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Editor
Prof. Dr Snežana Šerbula

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HUMAN HEALTH RISK ASSESSMENT OF PTEs IN ELECTROFILTER ASH AND CHRONOSEQUENCE FLY ASH FROM „TENT A“ DISPOSAL SITES

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Abstract

The aim of the present study was to evaluate the health risk of potentially toxic elements (PTEs) As, B, Cr, Cu, Mn, Ni and Zn in electrofilter ash (EFA) and fly ash (FA) from chronosequential FA lagoons L0, L1 and L2 (with weathering and revegetation duration of 0, 3 and 11 years, respectively) for the health of residents (children and adults) in the vicinity of Nikola Tesla A Thermal Power Plant (TENT A), Obrenovac, Serbia. Namely, spreading FA on the surrounding agricultural land, roadside and residential areas may expose the surrounding population to the harmful effects of PTEs and endanger their health through direct ingestion, dermal contact or inhalation. Health risk analysis has shown that oral ingestion of EFA and FA poses the highest potential risk to both adults and children. Children are more susceptible to the health effects of PTE compared to adults, and As poses a potential noncarcinogenic risk to children from ingestion, especially in the case of EFA and raw FA from L0 , while the noncarcinogenic risk potential of Cr in EFA is present in both children and adults. The cumulative noncarcinogenic effect of all tested elements was present in children in the case of ingestion of both EFA and FA from L0 and L1, while for adults only in the case of ingestion of EFA. On the other hand, the carcinogenic risk of EFA and FA from all lagoons was within acceptable limits. The results of this study could be useful to obtain basic information about the health risk status of people living in these areas.

Keywords: fly ash; potentially toxic elements; health risk.

INTRODUCTION

Fly ash (FA), a byproduct of coal combustion, is a hazardous material that is stored in landfills in the open because of its low utilization. The content of potentially toxic elements (PTEs) in FA is often excessive, so the possibility of fine particles from FA being dispersed into surrounding habitats means that these landfills are a constant source of pollution and a serious global environmental and ecological threat to air, water, and soil, which can also affect public health [1]. Human exposure to PTEs occurs through ingestion, inhalation, and dermal contact [2,3], and any high concentration of PTEs that enters body tissues threatens human health and leads to serious health risks [4]. Unfortunately, research on the effects of FA on human health is limited and mostly based on animal testing. However, some studies have shown that workers in thermal power plants have a higher risk of malignancy, cytogenic damage and chromosomal aberrations, while studies on parents' perceptions of children's health have shown that 85% of parents report harmful effects of coal FA on respiratory organs, emotional and behavioral disorders in their children [5]. For these reasons, the main objective of this study was to evaluate the noncarcinogenic and carcinogenic health risks of PTEs (As, B, Cr, Cu, Mn, Ni, and Zn) for children and adults through different exposure pathways based on the content of PTE in electrofilter ash (EFA) and ash from three ash landfill lagoons where the ash was deposited and exposed to weathering and vegetation influence for 0 (L0), three (L1), and 11 (L2) years.

MATERIALS AND METHODS

Sampling and PTEs analysis

Nikola Tesla A thermal power plant (TENT A) is located in the municipality of Obrenovac (44°30' N, 19°58' E, average altitude 80 m) on the right bank of the Sava River, 41 km upstream from Belgrade, the capital of the Republic of Serbia. TENT A consists of 6 generator units with a total capacity of 1726.5 MW. Approximately 2.2–2.5 × 109 kg FA is produced annually, deposited in three lagoons on an area of 400 ha. The studies were conducted on samples of electro filter ash (EFA) and FA from all three lagoons (from a depth of 0–10 cm) characterised by ash of different ages: active lagoon – raw ash (L0), passive lagoon weathered and revegetated for 3 years (L1), and passive lagoon weathered and revegetated for 11 years (L2). Total concentrations of PTEs (As, B, Cr, Cu, Mn, Ni, and Zn) in the FA samples were analysed using inductively coupled plasma optic emission spectrometry (ICP-OES, Spectro Genesis, Spectro-Analytical Instruments GmbH, Kleve, Germany). The obtained concentrations of PTEs, which were the subject of health risk assessment, are described in detail in Kostić *et al*. [6]. In the EFA (As, B, Cr, Cu and Ni) as well as in FA from L0 (As, B, Cr and Ni) and in the two passive lagoons L1 and L2 (Ni), the concentrations of some hazardous and harmful substances exceeded the maximum permissible values in soil [7].

Health risk assessment

Noncarcinogenic risks (HQs) of PTEs to children and adults in residential areas by ingestion ($HQing$), dermal absorption ($HQder$), and inhalation ($HQinh$), and carcinogenic risks (CRs) are calculated according to USEPA recommendations [8,9] using the following equations (1)–(8):

Noncarcinogenic risk:

$$HQing = [(C \times \mathrm{IngR} \times RBA \times EF \times ED)/(BW \times AT \times RfDo)] \times 10^{-6} \quad (1)$$

$$HQder = [(C \times SA \times AF \times ABS \times EF \times ED)/ (BW \times AT \times RfDo \times GIABS)] \times 10^{-6} \quad (2)$$

$$HQinh = [(C \times \mathrm{InhR}\ \mathrm{x} EF \times ED)/(\mathrm{BW\ x}\ AT \times RfC \times PEF)] \quad (3)$$

Carcinogenic risk:

$$CRing = (C * IFS * RBA * CSFo)/AT) \times 10^{-6} \quad (4)$$

$$IFS = (EF \times EDa \times \mathrm{IngR}\ a/BWa) + (EF \times EDc \times \mathrm{IngR}\ c/BWc) \quad (5)$$

$$CRder = [(C \times DFS \times ABS \times CSFo)/(AT \times GIABS)] \times 10^{-6} \quad (6)$$

$$DFS = (EF \times EDa \times SAa \times AFa/BWa) + (EF \times EDc \times SAc \times AFc/BWc) \quad (7)$$

$$CRinh = C \times EF \times ED \times IUR \times 1000/AT \times PEF \quad (8)$$

The total noncarcinogenic risk for each of the three exposure pathways was assessed using the hazard index ($HI = HQing + HQder + HQinh$), which is the sum of the HQs for all exposure pathways for each PTE. The total carcinogenic risk ($TCR = CRing + CRder + CRinh$) is calculated using the same principle as the noncarcinogenic risk. Cumulative values (CHQs and CCRs) were calculated to obtain the total impact of all tested elements for each exposure route and the impact of all elements through all exposure routes together (CHI and CTCR). If the values for the noncarcinogenic risk HQ and HI are below 1, no adverse health effects are expected, whereas an increase in these values increases the possibility of adverse noncarcinogenic effects [3,10,11]. The carcinogenic risks that are between 10–4 and 10–6 are considered acceptable [3,11,12]. The values and units associated with these equations are listed in Table 1.

Table 1 *Description and values of all parameters related to health risk assessment for PTEs*

Symbol	Parameters (units)	Values	Ref.
C	PTE concentration (mg/kg)	Site specific	
IngR	Ingestion (mg/day)	200 (child) 100 (adult)	[8]
InhR	Inhalation rate (mg/day)	7.63 (child) 20 (adult)	[8]
EF	Exposure Frequency (days/year)	350 (adult, child)	[8]
ED	Exposure Duration (years)	6 (child) 38 (adult)	[8]
BW	Body Weight (kg)	15 (child) 80 (adult)	[8]
AT	Averaging time (days)	365 x ED; 365*LT=27740 (Carcinogenic) Site specific	[8]
SA	Exposed skin area (cm^2)	2373 (child) 6032 (adult)	[8]
AF	Skin adherence factor (mg/cm^2)	0.2 (child) 0.07 (adult)	[8]
ABS	Dermal absorption factor	0.03 (As) 0.001 (all other PTE)	[9]
RfD_o	Reference Dose – Oral (mg/kg-day)	0.0003 (As); 0.2 (B); 0.003 (Cr); 0.04 (Cu); 0.024 (Mn); 0.02 (Ni); 0.3 (Zn)	[9]
RfC	Reference Concentration – Inhalation (mg/m^3)	0.000015 (As); 0.02 (B); 0.0001 (Cr); 0.0024 (Cu); 0.00005 (Mn); 0.00009 (Ni); 0.0353 (Zn)	[8,13]
GIABS	Fraction of contaminant absorbed in gastrointestinal tract (unitless)	1.0 (As, B, Cu, Zn); 0.025 (Cr); 0.04 (Mn, Ni)	[9]
PEF	Particulate Emission Factor (m^3/kg)	1.36 x 10^9(region-specific)	[8]
RBA	Relative bioavailability factor	0.6 (As); 1 (all other PTE)	[8]
IFS	Resident Soil Ingestion Rate (mg/kg)	Calculated using the age adjusted intake factors equation 44625	[8]
CSFo	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	1.5 (As); 0.5 (Cr); 0.84 (Ni)	[9,13]
DFS	Resident soil dermal contact factor (mg/kg)	Calculated using the age adjusted intake factors equation 136641.4	[8]
IUR	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	0.0043 (As); 0.084 (Cr); 0,0003 (Ni)	[9,13]
LT	Life time (years)	76 Site specific	

RESULTS AND DISCUSSION

Noncarcinogenic and carcinogenic risks were determined for the respective PTEs in EFA and FA of L0, L1, and L2 for both adults and children via different pathways, whereas carcinogenic risk was quantified only for the elements with defined slope factor (As, Cr, and Ni). The highest HQs, HIs, CHQs, and CHIs were found in EFA and decreased in the following order: EFA > L0 > L1 > L2, which is consistent with the fact that the concentrations of PTE in the studied samples were the highest in EFA [6]. These results suggest that the risk of non-carcinogenic toxicity decreases with decreasing PTE content and aging of FA during exposure to weather conditions and the influence of vegetation. The risks of noncarcinogenic toxicity from ingestion of EFA and FA from all three lagoons were greater than those from dermal contact or inhalation (HQing > HQder > HQinh) for both children and adults (Tables 2 and 3), suggesting that ingestion is the most important route of exposure in terms of health risks [11,14]. In children, considering all three exposure routes of PTE, the noncarcinogenic risk was the highest for As and decreased in the following order: As > Cr > Mn > Ni > B > Cu > Zn, while in adults it decreased as follows: HQing Cr > As > Mn > Ni > B > Cu > Zn; HQder As > Cr > Mn > Ni > B > Cu > Zn; and HQinh As > Mn > Cr > Ni > Cu > B > Zn.

Table 2 *Noncarcinogenic risk (HQ, CHQ, HI and CHI) to children from ingestion, inhalation and dermal contact*

HQing	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQing**
EFA	**4.04**	6.26 x 10^{-2}	**1.32**	4.22 x 10^{-2}	2.02 x 10^{-1}	7.80 x 10^{-2}	4.56 x 10^{-3}	**5.75**
L0	**1.54**	5.95 x 10^{-3}	6.38 x 10^{-1}	2.54 x 10^{-2}	1.78 x 10^{-1}	5.48 x 10^{-2}	2.75 x 10^{-3}	**2.44**
L1	5.53 x 10^{-1}	2.56 x 10^{-3}	3.18 x 10^{-1}	1.48 x 10^{-2}	1.16 x 10^{-1}	3.97 x 10^{-2}	1.68 x 10^{-3}	**1.05**
L2	4.83 x 10^{-1}	1.84 x 10^{-3}	2.48 x 10^{-1}	1.24 x 10^{-2}	1.14 x 10^{-1}	3.79 x 10^{-2}	1.51 x 10^{-3}	8.98 x 10^{-1}
HQder	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQder**
EFA	4.79 x 10^{-1}	1.49 x 10^{-4}	1.25 x 10^{-1}	1.00 x 10^{-4}	1.20 x 10^{-2}	4.63 x 10^{-3}	1.08 x 10^{-5}	6.22 x 10^{-1}
L0	1.83 x 10^{-1}	1.41 x 10^{-5}	6.05 x 10^{-2}	6.04 x 10^{-5}	1.05 x 10^{-2}	3.25 x 10^{-3}	6.53 x 10^{-6}	2.57 x 10^{-1}
L1	6.56 x 10^{-2}	6.07 x 10^{-6}	3.02 x 10^{-2}	3.52 x 10^{-5}	6.90 x 10^{-3}	2.36 x 10^{-3}	3.99 x 10^{-6}	1.05 x 10^{-1}
L2	5.73 x 10^{-2}	4.37 x 10^{-6}	2.35 x 10^{-2}	2.95 x 10^{-5}	6.74 x 10^{-3}	2.25 x 10^{-3}	3.59 x 10^{-6}	8.99 x 10^{-2}
HQinh	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQinh**
EFA	3.78 x 10^{-3}	1.76 x 10^{-5}	1.11 x 10^{-3}	1.97 x 10^{-5}	2.73 x 10^{-3}	4.86 x 10^{-4}	1.10 x 10^{-6}	8.14 x 10^{-3}
L0	1.44 x 10^{-3}	1.67 x 10^{-6}	5.37 x 10^{-4}	1.19 x 10^{-5}	2.39 x 10^{-3}	3.42 x 10^{-4}	6.62 x 10^{-7}	4.72 x 10^{-3}
L1	5.17 x 10^{-4}	7.18 x 10^{-7}	2.67 x 10^{-4}	6.94 x 10^{-6}	1.57 x 10^{-3}	2.48 x 10^{-4}	4.04 x 10^{-7}	2.61 x 10^{-3}
L2	4.52 x 10^{-4}	5.16 x 10^{-7}	2.08 x 10^{-4}	5.81 x 10^{-6}	1.53 x 10^{-3}	2.36 x 10^{-4}	3.64 x 10^{-7}	2.43 x 10^{-3}
HI	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHI**
EFA	**4.52**	6.28 x 10^{-2}	**1.45**	4.23 x 10^{-2}	2.17 x 10^{-1}	8.31 x 10^{-2}	4.57 x 10^{-3}	**6.38**
L0	**1.72**	5.97 x 10^{-3}	6.99 x 10^{-1}	2.55 x 10^{-2}	1.91 x 10^{-1}	5.84 x 10^{-2}	2.76 x 10^{-3}	**2.71**
L1	6.19 x 10^{-1}	2.57 x 10^{-3}	3.48 x 10^{-1}	1.49 x 10^{-2}	1.25 x 10^{-1}	4.23 x 10^{-2}	1.69 x 10^{-3}	**1.15**
L2	5.41 x 10^{-1}	1.84 x 10^{-3}	2.71 x 10^{-1}	1.25 x 10^{-2}	1.22 x 10^{-1}	4.04 x 10^{-2}	1.52 x 10^{-3}	9.90 x 10^{-1}

HQ—hazard quotient; CHQ—cumulative HQ; HI—hazard index; CHI—cumulative HI. Values > 1 are in bold. [a] Cr(VI).

Table 3 *Noncarcinogenic risk (HQ, CHQ, HI, and CHI) to adults from ingestion, inhalation, and dermal contact*

HQing	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQing**
EFA	3.79 x 10^{-1}	5.87 x 10^{-3}	**1.24**	3.96 x 10^{-3}	1.90 x 10^{-2}	7.31 x 10^{-3}	4.28 x 10^{-4}	**1.65**
L0	1.44 x 10^{-1}	5.58 x 10^{-4}	5.98 x 10^{-1}	2.38 x 10^{-3}	1.66 x 10^{-2}	5.14 x 10^{-3}	2.58 x 10^{-4}	7.67 x 10^{-1}
L1	5.18 x 10^{-2}	2.40 x 10^{-4}	2.98 x 10^{-1}	1.39 x 10^{-3}	1.09 x 10^{-2}	3.72 x 10^{-3}	1.58 x 10^{-4}	3.66 x 10^{-1}
L2	4.53 x 10^{-2}	1.72 x 10^{-4}	2.32 x 10^{-1}	1.17 x 10^{-3}	1.06 x 10^{-2}	3.55 x 10^{-3}	1.42 x 10^{-4}	2.93 x 10^{-1}
HQder	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQder**
EFA	8.00 x 10^{-2}	2.48 x 10^{-5}	2.09 x 10^{-2}	1.67 x 10^{-5}	2.00 x 10^{-3}	7.72 x 10^{-4}	1.81 x 10^{-6}	1.04 x 10^{-1}
L0	3.05 x 10^{-2}	2.36 x 10^{-6}	1.01 x 10^{-2}	1.01 x 10^{-5}	1.76 x 10^{-3}	5.42 x 10^{-4}	1.09 x 10^{-6}	4.29 x 10^{-2}
L1	1.09 x 10^{-2}	1.01 x 10^{-6}	5.03 x 10^{-3}	5.87 x 10^{-6}	1.15 x 10^{-3}	3.93 x 10^{-4}	6.66 x 10^{-7}	1.75 x 10^{-2}
L2	9.57 x 10^{-3}	7.28 x 10^{-7}	3.92 x 10^{-3}	4.92 x 10^{-6}	1.12 x 10^{-3}	3.75 x 10^{-4}	5.99 x 10^{-7}	1.50 x 10^{-2}
HQinh	**As**	**B**	**Cr[a]**	**Cu**	**Mn**	**Ni**	**Zn**	**CHQinh**
EFA	1.86 x 10^{-3}	8.64 x 10^{-6}	5.46 x 10^{-4}	9.69 x 10^{-6}	1.34 x 10^{-3}	2.39 x 10^{-4}	5.34 x 10^{-7}	4.00 x 10^{-3}
L0	7.08 x 10^{-4}	8.20 x 10^{-7}	2.64 x 10^{-4}	5.84 x 10^{-6}	1.18 x 10^{-3}	1.68 x 10^{-4}	3.23 x 10^{-7}	2.32 x 10^{-3}
L1	2.54 x 10^{-4}	3.53 x 10^{-7}	1.31 x 10^{-4}	3.41 x 10^{-6}	7.69 x 10^{-4}	1.22 x 10^{-4}	1.97 x 10^{-7}	1.28 x 10^{-3}
L2	2.22 x 10^{-4}	2.54 x 10^{-7}	1.02 x 10^{-4}	2.86 x 10^{-6}	7.51 x 10^{-4}	1.16 x 10^{-4}	1.77 x 10^{-7}	1.20 x 10^{-3}
HI	**As**	**B**	**Cra**	**Cu**	**Mn**	**Ni**	**Zn**	**CHI**
EFA	4.61 x 10^{-1}	5.91 x 10^{-3}	**1.26**	3.98 x 10^{-3}	2.23 x 10^{-2}	8.32 x 10^{-3}	4.30 x 10^{-4}	**1.76**
L0	1.76 x 10^{-1}	5.61 x 10^{-4}	6.08 x 10^{-1}	2.40 x 10^{-3}	1.96 x 10^{-2}	5.85 x 10^{-3}	2.60 x 10^{-4}	8.13 x 10^{-1}
L1	6.30 x 10^{-2}	2.41 x 10^{-4}	3.03 x 10^{-1}	1.40 x 10^{-3}	1.28 x 10^{-2}	4.24 x 10^{-3}	1.58 x 10^{-4}	3.85 x 10^{-1}
L2	5.51 x 10^{-2}	1.73 x 10^{-4}	2.36 x 10^{-1}	1.17 x 10^{-3}	1.25 x 10^{-2}	4.04 x 10^{-3}	1.43 x 10^{-4}	3.09 x 10^{-1}

HQ—hazard quotient; CHQ—cumulative HQ; HI—hazard index; CHI—cumulative HI. Values > 1 are in bold. [a] Cr(VI).

Compared with children, non-cancer risk values for adults were significantly lower for all three exposure pathways, which is in accordance with previous studies [3,14]. Higher risk values for children may be the result of higher ash intake (200 mg/day), lower body weight, longer outdoor play time, hand-to-mouth activities, intentional consumption of contaminated foods, and a less developed immune system [15]. The HQ and HI values for both children and adults were found to be lower than 1 for B, Cu, Mn, Ni, and Zn in all analyzed samples, indicating that exposure to these elements doesn't pose a significant noncarcinogenic health risk (Tables 2 and 3). However, HQing and HI, which are higher than 1 for As and Cr in EFA and FA from L0 for children and Cr in EFA for children and adults, indicate that these elements in EFA and FA from L0 pose a significantly higher noncarcinogenic risk compared with the other PTE tested.

Table 4 *Carcinogenic risk (CR, CCR, TCR and CTCR) to residents from ingestion, inhalation and dermal contact*

CRing	**As**	**Cr [a]**	**Ni**	**CCRing**
EFA	2.29×10^{-4}	2.49×10^{-4}	8.29×10^{-5}	5.61×10^{-4}
L0	8.72×10^{-5}	1.20×10^{-4}	1.16×10^{-4}	3.23×10^{-4}
L1	3.13×10^{-5}	6.00×10^{-5}	8.40×10^{-5}	1.75×10^{-4}
L2	2.74×10^{-5}	4.67×10^{-5}	8.01×10^{-5}	1.54×10^{-4}
CRder	**As**	**Cr [a]**	**Ni**	**CCRder**
EFA	8.55×10^{-5}	3.05×10^{-5}	6.35×10^{-6}	1.22×10^{-4}
L0	3.26×10^{-5}	1.47×10^{-5}	8.87×10^{-6}	5.62×10^{-5}
L1	1.17×10^{-5}	7.35×10^{-6}	6.43×10^{-6}	2.55×10^{-5}
L2	1.02×10^{-5}	5.72×10^{-6}	6.13×10^{-6}	2.21×10^{-5}
CRinh	**As**	**Cr [a]**	**Ni**	**CCRinh**
EFA	2.77×10^{-7}	1.06×10^{-5}	7.51×10^{-9}	1.09×10^{-5}
L0	1.06×10^{-7}	5.13×10^{-6}	1.05×10^{-8}	5.25×10^{-6}
L1	3.79×10^{-8}	2.56×10^{-6}	7.61×10^{-9}	2.60×10^{-6}
L2	3.32×10^{-8}	1.99×10^{-6}	7.26×10^{-9}	2.03×10^{-6}
TCR	**As**	**Cr [a]**	**Ni**	**CTCR**
EFA	3.14×10^{-4}	2.91×10^{-4}	8.93×10^{-5}	6.94×10^{-4}
L0	1.20×10^{-4}	1.40×10^{-4}	1.25×10^{-4}	3.85×10^{-4}
L1	4.30×10^{-5}	6.99×10^{-5}	9.04×10^{-5}	2.03×10^{-4}
L2	3.76×10^{-5}	5.44×10^{-5}	8.62×10^{-5}	1.78×10^{-4}

CR—carcinogenic risk; CCR—cumulative CR; TCR—total CR; CTCR—cumulative TCR; [a] Cr(VI).

Moreover, the cumulative noncarcinogenic effect of all tested elements (CHQing and CHI) in children was also present in the case of FA from L1, indicating an increased sensitivity of children to the effects of PTEs [3,12].

In our study, CCR values decreased for all three exposure pathways in the following order: CCRing > CCRder > CCRinh, and when comparing the studied samples, it can be seen that EFA has the highest potential risk for the development of cancerous diseases in residents near TENT A, which decreased in the order EFA > L0 > L1 > L2 (Table 4). The highest CR values were found for As and Cr, and it is known that chronic exposure to As can cause skin, lung, and bladder cancer in humans [16], and Cr(VI) is classified in the A group of carcinogens. elements [17]. However, the carcinogenic risks of EFA and FA from all tree lagoons were within acceptable limits of 1×10^{-4} to 1×10^{-6}, indicating that carcinogenic risks to residents around TENT A were not expected.

CONCLUSION

The potential health risks of PTEs (As, B, Cr, Cu, Mn, Ni, and Zn) in elecrtofilter ash (EFA) and fly ash (FA) from chronosequence disposal lagoons to residents near TENT A, Obrenovac, Serbia, were evaluated using a model developed by USEPA. The health risk analysis showed that children are more susceptible to the health effects of PTE compared to adults and that the main route of adverse effects is ingestion. The noncarcinogenic risks of the tested samples were in the acceptable range for all tested PTEs, except for As in EFA and FA from L0 for children and Cr in EFA for both children and adults, while the cumulative noncarcinogenic effect of all tested PTEs was present in children and adults in case of ingestion of EFA, while it was also present in children in case of ingestion of FA from L0 and L1. Although the results show that the total potential carcinogenic risk for residents near TENT A is in the acceptable range, the potential for the development of carcinogenic diseases is the highest in the case of EFA ingestion and decreases with decreasing concentration of PTEs (EFA > L0 > L1 > L2). Finally, the results of this study may be useful in providing baseline information on the health risk status of people living near TENT A.

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