (=0.139%) remains as bisphenol-A.

Polyethylene occurs with a very thin layer of 120 µm and the contribution of mainly CO compounds can be neglected.

60 g/m^2 of polyethylene terephthalate fibres is found. Pipe area is A=2*Π*r*h = 2*Π*0.075m*5m = 2.355 m^2. Total polyethylene terephthalate fibres quantity = 2.355 m^2*60 g/m^2 = 141.3 g. Approx. 60% is transformed into CO compounds => 141.3 g*0.6 = 84.78 g.

$\sum$ CO = 0.056% + 0.46% + 0.47% + 0.160% + 1.098% = <u>2.244% (+ 84.78 g)</u>

$\sum$ NO_2 = 0.015% + 0.376% + 0.376% = <u>0.767%</u>

$\sum$ SO_2 = <u>0.179%</u>
$\sum$ Aniline black = <u>0.011%</u>

Σ p-Toluene sulphonic acid= 0.094%

Σ Hexamethylenetetramine = 0.094%

Σ Carbamide = 0.080%

Σ Bisphenol-A = 0.139%

Σ Polyethylene= negligible

Σ Polyethylene terephthalate fibres = 14.13 g

As the amount of polyethylene terephthalate is stated in g/m^2 the product amount minus PET-fibres can be calculated => $m_{product} - m_{PET\text{-}fibres}$ = 7000 g – 141.3 g = 6858.7 g.

Thus all compounds can be calculated in g:

CO => 6858.7 g*0.0244 = 160.49 g + 84.78 g = 252.13 g

NO_2 => 6858.7 g*0.00767 = 52.13 g

SO_2 => 6858.7 g*0.00179 = 12.28 g

Aniline black => 6858.7 g*0.00011 = 0.75 g

p-Toluene sulphonic acid=> 6858.7 g*0.00094 = 6.44 g

Hexamethylenetetramine => 6858.7 g*0.00094 = 6.44 g

Carbamide => 6858.7 g*0.00080 = 5.49 g

Bisphenol-A => 6858.7 g*0.00139 = 9.53 g

Polyethylene=> negligible

Polyethylene terephthalate fibres => 14.13 g

We have assumed that by accident 5% of the compounds could ooze into the room. This would result in the following concentrations in the room due to FuranFlex/FuranFix.

CO = 252.13 g*0.01 = 2.52 g => C_{CO} = 2.52 g/25 m^3*1000 = **100.85 mg/m^3** equivalent to **88.10 ppm**.

NO_2 = 52.13 g*0.01 = 0.52 g => C_{NO2}= 0.52 g/25 m^3*1000 = **20.80 mg/m^3** equivalent to **11.10 ppm**.

SO_2 = 12.28 g*0.01 = 0.12 g => C_{SO2} = 0.12 g/25 m^3*1000 = **4.91 mg/m^3** equivalent to **1.87 ppm**.

Aniline black = 0.75 g*0.01 = 0.0075 g => $C_{Aniline\ black}$ = 0.0075 g/25 m^3*1000 = **0.3 g/m^3** equivalent to **0.01 ppm**.

p-Toluene sulphonic acid= 6.44 g*0.01 = 0.0644 g => $C_{p\text{-Toluene sulphonic acid}}$= 0.0644 g/25 m^3*1000 = **2.58 mg/m^3** equivalent to **0.37 ppm**.

Hexamethylenetetramine = 6.44 g*0.01 = 0.0644 g => $H_{examethylenetetramine}$ = 0.0644 g/25 m^3*1000 = **2.58 mg/m^3** equivalent to **0.45 ppm**.

Carbamide = 5.49 g*0.01 = 0.0549 g => $C_{Carbamide}$ = 0.0549 g/25 m^3*1000 = **2.20 mg/m^3** equivalent to **0.90 ppm**.

Bisphenol-A = 9.53 g*0.01 = 0.0953 g => $C_{Bisphenol\text{-}A}$ = 0.0953 g/25 m^3*1000 = **3.81 mg/m^3** equivalent to **0.41 ppm**.

Polyethylene=> negligible

Polyethylene terephthalate fibres = 14.13 g*0.01 = 0.1413 g => $C_{Polyethylene\ terephthalate\ fibres}$ = 0.1414 g/25 m^3*1000 = **5.65 mg/m^3**

95% of the compounds will be emitted to the surroundings.

CO = 252.13 g*0.99 = 249.61 g => C_{CO} = 249.61 g/1000 m^3*1000 = **249.61 mg/m^3** equivalent to **218.00 ppm**.

NO_2 = 52.13 g*0.99 = 51.61 g => C_{NO2}= 51.61 g/1000 m^3*1000 = **51.61 mg/m^3** equivalent to **27.44 ppm**.

SO_2 = 12.28 g*0.99 = 12.16 g => C_{SO2} = 12.16 g/1000 m^3*1000 = **12.16 mg/m^3** equivalent to **4.65 ppm**.

Aniline black = 0.75 g*0.99 = 0.743 g => $C_{Aniline\ black}$ = 0.743 g/1000 m^3*1000 = **0.743 g/m^3** equivalent to **0.03 ppm**.

p-Toluene sulphonic acid= 6.44 g*0.99 = 6.376 g => $C_{p\text{-Toluene sulphonic acid}}$= 6.376 g/1000 m^3*1000 = **6.376 mg/m^3** equivalent to **0.91 ppm**.

Hexamethylenetetramine = 6.44 g*0.99 = 6.376 g => $C_{Hexamethylenetetramine}$ = 6.376 g/1000 m^3*1000 = **6.376 mg/m^3** equivalent to **1.12 ppm**.

Carbamide = 5.49 g*0.99 = 5.435 g => $C_{Carbamide}$ = 5.435 g/1000 m^3*1000 = **5.435 mg/m^3** equivalent to **2.22 ppm**.

Bisphenol-A = 9.53 g*0.99 = 9.43 g => $C_{Bisphenol\text{-}A}$ = 9.43 g/1000 m^3*1000 = **9.43 mg/m^3** equivalent to **1.01 ppm**.

Polyethylene=> negligible

Polyethylene terephthalate fibres = 14.13 g*0.99 = 13.989 g => $C_{Polyethylene\ terephthalate\ fibres}$ = 13.989 g/1000 m^3*1000 = **13.99 mg/m^3**

Worst Case assessment (at 1000°C):

Assumption:

1. Minimum room size = 10 m^2. Floor-to-ceiling height = 2.5 m => V_{room} = 25 m^3.
2. Chimney height = Floor-to-ceiling height*safety factor = 2.5 m*2 = 5 m.
3. Diameter = 150 mm (according to information from SWEDCERT) => weight of product = 5 m*1400 g/m = 7000 g.
4. Approx. 1% of the compounds vaporising at approx. 1000°C enters the room, e.g. through leaks, open windows, fireplaces, etc. The remainder is given off to the surroundings and is thinned approx. 1000 times before being inhaled.
5. Organic compounds decompose to CO, NO_2, SO_2.

At 1000°C DTC assesses, that the following compounds decompose/vaporise:

Carbon black, aniline black, p-toluene sulphonic acid, hexamethylenetetramine, phenol-formaldehyde resin, furan resin, carbamide, bisphenol-A, polyethylene and polyethylene terephthalate fibres.

Carbon black occurs with 1.34% in the material. Approx. 1.34% CO may be generated.

Aniline black occurs with 0.11% in the material. Approx. 0.056% CO and 0.015 % NO_2 may be generated.

p-Toluene sulphonic acid occurs with 0.94% in the material. Approx. 0.460% CO and 0.179% SO_2 may be generated.

Hexamethylenetetramine occurs with 0.94% in the material. Approx. 0.470% CO and 0.376% NO_2 may be generated.

Phenol-formaldehyde resin occurs with 29.65% in the material. Approx. 23.5% CO may be generated.

Furan resin occurs with 7.96% in the material. Approx. 6.0% CO may be generated.

Carbamide occurs with 0.80% in the material. Approx. 0.160% CO and 0.376% NO_2 may be generated.

Bisphenol-A occurs with 1.39% in the material. Approx. 1.098 % CO may be generated.

Polyethylene occurs with a very thin layer of 120 µm and the contribution of mainly CO compounds can be neglected.

Polyethylene terephthalate fibres occur with 60 g/m^2. Pipe area is A=2*Π*r*h = 2*Π*0.075m*5m = 2.355 m^2. Total polyethylene terephthalate fibres quantity = 2.355 m^2*60 g/m^2 = 141.3 g. Approx. 60% is transformed into CO compounds => 141.3 g*0.6 = 84.78 g.

$\sum$ CO = 1.34% + 0.056% + 0.46% + 0.47% + 23.5% + 6.0% + 0.160% + 1.098% = <u>33.08% (+ 84.78 g)</u>

$\sum$ NO_2 = 0.015% + 0.376% + 0.376% = <u>0.767%</u>

Σ SO_2 = 0.179%

As the amount of polyethylene terephthalate is stated in g/m^2 the product amount minus PET-fibres can be calculated => $m_{product} - m_{PET\text{-}fibres}$ = 7000 g – 141.3 g = 6858.7 g.

Thus all compounds can be calculated in g:

CO => 6858.7 g*0.3308 = 2268.86 g + 84.78 g = 2353.64 g

NO_2 => 6858.7 g*0.00767 = 52.13 g

SO_2 => 6858.7 g*0.00179 = 12.28 g

We have assumed that by accident 5% of the compounds could ooze into the room. This would result in the following concentrations in the room due to FuranFlex/FuranFix.

CO = 2353.64 g*0.01 = 23.54 g => C_{CO} = 23.54 g/25 m^3*1000 = **941.46 mg/m^3** equivalent to **822.23 ppm**.

NO_2 = 52.13 g*0.01 = 0.52 g => C_{NO2}= 0.52 g/25 m^3*1000 = **20.85 mg/m^3** equivalent to **11.08 ppm**.

SO_2 = 12.28 g*0.01 = 0.12 g => C_{SO2} = 0.12 g/25 m^3*1000 = **4.91 mg/m^3** equivalent to **1.87 ppm**.

95% of the compounds will be emitted to the surroundings.

CO = 2353.64 g*0.99 = 2330.10 g => C_{CO} = 2330.10 g/1000 m^3*1000 = **2330.10 mg/m^3** equivalent to **2035.02 ppm**.

NO_2 = 52.13 g*0.99 = 51.61 g => C_{NO2}= 51.61 g/1000 m^3*1000 = **51.61 mg/m^3** equivalent to **27.44**

SO_2 = 12.28 g*0.99= 12.16 C_{SO2} = 12.16 g/1000 m^3*1000 = **12.16 mg/m^3** equivalent to **4.65**.