Non-Asbestos form building materials for Sustainable City Planning in Sri Lanka

P.C.T. Karunaratne[1,2] and G.W.A. Rohan Fernando[1,3]

1. Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka

2. Central Environmental Authority, 'Parisara Piyasa', Denzil Kobbekaduwa Mawatha, Battaramulla, Sri Lanka

3. Department of Physics, The Open University of Sri Lanka, PO. Box 21, Nugegoda, Sri Lanka

Abstract

Asbestos products have been banned and restricted in more than fifty (50) countries in the world, however, currently about 125 million people in the world have been exposed to asbestos and used in thousands of asbestos products. Large numbers of people are being died in the world due to asbestos related diseases such as asbestos-related lung cancer, mesothelioma and asbestosis from occupational exposures, which are categorized as disorders caused to the lung and pleura due to inhalation of fibres of asbestos. It is noticeable that a considerable amount of asbestos remains in buildings where constructions take place; weathering and aging of such buildings could also result in fragmentation of asbestos. Disturbing the asbestos-containing material for maintenance or renovation could also generate asbestos fibre and pose a threat to the life of the people who are exposed to such environments. The prohibition of more dangerous 'blue asbestos' by Sri Lankan government started in 1987, however, the usage of less dangerous 'white asbestos' in the forms of corrugated asbestos roofing sheets, water supply lines, fire blankets, insulation materials and some parts for automobiles in recent times has been increased, presuming that most of the asbestos have been imported from the countries that are not used asbestos products anymore. X-ray diffraction and its radiation measurements of corrugated asbestos-cement roofing sheets allows for characterization of commercially available corrugated asbestos roofing sheets in Sri Lanka (brand names of Sigiri, Sri Ramco, Elephant Masconite and Rhino). It was revealed that white hazardous asbestos fibre namely chrysotile was detected in the three (03) out of four (04) asbestos roofing sheet samples. However, the specific activity of ^{40}K, ^{226}Ra and ^{232}Th, the radium equivalent activity and gamma index evaluated in terms of Radium Equivalent Activity (Ra_{eq}), Gamma index ($I\gamma$), Absorbed gamma dose in air (D_{in}), Absorbed gamma dose out in air (D_{out}), annual indoor effective dose rate (D_{effin}) and Annual Outdoor Effective Dose Rate (D_{effout}) revealed it does not pose any significant radiation hazard.

The discussion on asbestos came to the surface, recently, since H.E. President of Sri Lanka wanted to ban the importation of asbestos from 2018. There are no acts

or regulations prohibiting the use of asbestos in Sri Lanka. However, it is necessary to revise existing asbestos related regulations and guidelines in Sri Lanka and to introduce to asbestos management plan and the phasing out plan with proper alternative for all asbestos-related products in line with the importation ban. In the meanwhile, stricter enforcement of occupational safety and health regulations related to the use and exposure of asbestos among workers in the manufacturing, construction, maintenance, and demolition sectors should have been discussed the urgency for a sustainable utilization of asbestos related products in city planning in Sri Lanka.

Introduction

Asbestos is the name used to describe a group of fibrous hydrous silicates which have outstanding physical properties including high tensile strength, heat and electrical insulation, and resistance to acids and alkali, resistance to biodegradation, non-combustibility and stability in the high pH range of the cement matrix, low electrical conductivity and a very powerful absorbant (Virta, 2003; Rawalt, 1998; Chissick, 1987). They were an important component in a variety of building and materials including loose-fill insulations, acoustic and thermal sprays, pipe and boiler wraps, plasters, paints, flooring products, roofing materials, and cementations products (Perkins and Harvey, 1993). These are nearly always complex mixtures of solids and in many instances asbestos is present as a minor component. The Environmental Protection Agency (EPA) regulated those materials that contain less than 1wt% asbestos as the permissible level with the accurate and precise quantification of asbestos in a real world material is a significant analytical challenge (Federal Register 1975,1990).

Asbestos minerals fall into two major classes, serpentines and amphiboles (United States Environmental Protection Agency, Bassani *et al.,* 2007). The ideal chemical composition of the commercial asbestos mineral families is shown in Table1.

Table 1: The Ideal Chemical Composition of the Commercial Asbestos Mineral Families

Mineral Group	Composition	Commercial Name
Serpentine Group		
Chrysotile	$Mg_3Si_2O_5(OH)_4$	white asbestos
Lizardite	$Mg_3Si_2O_5(OH)_4$	Less fibre
Antigorite	$Mg_3Si_2O_5(OH)_4$	Less fibre, but not used for asbestos
Amphibole Group		
Gunerite	$Fe_7Si_8O_{22}(OH)_2$	amosite
Riebeckite	$Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH)_2$	crocidolite or blue asbestos
Anthophylite	$Mg_7Si_8O_{22}(OH)_2$	More fibre
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$	More fibre
Actinolite	$Ca_2(Mg, Fe^{2+})_5Si_8O_{22}(OH)_2$	More fibre

Amphibole (crocidolite) class fibres are needle like appear called blue asbestos. Serpentine class generally occurs in three polymorphs which are chrysotile, lizardite and antigorite. Chrysotile is a fibrous variety, antigorite is a variety occurring in corrugated plates or fibres and lizardite is a very fine grained, platy variety. For the serpentine class minerals, the morphology of the fibres is generally cylindrical or tubular rolls whereas the amphiboles are usually recognized as solid rods (Fig.1). Both classes show chemically similar (fibres with a high tensile strength and aspect ratio) asbestiform and non-asbestiform members (Hrijaca *et al.,* 1997).

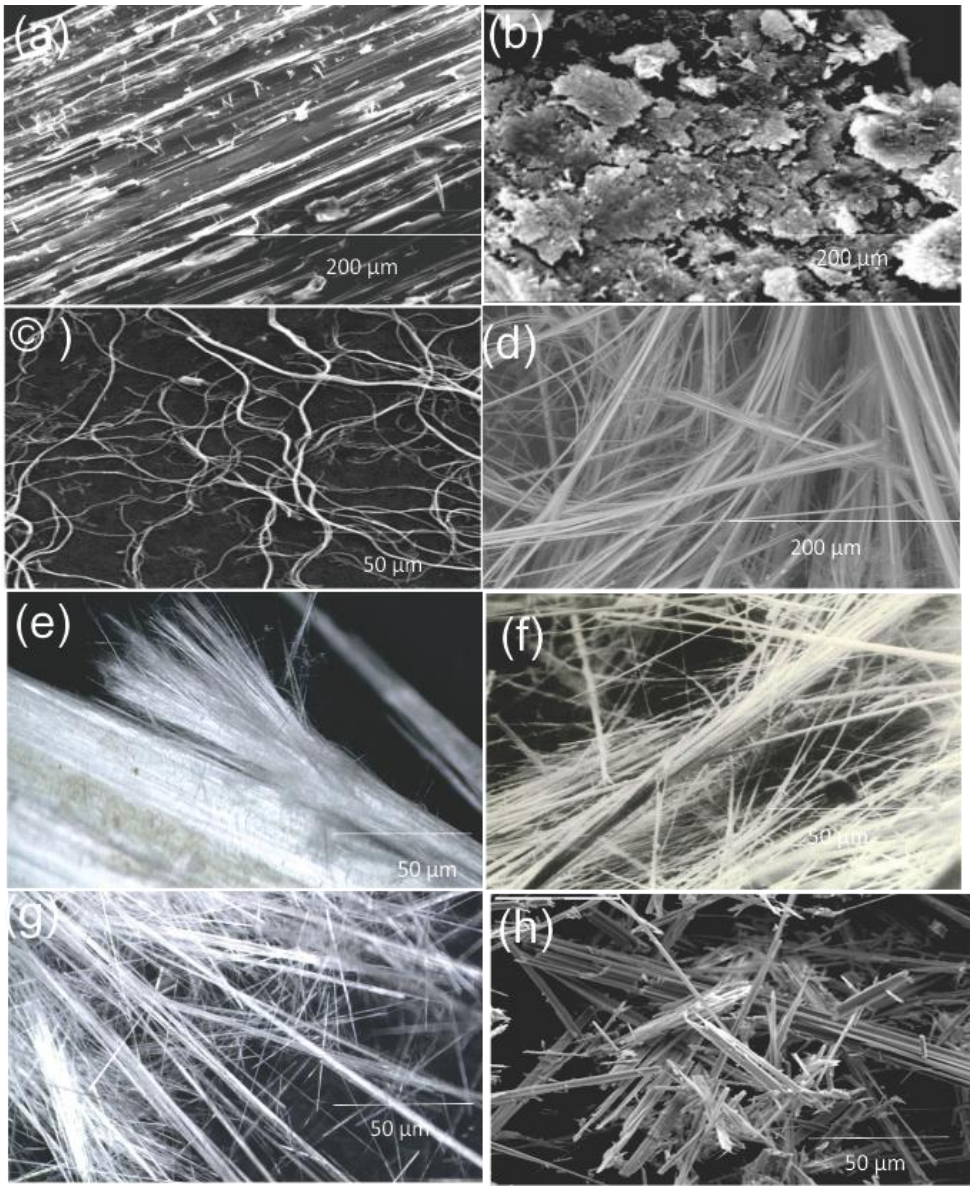

Fig.1: SEM Images of Common asbestos Raw Materials (Bassani *et al.,* 2007)
(a) antigorite; (b) lizardite; (c) chrysotile; (d) actinolite; (e) amosite; (f) crocidolite; (g) tremolite; (h) anthophyllite

Asbestos Products

Asbestos cement (AC) is a composite material composed of "Portland" cement reinforced with asbestos fibres with asbestos in the matrix ranging from 12% to 18% (Chandra and Berntsson, 2003). The "Portland" cement matrix binds the asbestos fibres into a hard mass in order to create a more durable material that is mechanically and chemically compatible with the fibres. Inherently, AC is a brittle material with low impact resistance. Therefore, even with the added reinforcement provided by the long thin asbestos fibres, the material is susceptible to cracking and chipping often caused by low impact forces, repeated cyclical loadings or deteriorated fasteners. The surface area of asbestos fibres in AC materials depends on the extent of their defiberization (i.e. opening and loss of cement matrix and resulting increase in exposure of asbestos fibres).The various types of asbestos are used, chrysotile is normally always present but crocidolite and amosite are also added to many products. Some sources of chrysotile asbestos also contain small amounts of tremolite asbestos however this can't to be detected during routine examination. Than if just cement alone was used, the product's performance requires that the cement matrix adheres to the outside of the fibres and fibres bundles so that the high tensile strength of the fibres is used to create a stronger product. The asbestos is added to the cement and wet mixed before being formed, compressed and cured to produce the end product. The addition of crocidolite and amosite is also used to support dewater the product quicker (e.g. increase production rate) and / or to allow greater compression to produce a product of greater strength (e.g. pressure pipes). Many other moulded products were made which is the cement, contains approximately 10–13% of asbestos by weight like guttering, down pipes, flues, vents, tiles, pressure pipes (Burdett, 2007).

Trend of Declining Asbestos Products in the World

Larger asbestos mines are located in Russia, China, Kazakhstan, Canada, and Brazil as well they are the major producers of asbestos in the world (reports from Central Environmental Authority of Sri Lanka, 2014). In recent years some countries have maintained or even increased their production or use of chrysotile. The usage of asbestos consumption has been increased in Asia-Pacific region (WHO, 2014). In some countries, such as China, India, Sri Lanka and Vietnam**,** the use of white asbestos have been increased between years 2000 to 2012. According to the United State Geological Survey, the world has 200 million tons of identified resources of asbestos and world production of asbestos at approximately 2 million tons per annum. The use of asbestos has declined in many countries as a result of increasing health concerns in the world.

As health risks related to exposure to asbestos is widely known, many countries have banned the commercial use of asbestos. The International Labour Organization (ILO) established an Asbestos Convention (C162) in 1986 to promote national laws and regulations for the "prevention and control of, and protection of workers against, health hazards due to occupational exposure to asbestos". As of March 4, 2008, 31 countries had ratified the Convention, 17 of them have banned use of all forms of asbestos, including chrysotile and other countries have introduced less stringent restrictions (Fig. 2). Sri Lanka, however, has not ratified this convention, and the use of asbestos has not been banned. Dust and fibres form of asbestos are listed as a category of controlled waste under the convention. Parties to the convention are required to prohibit or not permit the export of such waste to parties that have prohibited its importation under the convention.

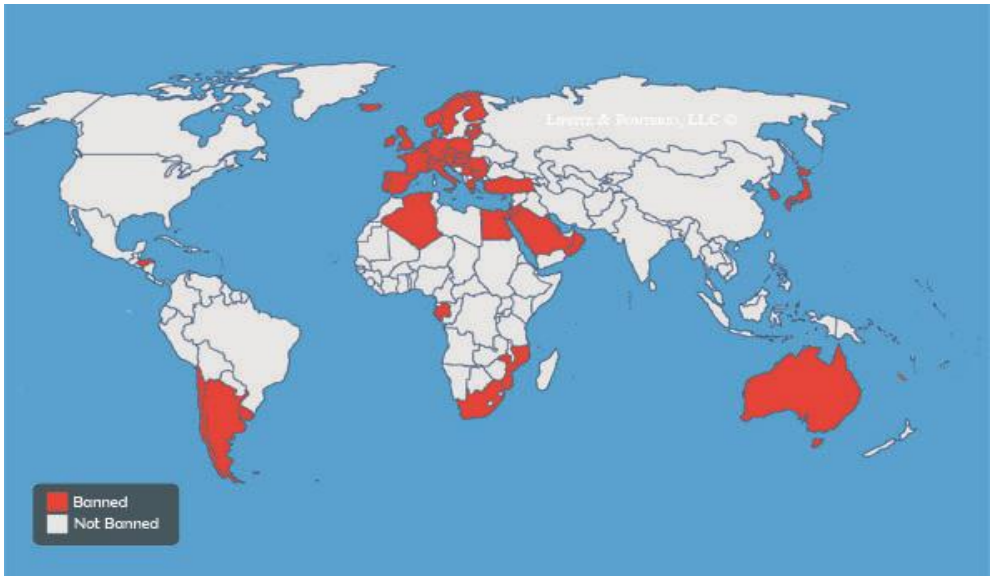

Fig. 2: The map showing the countries that have banned AsbestosProducts
Source: International Ban Asbestos Secretariat, 2014

Some countries in the developed world that have banned or restricted asbestos are engaged in exporting to other countries, mainly to Asia. For instance, Canada uses very little of asbestos and 96% of its production is exported to countries in Asia. For example, India imports largest amount of asbestos from Canada. India continues to use asbestos due to the cheapness, even though it has put asbestos in the hazardous material list. At the same time, the asbestos industry has generated 300,000 jobs in India, running more than 100 plants countrywide. Russia is considered to be another mega producer and user, along with Brazil, Kazakhstan, and China.

Health Impacts from Asbestos

Asbestos is exposed through inhalation of fibres in air in the working environment, ambient air in the vicinity of point sources such as factories handling asbestos, or indoor air in housing and buildings containing friable (crumbly) asbestos materials. Amphibole class minerals are considered more hazardous because of their excessively brittle and thin fibres (Bassani *et al.,* 2007). In serpentine class, only chrysotile has been recognized as hazardous fibre except antigorite and lizardite (WHO, 2014). All six asbestos mineral types, chrysotile, amosite, crocidolite, tremolite, anthophylite and actinolite have been recognized as human carcinogens and all types of asbestos cause lung cancer, mesothelioma, cancer of the larynx and ovary, and asbestosis (World Health Organization, 2014).Some authors have suggested that very long (>20 µm) and very thin fibres (>0.25 µm) may have greater carcinogenic potential than shorter and wider ones. However, according to point of some authors, the smallest fibres also (<1.5 µm in length and <0.25 µm in diameter) could be carcinogenic, even if their opinion is not yet clearly identified (Bloise *et al.,* 2014). The World Health Organization (WHO) is reported asbestos fibres that can be inhaled are generally assessed on dimensional characteristics as length >5 µm, width <3 µm and a length/width ratio >3.

According to the world health organization studies of asbestos concentrations in outdoor air, chrysotile is the predominant fibres detected. Low levels of asbestos which is having typical concentration, 10 fibres/m^3 have been measured in outdoor air in rural locations. Typical concentrations are about 10-fold higher in urban locations and about 1000 times higher in close proximity to industrial sources of exposure. At busy traffic intersections, presumably from braking vehicles, elevated levels of chrysotile fibres have also been detected. In indoor air such as in homes, schools and other buildings, measured

concentrations of asbestos are in the range of 30–6000 fibres/m^3 (WHO, 2014).Permissible Exposure Limit (PEL) for asbestos is 0.1 fibres per cubic centimeter of air as an eight-hour time-weighted average (TWA), with an excursion limit (EL) of 1.0 asbestos fibre per cubic centimeter over a 30-minute period. The employer must ensure that no one is exposed above these limits (Occupational Safety and Health Administration, 2014).Mixtures containing crocidolite and exposure to chrysotile, amosite and anthophylite result in an increased risk of lung cancer. Mesotheliomas have been diagnosed after occupational exposure to crocidolite, amosite, tremolite and chrysotile**,** as well as among the general population living in the neighborhoods of asbestos factories and mines and in people living with asbestos workers (WHO, 2014).The Thirteenth Session of the joint International Labour Organization /WHO Committee on Occupational Health also recommended that special attention should be paid to asbestos-related diseases.

Currently in the world about 125 million people are being exposed to asbestos at the workplace. According to global estimates, resulting from occupational exposures at least 107 000 people die each year from asbestos related lung cancer, mesothelioma and asbestosis. In addition, nearly 400 deaths have been attributed to non-occupational exposure to asbestos (WHO, 2014).Dust and fibres form of asbestos are listed as a category of controlled waste under the convention. Parties to the convention are required to prohibit or not permit the export of such waste to parties that have prohibited its importation under the convention (Central Environmental Authority, 2014).

Sustainable Town Planning while Phasing Out the Asbestos Materials

Current residential and public buildings in Sri Lanka frequently contain many materials made up with asbestos raw materials, some of which are even compliant with legal regulations in Sri Lanka. The discussion on the health impacts from asbestos in Sri Lanka has been surfaced among many of scientists and environmentalists in the last decade, although they could not make any meaningful impact to ban or control the use of asbestos products in Sri Lanka. The topic of discussion came to the fore again, recently, since the Head of the State n Sri Lanka wanted to ban the production and importation of asbestos from 2018, however, the phasing out plans and alternative measures have not been discussed. Authorities need to plan the constructions and amending the existing laws in construction in order to minimize the use of asbestos products in line with the prospective ban of importation of asbestos in 2018. Given the current situation in Sri Lanka, we take a non-traditional approach to identifying the current uses of asbestos, especially asbestos building materials, in this country.

Materials and Methods

This paper reviews the possible environmental impacts from asbestos products, especially from asbestos roofing sheets in Sri Lanka and to provide broad guidelines outlining measures, processes, institutional arrangements, procedures tools and instruments that need to be adopted by the Government of Sri Lanka to phase out asbestos products to asbestos-free town planning in Sri Lanka. This involves the examining the several stages in the supply chain of asbestos raw materials from the import, production, and consumption. We first examined documents pertaining to legislative measures on asbestos by identifying the relevant government agencies, including: Central Environmental Authority in Sri Lanka, Ministry of

Environment, and Ministry of Health. Document review was supported by semi-structured interviews with various government agencies as stated above. The chemical analyses of asbestos roofing sheets have done after the field visits done at the industrial areas and selling stores of *Rhino, Sigiri, Elephant Masconite and Sri Ramco* companies. Raw fibre samples as well as asbestos products from above trade names have been collected from each brand name. Samples were collected by composite sampling method. Powder X-ray diffraction was used for the characterization of the mineral fibres. Each asbestos roofing sheet samples were crushed, grinded, dried and sieved the sample to 50 µm mesh in order to characterized their mineralogical composition. The *D5000*X-ray diffractometer located at the University of Peradeniya and *"Rigaku- UltimaIV"* XRD machine at Industrial Technology Institute (ITI) were used for the data analyses. Qualitative analysis was carried out by comparing diffraction patterns of the samples with the patterns of the standards of the amphibole and serpentine minerals. Radiation of the asbestos samples was measured at the Department of Nuclear Science, University of Colombo.

Results and Discussion

Importation and Asbestos Usage in Sri Lanka

The import quantity of Asbestos raw materials from year 2000 to 2014 is shown in Table. 2. Over the period from 2000 to 2014, total asbestos consumption was a total of nearly half a million metric tons (Table 2), an average of 30, 352 metric tons/year (*United States Geological Survey, 2014*). After 2010, reconstructions of building and houses have been increased rapidly as well the usage of asbestos, especially in North and East parts of Sri Lanka. In 2014, annual importation of asbestos fibres is more than 56,000metric tons/year while other countries have banned or seriously restricted asbestos use, Sri Lanka seems bent on expanding this deadly industry. From that amount, the top four exporting countries were Brazil, Russia, and Kazakhstan *(Sri Lanka Customs)*. The number of occupied housing units in 2012 is 5,207,740 (*Central Environmental Authority, 2014*). Tiles are used for the roof in 48 percent of occupied housing units. The corresponding percentages for asbestos and metal sheets are 35 and 10 respectively (Fig. 3).

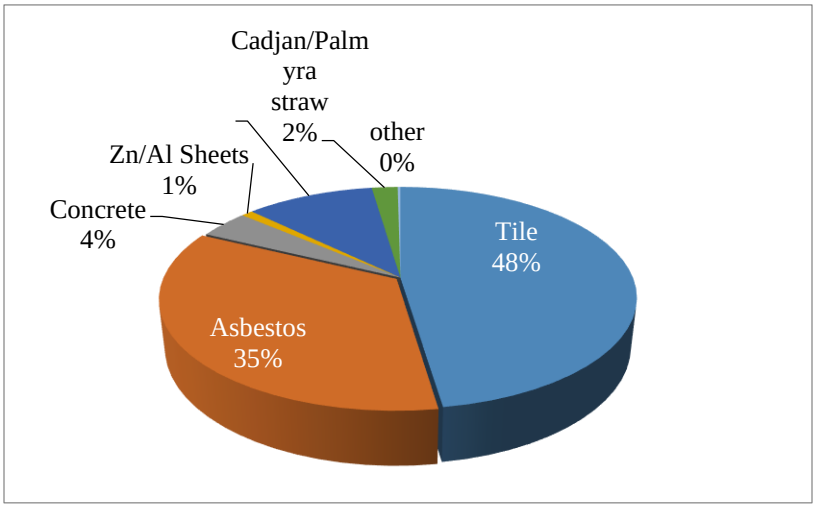

Fig. 3: Occupied housing units by principal material of roofs in 2012
Source: Central Environmental Authority in Sri Lanka, 2014

Table 2: The Quantity of Asbestos import in Sri Lanka

Year	Metric Tones
2000	12,640
2001	11,165
2002	8,659
2003	6,106
2004	38,388
2005	32,896
2006	17,417
2007	11,994
2008	58,109
2009	16,017
2010	47,892
2011	61,000
2012	54,000
2013	23,000
2014	56,000
Total from 2000-2014	455,283

Source: Central Environmental Authority in Sri Lanka, 2014

Results of X-ray powder diffraction data of asbestiform roofing sheets in Sri Lanka

Serpentine minerals such aslizardite and chrysotile were detected whereas amosite, tremolite, actinolite, anthophylite and crocidolite were not detected in all four commercial asbestos sheet productions from *Rhino*, *Sigiri*, *Sri Ramco* and *Elephant Masconite*. Hazardous fibre such as chrysotile mineral phase was detected all samples other than one sample from, in which non-hazardous lizardite was the main constituent (Fig. 4).

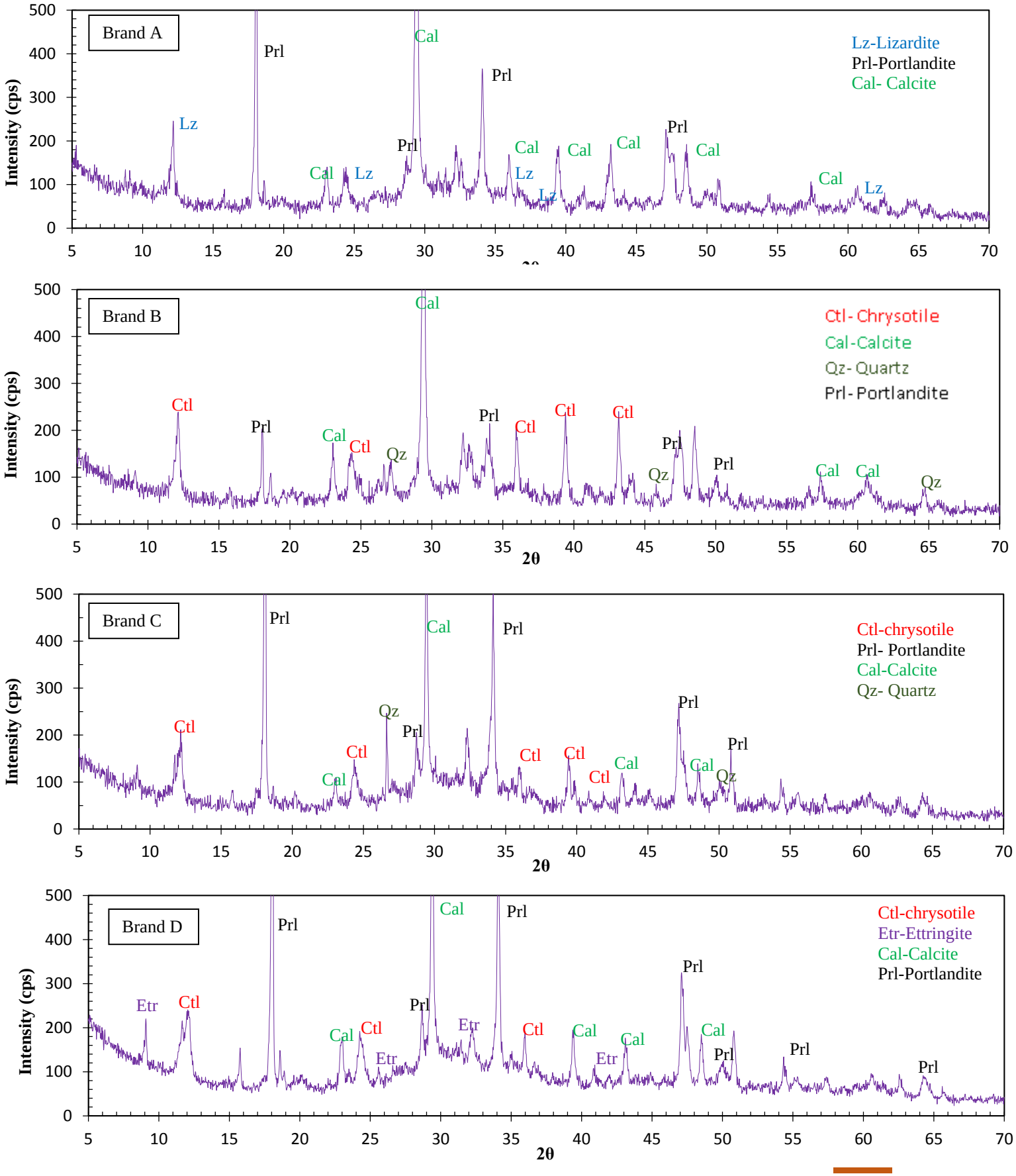

Fig. 4: X-Ray Diffraction Spectrum of Asbestos Roofing Sheets available in Sri Lanka

Health Risks from Asbestos in Sri Lanka

Asbestos covers several mineral fibres with 5 mm length and 3 mm in diameter such as chrysolite, lizardite, crocidolite, amosite, anthophylite, tremolite and actinolite. It was not until the 1960's that a relation between asbestos exposure and several specific diseases was established by the scientific evidence. By that time, only some mineral fibres (crocidolite – blue asbestos and amosite – brown asbestos) were judged as toxic and responsible for pleural mesothelioma from which most patients died, 12 months after being diagnosed (Bianchi *et al*., 1997, Jarvholm*et al*., 1999, Azuma *et al.,* 2009). Chrysolite (white asbestos) was left aside because it was thought that it had a low toxic risk and that is why asbestos continued to be produced. Only in the 1980's, the asbestos problem started to be taken more seriously. In the meantime, scientific evidence proved that all mineral fibres present a cancer risk as asbestosis (lung damage due to acid formation in an attempt of the body to dissolve the asbestos fibres) (Akira, 2010) or even lung cancer or other types of cancer (Ladou, 2004, Silverstein *et al.,* 2009, Antonescu-Turcu and Schapira, 2010). Although some may think asbestos is no longer a problem let, we cannot forget the vast number of fibre cement materials (e.g. asbestos roofing sheets), based which are still in place. One may argue that cement materials containing asbestos have a low toxicity risk but it is also true that cement will lose its binding capacity under environmental erosion, and that some cracking accidents could take place releasing asbestos fibres. Therefore, it is not possible to say that the people working (or living) under those roofing sheets are not subject to develop cancer problems after a long-term exposure.

More than fifty (50) countries in the world have already been diagnosed many asbestos related lung cancers and diseases and therefore, compelled these countered to ban the usage of asbestos. Asbestos-related diseases are currently responsible for more than 4000 deaths a year in the UK and the number is still increasing. Asbestos kills more people than any other single work-related illness. There is an increased risk of ill health associated with exposure to amphibole asbestos fibres (egamosite, crocidolite) in comparison with chrysotile (Hodgson and Darnton, 2000).In 1956, first asbestos company in Sri Lanka (*Elephant Masconite)* was functioned with both blue and white asbestos as raw materials until blue asbestos production asbestos was banned in 1987. Sri Lanka has been increased the usage of corrugated asbestos roofing sheets using white asbestos since 1987 with establishing four major asbestos companies namely *Rhino, Sigiri, Sri Ramco and Elephant Masconite* (Table 3).

In 1995, the first occupational patient has been diagnosed with asbestos related diseases named asbestosis and eventually he was died (reports from Central Environmental Authority of Sri Lanka). It is confirmed by the court order that the asbestos industry personals from asbestos industry has been given compensation for his family. The import quantity suggests that asbestos related diseases (ARDs) may be under-reported in Sri Lanka as only one ARDs patient was identified. Compared to Sri Lanka, 26 cases of ARDs were reported from 1999 to 2005 of 93, 664 metric tons imported in Malaysia (Lim, *et al.*, 2008, Zen *et al.*, 2013). Croatia imported 4,000 metric tons of asbestos minerals annually from 1995 to 2001 with 317 of ARDs reported from 1990 to 2000 (Trosic and Milkovic´-Kraus, 2004).

Table 3: Asbestos Imported Countries by Sri Lankan Companies *(Source: Central Environmental Authority of Sri Lanka, 2014)*

Sample Name	Country of origin of Asbestos Fibre
Elephant Masconite	Brazil, Russia
Sigiri	Kazakhstan, Russia
Sri Ramco	Brazil, Kazakhstan, Russia
Rhino	Russia, Kazakhstan

Even at the present day, those who have shielded corrugated asbestos roofing sheets during the period of 1956 and 1987 may contain more hazardous blue asbestos. According to reports from World health organization, white asbestos with chrysotile fibre also has been recognized as carcinogenic fibre (Peterson, 1991, WHO, 2014).This review confirms that a large amount of corrugated asbestos roofing sheets from three (03) out of four (04) branded companies mentioned above contain some form of toxicity as it was detected the hazardous chrysotile fibre, which could attribute health hazardous to occupational and non- occupational people in the country. They may be toxic to the environment during the production stage or by polluting indoor air, by releasing toxic fumes. Around 18,000 people in Sri Lanka are annually diagnosed with cancer, but collection of data relating to occupations of the cancer patients has been a difficult task. It can take about 20-30 years for the real cancer to emerge, which makes it harder to track its root causes.

The use of construction materials with some form of radiological contamination is known to be a matter of concern to public health because exposure over a long term even of low doses can develop cancer formations. Asbestos building materials have originated from mantle derived olivine and amphibole minerals, which could lead to substitute radioactive cations. Industrial materials produced with such raw materials may also have same level of radioactivity and could hard for human health. For an example, radioactive building materials could be recorded in Sweden because of 300,000 residential buildings were made with concrete based on aggregates from a uranium mine. Recent studies revealed that infants and children were more prone to develop leukaemia-related diseases because of such exposures (Axelson *et al.,* 2002).

Determination of radiation impact in corrugated asbestos roofing sheets under different brand names in Sri Lanka was too carried out as some construction materials are naturally more radioactive than others so it is necessary to study the radioactivity levels emitted by these materials in the country. Corrugated asbestos roofing sheets have become an important construction material for houses and buildings in urban and rural areas of Sri Lanka. Portland cement is the most common type of cement used in Sri Lanka. All building raw materials and products derived from rock and soil contain various amounts of mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K) (Turhan, 2008).Radiological significance of various corrugated asbestos roofing sheet samples has been investigated using gamma spectroscopy technique and mathematical models. The specific activity of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, Radium Equivalent Activity (Ra_{eq}), Gamma index ($I\gamma$), Absorbed gamma dose in air (D_{in}), Absorbed gamma dose out in air (D_{out}), Annual indoor effective dose rate (D_{effin}) and Annual Outdoor Effective Dose Rate (D_{effout}) were determined to assess the radiological hazards from asbestos roofing sheets. The Ra_{eq} values obtained in this study were determined to be lower than the recommended maximum level of radium equivalent of 370 Bq/kg for building raw materials and products (Table 4).

Table 4: Radium Equivalent Activity (Ra_{eq}),Gamma index ($I\gamma$),Absorbed gamma dose in air (D_{in}), Absorbed gamma dose out in air (D_{out}), Annual indoor effective dose rate (D_{effin}) and Annual Outdoor Effective Dose Rate (D_{effout})

Sample Name	Ra_{eq} ($Bqkg^{-1}$)	$I\gamma$ ($Bqkg^{-1}$)	D_{in} ($nGyh^{-1}$)	D_{out} ($nGyh^{-1}$)	D_{effin} ($mSvy^{-1}$)	D_{effout} ($mSvy^{-1}$)
Elephant Masconite	74.16	0.27	6.82	34.10	0.03	0.04
Sigiri	39.12	0.14	3.52	17.60	0.02	0.02
Sri Ramco	49.98	0.18	4.44	22.20	0.02	0.03
Rhino	75.42	0.28	6.81	34.08	0.03	0.04
Recommended maximum values by WHO	**370**			**80.00**		**0.46**

The calculated mean outdoor dose rates were which were lower than the permissible level of 80$nGyh^{-1}$. The corresponding annual effective dose rates were lower averages than the average annual outdoor effective dose rate of 0.46$msvy^{-1}$from the terrestrial radionuclides in the world. The calculated internal and external hazard indices in all the amount samples were less than unity.

Currently, asbestos workers are ignorant of such danger and they used to cut the asbestos products without wearing mask on their noses ignoring CEA guidelines. This will leads to exposing themselves to high danger levels, where experts advise using 100% body cover when exposed to asbestos.

Regulatory Mechanisms of Asbestos Products in Sri Lanka

A summary of current legislative measures of asbestos and its products since imported is presented in Table. 5. An explanation of the legislative measures in each stage of the supply chain is described.

Importation Stage

Sri Lanka is not an asbestos producing country. There are two (02) documents related to asbestos at the import stage (Table 5). These documents prohibit importation of hazardous chemical materials including a prohibition on importing crocidolite asbestos used for any purpose except research and analytical activity. The asbestos mineral prohibition does not cover other types of asbestos (actinolite, anthophyllite, amosite, tremolite, and chrysotile).

Since1960, raw asbestos mineral has been imported using the Harmonized System of Coding (HS Code) under the Import and Export (Control) Act, No.1of 1969.In 1960s blue asbestos (crocidolite) was identified as a carcinogen and in 1970's it was begun to ban throughout the world (84 countries signed Rotterdam Convention) including in Sri Lanka. Blue asbestos was banned in Sri Lanka in 1987 by extraordinary gazette notification No. 452/4 of 06.05.1987 after amending the Import and Export (Control) Act, No.1of 1969. However, the asbestos mineral prohibition does not cover other types of white asbestos (chysotile, lizardite, actinolite, anthophyllite and tremolite).

Currently, Import and Export Control Department of Sri Lanka, Customs are responsible to import white asbestos in to the country under the Regulations made under Section 20 read with subsection (3) of section 4 and section 14 of the Imports and Exports (Control) Act, No. 01 of 1969, as amended by Act, No. 48 of 1985 and No. 28 of 1987 and paragraph (2) of article 44 of the Constitution. Extraordinary gazette notification No.1739/3 on 2012.01.02 was issued to ban importing crocidolite with HS code of 2524.10. The all other asbestos substances are allowed to import under the same Gazette notification with HS code of 2524.90 as other asbestos types. However, according to this Regulation, every asbestos company has to take certificate of no objection from the Central Environmental Authority (CEA) for each shipment to import their fibre. Current practice at CEA is only to analyses for crocidolite fibre by the Fourier Transform Infrared Spectroscopy (FTIR) from the Industrial Technology Institute (ITI) as well as company needs to submit an analytical report of the each fibre shipment to the CEA. This procedure may allow other asbestos like amosite, tremolite, actinolite, anthophylite and hazardous white asbestos of chrysotile to be imported without any legal barrier. Possibilities are there to mix of hazardous asbestos during mining, which enable to add hazardous asbestos during production process. Asbestos production companies prefer some amount of blue asbestos to increase the strength of the products in the world.

Table 5: Supply Chain of Asbestos building Material-related laws and Regulations in Sri Lanka

	Import Mineral Asbestos	Banning of Mineral Asbestos	Production/Waste Management of Asbestos Building Materials	Building Constructions using Asbestos	Demolition of Asbestos Materials	Sustainable town planning
Supply Chain	1960-Commencement of Importation of asbestos raw materials Regulations made importation of end products of asbestos roofing sheets in 2014	blue asbestos (crocidolite) was banned in Sri Lanka in 1987	Work place environment should be maintained below the permissible exposure limit (PEL) of 0.1 Fiber Of Asbestos per Cubic Centimeter of air Controlling Asbestos sludge from waste water, Asbestos dust or loose Asbestos fibre wastes from Asbestos/cement products manufacturing plant and Empty bags or sack containing loose asbestos fibres	No monitoring mechanism	No monitoring mechanism	?
Laws and Related Guidelines	Import and Export (Control) Act, No.1of 1969 Extraordinary gazette notification No.1739/3 on 2012.01.02 Building Material contains Crocidolite Asbestos (HS 2524.10) Other Asbestos Mineral Raw Materials (HS 2524.90) Extraordinary gazette notification No. 1844/49 on 2014. 01.08 HS 6811.40.10 Asbestos Cement Corrugated Sheets HS 6811.40.20 Asbestos Cement Flat Sheets	Extraordinary gazette notification No. 452/4 of 06.05.1987	Waste Management under National Environmental Act No. 47 of 1980 as amended by Act No. 56 of 1988 and Act No. 53 of 2000. Renewal of a license shall be made as laid down in regulations No 8 of the National Environmental regulation No. 1 of 2008. **S 161** **S 162** **S 163**	The Urban Development Authority (UDA) Law, No.41 of 1978 amended by Act No.70 Municipal Council Ordinance– Act No.29 of 1947 amendments Act18 of 1979 Amendments Urban Council Ordinance 61 of 1939, Acts 13 of 1979 and Amendments		

Extraordinary gazette notification No. 1844/49 on 18th January 2014 was issued to monitor the importation of Asbestos Cement Corrugated Sheets. According to the Gazette, Companies need to get certification from Sri Lanka Standard Institute under HS 6811.40.10 (Asbestos Cement Corrugated Sheets SLS 9 Specification for Asbestos Cement Products Part 2 Corrugated Sheets) and HS 6811.40.20 (Asbestos Cement Flat Sheets SLS 9 Specification for Asbestos Cement Part 1 Flat sheets).

Production Stage

At the production stage, there are no direct Regulations to monitor the production of asbestos. Asbestos Industries come under the prescribed activities that Environment Protection Licenses (EPL) which should be obtained Central Environmental Authority (CEA). Waste Management under National Environmental Act No. 47 of 1980 as amended by Act No. 56 of 1988 and Act No. 53 of 2000 was enacted to ensure the discharging of asbestos-free wastewater at the place of work. The asbestos waste is scheduled as a hazardous waste which Scheduled Waste Management License (SWML) ought to be obtained from CEA. However, it is important that the authorities continuously monitor the situation, as these employees can be in the line of direct exposure. However, many of the asbestos manufacturing plants are being disposed of irresponsibly, ignoring the CEA guidelines to persuade the burial at the much deeper in the earth. Renewal of a license shall be made in every year as laid down in regulations No 8 of the National Environmental (Protection and Quality) regulation No. 1 of 2008. The asbestos sludge, asbestos dust of loose asbestos fibre waste and asbestos-bearing empty bags disposal mechanism are described in these Regulations under S161 (Asbestos sludge from the waste water treatment system of Asbestos/ cement products manufacturing plant), S162 (Asbestos dust or loose Asbestos fibre wastes from Asbestos/ cement products manufacturing plant) and S163 (Empty bags or sack containing loose asbestos fibres from asbestos/ cement product manufacturing plant) respectively. Work place environment should be maintained below the permissible exposure limit (PEL) of 0.1 Fiber of Asbestos per cubic centimetre of air as averaged over 8 –hour period, with an excursion limit of 1.0 asbestos fibers per cubic centimetre over 30 minute period, as per the Occupational Safety and Health Administration (OSHA).

Construction Stage/Use of goods Containing Asbestos

At this stage, the use of asbestos during the planning and construction involves various stakeholders such as architects, engineers, contractors, and building surveyors. Construction workers would be the first to get exposed to the asbestos dust during work. There is no such a Regulation to control these types of exposures other than normal construction Acts.

The Urban Development Authority (UDA) Law, No.41 of 1978 amended by Act No.70 and Amendments. The UDA is mandated to promote the integrated planning and implementation of social, economic and physical development of areas declared as "Urban 10 Development Areas" under the UDA Act with the overall vision of guidance, facilitation, and regulation of urban development through innovative and integrated physical planning. The UDA, as a part of its mandate provides technical support to local councils who require assistance in developing plans, and has the authority to develop plans when local authorities fail to do so. In case of conflict between local council laws and the Town and Country Planning Ordinance, the UDA Act is paramount in areas designated as urban development areas. The UDA monitors urban areas, including 1 km inland from the coasts in all areas of the coastal zone, and develops land use policies for designated development areas. Local Authorities: Municipal Council Ordinance–Act No.29 of 1947amendments Act18 of 1979 and Amendments, Urban Council Ordinance 61 of 1939, Acts 13 of 1979 and Amendments. The Municipal Councils and Urban Councils have similar powers to the *Pradeshiya Sabhas* regarding approval of buildings plans, maintenance of solid waste, sewerage and

public utilities etc. Under these laws all new construction and modifications to current buildings need to be approved by the appropriate Municipal or Urban Council. By-law, the mayor or urban council chairman has the authority to approve building plans. Municipal and Urban councils are required to follow interim planning and building guidelines of the UDA per regulations formulated and published by the UDA. Municipal and Urban councils including those in UDA declared areas approve building plans.

Demolition Stage

There is no current Regulations on demolishing asbestos containing buildings. Therefore, no control to monitor the asbestos containing construction wastes such as asbestos sheets, AC pipes, ceramics, roofs, and tiles are not only generated from removal and demolition of private buildings and government buildings, which waste amounted a huge uncounted numbers in the prospective town planning in Sri Lanka.

Asbestos Phasing Out Plan with Urban Development

Although ongoing discussions are made among Ministry of Health, World Health Organization and Ministry of Environment to phase out asbestos products in Sri Lanka, prospects seem very slim. The reasons for standstill the discussions are mainly due to unavailability of alternative proposal. Inorganic fibres, organic fibre and natural organic fibre have already been identified as alternative for natural asbestos fibre with less health impact. Sri Lanka has to find alternatives for asbestos fibre and better to use less harmful fibre to manufacture of corrugated asbestos sheets and other asbestos related products or strictly monitoring hazardous substances in currently available asbestos products.

Conclusions

This study has given a reader on detailed status of asbestos and its products in Sri Lanka and the world trend. The supply chain approach applied in this study succeeded in identifying the current status and the regulatory gaps related to the use of asbestos in Sri Lanka. Initiatives from the Sri Lankan government in banning asbestos containing materials from 2018 in construction development display a serious commitment to public health. In further, the specific concern on the public health needs to emphasize on the tight definition for phasing out plan for asbestos products with the importation ban. The special emphasis should be placed on the asbestos products manufactured before 1987, which included the considerable amount of banned substances of crocidolite (blue asbestos), at the phase out plan. This study further provides a framework for a sustainable city planning while addressing the total ban of using asbestos products in Sri Lanka. The first stage of phasing out plan would be banning of asbestos constructions in government and semi-government buildings and offices. Several new ministries have been established, mainly targeting sustainable city planning. Asbestos phasing out plan would be considered with its prospecting regulatory framework during the demolishing work and new constructions in this city planning. The cooperation required across government agencies in order to develop comprehensive regulatory frameworks.

References

Axelson, O., Fredrikson, M., Akerblom, G. and Hardell, L. (2002). Leukemia in childhood and adolescence and exposure to ionizing radiation in homes built from uranium-containing alum shale concrete. *Epidemiology,* Vol. 13, p.146–150.

Azuma, K., et al., (2009). Mesothelioma risk and environmental exposure to asbestos: past and future trends in Japan. *International Journal of Occupational and Environmental Health*, Vol.15, p.166–172.

Bassani, C., Cavalli, R.M., Cavalcante, F., Cuomo,V., Palombo , A., Pascucci, S., and Pignatti, S. (2007). Deterioration status of asbestos-cement roofing sheets assessed by analyzing hyperspectral data. *Remote Sensing of Environment* Vol. 109, p.361–378.

Bianchi, C., Giarelli, L., Grandi, G., Brollo, A., Ramani, L. and Zuch, C. (1997). Latency periods in asbestos-related mesothelioma of the pleura. *European Journal of Cancer Prevention,* Vol.6, p.162–166.

Bloise, A., Critelli, T., Catalano, M., Apollaro, C., Miriello, D., Croce, A., Barrese, E., Liberi, F., Piluso, E., Rinaudo, C. and Belluso, E.(2014).Asbestos and other fibrous minerals contained in the serpentinites of the Gimigliano-Mount Reventino Unit (Calabria, S-Italy).*Environmental Earth Science*, Vol. 71, p.3773–3786.

Burdett, G. (2006). Investigation of the chrysotile fibres in an asbestos cement sample, Available from: http:// www.hsl.gov.uk (Accessed 2 January 2015)

Chandra, S., & Berntsson, L. (2003). Lightweight aggregate concrete-science. Technology and applications *Norwich, NY: Noyes Publications,* 430 pp.

Chissick, S.S. (1987). In: R.A. Meyers (Ed.), *Encyclopedia of Physical Science and Technology, Academic Press, Orlando*, Vol. 2, p.79-108.

Federal. Register, the Daily Journal of the United Stated Government (1975). National Archives and Records Administration (NARA), *Government Printing Office (GPO), publ.,* The Federal Register Act of 1935, Vol. 40, p.53349(www.federalregister.gov).

Federal. Register, the Daily Journal of the United Stated Government(1990), National Archives and Records Administration (NARA), *Government Printing Office (GPO), publ.,* The Federal Register Act of 1935, Vol.55, p. 48431 (www.federalregister.gov).

Hodgson J T and Darnton A (2000). The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure' *Annals of Occupational Hygiene,* Vol.44, p. 565-601.

Hrijaca, A.J., Eylem, C., Zhu,Q., Sabatinia, R., Petrakisa,L., Hub, R. and Block B, J. (1997). On the use of X-ray powder diffraction for determining low levels of chrysotile asbestos in gypsum-based bulk materials: use of a synchrotron source. *Analytica Chimica Acta,* Vol. 350, p. 221-229.

Jarvholm, B., Englund, A. and Albin, M., (1999). Pleural mesothelioma in Sweden: an analysis of the incidence according to the use of asbestos. Occupational and Environmental Medicine, Vol. 56, p.110–113.

Ladou, J., (2004). The asbestos cancer epidemic. *Environmental Health Perspectives*, Vol.112, p. 285–290.

Lim G.C.C., Rampal, S. and Halimah, Y. (eds) (2008). Cancer incidence in peninsular Malaysia, 2003–2005. *National Cancer Registry. Kuala Lumpur: Ministry of Health.*

Peterson, M.W. (1991). Analysis of the asbestos permissible exposure level threshold standard, *Monterey, California. Naval Postgraduate School publ,*pp.71.

Rawalt, C. J. (1998). Asbestos Project for GO 536 optical mineralogy. Available .http://www.emporia.edu/earthsci/amber/students/rawalt/asbestos.htm(accessed: March 2015).

Trosic, I, Milkovic´-Kraus S (2004). Asbestosis in the republic of Croatia., *Int. J. Occup. Env. Health,* Vol. 2, p.198–201.

Turhan Ş.(2008). Assessment of the natural radioactivity and radiological hazards in Turkish cement and its raw materials, *Journal of Environmental Radioactivity,* Vol. 99, p.404-414.

Virta, R. L. (2003). Asbestos: Geology, Mineralogy, Mining, and Uses. U.S. Department of the Interior, U.S. Geological Survey, Open-File Report 02-149.Available: http://minerals.usgs.gov/minerals/pubs/commodity/asbestos/(accessed: 03/ 2015).

World Health Organization (2014). International program on chemical safe, Asbestoshttp://www.who.int/ipcs/assessment/public_health/asbestos/en/

Zen, Irina Safitri, Rahmalan Ahamad, Krishna Gopal Rampal and Wahid Omar (2013). Use of asbestos building materials in Malaysia: legislative measures, the management, and recommendations for a ban on use*, Intern. J. Occupational and Environmental Health,* Vol 19 (3), p. 169 – 178.

http://ibasecretariat.org/lka-latest-global-asbestos-data.php