ISTITUTO DI RICERCHE FARMACOLOGICHE MARIO NEGRI

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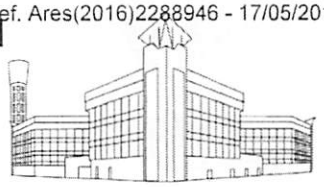

Human Health and the Safety of Exposure to Recycled Tire Rubber Research Project.

Preliminary Results

Milan, May 2016

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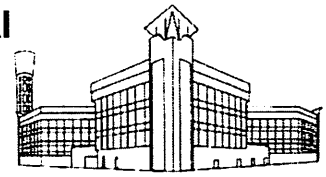
Human Health and the Safety of Exposure to Recycled Tire Rubber Research Project.

The recycling of End of Life Tyres (ELTs) has been increasing over the past 20 years. Artificial turf and shock-absorbing surfaces are the two most important markets for the ELT recycling sector, representing about 50% of the European recycled ELT market.
These modern artificial surfaces reduce the likelihood of personal injury, provide uniform recreational playing surfaces, promote energy conservation, eliminate pesticide and fertilizer usage, and support waste recycling.
However, concerns have been expressed regarding the health of both players and workers due to the presence of trace residues of polycyclic aromatic hydrocarbons (PAHs) in rubber compounds and the broad diffusion of this type of artificial turf infill.

Ecopneus Scpa therefore supported a research project to:

- characterize the PAH content in ELT materials
- define migration in artificial sweat and pulmonary surfactants under controlled conditions
- define adsorption with PAH metabolism product excretion in exposed volunteers

The results obtained from a preliminary human risk assessment (RA) based on experimental data are reported here.



Eight PAHs have been considered in this report: Benzo(a)anthracene, Chrysene, Benzo(b)+(j)fluoranthene, Benzo(k)fluoranthene, Benzo(e)pyrene, Benzo(a)pyrene and Dibenzo(a,h)anthracene. These PAHs were chosen because they are known to be powerful carcinogens (IARC, 2010; IPCS, 1998; NRCC, 1983; NTP,2005).
Levels of these substances have been considered in 25 different samples of ELT materials. Average values were used to assess risks to human health from exposure to PAHs, and the toxicity equivalent factors of each PAH were used to express the results as Benzo(a)pyrene equivalent (BaP eq) (Table 1).

Table 1 Concentrations found in tyre rubber and TEQ BaP equivalent values

PAH	ELT experimental average value	TEF (EPA) BaP eq	TEQ(mg/kg)
Benzo(a)antracene	0.42	0.4	0.17
Crisene	0.74	0.01	0.01
Benzo(j)+(f)fluorantene	0.90	0.1	0.09
Benzo(k)fluorantene	0.17	0.1	0.02
Benzo(a)pirene	1.30	1	1.30
Benzo(e)pirene	2.86	0	0
Dibenzo(a,h)antracene	0.17	0.1	0.02
TOTAL			**1.6**

An RA study based on PAH exposure has already been performed, assessing PAH concentrations with personal samplers. The results are available in a joint publication by Ecopneus and Waste and Chemicals.
The approach described by Ruffino et al. and Marsili et al. (Ruffino et al., 2013; Marsili et al., 2014) was used in order to perform a preliminary RA study based on analytical data regarding PAH content in ELTs. This approach assumes that environmental PM10 is made of 100% ELT derived rubber and that 100% of the PAHs in ELTs are released into the blood stream.
The approach does not consider actual PM10 levels during the players' or workers' exposure, but estimates PM10 levels from public available data on environmental air quality, since no differences have been reported in the literature. in order to proceed with this risk assessment, the particulate emission factor (PEF) of the outdoor particulate matter of the survey site was calculated. PEF was considered to be equal to local PM10 x 10^{-6} mg/kg, where the PM10 are the levels of total inhalable dusts (mg/m^3) potentially containing PAHs, assuming that all the particles present in the air as PM10 result from the volatilization of particles from the artificial turf; this therefore represents

the worst-case scenario. We considered the annual 2015 mean at Trecella site (Lombardy, Italy) as the PM10 value.
The PM10 value obtained was 0.0363 mg/m^3. The contaminant concentration in the air (C_a) given by the product of value obtained from the toxic equivalency factor (TEQ) of each contaminant considered (1.61 mg/kg) and the PEF value was evaluated. The value obtained was 5.83 x 10^{-8} mg/m^3. Two scenario expositions were then considered: inhalation and direct dermal contact. Four different scenarios were evaluated for each route of exposure: children, adults, athletes and workers.
For the inhalation route, the Average Daily Dose (ADD), expressed in terms of the mass of contaminant per unit of body weight per day (mg/kg day), and the Lifetime Average Daily Dose (LADD), used to evaluate carcinogenic effects, which is calculated with the same parameters as ADD, with the exception of the Average Time (AT), considered to be 70 years, was calculated:

$$ADD/LADD = (C_a \times IR \times EF_{do} \times EF \times ED) / (BW \times AT)$$

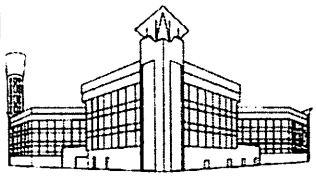
The parameters used are reported in Table 2.

Table 2 Parameters used to evaluate the health effects from the inhalation route

	Child	Adult	Athlete	Worker
Inhalation rate (IR) [m^3/h]	0.7	1.5	3.6	1.5
Daily exposure frequency (EF_{do}) [h/d]	2	2	4	6
Exposure frequency in a year (EF) [d/year]	100	100	208	120
Exposure duration (ED) [years]	6	30	20	30
Body weight (BW) [kg]	25	70	70	70
Average time (AT) [years x 365 days]	2190	10950	7300	10950
Average cancerogenic time (AT) [years x 365 days]	25550	25550	25550	25550

Starting from the ADD and LADD values, a Hazard Quotient (HQ) was calculated as an indicator of risks associated with health effects other than cancer, and an Excess Cancer Risk (CR) was calculated as the incremental probability of an exposed person developing cancer over a lifetime. The calculations were made using the inhalation pathway toxicological parameters, i.e. the Reference Dose (RfD) for the HQ calculation and the Slope Factor (SF) for the CR calculation, as follows:

$$HQ = ADD/RfD$$



and

CR = LADD x SF

The values of RfD and SF are 3.14 and 7.32, respectively. The two values are included in the ISS/ISPESL 2009 (Istituto Superiore di Sanità – Istituto Superiore per la Prevenzione e Sicurezza del Lavoro) Database.
Here an HQ less than 1 is defined as value of no concern for potential adverse systemic health effects in exposed individuals. An additional lifetime cancer risk of 10^{-6} is deemed to be acceptable for the individual CR while for the cumulative CR the maximum acceptable value is 10^{-5} (Leg. Dec. 152/2006).

The results of this study for the inhalation exposure route are listed in Table 3.

Table 3 Determination of ADD, LADD, HQ and CR for the inhalation exposure route

	ADD	LADD	HQ	CR
Child	8.95×10^{-10}	7.67×10^{-11}	2.85×10^{-10}	5.61×10^{-10}
Adult	6.85×10^{-10}	2.93×10^{-10}	2.18×10^{-10}	2.15×10^{-9}
Athlete	6.84×10^{-9}	1.95×10^{-9}	2.18×10^{-9}	1.43×10^{-8}
Worker	2.46×10^{-9}	1.06×10^{-9}	7.85×10^{-10}	7.73×10^{-9}

For direct dermal contact, again, it was considered that the concentration of exposure was equal to the amount of each PAH in the rubber granules, individually corrected for the TEF value. The value used for this scenario was the same as that used for the inhalation route.
As for the inhalation route, the dermal risk was divided into two categories: non-carcinogens and carcinogens.
The average daily intake (mg/kg day, ADI), defined as the estimated dose the recipient is exposed to from an exposure route, and the lifetime daily intake (mg/kg day, LDI), defined as the dose of contaminant the recipient is exposed to for his entire life through an exposure route, were calculated. ADI and LDI were calculated as the product of the specific exposure rate (E, daily amount, normalized for body weight, of crumb rubber) and the concentration of the contaminant.
The exposure rate was calculated with the following equation:

E (mg/kg day) = (SA x AF x ABS x EF x ED x BIO) / (BW x AT)

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The parameters used are reported in Table 4.

Table 4 Parameters used to evaluate the health effects from direct dermal contact.

	Child	Adult	Athlete	Worker[a]
Amount of skin exposed to crumb rubber (SA) [cm²]	4000	8600	8600	6253
Soil-to-skin adherence (AF) [mg/cm²/day]	1	1	1	1
Dermal adsorption factor (ABS)	0.1	0.1	0.1	0.1
Exposure frequency in a year (EF) [d/year]	100	100	208	120
Exposure duration (ED) [years]	6	30	20	30
Bioavailability factor (BIO)	0.001	0.001	0.001	0.001
Body weight (BW) [kg]	25	70	70	70
Average exposure duration for non-carcinogenic substances (AT) [years]	6	30	20	30
Average exposure duration for carcinogenic substances (AT) [years]	70	70	70	70

a) value taken from the Waste and Chemicals RA to allow for comparison.

As per the EPA methods (NDEQ, 2009) for non-carcinogenic chemicals, the total hazard quotient (HQ) was calculated as in the following equation:

HQ = ADI / RfD

For non-carcinogenic compounds, acceptable HQ values are less than 1.

For carcinogenic substances, the cancer risk (CR) was calculated as follows:

CR = LDI X CSF

An additional lifetime cancer risk of 10^{-6} is deemed to be acceptable for the individual CR while for the cumulative CR the maximum acceptable value is 10^{-5} (Leg. Dec. 152/2006).
The pertinent RfD and CSF values are listed in the ISS-ISPESL (Istituto Superiore di Sanità – Istituto Superiore per la Prevenzione e Sicurezza del Lavoro) Database.

Table 5 Determination of ADI, LDI, HQ and CR for the direct dermal contact exposure route

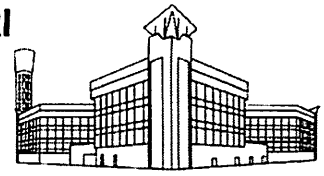
	ADI	LDI	HQ	CR
Child	7.17×10^{-8}	3.07×10^{-8}	2.28×10^{-8}	2.44×10^{-7}
Adult	9.33×10^{-8}	8.00×10^{-9}	2.97×10^{-8}	5.84×10^{-8}
Athlete	1.49×10^{-7}	4.26×10^{-8}	4.75×10^{-8}	3.11×10^{-7}
Worker	6.25×10^{-8}	2.68×10^{-8}	1.99×10^{-8}	1.96×10^{-7}

Concluding remarks

This study supports the previous study performed by Ecopneus / Waste and Chemicals on athletes and workers. The original study was based on direct personal sampling and the analysis of PAHs during activities. The results showed no human health risk for both carcinogenic and non-carcinogenic effects, for workers and players.

The results proposed from this scenario are based on published observations that PM10 levels do not increase significantly with respect to environmental PM10 levels during activities on artificial turf. This is a worst-case scenario, as it considers 100% PM10 made of ELT derived rubber, with a 100% release in the blood stream of the exposed population.

The risk assessment results, obtained using experimental PAH levels from representative samples of rubber recycled from ELTs collected in Italy between October 2014 and January 2015, confirm previous observations that no human health risks derive from activities on artificial turf, in terms of both carcinogenic and non-carcinogenic effects.



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