

A STATISTICAL PROCEDURE FOR THE QUALIFICATION OF INDOOR DUST

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ABSTRACT

The materials science advance has contributed to the humanity. Notwithstanding, serious environmental and human health problems are often observed. Thereby, many worldwide researchers have focused their work to diagnose, assess and monitor several environmental systems. In this work, a statistical procedure (on a 0.05 significance level) that allows verifying if indoor dust samples have characteristics of soil/sediment is presented.

Dust samples were collected from 69 residences using a domestic vacuum cleaner in four neighborhoods of the Sao Paulo metropolitan region, Brazil, between 2006 and 2008. The samples were sieved in the fractions of 150-75 (C), 75-63 (M) and <63 μm (F). The elemental concentrations were determined by X-ray fluorescence (WDXRF). Afterwards, the indoor samples results (group A) were compared to the group of 109 certificated reference materials, which included different kinds of geological matrices, such as clay, sediment, sand and sludge (group B) and to the continental crust values (group C). Initially, the Al/Si ratio was calculated for the groups (A, B, C). The variance analysis (ANOVA), followed by Tukey test, was used to find out if there was a significant difference between the concentration means of the considered groups. According to the statistical tests; the group B presented results that are considered different from others. The interquartile range (IQR) was used to detected outlier values. ANOVA was applied again and the results ($p \geq 0.05$) showed equality between ratios means of the three groups. Accordingly, the results suggest that the indoor dust samples have characteristic of soil/sediment. The statistical procedure may be used as a tool to clear the information about contaminants in dust samples, since they have characteristic of soil and may be compared with values reported by environmental control organisms.

1. INTRODUCTION

Technological advances have undoubtedly promoted better conditions for human survival. Notwithstanding, associated with these benefits; the biosphere degradation with the same speed is noted. An effort at reconciliation or harmony between the environment and technological development began in 1980s, when it became more visible and worrying in the human landscape, such as: greenhouse effect, acid rain, global warming, ozone hole, oceans pollution, deforestation and animal species extinction, non-renewable resources depletion and others. Thereby, many worldwide researchers have focused their studies to monitor the air, water and soil quality, in particular outdoors and to identify the probable pollution sources that contribute to such environmental impacts. Currently, 10,000 new organic and inorganic substances are added every day in a database of a division of the American Chemical Society

(CAS) [1], which already has registered more than 45 million substances. These substances are destined to fabrication of a variety of artifacts and compounds that are used in automobile, pharmaceutical and cosmetics industries, agriculture, engineering civil and others. Among the most used substances, the polychlorinated biphenyls, organochlorine and organophosphorus pesticides, the esters phthalic, brominated flame retardants and some metals as Ni, Zn, Cd, Sn, As, Ba, Hg, Pb and others may be highlighted [2,3]. According to researchers, these substances (that are considered potentially toxic) are incorporated to manufactured product due to natural process of wearing or weather incidents. After, they will probably be released into the environment in the steam form or by leaching from final products. There are very few studies about indoor environments, which is worrying since people spend most of their time (80-90%) in enclosed spaces, whether at home, school or work [4, 5, 6, 7]. Furthermore, according to the United States Environmental Protection Agency (EPA) the pollutants concentration levels may be 2 to 5 times higher in indoor environments than outdoor. This fact may be not attributed only to poor air quality, but also by the formation of a material (known as "indoor dust" or "house dust") which are derived from rocks and soil fragments, sea salt, waste of pieces wear and vehicular gas emissions, skin and hair, plants and animals, building materials, maintenance products, cleaning and hygiene. The indoor dust is a heterogeneous mixture and has the property to adsorb pollutants, which are not degraded or are slowly degraded; therefore, they could be accumulated and enriched in the dust material [8]. Accordingly, indoor environments may offer several risks for human health, since the correlation between substances potentially toxic and health effects (such as allergic, immune system, respiratory, cardiovascular, nervous system, irritation of the eyes and mucous, reproductive system and cancer) is frequently observed [9]. Hence, in this work a statistical procedure to qualify the indoor dust samples in soil/sediment or organic material was proposed. In addition, the enrichment factor was calculated to identify the main source (natural or anthropogenic) of the elements present in the indoor dust samples. The elemental concentrations were determined by X-ray fluorescence (WDXRF) and the data set was compared with the values of exposure (ingestion, inhalation and dermal contact) and risk for human health.

2. MATERIALS AND METHODS

2.1. Sampling

The indoor dust was collected from 69 dwelling in the north of the São Paulo metropolitan region, in neighborhoods: Pirituba, Freguesia do Ó, Jaraguá and Perus, 10 km² far from each other, between 2006 and 2008. The sampling sites were chosen according to: traffic volume (low and heavy), residential category (apartments and houses) and proximity to train station, parks, dumpsites and cemeteries, besides, the per capita income (estimated at 2 to 20 minimum wages) was also taken into consideration. The collect was performed by the residents themselves, by using a domestic vacuum cleaner with disposable bags (paper), according to the manufacturer model. The sampling procedure followed a protocol designed to capture all the surface dust, based on documents provided by the EPA [10]. Participants were instructed to vacuum only the internal residence and all the routine surfaces, which included bare floors, rugs and wall-to-wall carpets. To achieve a balance between the internal and external environment, the samples were stored during 1-4 months. After the dust collection, the vacuum cleaner bags were sealed with filter paper and then taken to the laboratory. In addition, a questionnaire containing various information about the householder

habits (number of adults, children and pets and lifestyle factors) and the internal and external characteristics of the sampling locations (kind of the house structure, heating sources, renovation/redecoration) were obtained for each dwelling place.

2.2 Preparation of samples

The indoor dust samples were sieved at 150-75 μm (C: coarse), 75-63 μm (M: medium) and <63 μm (F: fine) particle size fraction by vibrational sifting (Bertel), using sieves of 30 cm diameter, at 60 Hz frequency for one hour. Subsequently, the samples were prepared as simple pressed pellets. *Circa of* 2g to 3g of acid boric (H_3BO_3) were accommodated in a cylindrical mould (Hydraulic press-B. Herzog, model HTP40) and pressed at 100 MPa for 1 minute, obtaining one basis; then, dust sample amounts 0.3-0.5g were added on this base and pressed under 203 MPa for 1 minute, resulting a 20 \pm 1mm diameter and 10 \pm 1mm thickness.

2.3 Analytical Procedure

The elemental concentrations for Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Rb, Sr, Zr, Cd, Ba, Hg and Pb were determined using a Rigaku Co., model RIX 3000, X-ray fluorescence spectrometer. The following instrumental conditions were established for each element: X-ray tube: Rh; Excitation: 50kV x 50mA; Collimators: 160 and 480 μm ; Analyzing crystals: lithium fluoride (LiF-200), germanium (Ge-111), thallium phosphate (TAP) and pentaerythritol (PET-111); Detectors: scintillation (SC) and flow-proportional counters (FPC). The matrix effect was corrected using the fundamental parameters method (FP).

2.4 Statistical methods

The samples characterization was performed by WDXRF. The ratios of Al/Si for the dust samples, the 109 certified reference materials (clay, sediment, sand and sludge, supplied by GSJ, IPT, NIST and BCS) for the continental crust values reported by literature were obtained. The results were statistically evaluated by variance analysis (ANOVA) and Tuckey test, using the software Microsoft Excel and Origin version 7.5. The values outliers found by the interquartile range (IQR) test were discarded. The ANOVA was run after the elimination of outliers.

2.4 Enrichment factor

The enrichment factor (EF) is a standardization method that allows identifying if a determinate element is contaminant or constituent, frequently used on soil, sediment and dust samples. The requisite to apply this method is identifying the conservative element; which it must be the most abundant constituent of the earth crust, i.e. without enrichment due to the anthropogenic activities. According to the literature, the metals Al, Fe, Mn, Sc and Ti are the most commonly used to calculate the EF [11, 12, 13, 14, 15, 16]. In this study, the most appropriate conservative element was chosen after using the Mahalanobis distance to detect and reject the outliers values for the sample set (n=69). Then, the Shapiro Wilk test was applied to check the normality of the data. Afterwards, the analysis of factors (AF) was used to calculate the correlations between variables and extract the latent factors, also called loadings (significance level $p = 0.05$), for the data samples obtained from each fraction (C, M

and F). The ratio between the concentration of the element present in the sample and the element conservative was calculated. The same calculation for the concentrations of continental crust elements was performed.

The EF was obtained by the quotient between the ratios of the samples and continental crust, according to Eq. 1 [12]:

$$EF = \frac{\left(\frac{Me}{Al}\right)_{sample}}{\left(\frac{Me}{Al}\right)_{background}} \quad (1)$$

In which,

Me_{sample} = element concentration in the sample (fractions C, M and F);

$Me_{background}$ = element concentration in the background (continental crust).

The statistical calculations described in this procedure were developed using the software, STATISTICA version 8.

2.4 Multivariate analysis

The cluster analysis (CA) is a multivariate statistical method widely used in environmental studies [17, 18]. The hierarchical cluster analysis was performed using the Ward's method and squared Euclidean. The main objective of this analysis was to explore the similarities between the variables within a large data set and identifying the elemental composition qualitatively, characterizing a source or an emission of pollutant. Before, the database was scaled using the normalization standard to facilitate the data interpretation. Statistical calculations were performed by using a data analysis software system STATISTICA, version 6 from StatSoft, Inc.

3. RESULTS AND DISCUSSIONS

3.1 Indoor dust Qualification

The quantitative analysis results by WDXRF showed Si, Ca, Al, Mg, Fe, S, K, Cl and Na may be considered as the major elements in the three fractions from indoor dust samples. The highest contents of these elements were observed for the fine fraction (F: $\leq 63 \mu\text{m}$). The highest concentrations were also observed for the minor elements (Ti, Zn, Cu, P, Mn, Pb, Sr, Cr, Ni, Zr, Rb and Br) in the F fraction, as shown in Table 1.

The mathematical procedure used in this study to qualify the indoor dust like soil/sediment following steps: firstly, the ratio Al/Si for concentrations obtained by WDXRF from 69 samples in fractions C, M and F (group A), 109 certificate reference materials (group B) and the continental crust values (group C) were calculated. The statistical tests ANOVA and Tukey to data set were applied, which showed inequality between the means. Then, applied the interquartile range (IQR) test, to measure the data dispersion in group B, which eliminated 25% of lower and higher values (outliers), reducing from 109 to 36. The ANOVA

test (significance level 0.05) was run again to the new data set (69 samples for the group A and 36 samples for the groups B and C). The results showed that there is no significant difference between the groups. This mathematical procedure was also performed for the three fractions of the dust samples. Therefore the statistical treatment suggested that all samples analyzed presented soil chemical composition.

Table 1. Means, range of 69 indoor dust samples in fractions C, M e F and continental crust values

Elements	Mean			Range			Continental Crust
	C	M	F	C	M	F	
	$\mu\text{g g}^{-1} \text{ day}$						
LOI	56 \pm 12	68 \pm 11	51 \pm 10	36-87	40-94	22-74	***
Si	41 \pm 133	19 \pm 51	154 \pm 588	2-1094	1-419	3-4918	304733
Ca	34 \pm 87	15 \pm 37	74 \pm 150	1-610	1-243	1-1204	29800
Al	13 \pm 40	7 \pm 17	49 \pm 199	1-330	0.4-144	1-1665	78333
Mg	5 \pm 13	3 \pm 6	25 \pm 40	0.2-101	0.1-40	0.3-273	14933
Fe	11 \pm 26	5 \pm 11	28 \pm 86	1-180	0.4-87	2-716	41433
S	10 \pm 33	5 \pm 17	13 \pm 22	1-270	0.3-138	1-152	***
K	6 \pm 14	3 \pm 8	16 \pm 50	0.3-117	0.2-71	1-416	19200
Cl	7 \pm 8	3 \pm 3	10 \pm 13	0.5-43	0.3-17	0.3-75	***
Na	6 \pm 8	2 \pm 3	10 \pm 27	0.1-50	0.3-26	1-222	19633
Ti	2.14 \pm 6.14	0.91 \pm 2.17	4.5 \pm 14.0	0.18-49.7	0.1-17	0.5-117	4067
Zn	0.71 \pm 0.87	0.41 \pm 0.43	1.9 \pm 2.0	0.06-4.9	0.04-3	0.1-11	65
Cu	0.24 \pm 0.36	0.18 \pm 0.26	1.2 \pm 2.3	0.01-2.1	0.02-1.4	0.03-16	23
P	0.91 \pm 1.36	0.38 \pm 0.50	2.0 \pm 4.7	0.07-9.2	0.04-3.8	0.2-36	750
Mn	0.16 \pm 0.42	0.09 \pm 0.20	0.6 \pm 1.7	0.01-3.4	0.01-1.6	0.1-14	750
Pb	0.08 \pm 0.18	0.08 \pm 0.19	0.2 \pm 0.4	0.0003-1.4	0.002-1.3	0.01-3	14
Sr	0.08 \pm 0.30	0.04 \pm 0.13	0.2 \pm 0.5	0.002-2.2	0.002-1	0.01-4	325
Cr	0.06 \pm 0.07	0.05 \pm 0.08	0.1 \pm 0.1	0.001-0.4	0.003-0.6	0.02-1	85
Ni	0.06 \pm 0.12	0.03 \pm 0.04	0.1 \pm 0.2	0.004-0.8	0.003-0.3	0.01-6	37
Zr	0.03 \pm 0.14	0.02 \pm 0.09	0.1 \pm 0.7	0.001-1.1	0.0003-0.7	0.01-6	204
Rb	0.01 \pm 0.02	0.004 \pm 0.008	0.03 \pm 0.07	0.0002-0.1	0.0001-0.1	0.0005-0.5	90
Br	0.01 \pm 0.02	0.01 \pm 0.02	0.02 \pm 0.03	0.0002-0.1	0.003-0.2	0.0003-0.2	***

Source: Crosta Ccontinental [19, 20, 21]. 150-75 μm (C: coarse), 75-63 μm (M: medium) and <63 μm (F: fine) particle size fraction

A control chart to inquire with greater practicality and quickness if a sample has characteristics of soil/sediment was constructed for each fraction, containing the ratios for the 69 samples, 36 certificates reference materials and the continental crust, in the interval $\mu \pm \sigma$, $\mu \pm 2\sigma$; $\mu \pm 3\sigma$ (68%, 95% and 99.7%), according to Figure 1.

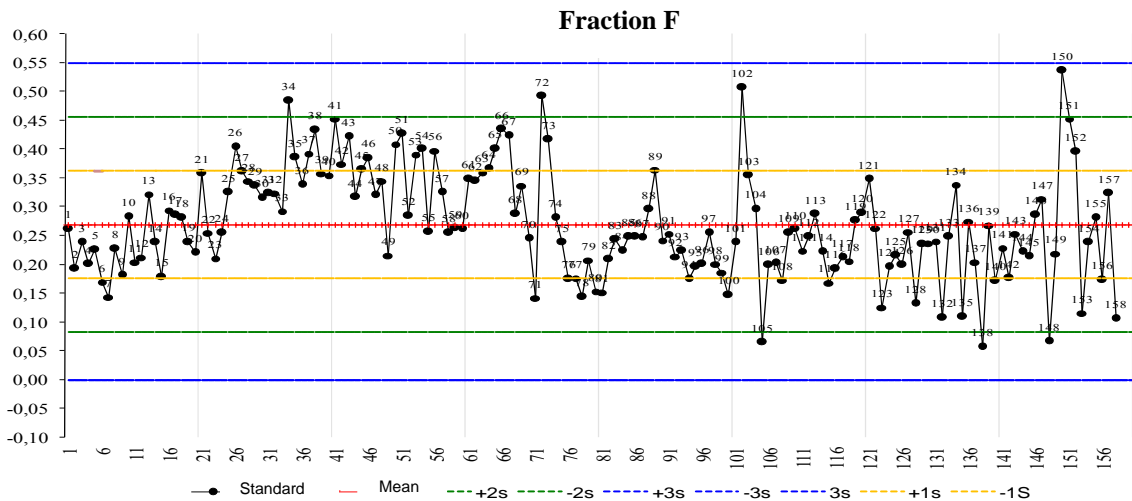
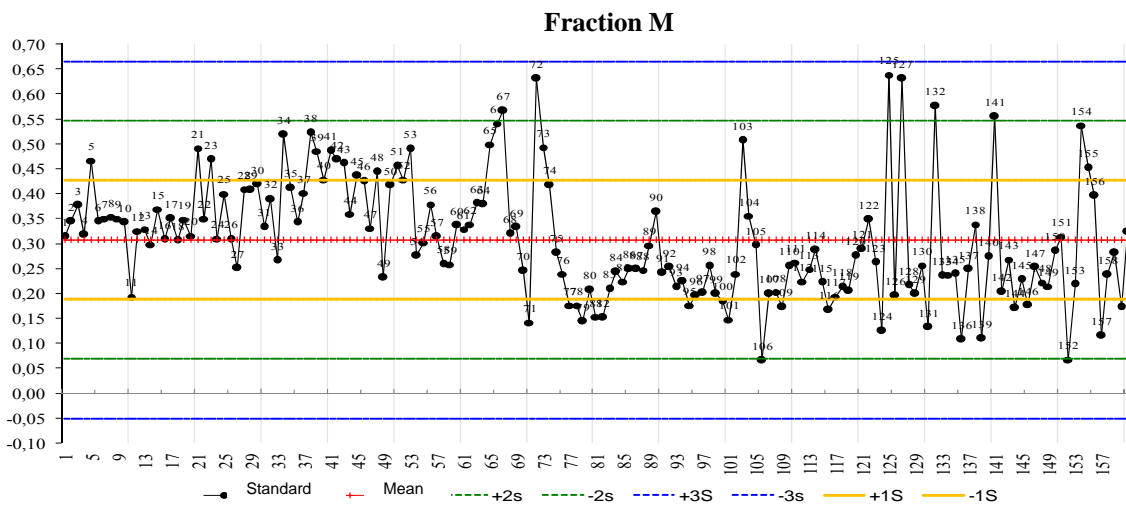
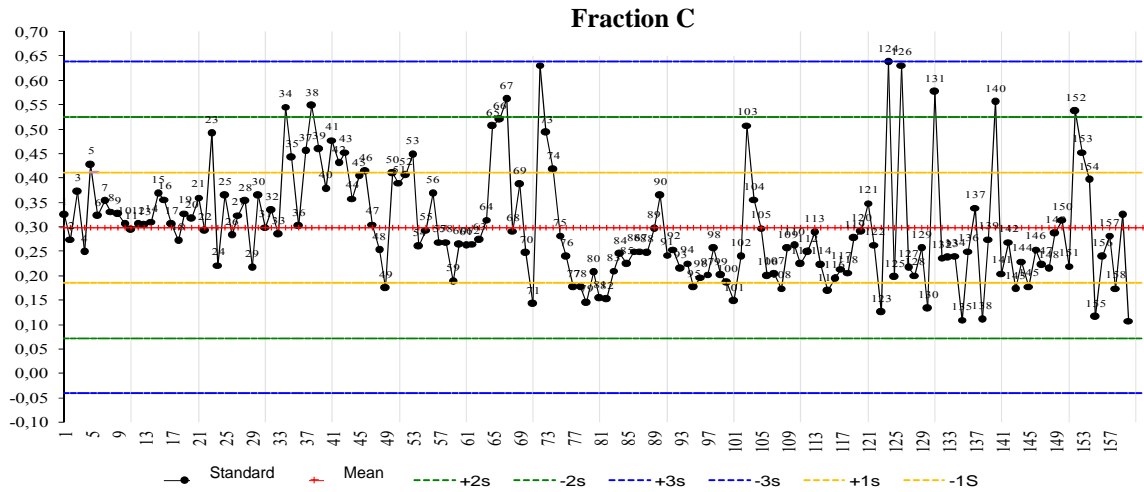


Figure 1. Control chart of ratios for the fractions C, M and F.

The materials with composition and characteristics similar to this study and the ratios (Al/Si) in the range $\mu \pm 3\sigma$ (99.7%) are classified like soil.

3.2 Analysis of enrichment factor

To evaluate if the elements present in the samples were contaminants or constituents the enrichment factor (EF) was calculated. First, it was applied the Mahalanobis test to data set obtained by WDXRF in fractions C, M and F. The outliers values were eliminated, reducing the samples number from n=69 to n=65, 55 and 60, respectively. The Shapiro Wilk 'W' test confirmed the hypothesis of normality. Thus, it may apply the statistical test for parametric data. The analysis of factors (AF) was applied to matrix 65, 55 and 60 cases (samples) versus the 22 variables (elemental concentrations determined by WDXRF), for each fraction. The results obtained from EF showed that Al presented the highest correlation with the other constituents. Therefore, this metal may be used as standardized element for the data set. Accordingly, the EF was estimated (Eq 1) for the dust samples analyzed. The Table 2 shows the enrichment factor values and contamination class, reported in the literature [22, 23, 24, 25, 26, 27, 28].

Table 2. Enrichment factor values (EF) and contamination class

Enrichment factor (EF)	Contamination class of enrichment
<2	least
2-5	moderate
5-20	significant
20-40	high
>40	extremely high

The comparison between the mean of the enrichment factors calculated for samples (WDXRF) and above mentioned values (Table 2) revealed six elements potentially enriched Zn, Cu, P, Cr, Pb and Ni (Table 3). The Zn, Cu and Pb elements were classified as extremely high (> 40). The EF of Zn decreases from C to F fraction, on the contrary, the Cu from thin to thick fraction, which demonstrate the fraction F be much more contaminated. In relation to Pb the fraction M keep the higher enrichment value. The other elements P, Cr and Ni are included into the class of significant enrichment and fraction more contaminated is C, decreasing from coarse fraction to fine.

Table 3. Mean, P-75 and P-95 of the enrichment factor calculated (EF) in fractions C, M and F

Elements	Enrichment factor (EF)								
	Fraction C			Fraction M			Fraction F		
	Mean	P-75	P-95	Mean	P-75	P-95	Mean	P-75	P-95
Zn	158	134	681	150	128	625	149	114	400
Cu	149	132	309	255	170	875	408	134	1442
P	15	14	53	10	10	36	8	7	23
Cr	12	9	22	12	9	20	6	6	10
Pb	92	60	216	112	52	199	42	42	111
Ni	16	18	41	12	13	28	9	9	14

3.3 Cluster Analysis (CA)

Cluster analysis of variables to identify the probable anthropogenic and natural sources in the fractions C, M and F was applied, on an extensive database of 23 variables (LOI (loss on ignition), W (weight), Si, Ca, Mg, Al, S, Fe, K, Cl, Na, Zn, Ti, P, Mn, Cu, Sr, Cr, Pb, Zr, Ni, Rb and Br) and 65, 55 and 60 cases (samples), respectively.

The dendrogram (Fig. 2) show graphically the results of cluster analysis, which prove a qualitative idea of the association degree between the indoor dust elements (for all fractions. Before the CA, the variables by z-scores mean were standardized and the Euclidean distances for similarity in variables were calculated. A hierarchical cluster using Ward's method with the standardized data set was developed.

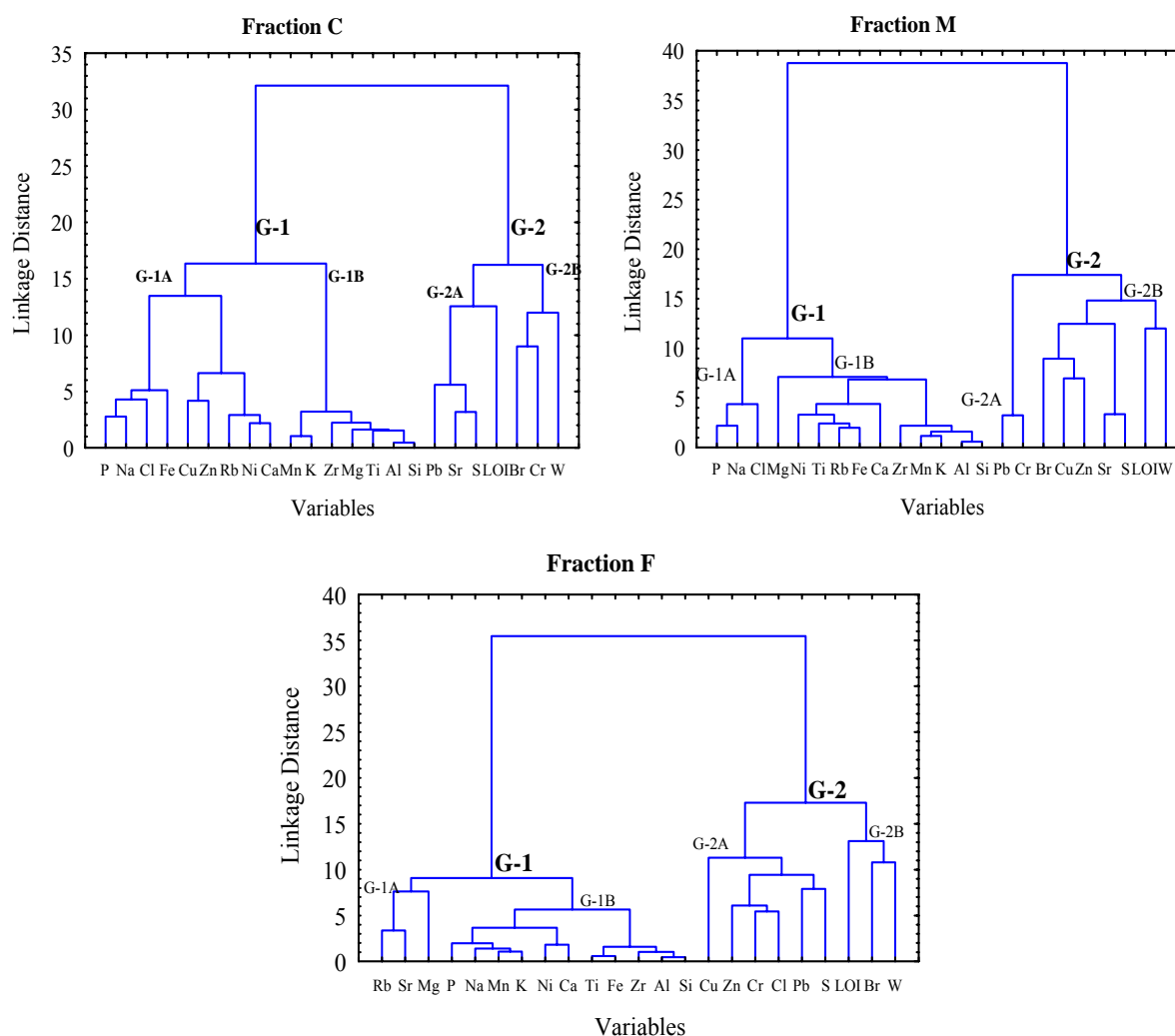


Figure 2. Dendrogram resulting from standardize data, using the Ward's method of hierarchical cluster analysis for the 23 variables and the 65, 55 and 60 samples. Similarities have been calculated from Euclidean distance.

Indoor dust of fractions C, M and F two cluster distances was identified G-1 and G-2, subdividing into, G-1A, G-1B, G-2A and G-2B (Fig. 2):

Fraction C:

- G-1A: contains P, Na, Cl, Fe, Cu, Zn, Rb, Ni and Ca This group presents elements characteristic of soil, however, strong correlation between Cu and Zn is a sign of contamination, which may have been added to dust by wet or dry deposition. The association between Na and Cl, characterize the maritime influence that crosses the city in afternoon [29];
- G-1B: Mn, K, Zr, Mg, Ti, Al and Si these elements may be of natural origin, once, are constituent parts of the soil chemical composition [30]. Comparing the concentrations (WDXRF) with the background values as well as enrichment factor, there is no anthropogenic interference;
- G-2A: contains Pb, Sr, S and LOI. This association may reflect the contributions of some anthropogenic activities and/or natural. In general, in urban areas, the S is found mainly in the sulphate, ammonium sulphate and ammonium bisulfate forms. One of the formation processes of these particles is by fossil fuels combustion [31, 32]. The Pb per year was used like antiknock additive for gasoline, however, is no longer used by the Brazil since 1989, but its presence may also be due to the past or household products such as insecticides, paints, ceramics, glass, waterproofing, solders and batteries.
- G-2B: Br, Cr and W. The element Cr aggregate to dust may be natural or anthropogenic origin, once; it is used by several industries in the manufacture of porcelain, wooden furniture, electric-electronic components and others.

Fraction F:

- G-1A: contains P, Na and Cl. This association reflects the influence of the sea breeze to dust in indoor environments;
- G-1B: Mg, Ni, Ti, Rb, Fe, Ca, Mn, K, Al and Si This group is typical of the soil composition, which may be transported by the shoes and clothes of occupants from outdoor environments to indoor, as well as the particles deposition brought by air;
- G-2A: contains Pb and Cr. These elements are probably from anthropogenic sources aggregated to dust;
- G-2B: Br, Cu, Zn, Sr, S, and LOI W. The combination of these elements may reflect influences of urban activities and the natural geochemical behavior.

Fraction F:

- G-1A: contains Rb, Sr and Mg. These elements are characteristic of the soil composition;
- G-1B: P, Na, Mn, K, Ni, Ca, Ti, Fe, Zr, Al and Si The combination of these elements may be from natural origin, i. e., soil;
- G-2A: contains Cu, Zn, Cr, Cl, Pb and S. This group of elements reflects the great influence of anthropogenic sources, e.g., particles generated from vehicular traffic. According to Jiries

et al (2001), the Zn and Cu can be derived from the mechanical wear of vehicles (tire, metal bath, brake lining wear and fuel combustion). Furthermore, the wear of artifacts and/or household objects the basis of plastics, rubber, glass and ceramics may influence in the pollutant enrichment;

- G-2B: LOI, Br and W. The mass and Br are correlated with the concentration of organic matter.

3.4 Risk Assessment

The previous items allowed characterizing the contamination in the domestic environment and its probable chemical contaminants and pollution sources. The human exposure to these contaminants (by inhalation, ingestion or dermal contact) may cause adverse health effects and an especial concern about children. According to terms of consumption by human body weight, children usually ingest higher amounts of metals in comparison with adults. Table 4 are shown the dose of total exposure (sum of all contamination routes) for adults and children with body mass of 60 and 15 kg, respectively, in indoor environment, the tolerable daily intake (TDI) and risk values.

Table 4. Dose of total exposure in different scenarios, tolerable daily intake (TDI) and risk values for adults and children (CETESB, 2001)

Contaminants	Exposure route								TDI	Risk	
	Dermal application		Inhalation of particles		Soil ingestion		Total exposure (TE)			Adult	Child
	Adult	Child	Adult	Child	Adult	Child	Adult	Child			
	mg kg ⁻¹ day										
Ni	5.78 10 ⁻⁰⁷	1.72 10 ⁻⁰⁴	1.35 10 ⁻⁰⁶	5.25 10 ⁻⁰⁶	2.39 10 ⁻⁰⁵	2.43 10 ⁻⁴	2.58 10 ⁻⁰⁵	4.20 10 ⁻⁰⁴	5.00 10 ⁻⁰²	0.0006	0.008
Zn	2.89 10 ⁻⁰⁶	8.60 10 ⁻⁰⁴	2.36 10 ⁻⁰⁶	2.36 10 ⁻⁰⁶	1.19 10 ⁻⁴	1.22 10 ⁻³	1.25 10 ⁻⁰⁴	2.08 10 ⁻⁰³	1.00	0.0001	0.002
Cu	1.44 10 ⁻⁰⁶	4.30 10 ⁻⁰⁴	3.37 10 ⁻⁰⁶	2.19 10 ⁻⁰⁶	5.97 10 ⁻⁰⁵	6.08 10 ⁻⁴	6.45 10 ⁻⁰⁵	1.04 10 ⁻⁰³	1.40 10 ⁻⁰¹	0.0004	0.007
Pb	1.01 10 ⁻⁰⁶	3.01 10 ⁻⁰⁴	2.36 10 ⁻⁰⁶	1.53 10 ⁻⁰⁶	4.18 10 ⁻⁰⁵	4.25 10 ⁻⁴	4.52 10 ⁻⁰⁵	7.30 10 ⁻⁰⁴	3.60 10 ⁻⁰³	0.01	0.2
Cr	2.02 10 ⁻⁰⁶	6.02 10 ⁻⁰⁴	4.72 10 ⁻⁰⁶	1.84 10 ⁻⁰⁶	8.36 10 ⁻⁰⁵	8.51 10 ⁻⁴	9.03 10 ⁻⁰⁵	1.45 10 ⁻⁰³	5.00 10 ⁻⁰³	0.02	0.2

Tolerable daily intake (TDI)

The analysis results by WDXRF (Table 1) compared with the values of total exposure for children in indoor environments showed that Pb and Cr are about 10 and 6 times, respectively and Ni, Zn and Cu 100 times above in the C fraction. The same values are kept in fraction M. Nevertheless, the fraction F values are much higher than reported, about 100 and 10 times for Pb and Cr and 1.000 times for Ni, Zn, and Cu, respectively. The risk values (calculated using the ratio of total exposure by the tolerable daily intake - TDI) showed that the elements Ni, Zn and Cu were 4-950 times higher and Pb and Cr about 1-3 times lower than the WDXRF values. These comparisons confirm the contamination of indoor domestic environments by heavy metals.

The elements such as Zn, Cr, Cr and Ni are considered essential for the growth of all organism types, from bacteria to humans even, but in low concentrations, once the excess can affect several organs, change the process biochemistry, organelles and membranes cellular.

4. CONCLUSIONS

The mathematical procedure applied to the results obtained by WDXRF showed to be adequate to qualify the indoor dust samples like soil/sediment.

The comparison of the enrichment factor results (EF) with the reported in the literature indicated that the samples are found enriched for Zn, Cu, Cr, Pb and Ni. The results showed that anthropogenic sources originated from indoor and outdoor environments. The probable hypotheses for the indoor contamination were the migration of these elements released from artifacts, objects, and in general products and vehicle pieces wear and emission. Another relevant aspect was the significantly elevated concentrations of these elements, since overcome the total exposure and risk values reported by CETESB. These results showed a concern about the human exposure to the elements that are considered potentially toxic.

This work also showed that indoor dust is a suitable material to be used as contamination monitor who allows identifying the anthropogenic sources and the quality of these environments for the human health.

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