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Assessment of the Elements and Oxides Concentration in the Dust of Asbestos Used in Roofs of Houses in Al-Qalluah Town, Yemen

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Abstract: In this research we evaluated elements and oxides concentration of corrugated asbestos cement used in the roofs of houses in Al-Qalluah area- Aden city, Yemen in the period from August to September 2018. In Aden city, many houses were built between 1880 and 1990 and therefore corrugated asbestos cement roofs as one type of asbestos boards, were used widely in coverage of the buildings and garages. Airborne asbestos fibers may remain suspended in the air for some time and can be carried long distances by wind before settling down. The risk of developing asbestos-related diseases, like lung cancer, is associated with the level and duration of exposure. All the dust samples collected from different sites in Al-Qalluah area were sent to the National Research Center- Cairo and analyzed by QUANTA FEG 250 polarized-light microscopy (PLM), using the EPA 600/R-93/116 method. The overall results of scanning PLM for dust samples have shown fibers of asbestos with diameter ranged between 2.634-22.49µm. PLM quantitative analysis coupled with EDAX TEAM have found the mean concentrations 39, 36.5, 19.2, 31.8, 36.7 and 28.4 wt/wt% with respect to C, O, Mg, Al, Si, and Ca, while the mean concentrations of oxides CO_2, MgO, Al_2O_3, SiO_2, CaO, SO_3, Fe_2O_3, K_2O and Cl_2O, were 46.4, 13.6, 34.8, 47.5, 29.0, 29.1, 31.5, 32.0 and 43.8 wt/wt% respectively.
Asbestos boards should be encapsulated by a safe material to prevent or reduce their risks and the authorities should stop asbestos impacts on the environment and human health.

Keywords: Elements and oxides analysis, asbestos cement corrugated, polarized-light microscopy, quantitative analysis.

تقدير تركيز العناصر والأكاسيد في غبار أسقف الأسبستوس المستخدمة في منازل بلدة القلوعة، اليمن

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الملّخص: تمّ في هذه الدّراسة تقدير تركيز العناصر والأكاسيد في أسبستوس الإسمنت المتموّج المستخدم كأسقف في منازل بلدة القلوّعة-عدن، اليمن وذلك خلال الفترة من آب وحتّى أيلول 2018م. هناك العديد من المنازل الّتي بنيت في عدن بين عامي 1880-1990م، لذلك يعدّ استخدام إسمنت الأسبستوس المتموّج كأغطية وأسقف هذه المباني والجراجات شائعا. يمكن لدقائق ألياف الأسبستوس أن تبقى معلّقة في الهواء لفترة وتنتقل بالرّياح لمسافات طويلة قبل وقوعها. إنّ مخاطر تطوّر الأمراض المرتبطة بالأسبستوس، مثل سرطان الرّئة، يرتبط بمستوى وفترة التّعرّض له. تمّ جمع عيّنات الغبار من مناطق مختلفة في بلدة القلّوعة وأرسلت للمركز القومي للبحوث-القاهرة

لتحليلها باستخدام تقنيّة المجهر الضّوئي المستقطب (كوانتا فيج-250) باتّباع طريقة التّحليل EPA 600/R-93/116. أظهرت النّتائج الكلّيّة لمسح عيّنات الغبار وجود ألياف الاسبستوس بأقطار تتراوح ما بين 6-18 مايكرومتر، بينما التّحليل الكمّي باستخدام مجهر الضّوء المستقطب المرتبط بـ EDAX TEAM أظهرت متوسّطات تراكيز 39، 36.5، 19.2، 31.8، 36.7 و28.4 (وزن/وزن%) للعناصر: كربون، أوكسجين، مغنيسيوم، ألمنيوم، سيليكون والكالسيوم على التّرتيب، بينما كانت تراكيز الأكاسيد CO_2، MgO، Al_2O_3، SiO_2، CaO، SO_3، Fe_2O_3، K_2O و Cl_2O: 46.4، 13.6 ، 34.8، 47.5 ، 29.0، 29.1، 31.5، 32.0 و 43.8 (وزن/وزن%) على التّوالي. ينبغي تغليف ألواح الأسبستوس المستخدمة في البناء بمادة واقية لمنع أو تقليل مخاطر الأسبستوس وعلى المسؤولين إيقاف تأثير الأسبستوس على البيئة وصحّة الأنسان.

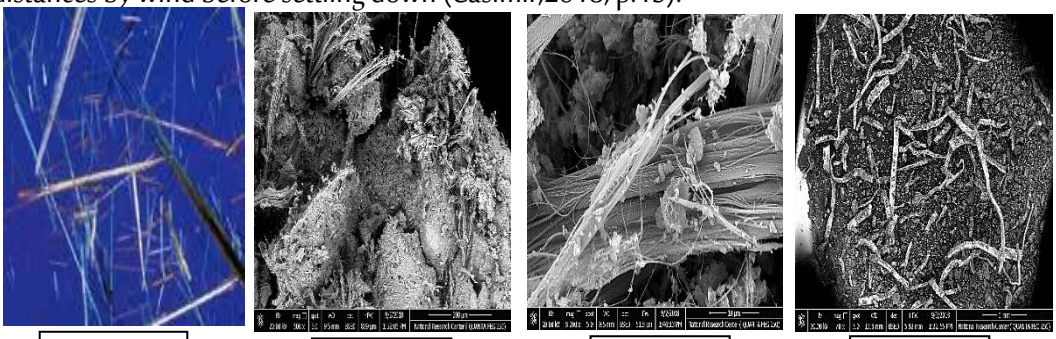
الكلمات المفتاحية: تحليل العناصر والأكاسيد، إسمنت الأسبستوس المتموج، المجهر الضّوئي المستقطب، التحليل الكمي

Introduction:

Asbestos is a generic term used for a group of several naturally-occurring minerals found in rock, its mining was completely stopped in 1983 but its usage has not been denied or regulated promptly and universally in all countries. It is still an important social issue in many countries, both industrialized and economically developing ones (Sato, 2010, p.23; Casimir, 2018, p.1; Roccaro & Vagliasindi, 2018).

Asbestos fibers are minerals with exceptional physical and chemical properties: they do not burn; they are remarkably resistant to diverse chemical attacks, depending on the asbestos type, and they show a heightened mechanical tensile strength. They are good thermal and electrical insulators. These properties have led to the development of the use of asbestos fibers in multiple forms for manufacturing numerous widely-consumed industrial products and in the construction of buildings (Lee, et al., 1992).

While asbestos is not volatile, small fibers and clumps of asbestos fibers may be released to ambient air as a dust (Lee, et al., 1992; Khadem, et al., 2018), and the health risks of exposure to such fibers/dust have been studied and debated for many years (Hwang & Park, 2016; Kwon, et al., 2017; Algranti, et al.,2019; Fitzgerald, et al.,2019). Clumps of mined asbestos can be broken down into loose fibers or fiber bundles, and can be mixed with other materials, such as cement, to produce a variety of building products (Figs. 1.b-1.c and Fig. 3.f gaskets disk). Asbestos fibers are not visible to the naked eye but, they are very light, remain airborne for a long time, and can be carried by wind and air currents over large distances by wind before settling down (Casimir,2018, p.15).



(1.a) (1.b) (1.c) (1.d)

Figure (1) Exhibit PLM image of asbestos fibers in a free form (1.a, 1nm) and in products (1.b ,100µm), (1.c,10µm) and (1.d,1nm)

Asbestos fibers can be found in the air from the breakdown of natural asbestos deposits, fibers do not dissolve in water or move through soil. They are generally not broken down to other compounds and remain virtually unchanged over long periods (Casimir,2018, p.15). It should be noted that certain tiles and corrugated sheets used on roofs of buildings prior to 1990 are likely to contain asbestos fibers. However, since the early 1990s, such products have been gradually replaced or substituted with equivalent non-asbestos containing materials – this change occurred on a voluntary basis prior to the formal ban on their use which came into force in the year 2000 (Lee, et al., 1992; Benarde, 2018, pp11,32,45). However, in Yemen asbestos products still use up to now. Asbestos only poses a risk to health when asbestos fibers are breathed in. Undisturbed asbestos cement materials in good condition do not pose a health risk because the asbestos fibers are bound together in solid cement, however, if the material is damaged or crumbling with a long time (that is, has become friable), or is disturbed by breaking, cutting, drilling or sanding, fibers are released into the air (Casimir,2018, p.17).

Asbestos cement corrugated roofing one type of asbestos boards, were used widely in coverings for building and garage, connecting pieces and stays made of steel or wood, ducts and for fire-stopping, infill panels, partitions, roof underlays, wall lining, bath panels, external canopies, porch linings and ceiling tiles. Asbestos is also found in insulating board cores and linings of composite products used for acoustic attenuators, cladding infill panels, domestic boiler casings, partition and ceiling panels, oven linings and suspended floor systems. 'Asbestolux' and 'Marinite' are examples of the trade names. All these types can contain chrysotile, amosite or crocidolite or a mixture of asbestos types. All three common types (Crocidolite, Amosite and Chrysotile) of asbestos have been used but Chrysotile (white asbestos) is the most common asbestos type found in the majority of asbestos applications such as asbestos cement (Lee, et al., 1992; Casimir,2018, pp1,2; Ramos-Bonillaa, et al., 2019; Girotto,et al.,2020). Eighty years ago in Aden city, Asbestos cement corrugated roofing were widely used in houses (Fig. 2), factories, schools, garage...etc., the majority of buildings built before 1990, during which time asbestos production peaked.

Asbestos is a toxic mineral known to produce debilitating health effects in humans. Because of its toxicity, it is necessary to have effective techniques and methods to detect and quantify asbestos in the environment (Santee & Lott, 2003, pp355,356; Perry, 2004, pp10-28).

Asbestos is related to a category 1 carcinogen and all its types can cause cancer. Blue and brown asbestos are known to be more dangerous than white asbestos. There is no cure for asbestos-related disease. Following exposure to asbestos, a person may develop one of the following three fatal diseases such as Asbestosis, Asbestos-related lung cancer (bronchial carcinoma and mesothelioma) (Nicholson, 2001; Butnor, et al., 2003; Kazan-Allen, 2005; Azari, et al., 2010; Craighead, 2011). The diseases can take many years (15–60) to develop. There are no immediate changes in someone's health after breathing asbestos materials. The likelihood of developing an asbestos-related disease depends on asbestos type (blue, brown or white), age at first exposure (likelihood increases if exposures start young), dose or

number of fibers inhaled, number of exposures and duration of each exposure, and a smoker who inhales asbestos is fifty times more likely to develop lung cancer than a non-smoker who has not been exposed to asbestos (Lee, et al., 1992; Perry, 2004, pp3,4; Tossavainen & Dtechn, 2004; Dorsett, 2016, pp 7,13,17,67; Luberto, et al., 2019; Ramos-Bonillaa, et al., 2019).

In this work, exposure to airborne/dust asbestos in houses of Al-Qalluah town, Yemen was measured by collecting bulk samples from representative sites (Fig.2) and then counting and analyzing by polarized light microscopy (PLM).

Figure (2) Houses (yellow color) covering asbestos cement corrugated roofing, in Al-Qalluah Town-Aden

Method Analysis:

Ten dust samples (numbered D1-D9 and sample no. 10 (DS) as a control) collected from the houses of Al-Qalluah area- Aden city, Fig.2, and analyzed in The National Research Center- Cairo on September 2018, for asbestos testing using the EPA method (Hwang & Park, 2016), by Polarized-Light Microscopy (PLM), model QUANTA FEG 250, because PLM is used for the determination of asbestos in bulk building materials and other samples such as soil, dust and rock (Weaver, 2003; Ham, et al., 2019).

All the dust samples were collected from the old houses whose roofs are the corrugated Asbestos cement. All houses have the same design, and were built between 1880 and 1990 by UK Government Monarchy for living of port workers. Questioner pattern was followed and put all information of houses and inhabitants' medical history. The Samples were prepared on Aluminum slats and covered with Gold by SPUTTER COATER model S150A and analyzed by PLM (instrumental precision (RSD% ≈2.1)).

Replicate analyses were performed at a frequency of one per sample set and used at least 400 points counted per sample.

Result and Discussion

The overall results of scanning PLM for dust samples in the study sites of Al-Qalluah area-Aden city have shown asbestos fibers with diameter ranged between 2.634 µm to 22.49 µm Fig.(3.a-3.f). EDAX TEAM analyzed by PLM have shown mean concentration of C, O, Mg, Al, Si, and Ca presented in Table (1) and mean concentration of oxides CO_2, MgO, Al_2O_3, SiO_2, CaO, SO_3, Fe_2O_3, K_2O and Cl_2O, presented in Table (2). The maximum mean concentrations of C, O, Mg, Al, Si, and Ca were 31.1, 48.21, 2.05, 4.27. 22.05 and 9.18 w%, found in samples D2, D1, D9, D7, D1 and D9 respectively, while the minimum mean concentrations were 16.77, 21.05, 0.82, 2.75, 8.17 and 5.73 wt%, in samples D6, D9, D2, D2, D4 and D3 respectively. The range values of standard error (SE), average deviation ($D_{avg.}$) and standard deviation (SD) were (0.145-2.49),(0.356-4.85) and (0.58-7.48) correspondingly. On the other hand, the extreme concentrations of oxides CO_2, MgO, Al_2O_3, SiO_2, CaO, SO_3, Fe_2O_3, K_2O and Cl_2O, were 69.05, 6.21, 6.11, 38.09, 9.02, 4.31, 6.27, 8.91 and 1.08 wt% found in sample D2, D9, D6, D1, D9, D7, D8, D5 and D6 respectively, whereas minimum mean concentrations were 33.54, 1.04, 3.61, 12.99, 5.32, 2.29, 3.06, 0.72 and 0.46 found in sample D8, D2, D2, D2, D3, D3, D2, D3 and D2 respectively. The values of standard error (SE), average deviation ($D_{avg.}$) and standard deviation (SD) ranged between (0.070-3.91),(0.149-8.58) and (0.199-11.74) respectively.

Images of PLM scanning, Figs.(3.a-3.f), advocate our anticipation for presence of asbestos fibers in the dust samples, collected from houses which covered by asbestos boards, that confirms the source of asbestos fibers refer to smash asbestos boards and detritus or fibers specially without other sources of asbestos fibers in the dust samples.

High mean concentration of MgO and SiO_2, were 13.6% and 47.5% in comparison with a control sample Table (2), confirms presence asbestos in the dust samples, because all types of asbestos products contains MgO and SiO_2 (Zussman, 1979; Sergeev & Goncharov, 1990; Nicholson, 2001; Butnor, 2003; Ross, et al. 2008; Lippmann, 2009, pp395-446; Dorsett, 2016, p.31; Testa, 2017, pp 1-4,11,12; Ramos-Bonillaa, et al., 2019).

Our questionnaires that included the data about the buildings from which the samples were taken and the health condition of their inhabitants showed that the age of those buildings built by the British authorities during the British occupation of Aden is from 60-150 years ago and all the buildings designed similarly.

The buildings from which the samples were taken are in the second floor and all of them covered with asbestos whose age is ranged nearly as the same period as that of the construction. Also, the families' living period in the houses is ranged between 40 to 70 years.

The findings also showed that the condition of the asbestos boards are similar and their age is more than 40 years and some of the asbestos boards are not covered with internal roofs (decorations) or with wooden roofs inexactly and this causes the falling down of asbestos dust on the grounds and on the furniture in the houses.

What has been mentioned above confirms the results of the analysis of the samples which included the fibers of asbestos with various percentages and that the fibers of asbestos represent the main reason of asthma and respiratory system diseases from which most of the inhabitants of those houses suffer from. The results showed that about 90% of the total inhabitants suffer from those diseases which is considered as a very high percentage. The results evaluated that the main reason of those diseases is attributed to their inhalation of the fibers of asbestos constantly.

Table (1) Concentration (Wt%) of major elements in dust samples

Element	C	O	Mg	Al	Si	Ca
Sample	Wt.%	Wt.%	Wt.%	Wt.%	Wt.%	Wt.%
D1	17.56	48.21	1.6	3.73	22.05	6.85
D2	31.1	40.71	0.82	2.75	9.15	6.00
D3	30.65	41.7	1.30	3.04	9.04	5.73
D4	22.15	43.11	1.51	3.08	8.17	6.08
D5	19.25	35.66	1.06	2.87	10.63	7.03
D6	16.77	40.61	2.03	3.67	11.91	7.24
D7	19.07	38.12	1.08	4.27	8.35	8.01
D8	18.25	39.20	1.74	3.22	9.12	8.66
D9	27.49	21.05	2.05	4.17	12.38	9.18
Mean	22.48	38.71	1.47	3.42	11.20	7.20
Standard error (SE)	1.91	2.49	0.145	0.186	1.44	0.403
Average deviation (Davg.)	4.85	4.73	0.356	0.478	2.83	0.955
Standard deviation (SD)	5.73	7.48	0.435	0.558	4.34	1.21
DS (Mean ±SD)	35.12±0.51	67.25±0.92	6.17±0.07	7.32±0.08	28.25±0.43	11.41±0.13

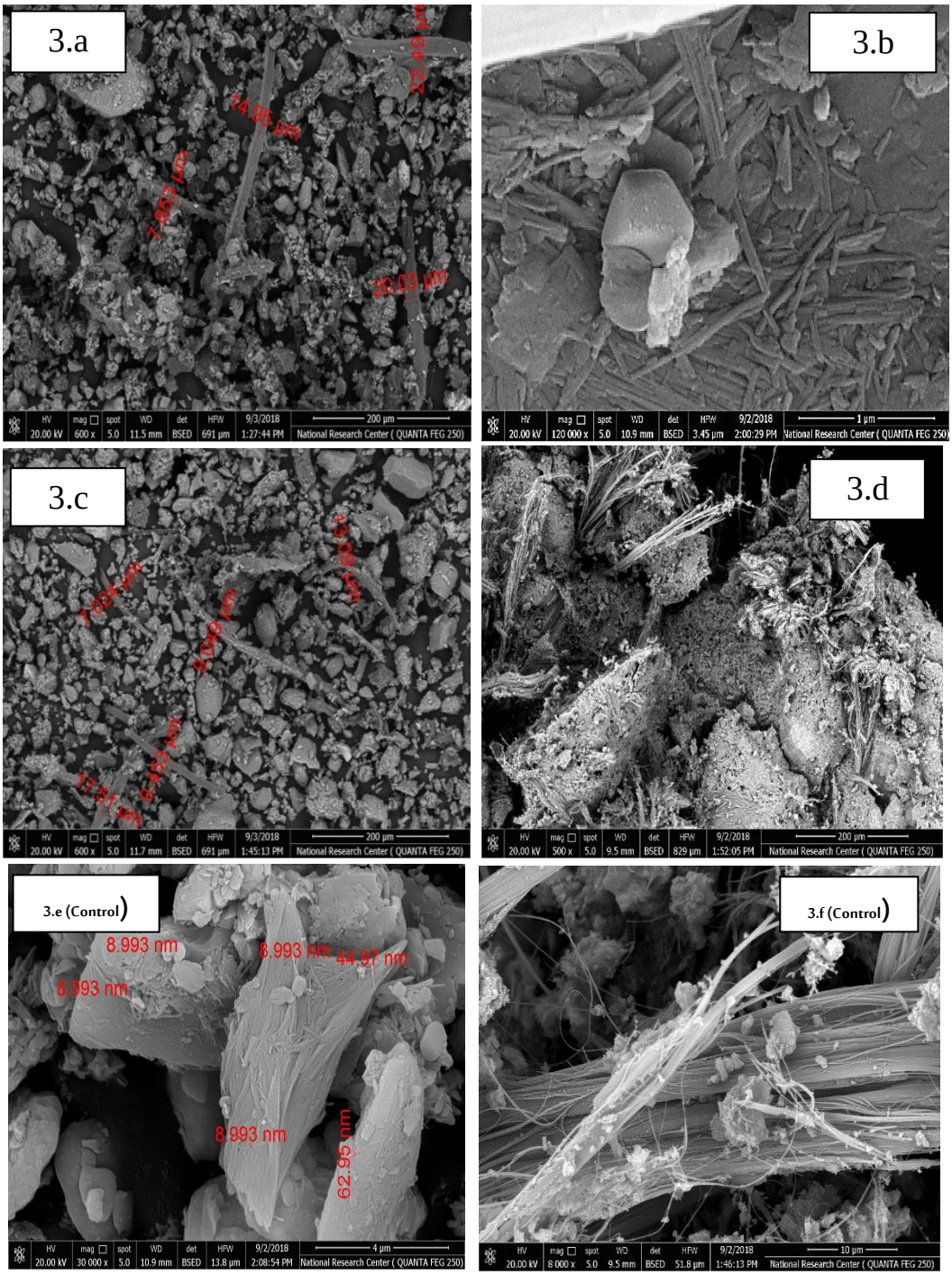


Figure (3) PLM images of asbestos fibers contents in samples (a, b, c and d) and a control (e and f). Magnification from 500 to 120,000 times. Scale was 1 µm-200µm

Table (2) Concentration (Wt%) of Oxides in dust samples using EDAX TEAM analysis by PLM

Oxides	CO_2	MgO	Al_2O_3	SiO_2	CaO	SO_3	Fe_2O_3	K_2O	Cl_2O
Sample	%Wt.	%Wt.	%Wt.	%Wt.	%Wt.	%Wt.	%Wt.	%Wt.	%Wt.
D1	46.07	2.38	5.93	38.09	7.52	--	---	--	--

Oxides	CO_2	MgO	Al_2O_3	SiO_2	CaO	SO_3	Fe_2O_3	K_2O	Cl_2O
D2	69.05	1.04	3.61	12.99	5.35	2.34	3.06	6.00	0.46
D3	66.44	1.64	4.11	13.26	5.32	2.29	3.23	0.72	0.74
D4	54.28	2.03	4.67	18.23	6.45	2.55	4.17	3.45	0.93
D5	37.37	2.66	5.06	20.35	7.23	2.59	5.66	8.91	00.85
D6	48.76	3.08	6.11	17.07	8.41	3.59	6.20	4.52	1.08
D7	50.44	4.66	5.78	18.34	6.94	4.31	5.22	5,75	0.94
D8	33.54	5.11	4.69	16.41	7.01	3.82	6.27	6.14	1.04
D9	47.66	6.21	5.24	20.45	9.02	4.11	4.55	4.27	0.75
Mean	50.40	3.20	5.02	19.47	7.03	3.20	4.80	4.86	0.85
Standard error (SE)	3.91	0.581	0.281	2.49	0.412	0.298	0.443	0.963	0.070
Average deviation ($D_{avg.}$)	8.58	1.42	0.669	4.55	0.904	0.758	1.04	1.85	0.149
Standard deviation (SD)	11.74	1.74	0.843	7.47	1.24	0.842	1.25	2.55	0.199
DS (Mean ±SD)	51.71± 0.72	20.39± 0.11	9. 39± 0.08	21.51± 0.77	14.05± 0.09	7.78± 0.04	10.43± 0.06	11.56± 0.09	1.09±0.03

Conclusion:

Owing to the higher risk confirmed by studies that the asbestoses products especially asbestoses boards that cover the roofs of houses, the authorities concerned with the environment and health must do the following:

- Asbestos boards should be encapsulated by a safe material (such as polyethylene barrier) to prevent or reduce their health and environment risks.
- The Ministry of Environment and Water has to participate actively in increasing the awareness of the people regarding the risk of those substances and the negative healthy effects that the inhabitants of those risky houses may get.
- The Ministry of Environment and Water has to contact with the local authorities and the concerned organizations to convince them with the necessity of including those boards in their projects and priorities.
- Further studies should be conducted on phlegm of asthma and disorder in the respiratory system patients to detect any traces amount of asbestos fibers inside their lungs.

- The principles of law should be activated concerning the import or use of asbestos cement corrugate on rooftops buildings and the asbestos boards found in the local market should be got rid of.

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