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Article

Global Asbestos Disaster

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Abstract:

Background. Asbestos has been used for thousands of years but in a large industrial scale for about 100–150 years. The first identified disease was asbestosis, a type of incurable pneumoconiosis caused by asbestos dust and fibres. The latest estimate of global number of asbestosis deaths from the Global Burden of Disease estimate 2016 is 3495. Asbestos caused cancer was identified in the late 1930's but despite of today's overwhelming evidence of the strong carcinogenicity of all asbestos types including chrysotile it is still widely used globally. Various estimates have been made over time including those of WHO and ILO 107,000–112,000 deaths. Present estimates are radically higher. This special edition of the Journal summarizes key aspects of the past and present of the asbestos problem globally.

Methods. Documentation on milestones of asbestos related diseases, ARDs, their recognition, reporting, compensation and prevention efforts were examined, in particular from the regulatory and prevention point of view. Estimated global numbers of incidence and mortality of ARDs were looked at.

Results. Asbestos causes an estimated 257,000 deaths (243,223–270,635) annually according to latest knowledge. Work-related exposures are responsible for 235,000 deaths (222,322–247,363) of those. In the European Union, USA and in other High income economies (WHO regional classification) the direct costs for sickness, early retirement and death, including production losses, have been estimated to be very high, in the Western European countries and EU equivalent of 0.70% of the GDP or 114.9*109 USD. Intangible costs could be much higher. When applying the Value of Statistical Life (VSL) of 4 million EUR per cancer death used by the European Commission we arrived 5at 410*109 USD while the human suffering and loss of life is impossible to quantify. The numbers and costs are increasing practically in every country and region in the world. Asbestos has been banned in 55 countries but used widely today, some 2,030,000 tons consumed annually according to latest available consumption data. Every 20 tons of asbestos produced and consumed kills a person somewhere in the world. Buying 1 kg asbestos powder format e.g. in Asia costs some 0.38 USD and 20 tons would cost in such retail market 7600 USD.

Conclusions. Present efforts to eliminate this man-made problem, in fact an epidemiological disaster, and preventing exposures leading to it are insufficient in most countries in the world. Applying

programmes and policies, such as those on the elimination of all kind of asbestos use—that is banning of new asbestos use and tight control and management of existing structures containing asbestos—need revision and resources. The ILO/WHO Joint Programme for the Elimination of Asbestos-related Diseases need to be revitalized. Exposure limits do not protect properly against cancer but for asbestos removal and equivalent exposure elimination work we propose a limit value of 1000 fibres/m^3.

Keywords: asbestos; ban; global estimates, costs

1. Introduction

The First Supplement to the "Occupation and Health - An Encyclopedia of Hygiene, Pathology and Social Welfare" of the International Labor Office, ILO, Vol. I, 999 pp.; Vol. II, 1310 pp. was published in 1938 and contained a Chapter on Asbestos [1]. It was the first time when an ILO document refers to cancer in relation to asbestos when identifying the criteria for action in asbestos-related workplaces. Asbestosis had been well recognized already at that time but the magnitude of the problem was revealed gradually better when the carcinogenic properties of all kinds of asbestos fibres were convincingly identified.

It took some 40 years to start international action. The ILO Asbestos Convention No. 162 was adopted in 1986 [2]. This Convention itself was a compromise of the pro-asbestos parties and those who wanted strict measures to stop using asbestos. Later the Convention wording has been misused against the original intent.

Most of the asbestos exposures were considered to be limited to asbestosis and mesothelioma until recently – this millennium - when the magnitude of lung cancer, ovary and larynx cancer deaths have come to be better known. IARC - International Agency for Research on Cancer, of WHO has classified all types of asbestos causing these cancers and possibly other cancers and diseases. Other cancers may be confirmed as asbestos induced in future.

"ILO Resolution concerning asbestos in 2006"[3] finally corrected the missing parts of the Convention in stating that "all forms of asbestos, including chrysotile, are considered as known human carcinogens." and "elimination of the future use of asbestos and the identification and proper management of asbestos currently in place are the most effective means to protect workers from asbestos exposure."

Asbestos is the most significant factor for work-related cancer and work processes including asbestos affect indirectly family members of asbestos workers, and the environment anywhere where asbestos and related products are present. Lung cancer counts for 54–75 per cent of all occupational cancer. Epidemiological studies indicate that occupational exposures cause 5.3–8.4 per cent of all cancers and among men 17–29 per cent of all lung cancer deaths, according to best estimates. Asbestos accounts for 55–85 per cent of lung cancer and causes other cancers and other ARDs today [4].

2. Materials and Methods

Materials and data were obtained from ILO, WHO, and from the Institute of Health Metrics and Evaluation, and by using individual scientific papers and country and using global trade and health statistics. Crude mortality numbers and age-adjusted mortality rates were used to balance and compare outcomes for different countries and populations with varying age structures. Comparisons were made based on selected regions, countries, asbestos consumption, deaths and disability adjusted life years (DALY's) for several confirmed asbestos-related diseases. In many workers' compensation schemes the individual worker's smoking status is not a reason to exclude a victim from compensation. In practice, however, most asbestos caused cancers are not reported, recorded and compensated and in most countries none of them are properly identified and compensated. The synergistic additive or sometimes multiplicative impact of smoking and asbestos often confuses and masks the identification asbestos caused problems. Major ARDs and, in particular, lung cancer is a typical major manifestation of multiple simultaneous exposures complicating individual diagnosis. Depending on the reliability of source materials and methods of estimation a considerable number of asbestos exposure victims may have been be classified as victims of smoking only thus producing gross under-estimates of the role of asbestos. According to the definition of the attributable fraction the baseline for estimation should be to count the difference between the numbers of negative outcomes in studied comparable populations when the related exposure, such as asbestos exposure, is or is not present. This means independence of the impact of other simultaneously present factors. The practice of adjusting attributable fractions for smoking may not be ethically sound.

Direct statistics and relatively reasonable estimates of asbestos related pneumoconiosis are available from WHO and IHME statistics. For pleural and peritoneal mesothelioma which are overwhelmingly caused by asbestos exposure this is also the case. However, a serious under-diagnosing or non-diagnosing is a source of error for recording, in particular, lung cancer cases. Recorded lung cancer, ovary and larynx cancers do not usually indicate asbestos as a cause of death. Diagnosing these properly for individual needs a post mortem including fibre counts of the lung tissue, which is not a usual practice for the huge majority of cases. Consequently, the numbers may be estimated either using the attributable fraction method based on quantity of asbestos exposure and number of exposed workers. Furthermore, the number of mesothelioma cases - where almost all cases/deaths are linked to asbestos exposure - can be used as a proxy for asbestos exposure exactly in the same way as has been done for the IHME estimates on the Global Burden of Diseases and Injury GBD 2016 [5].

Cost comparisons were made using the estimated disability adjusted life years, DALYs, caused by asbestos as compared to an ideal case where no ARDs, no asbestos consumption and no asbestos exposures were present [6]. This itself is somewhat challenging and may cause a source of error as it is practically impossible to find a populated location without any asbestos fibres in air globally. Statistics are not available from most countries in the world and proxy estimates based on comparable countries and regions were made when no data was available. Exposures and negative outcomes were estimated separately – when data was available - for occupational exposures and non-occupational sources. The IHME/GBD number of DALYs, Years of Lost Life (YLL) and Years Lived in Disability were taken as a baseline while the mortality numbers were extrapolated from available data by Chimed-Ochir et al. The method is equal to that of ILO study on economic costs of occupational injuries and illnesses, including cancer. That was based on results of a team of

researchers including ILO, ICOH, WSH Institute of Singapore, Finnish Institute of Occupational Health, ministries of Finland and Singapore and the European Agency for Safety and Health at Work [7].

3. Results

Deaths and diseases caused by asbestos were studied and presented globally. A summary of present knowledge related to mesothelioma is presented in Table 1. We have used the occupational component of work-related mesothelioma 94.9% from Rushton et al [8]. A corresponding value for work-relatedness of all mesothelioma deaths by the GBD2016 was 91.4%, see Supplementary Table 1.

Table 1. Summary of most recent information related to mesothelioma

Sources		Global	China	EU28
Takala 2015				10,368
Odgerel 2017	Reported	15,011	NA	8,363
	Estimated[i]	21,247-23,377	6,456-10,459	NA
	Total	36,258-38,388		
GBD 2016		30,208	2,747	10,700
Work related mesothelioma	GBD 2016	**27,612**		
	Odgerel 2017	**35,087**[ii]		

[i] Mesothelioma deaths were estimated based on continental region, % of employment in industrial sector and asbestos consumption. Please refer to original article for details.

[ii] Calculated from asbestos adjusted estimation which is 38,388.

Mesothelioma deaths were estimated by GBD2016 to be 30,208. The latest scientific paper by Odgerel Chimed-Ochir et al [9] estimated the number of deaths to be 38,388 using asbestos consumption related estimation method. Equivalent work-related outcomes were correspondingly 27,612 (GBD2016) and 35,087 (Chimed-Ochir). Earlier data for GBD2016 are given as a comparison for China and EU28 in Table 2. Further details and table on country level mesothelioma deaths by Chimed-Ochir et al. are given by the authors, in addition a mesothelioma excel table by country based on WHO data is included in the CEJOEM journal web version [10].

Table 2. Asbestos related lung cancer and other asbestos related deaths

Methods of estimated lung cancer deaths using mesothelioma as a proxy for asbestos use	Lung cancer or asbestos related cancers/ mesothelioma death ratio	Global	China	EU28
McCormack, Peto et al. (2013) average estimate using chrysotile, lung cancer, all , GBD 2016	6.1	184,269		
McCormack, Peto et al. (2013), low - high estimates, lung cancer, all, GBD 2016	2.0-10	55,224-302,208		
Asbestos-related cancers[iii] & asbestosis (occupational exposure to asbestos, GBD 2016)	7.05[iv]			
Mesothelioma		27,612	2,178	10,480
ARLC (Asbestos related lung cancer)		181,450	17,971	70,291
Ovarian cancer		6,022	270	2,868
Larynx cancer		3,743	198	1,287
Total asbestos related cancer at work (GBD 2016/Odgerel 2017)		222,322$_{work}$ /247,363[v]$_{work}$ Mid point 234,840		
Total asbestos using mesothelioma $_{all\text{-}work}$ as proxies (GBD 2016/Odgerel 2017)		243,223$_{all}$ /270,635[vi]$_{all}$ Mid point 256,930		

iii - Mesothelioma, ARLC, ovarian and larynx cancer

iv- (ARLC+Ovarian+Larynx cancer+Asbestosis)/Occupational mesothelioma

v- 35,087 x 7.05

vi - 38,388 x 7.05

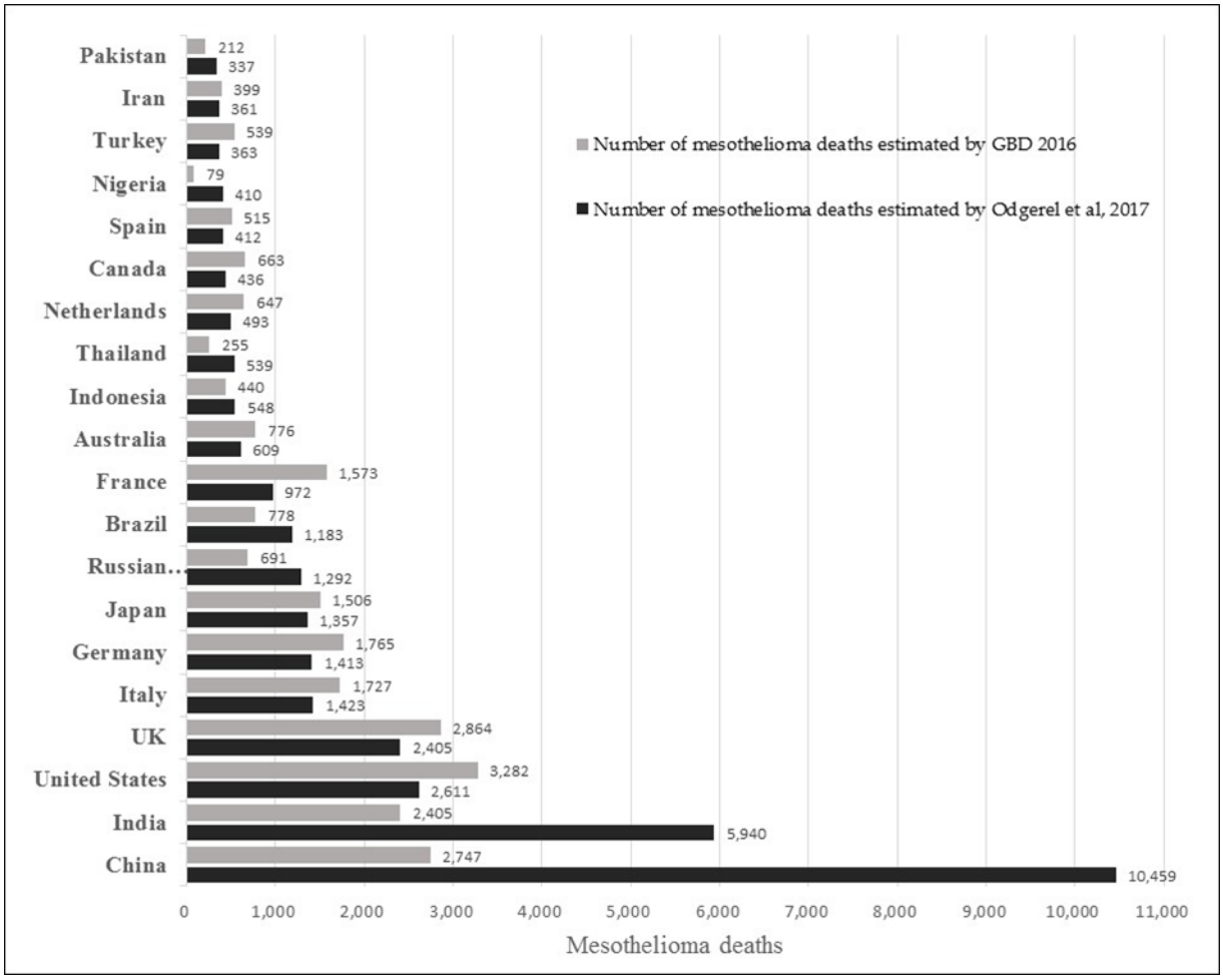
Table 2 provides estimated summary outcomes for the GBD2016 of the four types of asbestos related cancers and asbestosis which was 222,322 deaths at work and extrapolating the number to all asbestos deaths was 243,223 deaths. Corresponding numbers of deaths based on the higher mesothelioma estimates by Chimed-Ochir et al. and a similar extrapolating method will come to 247,363 at work, and 270,635 including all exposures at work, semi-occupational exposures, such as family members of workers, and environmental exposures.

A mid-point has been shown for both work-related and all asbestos exposed death cases, 234,840 and 256,930 correspondingly. These are updated from the CEJOEM paper [10].

Supplementary Tables 2 and Figure 1 compare the outcomes of the two estimation methods for mesothelioma of the biggest asbestos using countries in the past as the mesothelioma case number is a reasonable proxy for asbestos exposures and interlinked on other asbestos caused cancers.

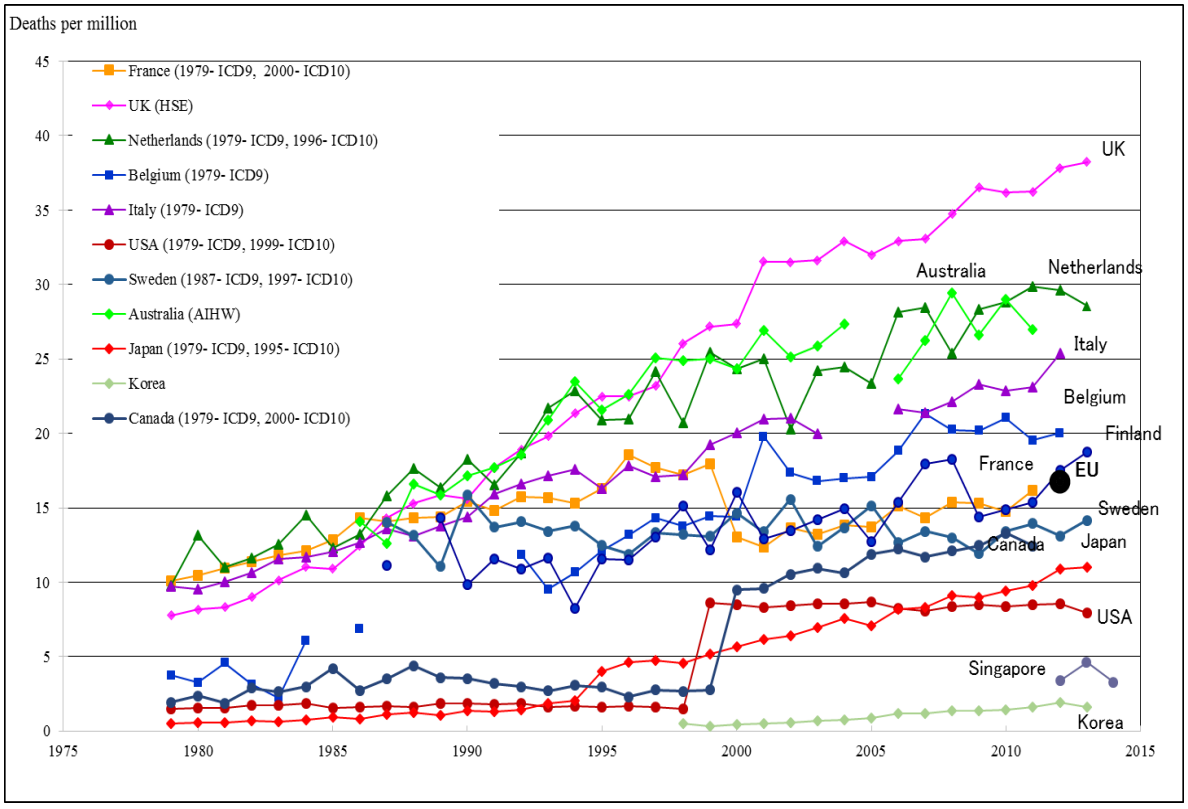
Asbestosis victims may develop cancers as well while cancer and asbestosis do not necessarily develop simultaneously.

Figure 1. Comparison of Global Burden of Mesothelioma Deaths for leading countries in terms of mesothelioma death (Odgerel et al 2017/ GBD 2016)



Evidence on the rising numbers of numbers of mesothelioma deaths are given in Figure 2. It appears that these numbers go up for some time in future [11]. Figure 2 shows that there is so far no solid evidence that the total mesothelioma numbers would be starting to go significantly down in any country while reports of younger cohorts in Sweden - and the Netherlands - will show that the cessation to use asbestos in the 1980's started to have impact after the long latency period [12].

Figure 2. Mesothelioma death rate for selected countries



WHO Mortality Database, ICD 10: C45 Mesothelioma, ICD 9: 163 Malignant Neoplasm of Pleura
UK: HSE Statistics - Mesothelioma, http://www.hse.gov.uk/statistics/causdis/meso.htm
Australia: National Cancer Statistics Clearing House of Australian Institute of Health and Welfare (AIHW)

Supplementary Table 1 shows the relative importance of lung cancer in the burden caused by asbestos in major asbestos using countries and globally. The data are based on the relatively conservative estimates of the GBD 2016 outcome of the Institute of Health Metrics and Evaluation. The evidence from the U. K. shows that the numbers are likely to start going down in the 2020's based on the gradually reduced asbestos consumption and exposures first and later legally banning the use altogether, see Figure 3 [13].

In addition to numbers of deaths data exist on rates per 1 million population.

Figure 3. Mesothelioma annual deaths, IIDB cases and projected future deaths to 2030 in GB, HSE/UK 2016

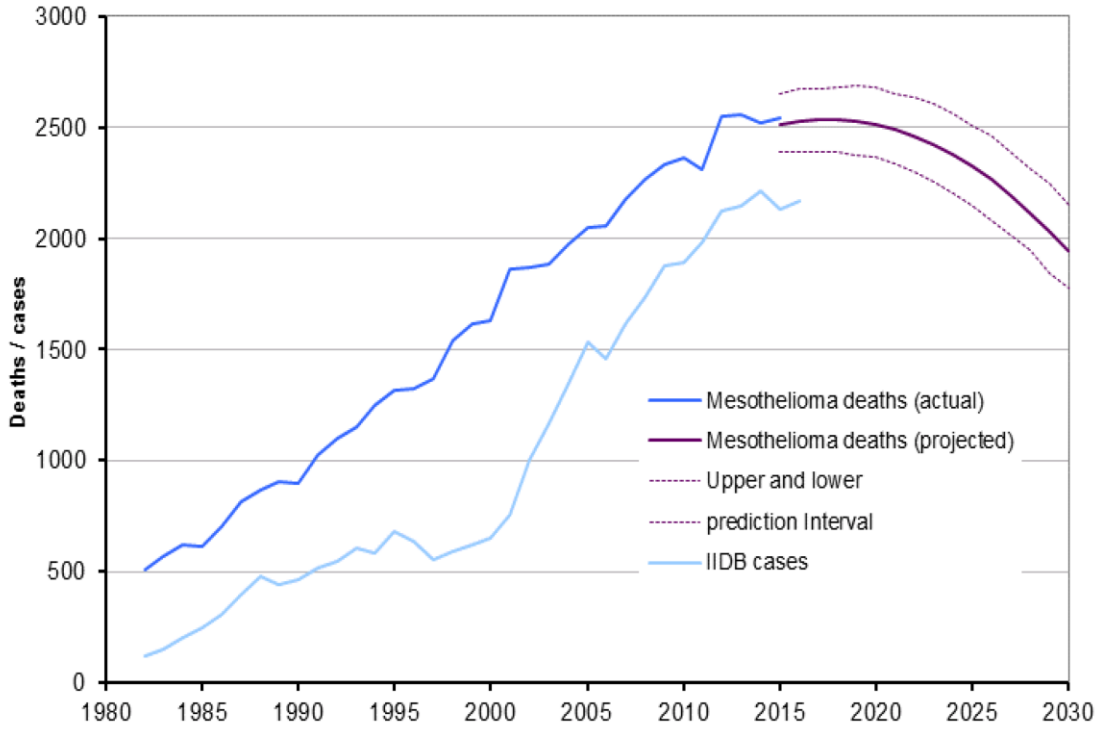
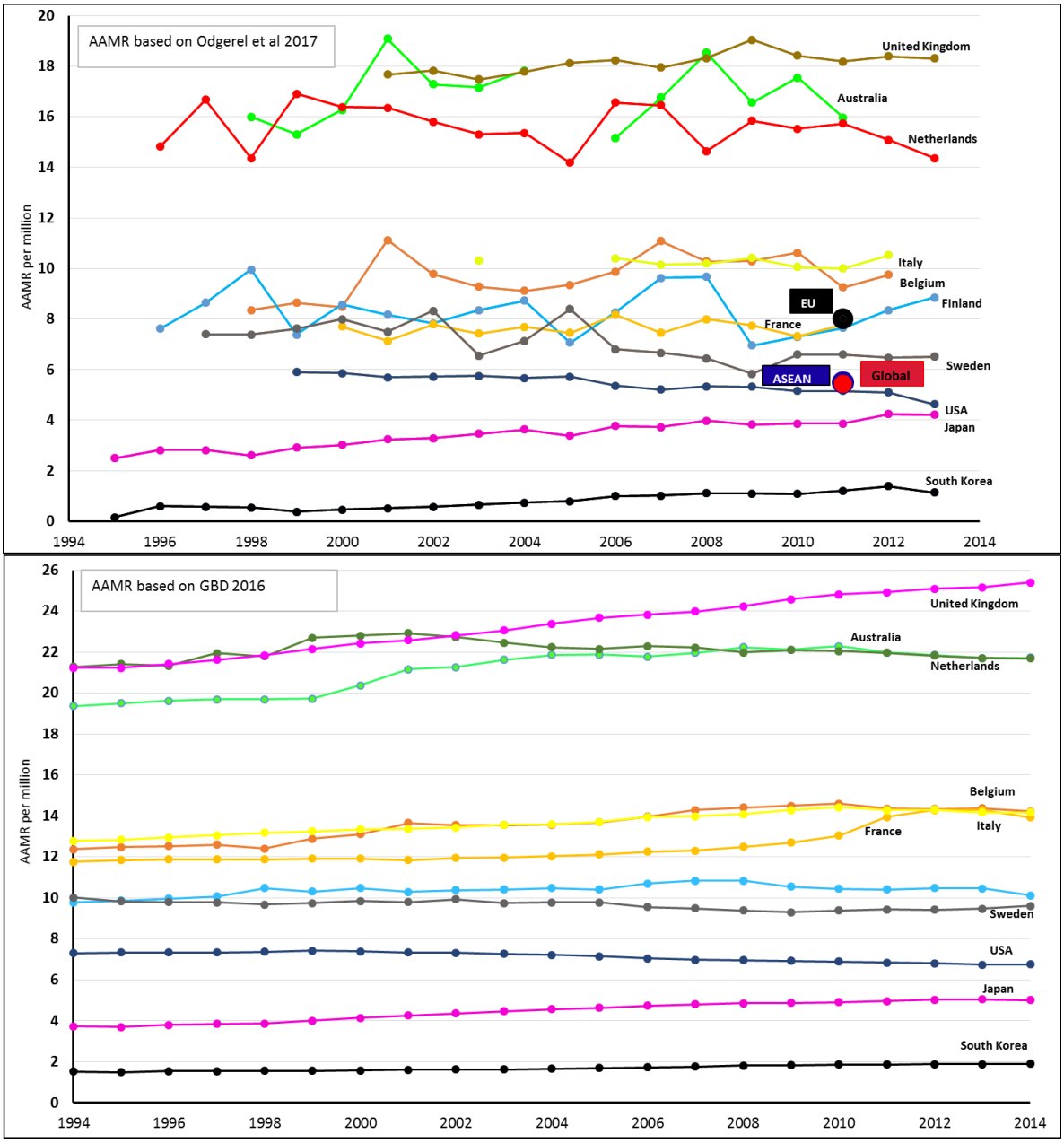


Figure 4 shows the age-adjusted rates for selected countries and the rising trend is visible in some countries in the GBD2016 measures while the trends based on reported data in Chimed-Ochir paper are less clear. This may be caused by the recent increases of young migrant populations in selected countries that may result in significantly bigger young populations today as compared to the originally exposed populations some 30-50 years earlier. Note that in the Chimed-Ochir paper, for each calendar year, age-adjusted rates were directly calculated from actually reported numbers of mesothelioma deaths in these countries, without accounting for statistical fluctuation caused by generally low rates. In contrast, the GBD2016 paper provide estimates accounting for fluctuation of "rare events." Most likely the estimates in the GBD2016 study "smooths out" fluctuations by statistical modelling.

Figure 4. Age adjusted mortality rate of mesothelioma for selected countries



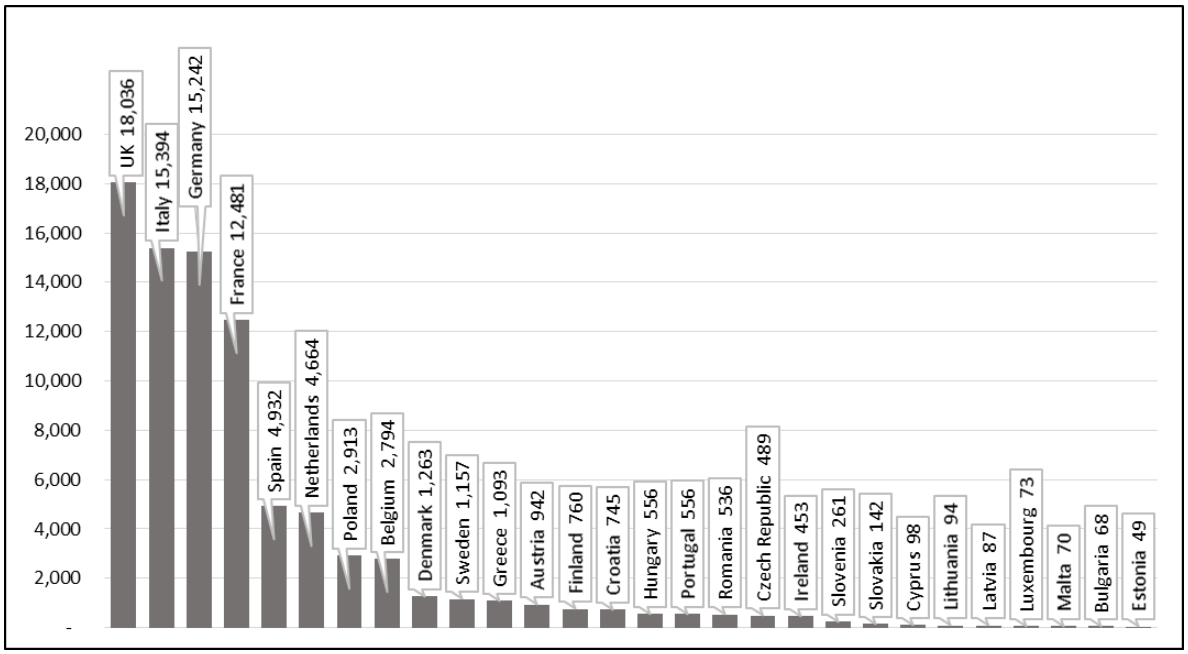
Based on these numbers and the global peak annual consumption of asbestos globally in 1980, which was 4,728,619 metric tons [14] and the Table 2 number in 2016 of asbestos caused deaths by the mid-point value of asbestos deaths 257,000 deaths would provide a rough estimate of 18.4 tons of asbestos consumption killing one person some 37 years later. Using the lowest GBD2016 estimate provides an amount of 19.4 tons causing one death. It would be safe to say that – as a thumb rule - 20 tons of asbestos use will cause one death.

As it appears the mesothelioma death numbers are consistently still going up. This leads to the conclusion – based on the earlier method of using the mesothelioma deaths as a proxy to asbestos exposure and consequently asbestos related cancer deaths are equally going up. The amount of the peak consumption of asbestos in 1980 causes one death by the use and consumption of slightly lower

than 20 tons. The increasing mesothelioma and other cancer numbers would mean that the number of all asbestos caused deaths are expected to grow for some years ahead.

The EU28 is one of the heaviest exposed world region and Figure 5 provides details of the GBD 2016 estimates.

Figure 5. Asbestos cancer deaths at work (GBD 2016)



The International Labour Organization and the European Agency for Safety and Health at Work have estimated the costs of poor safety and health at work. The overall global estimate was equal to 3.94 % of the global GDP equalling 2,966,000 million USD. This estimate was made in using the work-related Disability Adjusted Life Years, DALYs as a share of a maximum number of years of gainfully productive worker years if no one was out of work due to occupational injuries and work-related diseases[15]. Asbestos is likely to be the most significant individual occupational risk factor and consequently the most significant component in such economic losses. Using the same method for specific countries and regions one may estimate the losses caused by asbestos related risks.

Based on the GBD 2016 estimated 85,419 work-related deaths and 1,277 million DALYs [5] in the European Union of 218.3 million workers and an equal number of productive years, the rate :
DALY asbestos/Employment years without losses will end up in 0.70 % loss of productive output caused by asbestos at work, which could be compared to the Gross Domestic Product, GDP of the region.

Equal comparable rate for United States of America using GBD 2016 classification is presented below. USA has a somewhat lower incidence rate, lower loss rate and smaller population while higher GDP per capita:

European Union	0.70 % of GDP	equal to	114,900 million USD losses by asbestos
United States	0.36 % of GDP	equal to	86,100 million USD losses by asbestos

All WHO region "High income countries" together had an estimated loss of 0.48 % of GDP caused by asbestos risk, while the global rate and losses are significantly lower due to lower asbestos use - so far in the past – and much lower average GDP levels. Comparing countries at different levels of development globally or regionally based on different GDP levels may not be appropriate.

These estimates were based on lower mesothelioma estimates. Using the latest and higher mesothelioma estimates 38,400 as a proxy for asbestos exposure all these numbers, rates and costs will be higher, see Tables 1 and 2. As a result also asbestos related lung cancer, other cancers and asbestosis death numbers of the high end of the estimate 270,635 would result to corresponding higher DALY level, and higher cost estimate.

4. Discussion

The metrics to appropriately estimate the magnitude of asbestos related disorders are gradually improving and the size of the problem is increasing. Meanwhile "fake news" not based on facts are still actively advocated against all and overwhelming scientific evidence of carcinogenicity of all types of asbestos.

It is not an easy task to estimate the intangible costs of using asbestos. Production losses are simpler to calculate. However, when applying the Value of Statistical Life (VSL) of 4 million EUR per cancer death used by the European Commission we could arrive at a cost of 410 * 109 USD while the human suffering and loss of life is impossible to quantify. These costs for the European Union 85,419 deaths are much higher than the traditional estimates presented here above. Furthermore, the same VSL case cost could be applied to the global deaths – 222,000 – if based on the conservative GBD 2016 estimate, or the alternative latest estimate of 270,635 in Table 2. This would go far beyond the practice of just looking at the productive losses through DALYs. The earlier presented DALY and productivity loss based estimates are, however, in line with the ILO's costs estimate method. A detailed study by HSE in United Kingdom on occupational cancer – of which asbestos was the overwhelmingly main cause arrived to a cost in U.K of 12.3 * 109 GBP in 2010 [16]. Lung cancer (£6.8 billion) and mesothelioma (£3.0 billion were the main causes of costs. The method above used for economic costs of occupational cancer and asbestos-related cancer arrived at 18.3*109 USD in 2015 which is practically equal to the result of a detailed study in the U.K. taken the GBP/USD rate and the different years. While the methods were quite different the background information of the magnitude and the numbers of deaths are obviously based on the same sources and research reports [8].

The numbers and costs are increasing practically in every country and region in the world. Asbestos has been banned in 55 countries but used widely today, some 2,030,000 tons consumed annually according to latest available consumption data. Every 20 tons of asbestos produced and consumed kills a person somewhere in the world. Buying 1kg asbestos in powder format e.g. in Asia costs some 0.38 USD and 20 tons would cost 7600 USD. The present asbestos consumption and exposures will cause the negative outcomes some 30-50 years later.

While banning of asbestos is a simple way to stop future exposures, the management of existing asbestos in buildings and structures and the work to remove of asbestos needs exposure limits. The present limits are not protective enough and millions of workers and others are still exposed in

countries that have banned asbestos tens of years ago. A present commonly used limit of 0.1 fibres/cm3 means 100,000 asbestos fibres in one cubic meter m3. Human lungs will easily inhale 100,000 asbestos fibres in an hour. An appropriate limit at work would be 1,000 fibres/m3.

5. Conclusions

Present efforts to eliminate this man-made problem and exposures leading to the present epidemiological disaster have been insufficient in most countries in the world. Applying programmes and policies, such as on the elimination of all kind of asbestos use – that is banning of new asbestos use and tight control and management of existing structures containing asbestos – need strengthening and follow up. The present policies and practices need revision and resources. The ILO/WHO Joint Programme for the Elimination of Asbestos-related Diseases needs to be revitalised. Exposure limits do no protect properly against cancer but for asbestos removal and equivalent exposure elimination work we propose a limit value of 1,000 fibres/m3.

Supplementary Materials: The following are available online, Table S1: All estimated asbestos related deaths at work (semi-occupational and non-occupational), Table S2: Comparison of Global Burden of Mesothelioma Deaths (Odgerel et al 2017/ GBD 2016)

Author Contributions: SF and OC compiled data, analyzed data and produced figures and tables. SF, OC, KT and AD provided comments for manuscript. JT wrote the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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