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Contamination Level and Probabilistic Health Risk of Exposure to Toxic Elements (TEs) In Trapped Air Conditioner Filter Dusts (ACFDs) from Primary Healthcare Environments

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Competing Interests.

The authors declare no competing interests.

ABSTRACT

Background: Chemical exposure from the environment is on the rise globally, and its monitoring and risk assessment is crucial
Objective: The study aimed to assess the contamination level and health risk of exposure to toxic elements (TEs) in trapped air conditioner filter dust (ACFD) from Primary healthcare (PHC) environment in Ado-Odo/Ota LGA, Ogun State, Nigeria.
Methods: Nine (9) dust samples were collected from various sections of the study area and then transported to the laboratory for analysis. One (1) g of the sample was digested using *aqua regia* and the TE level was estimated with an Atomic Absorption Spectroscopy (AAS). The contamination level was evaluated using the geo-accumulation index (I-geo) and enrichment factor (EF).
Results: The results show that Cr and Zn in some collected samples were higher than the Canadian guidelines value. The majority of the TEs were high in sample PHC04 while Cd is the major contaminant in the dust emanating from an anthropogenic source. Ingestion remains the primary route of TE exposure to humans in the PHC with the children being the most vulnerable. The health risk assessment revealed that the population are free from a significant non -carcinogenic risk but there exists a concern for Pb and Cr in the children population. More so, there is no risk of developing cancer from the TEs on prolonged exposure but the total cancer risk value for Cr in the dust is of concern.
Conclusion: The ACFD is primarily polluted with some of the studied TEs, therefore, regular cleaning of the AC filter dust and wet cleaning of the rooms should be encouraged.

Keywords: Contamination Level, Health Risk, Toxic Elements, Air Conditioner Filter Dust, Primary Healthcare Environments

1. Introduction

In an indoor environment such as a home, workplace, or hospital, an air conditioning system regulates the temperature (Famuyiwa *et al.,* 2024). Temperature, humidity, air movement, ventilation, particulate matter concentration, and biological and gaseous contaminants are just a few of the factors affecting indoor environmental conditions, which have a significant impact on human health (Famuyiwa *et al.,* 2022). Air conditioner filters, according to Rashed (2018), are the most important component of an air conditioner, and studies have shown that these filters tend to remove pollutants efficiently and consistently, causing them to be deposited on them. However, the deposited dust could be a cause of contamination or pollution (Raja and Namburu, 2014).

Pollutants/contaminants from dust have a wide range of compositions, which can be due to both natural and anthropogenic activity (Umoren *et al.,* 2025). Toxic Elements (TEs) are defined by features such as high atomic mass, toxicity, and density, and are a major source of pollution on a worldwide scale (Ljung *et al.,* 2006; Umoren *et al.,* 2024a). Toxic elements and metalloids are found in higher concentrations in indoor dust than in exterior-settled dust in ordinary urban environments, and many TEs and metalloids

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are found in higher concentrations in indoor dust than in exterior-settled dust in ordinary urban environments (Gurzau *et al.,* 2007). Moreover, depending on the quantity and length of exposure, practically any TE might be life-threatening (Jaishankar *et al.,* 2014). Chromium, Lead, Mercury, Cadmium, Arsenic, Copper, Manganese, Nickel, Zinc, and Silver are among the Toxic Elements categorized according to their toxicity and/or biological relevance, according to a report by Umoren et. al. (2024b)**.** Humans are exposed to TE through a variety of routes, including consumption of contaminated foods/drinnks, skin contact, and inhalation of contaminated airborne particles (Ljung *et al.,* 2006; Malik *et al.,* 2024; Ajani et al., 2024).

The healthcare environment is a site where many activities take place daily, including both adults and children who are exposed to dust from the healthcare air conditioning (AC) system (Wang *et al.,* 2018). Toxic Element pollution has become a major source of concern for global public health in recent decades, and human exposure has increased dramatically as a result of an exponential increase in their use in various work fields, including but not limited to industrial, domestic, and technological applications (Adekola and Dosumu 2011).

Morgan (2013) found that long-term exposure to indoor dust containing TEs like lead can cause brain and nephron damage, as well as learning disabilities, poor muscle and bone growth, hearing loss, and high blood pressure. Needleman (2004) conducted another study that associated neurological issues with lead exposure in children, resulting in a lower intelligence quotient, as well as reduced vocabulary and grammatical thinking skills. Specifically, high levels of hexavalent chromium (Cr6+), which is known to be carcinogenic and hazardous to humans (Olujimi *et al.,* 2015).

Toxic elements (TEs) are usually non-degradable and thus increased amounts of TEs are a possible future threat to life. They can build up in the body's fatty tissues and cause problems with the brain and nervous system. They may also interfere with the normal performance of the human body and act as co-factors in the development of other illnesses (Famuyiwa *et al.,* 2022)**.** Toxic Elements that have been emitted into the environment can make their way into your home via the air or dust (Kurt-Karakus, 2012). Since the air conditioning system is one of the most widely used, in an indoor environment including a hospital, it is crucial to determine the concentration, pollution level and human health risk of such toxic TEs in dust from healthcare air conditioner filters in Ado-Odo / Ota LGA. Hence the aim of this study.

2. MATERIALS AND METHODS

2.1 Research Area

The study was carried out in some offices from the Ado-Odo/Ota local government area (LGA) of Ogun state, one of nineteen local government areas, estimated to be the second largest in Ogun State, South-West Nigeria. Coordination 6^o 38'N and 3^o 06'E. It is an industrial local government area with the largest number of industries in the state, it has an area of 878 km^2 and an estimated population of 526,565 as at the last census in 2006. It is primarily agricultural, producing cassava, cocoa, kola nut, maize and minerals such as glass and silica sand; and gypsum. It is indigenous to the Awori people a subset of the Yoruba tribe (Famuyiwa *et al.,* 2022).

2.2 Sampling

Dust samples were collected from air conditioner filters by tapping the AC filters and using a plastic brush to remove the dust then one composite sample was made for each of the Nine (9) primary healthcare labelled PHC 01- 09 respectively in Ado-Odo/ Ota LGA. Samples were stored in clean labeled polyethylene sample bags and transported to the laboratory for analysis.

2.3 Digestion and Toxic Element Estimation

Dust samples were sieved with a 1mm mesh size and then stored for digestion. Nine (09) composite dust samples were collected from selected offices using a plastic brush to remove dust from window slits, fans, and corners of rooms into a clean polythene sample bag, then transported to the chemical science laboratory unit of Pure Sciences, Abeokuta, Nigeria for Acid digestion. Exactly, 1g of the sample was digested using 20 cm^3 of mixed concentrated nitric acid (HNO_3) and Hydrochloric acid (HCl) in a ratio of 1:3. The digest was cooled off, filtered and diluted with deionized water up to 50 cm^3 . Diluent was sent to the central laboratory of the Federal University of Agriculture, Abeokuta Ogun

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State for TE estimation using subjected to Atomic Absorption Spectrophotometry.

2.4 Pollution Indices

The degree of pollution can be estimated using various methods, the study however, uses the Geo-Accumulation Index and Enrichment factor for estimating the degree of TE pollution in ACFD (Famuyiwa *et al.,* 2024).

2.4.1 Geo-accumulation Index

A quantitative measure of the extent of TE pollution in the studied ACFD was calculated using the geo-accumulation index. This was calculated using the equation 1 below.

$$Igeo = \text{Log}\,2\ x\left({Cn}/{1.5\ x\ Bn}\right) \quad Equation\ 1$$

Where Cn denotes the TE concentration in ACFD, Bn denotes the TE concentration in shale (background), and 1.5 denotes the factor compensating for the background data due to lithogenic impact. The following interpretation is for the geo-accumulation index; Igeo<0=practically unpolluted, 0<Igeo<1=unpolluted to moderated polluted, 1<Igeo<2= moderately polluted, 2<Igeo<3= moderately to strongly polluted, 3<Igeo<4=strongly polluted, 4< Igeo<5= strongly to extremely polluted and Igeo >5=extremely polluted

2.4.2 Enrichment factor

The enrichment factor is used to determine the degree of anthropogenic contribution and TE pollution in ACFD, as well as to differentiate between anthropogenic and natural sources of TEs (Yuen *et al.,* 2012; Famuyiwa *et al.,* 2024). It was calculated using equation 2.

$$EF = \frac{Cn\,(TE)\,/C\,(TE crust)}{Bn\,(reference\,TE)\,/B(reference\ crust\,)} \quad Equation\ 2$$

Where: Cn (TE)=concentration of the measured element, C (TE crust) =concentration of the TE in the crustal region, Bn (reference TE) = concentration of the reference TE (Fe) in the measured sample, B = concentration of reference TE (Fe) in the crustal region. A toxic element is regarded as a reference TE if it is of low occurrence variability and is present in trace amounts (Turekian and Wedephol, 1961; Iwegbue *et al.* 2019). In this study, Iron (Fe) was employed as the reference TE. According to Famuyiwa *et al.* (2022), there are five categories of degree of pollution based on enrichment factor: EF<2 No or minimal enrichment, EF=2- 5 moderate enrichment, EF=5–20 significant enrichment, EF=20–40 Very high enrichment, EF>40 Extremely high enrichments.

2.5 Human Health Risk Assessment

The potential health risk due to human exposure to TEs from dust through inhalation, dermal contact and ingestion pathways was calculated using the following equation (Zhang *et al.,* 2011). Exposure calculation for daily estimation was achieved using equations 3-5.

$$MDD_{ingest} = C\ x\left({IngR\ x\ EF\ x\ ED}/{BW\ x\ AT}\right)\ x\ 10^{-6}$$

Equation 3

$$MDD_{inhale} = C\ x\left({InhR\ x\ EF\ x\ ED}/{PET\ x\ BWx\ AT}\right)$$

Equation 4

$$MDD_{dermal} = C\ x\left({SA\ x\ DAF\ x\ SAF\ x\ EF\ x\ ED}/{BW\ x\ AT}\right) x\ 10^{-6}$$

Equation 5

Where MDD ($mgkg^{-1}day^{-1}$) is the mean daily dose on exposure via ingestion (MDD_{ingest}),

inhalation (MDD_{inhale}) and dermal contact (MDD_{dermal}). C is the concentration of TE in the ACFD measured in mg/kg, IngR (ingestion rate) is 200 mg/day for children and 100 mg/ day for adults and IhR (inhalation rate) is 7.63 mg/day for children and 12.8 mg/day for adult of TE in dust respectively (USEPA 2011). ED (exposure duration) is 6 years for children and 30 years for adults, and EF (exposure frequency) is 350 days/year for children and adults. BW and AT are the Mean body weight (15 kg for children and 70 kg for adults) and the Mean exposure period (6 years for children and 30 years for Adults) respectively (Chen *et al.,* 2014). CF is the conversion factor ($1x10^{-6}$ kg/mg), SA is the exposed skin surface area (2800 cm^2 for children and 4340 cm^2 for adults), SAF is the skin adherence factor (0.2 $mg/cm^2/d^1$ for children and $0.7mg/cm^2/d^1$ for adult), DAF is the dermal absorption factor used in this study is 0.001 for both children and adult, and PEF is the particle emission factor ($1.36\ x\ 10^9\ m^3/kg$) for both children and adult.

The reference dose is used as a measure of non -cancer chronic hazards. Toxic effects are likely to ensue when the exposure dose of the target contaminant exceeds the reference dose, which is generally articulated as HQ and HI.

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and cancer risk method were used to assess the human health risk due to dust exposure, before calculating the HI, a hazard quotient (HQ) based on non-cancer toxic risk was calculated for individual TE according to equation 6. (Famuyiwa *et al.,* 2022).

$$HQ = {}^{MDD}/_{RfD} \quad \textit{Equation 6}$$

RfD (mg/kg/day) is the daily maximum allowable dose of TE without posing a non-carcinogenic risk to humans during their lifespan. Three different types of RfDs are used for three different exposure pathways: reference dose RfD_{ingest} (mg/kg/day) for ingestion, RfD_{dermal}, (mg/kg/day) for dermal contact and RfD_{inhale} (mg/m^3) for inhalation. The hazard index measures the cumulative risk of specific chemicals from multiple exposures (HI). Equation 7, can be used to measure the cumulative risk of TEs in ACFD from multiple exposures.

$$HI = \sum HQi \quad \textit{Equation 7}$$

Where i = different exposure pathways. The value of HI less than 1 shows that there is no significant risk of non-carcinogenic effects. However, when the HI value is greater than 1, significant non-carcinogenic effects are probable (USEPA, 2011). The carcinogenic risks to humans are estimated using the reference dose (RfD) multiplied by the respective cancer slope factor (CSF, 1 mg/kg). A cancer slope factor is an upper bound probability of an individual developing cancer as a result of lifetime exposure to dust by ingestion, inhalation and dermal contact using equation 8 (Olujimi *et al.,* 2015).

$$Total\ Cancer\ Risk = RfD\ x\ CSF \quad \textit{Equation 8}$$

Cancer risk (CR) is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazards. Total cancer risk (TCR) less than $1x10^{-6}$ specifies negligible carcinogenic risk, while TCR greater than $1x10^{-4}$ recommends high carcinogenic risk to humans on dust exposure (Wu *et al.,* 2015).

2.6 Data Analysis

Mean and standard deviation were obtained using SPSS version 21, while Microsoft Excel 2016 was used for calculating pollution indices and health risk assessment

3. RESULTS AND DISCUSSION

3.1 Toxic Element (TE) Level in air conditioner filter dust (ACFD)

The concentration of TEs in the healthcare ACFDs is shown in Table 1; The concentration of Iron (Fe) ranges from 4400-9860 mg/kg with a Mean of 6780 mg/kg. In the human body, iron is beneficial, Iron (Fe) is found in protein molecules such as haemoglobin and myoglobin which make up approximately 4 grams of the adult human body. These two proteins are needed for a variety of metabolic processes in humans, as well as oxygen transport and storage in muscles (Harrison *et al.,* 2001). A high concentration of iron > 5000 mg/kg was recorded for 77.8% of the samples. The highest value was recorded in PHC 06 (9860 mg/kg) followed by PHC 08 (8830 mg/kg). The mean value of Fe from the study was higher than the concentration reported in various indoor dust such as Mansour *et al.* (2019), Abeokuta (13.7 mg/kg), Olujimi *et al.* (2015) and Shah Alam City, Malaysia (4230 mg/kg), Darusa *et al.* (2012) but lower than that of Southern-Nigeria (23,499 mg/kg), Jeddah, Saudi Arabia (8,750 mg/kg), Iwegbue *et al.* (2019) and Jenka, Malaysia (10800 mg/kg), Sulaiman *et al.* (2017).

The concentration of Lead from the study ranges from 11.9 -33.5 mg/kg with a Mean value of 23.4 mg/kg. The highest concentration of lead was recorded in the ACFD from PHC 04 (33.5 mg/kg). Lead poisoning is a toxicity caused by excessive lead consumption and this disease affects both children's and adults' gastrointestinal tracts and central nervous systems (Kang *et al.,* 2012). Lead concentrations from the study were largely lower than the soil guideline value stated by the CLEA, UK (450 mg/kg), Canada (140 mg/kg) and Dutch guideline value (530 mg/kg) for Pb in dust. In comparison to other dust studies, the Mean value is similar to the study by Olujimi *et al.* (2015) in Abeokuta, Nigeria (27.6 mg/kg) and Kurt-Karakus (2012) in Istanbul, Turkey (28.0 mg/kg) but lower to the study of Darus *et al.* (2012) in Shah Alam city, Malaysia (31.2 mg/kg). The concentration is also two or more times lower than various dust studies by Bhandari *et al*. (2021) in Kathmandu, Nepal

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(65.3 mg/kg), Sulaiman *et al.* (2017) in Jenka, Malaysia (121 mg/kg), Rasmussen *et al.* (2013) in Ottawa, Canada (406 mg/kg) and from house vacuum dust Israel *et al.* (2019) in Sydney, Australia (199 mg/kg).

Copper (Cu) concentrations from the study range from 11.1-66.1 mg/kg with a mean of 26.2 mg/kg. The highest Cu was recorded in PHC 05 (66.1 mg/kg) followed by PHC 04 (41.3 mg/kg). The sources of Cu are from cables, air conditioner components and various Cu-coated equipment. Excessive exposure to Cu could result in cellular damage resulting in DNA damage (Mutation) and proteins and lipids oxidation (Iwegbue *et al.*, 2019). The concentration of Cu from the study was lower than the SGV for Cu by Canada (140 mg/kg) and the Dutch guideline value (190 mg/kg) and also values recorded from studies by Darus *et al.* (2012) in Shah Alam City, Malaysia (30.2 mg/kg), Abeokuta, Nigeria (59.4 mg/kg) by Olujimi *et al.* (2015), Jenka, Malaysia (97.4 mg/kg) by Sulaiman *et al.* (2017), Bushehr, Iran (234 mg/kg) by Ardashiri and Hashem (2017), Southern, Nigeria (233 mg/kg) by Iwegbue *et al.* (2019) and Ottawa, Canada (206 mg/kg) by Rasmussen *et al.* (2013).

Chromium (Cr) concentration from the study ranges from 89.1-515 mg/kg with a n Mean of 198 mg/kg. The Chromium concentration in all samples was higher than the Canada soil guideline value (64 mg/kg), 33.3% (3 of 9) of the samples were higher than the UK value (200 mg/kg) while 11.1% (1 of 9) of the samples were higher than the Dutch value (380 mg/kg). The highest chromium concentration in the hospital filter dust was recorded in PHC 02 (515 mg/kg) followed by PHC 04 (298 mg/kg). The high Cr in the sample could be linked to wall paints from the room and the components of Air conditioners (Mohanty *et al.,* 2013). Chromium exists as trivalent Cr^{3+} and Hexavalent metals, with the hexavalent Cr^{6+} being the most toxic. A prolonged exposure to Cr the healthcare can result in health problems such as cardiac, renal, hepatic, blood and brain effects on the patients (Gupta *et al.,* 2013). Mean Cr concentrations were higher than the values recorded from indoor dust studies such as Olujimi *et al.* (2015) in Abeokuta, Nigeria (41.8 mg/kg), Ardashiri and Hashem (2017) in Bushehr, Iran (49.0 mg/kg), Kurt-Karakus (2012) in Istanbul, Turkey (55.0 mg/kg), Rasmussen *et al.* (2013) in Ottawa, Canada (86.7 mg/kg) and Iwegbue *et al.* (2019) in Southern, Nigeria (27.1 mg/kg) but lower than a study by Bhandari *et al.* (2021) in Kathmandu, Nepal.

Cadmium (Cd) concentration from the study ranges from 2.55-10.2 mg/kg with a mean of 6.07 mg/kg. The highest concentration of Cd was recorded in PHC 03 (10.3 mg/kg). The primary sources of Cd are infiltration of automobile exhaust-contaminated particles. Prolonged exposure to excessive Cd can seriously affect the lungs, DNA and testicular damage or cancer development (Faridi *et al.,* 2014). The mean Cd concentration was lower than the SGV stated by the UK (150 mg/kg), Canada (22 mg/kg) and Dutch intervention value (12 mg/kg). The mean Cd concentration from the study was similar to that of the concentration recorded in Ottawa, Canada (6.46 mg/kg) by Rasmussen *et al.* (2013), and higher than the studies from Jeddah, Saudi Arabia (2.09 mg/kg) by Mansour *et al.* (2019), Bushehr, Iran (3.1 mg/kg) by Ardashiri and Hashem (2017), Istanbul, Turkey (0.84 mg/kg) by Kurt-Karakus (2012) and USA (4.3 mg/kg) by Zota *et al.* (2011). The concentration is lower than the record from Southern Nigeria (32.0 mg/kg) by Iwegbue *et al.* (2019) and Abeokuta, Nigeria (855 mg/kg) by Olujimi *et al.* (2015).

Zinc (Zn) concentration ranges from 121-444 mg/kg with a mean of 254 mg/kg. Zinc concentration in 22.2 % of the samples was higher than the Canadian value (360 mg/kg). The mean value was lower than the Canadian (360 mg/kg) and Dutch values (720 mg/kg). The zinc concentration with the highest value was recorded in PHC 05. (444 mg/kg). Zinc is mostly found in the crustal region including several ores, it is also used to galvanize other metals to avoid rusting. Paint pigments, pesticides, batteries and electrical appliances are all made from zinc (Tripathi, 2017). The sources of Zn in the majority of the samples are wall paints, AC components and roofing sheets. Prolonged exposure to zinc in the above samples can result in both acute and chronic effects, Acute ingestion may cause abdominal pain, nausea, vomiting, diarrhoea, headache, lethargy and possibly bleeding. More so, may cause muscle weakness, shortness of breath,

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Table 1: Toxic element level in ACFDs

Healthcare	Fe	Pb	Cu	Cr	Zn	Co	Cd	Mn
PHC 01	5940	11.9	18.3	148	225	4.38	9.42	203
PHC 02	6220	20.6	15.9	515	121	8.85	3.25	456
PHC 03	4401	15.6	11.7	89.1	168	3.3	10.2	149
PHC 04	7520	33.5	41.3	298	225	15.2	6.85	112
PHC 05	6990	28.1	66.1	225	444	9.45	2.55	106
PHC 06	9860	19.6	40.3	142	258	11.5	5.56	112
PHC 07	6660	21.4	13.5	109	361	7.45	4.58	356
PHC 08	8830	30.0	17.5	135	153	6.58	6.75	106
PHC 09	4580	29.5	11.1	118	334	7.45	5.43	459
Range	4400-9860	11.9-33.5	11.1-66.1	89.1-515	121-444	3.30-15.22	2.55-10.2	105-459
Mean	6780	23.4	26.2	198	254	8.24	6.07	229
Std. Dev.	179	7.29	18.9	136	107	3.62	2.57	152
UK (2013)	-	450	-	200	-	-	150	-
CSGV (2009)	-	140	140	64	360	50	22	-
DIV(Qing *et al.*, 2015)	-	530	190	380	750	-	12	-

Table 2: Geo-accumulation index (I-geo) value of TEs in ACFD

TE	Mean	I-geo value	I-geo grade	Pollution Level
Fe	678	-2.02	0	Unpolluted
Pb	23.4	-0.11	0	Unpolluted
Cr	198	0.17	0-1	Unpolluted to Moderately polluted
Zn	254	0.25	0-1	Unpolluted to Moderately polluted
Mn	229	-0.75	0	Unpolluted
Co	8.24	-0.54	0	Unpolluted
Cu	26.2	-0.41	0	Unpolluted
Cd	6.07	1.13	1-2	Moderately polluted

Table 3: Enrichment factor (EF) of the TEs in ACFD

TE	Mean	EF Value	EF Scale	EF Grade
Fe	678	1	EF<2	Minimal Enrichment
Pb	23.4	4.45	EF = 2-5	Moderate Enrichment
Cr	198	8.37	EF = 5-20	Severe enrichment
Zn	254	10.2	EF = 5-20	Severe enrichment
Mn	229	1.03	EF<2	Minimal Enrichment
Co	8.24	1.65	EF<2	Minimal Enrichment
Cu	26.2	2.22	EF = 2-5	Moderate Enrichment
Cd	6.07	77.0	EF>40	Extremely High Enrichment

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copper deficiency, suppressed immunity, and reduced High-Density Lipoprotein which can stimulate heart attack (Tripathi, 2017). The Mean zinc concentration from the study was lower than the report from various dust studies such as Ottawa, Canada (717 mg/kg) by Rasmussen *et al.* (2013), Istanbul, Turkey (832 mg/kg) by Kurt-Karakus (2012), Southern-Nigeria (825 mg/kg) by Iwegbue *et al.* (2019), Jenka, Malaysia (2879 mg/kg) by Sulaiman *et al.* (2017), Sydney, Australia (1876 mg/kg) by Israel *et al.* (2019) and Bushehr, Iran (1423 mg/kg) by Ardashiri and Hashem (2017) but lower than the report from Shah Alam city, Malaysia (149 mg/kg) by Darus *et al.* (2012).

Cobalt (Co) concentration from the study ranges from 3.30-15.22 mg/kg with a Mean of 8.24 mg/kg. The highest concentration was recorded in PHC 04 (15.2 mg/kg), although all samples were within the Canada SGV (50 mg/kg). Cobalt sources in the filter dust may be dust particulates from outdoor pollution and air conditioner casing (Iwegbue *et al.*, 2019). Prolonged exposure to Co results in asthma, pneumonia, eye effects, cardiac problems, and thyroid damage (Al-Fartusie and Mohssan, 2017). The Mean Co concentration from the study was similar to the various dust studies in Jeddah, Saudi Arabia (8.2 mg/kg) by Mansour *et al.* (2019), Ottawa, Canada (8.92 mg/kg) by Rasmussen *et al.* (2013) but slightly higher than those recorded in Abeokuta, Nigeria (4.21 mg/kg) by Olujimi *et al.* (2015) and Istanbul, Turkey (5.0 mg/kg) by Kurt-Karakus (2012) while it was lower than that of Southern, Nigeria (31.3 mg/kg) by Iwegbue *et al.* (2019).

Manganese (Mn) is an essential element in the human body however, the deficiency can lead to blood clotting, skeletal abnormalities, changes in hair colour, fatness, glucose sensitivity, and reduced cholesterol levels (Spangler and Reid, 2010). Manganese concentration in the study ranges from 105-459 mg/kg with a Mean of 229 mg/kg. Manganese Mean concentration higher than 200 mg/kg was recorded in 44.4 % of the samples with the highest in PHC 09 (459 mg/kg). Prolonged exposure to manganese causes damage to the respiratory tract and brain, headaches, sluggish joints, insomnia, forgetfulness, and nerve damage. Lung embolism, bronchitis and impotency in men (Hock *et al.,* 2013). Mean Mn concentration from the study was higher than reports from various dust such as Sydney, Australia (220 mg/kg) by Israel *et al.* (2019) and Istanbul, Turkey (136 mg/kg) by Kurt-Karakus (2012) but lower than reports made from Jeddah, Saudi Arabia (391 mg/kg) by Mansour *et al.* (2019), Ottawa, Canada (267 mg/kg) by Rasmussen *et al.* (2013), Japan (266) by Yoshinaga *et al.* (2014), Abeokuta, Nigeria (328 mg/kg) by Olujimi *et al.* (2015) and Xi'an, China (565 mg/kg) by Chen *et al.* (2014), Southern-Nigeria (825 mg/kg) by Iwegbue *et al.* (2019).

3.2 Pollution Indexing

3.2.1 Geo-Accumulation Index (I-geo)

Pollution assessment through the geo-accumulation index of TEs in the air conditioner filter dust (ACFD) is shown in Table 2. The ACFDs are unpolluted for the majority of the TEs; Fe, Pb, Mn, Co, and Cu while they are also unpolluted to moderate polluted for Cr and Zn. The dust was moderately polluted with Cd. The geo-accumulation index value of TE occurs in the descending order of Cd>Zn>Cr>Pb>Cu>Co>Mn>Fe. The filter dusts were not polluted for all TEs except Cd (1.13), since their values were less than 1.

3.2.2 Enrichment Factor (EF)

The enrichment factor values estimated for TE in AC filer dust from Hospitals are represented in Table 3, which reveals that Fe, Mn and Co are of minimal enrichment, Pb and Cu are of moderate enrichment, Cr and Zn are of severe enrichment while Cd (77. 0) an extremely high enrichment in the filter dust. The enrichment of TEs is in the descending order of Cd>Zn> Cr> Pb> Cu>Co>Mn>Fe. The EF values for Cd and Zn were above 10, suggesting a strict anthropogenic source, other TEs were lower than 10 and also greater or equal to 1. This suggests a partial emergence from mixed anthropogenic and natural sources. However, Fe was strictly from a natural origin.

3.3 Health Risk Assessment

3.3.1 Mean Daily Dose, Non-Cancer and Cancer Risk

The exposure of the human population to TEs in the ACFD through ingestion, inhalation and skin contact can be estimated using the mean daily dose (Bhandari *et al*. 2021). The mean daily dose of TEs in the filter dust on exposure is presented in Table 5, The values are higher in ingestion and skin contact for the human population. This occurs in the order of ingestion>dermal contact>inhalation. Children in the hospital environment are more vulnerable to TEs in dust than adults, this is justifiable

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Table 4: Mean Daily Dose of TE in ACFD

Receptor	Pathways	Fe	Pb	Cr	Zn	Mn	Co	Cu	Cd
Children	MDD_{ingest}	4.46E-02	1.54E-03	1.30E-02	1.67E-02	1.51E-02	5.42E-04	1.72E-03	3.99E-04
	MDD_{inhale}	1.69E-09	5.85E-11	4.95E-10	6.35E-10	5.72E-10	2.06E-11	6.55E-11	1.52E-11
	MDD_{dermal}	1.25E-04	4.31E-06	3.65E-05	4.68E-05	4.22E-05	1.52E-06	4.82E-06	1.12E-06
Adult	MDD_{ingest}	4.78E-03	1.65E-04	1.39E-03	1.79E-03	1.61E-03	5.81E-05	1.85E-04	4.28E-05
	MDD_{inhale}	9.55E-10	3.30E-11	2.79E-10	3.58E-10	3.23E-10	1.16E-11	3.69E-11	8.55E-12
	MDD_{dermal}	1.10E-04	3.81E-06	3.22E-05	4.13E-05	3.73E-05	1.34E-06	4.26E-06	9.88E-07

Table 5: Non-Cancer risk of TE in ACFD

Recep-tor	Path-way	Pb	Cr	Zn	Mn	Co	Cu	Cd
Chil-dren	HQ_{ingest}	5.13E+00	4.33E+00	4.07E-02	4.39E-02	2.75E-02	6.43E-02	5.19E-05
	HQ_{inhale}	-	1.65E-05	-	4.68E-09	3.67E-06	-	-
	HQ_{dermal}	1.23E-03	-	1.14E-04	1.23E-04	2.70E-01	1.80E-04	-
	HI	**5.13E+00**	**4.33E+00**	**4.08E-02**	**4.41E-02**	**2.98E-01**	**6.44E-02**	**5.19E-05**
Adult	HQ_{ingest}	5.50E-01	4.63E-01	5.57E-02	1.08E-01	2.71E-02	4.30E-02	6.33E-05
	HQ_{inhale}	-	9.30E-06	-	1.14E-08	3.61E-06	-	-
	HQ_{dermal}	1.09E-03	-	1.56E-04	3.01E-04	2.67E-01	1.21E-04	-
	HI	**5.51E-01**	**4.63E-01**	**5.58E-02**	**1.08E-01**	**2.94E-01**	**4.31E-02**	**6.33E-05**

Table 6: Cancer Risk of TEs in ACFD

Receptor	Pathway	Pb	Cr	Cd
Children	CR_{ingest}	1.12E-06	5.60E-04	-
	CR_{inhale}	2.10E-13	1.74E-09	8.19E-12
	CR_{dermal}	-	-	-
	TCR	**1.12E-06**	**5.60E-04**	**8.19E-12**
Adult	CR_{ingest}	4.80E-07	2.39E-04	
	CR_{inhale}	4.75E-13	3.99E-09	1.85E-11
	CR_{dermal}	-	-	-
	TCR	**4.80E-07**	**2.39E-04**	**1.85E-11**

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Conclusion

The study investigated the concentration of toxic element in air conditioner filter dust (ACFD) from the selected healthcare environment in Ado-Odo/ Ota LGA. The dust samples were collected, digested and analyses using Atomic Absorption spectroscopy (AAS). The result revealed that the levels of Cr and Zn in some of the PHCs were higher than the Canadian guideline value, 2009. While I-geo showed that the ACFD is moderately polluted with Cd, and severe enrichment with Cr and Zn, and extremely high enrichment with Cd according to EF. Furthermore, the humans exposed to the dusts are free from significant non–cancer and cancer risks but there is a concern for Pb and Cr in the children group for non-cancer risk, and Cr in the human group for cancer risk. It is therefore recommended that regular cleaning of the AC filter dust and wet cleaning of the rooms should be encouraged.

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