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Relating the Global Burden of Disease to life cycles

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Abstract

The Global Burden of Disease (GBD) study for the year 2016 reports a global disease burden of 0.32 DALY/person-year, given in disability-specific DALYs per country for 188 countries. However, the human health impacts from all LCIA categories included in the ReCiPe global normalisation reference for the year 2012 together account for <0.02 DALY/person-year. The difference of 0.30 DALY/person-year represents mortality and morbidity that to a large extent are caused by human activities and for which we identify the corresponding elementary flows and unit processes that should be included in product life cycle inventories. In total, we attribute 37% of the GBD to one or more of 79 specific risk factors (e.g. air pollution or dietary risks). The remaining GBD, not attributable to specified risk factors, we then divide in two parts: The 'Unavoidable GBD' (19%) and the residual (44%) that we find attributable to an 'insufficient health care system'.

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Keywords: Life Cycle Impact Assessment (LCIA); impact pathways; unavoidable impacts; insufficient health care

1. The Global Burden of Disease

The Global Burden of Disease (GBD) study quantifies annually health loss for 188 countries across time, age, and sex, reported as Disability-Adjusted Life Years (DALY) per disability and country [1]. In a first consideration of how to include global human health impacts in life cycle assessments, we divide the reported DALY into three components: (i) one component representing the disease burden attributable to one or more of 79 risk factors currently considered in the GBD study, (ii) an 'unavoidable' component, which we define in relation to mortality and morbidity in the countries currently experiencing the lowest disease burden, and (iii) a residual component which we attribute to an 'insufficient health care system' as in principle avoidable by improving the availability, accessibility and quality of health care.

The GBD study attributes about 45% of total DALY to specified risk factors, such as air pollution or dietary risks. Of these attributable DALY, 80% are mortality-related and 20% morbidity-related. For each of these risk factors, we compare these DALY to what is currently included in Life Cycle Impact Assessment (LCIA) and seek to identify the relevant human activities of the LCI (Life Cycle Inventory analysis) and their pressure indicators (cross-boundary LCI elementary flows) and to suggest additional improvements to the current LCIA impact pathway descriptions. For a few additional disabilities that are not currently attributed to risk factors in the GDB study, we perform a similar analysis.

Nomenclature

GBD	Global Burden of Disease
DALY	Disability-Adjusted person-Life-Years (IHME)
GDP	Gross Domestic Product
IHME	Institute for Health Metrics and Evaluation
LCIA	Life Cycle Impact Assessment
LCI	Life Cycle Inventory analysis
PAH	Polycyclic Aromatic Hydrocarbons
PPP	Purchasing Power Parity

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The remaining DALY, i.e. those not attributed to specific risk factors, we divided in two parts: an 'unavoidable burden' and a residual that we attribute to an 'insufficient health care system', which ultimately can be traced back to a pressure indicator 'underpayment of labour and taxes'. The 'unavoidable burden' is, with a few exceptions described below, defined by the 1st decile (i.e. lowest 10%) of country prevalence for each disability. The idea is that the "gold standard" for each disability is the best performing country in terms of prevalence, while removing the influence of extreme outliers that cannot be explained at this stage, by using the 1st decile rather than the minimum.

Our analysis is performed on IHME-GBD DALY data for 2016 (ghdx.healthdata.org), aggregated over both sexes and all age groups. We did not consider covariance between risk factors, which would require taking into account all relative risk functions in a more detailed analysis.

2. Unavoidable burden of disease

We use age-standardised DALY rates per 100,000 persons for each disability and each country to calculate the 1st decile of country prevalence for each disability across all countries. In general (see exceptions below), we used this *1st decile* level as a cut-off for theoretically achievable prevalence in all countries, thereby ignoring potential inherent differences in minimum risk levels and within-country variation in prevalence. For each country, we then sum DALYs that fall below this 'achievable prevalence' as 'unavoidable burden of disease'.

For some disabilities we used a different cut-off than the 1st decile of country prevalences. In line with GBD, we regard some disabilities as 100% attributable to specific risk factors, i.e. with a *zero cut-off*, while for some disabilities we go further than the GBD study. We use a zero cut-off for:

- All disabilities related to drug and alcohol usage (GBD attributes only some),
- Some potentially eradicable tropical diseases (lymphatic filariasis listed as potentially eradicable by the International Task Force for Disease Eradication, trachoma for which WHO has set an eradication target by 2020, and yellow fever for which an effective vaccine exists),
- Nematode infections ascariasis and trichuriasis, which are fully preventable by sufficient sanitation,
- Food-borne trematodiases, because it is fully preventable by freezing fish before raw consumption,
- Mesothelioma, as this can be 100% attributed to avoidable asbestos contact,
- Pneumoconiosis, as this can be 100% attributed to predominantly occupational dust exposure,
- Hemoglobinopathies and hemolytic anemias, as these genetic diseases can be prevented in the long-term by carrier detection,
- Nutritional deficiencies and neural tube defects as these can be attributed to undernutrition,
- All road injuries, as the non-drug related residual can be attributed to motorized traffic,
- All interpersonal and collective violence, as the non-drug related residual can be attributed to specific avoidable human behaviour.

We regard some disabilities as being completely unavoidable, and thus use no cut-off, i.e. we attribute all related DALY as unavoidable for:

- Chromosomal unbalanced rearrangements, congenital heart anomalies, endocrine, metabolic, blood, and immune disorders, as these are genetically caused, but not preventable as long as genetic markers are not identified,
- The skin diseases psoriasis, acne vulgaris, and alopecia areata.

For cataract, we use a cut-off of *9.9 DALY per 100,000 persons* corresponding to the lowest country prevalence (The Netherlands), as achievable by treatment. For chronic obstructive pulmonary disease (COPD), we set a cut-off of *40 DALY per 100,000 persons*, as an estimate of the prevalence of genetic causes. We use the *median* as cut-off for 'Other neglected tropical diseases', since the 1st decile is unrealistically low due to non-exposure of large parts of the populations.

The resulting unavoidable GBD for 2016 is 460 million DALY or 19.2% of the total GBD or 0.11 DALY/person. The unavoidable DALY value per person is, as expected, rather invariant across countries (between 0.09 and 0.13 DALY/person) but because of the large variation in total DALY/person in different countries, the unavoidable burden expressed as share of the total burden of disease varies from 12% for Central African Republic to 63% for the Maldives.

3. Poverty-related health impacts

A large share of the avoidable GDB can be related to poverty. In this section, we identify and describe three impact pathways as entirely poverty-related: 'Insufficient health care system', 'Insufficient clean water supply and sanitation' and 'Food insecurity'. We call the corresponding causal (LCI) pressure indicator for poverty 'Underpayment of labour and taxes', since poverty can be caused by either insufficient private income or insufficient funds for public services (see also Figure 2).

3.1. Insufficient health care system

We define the share of the burden of disease attributable to an 'Insufficient health care system' as the residual of the total 2016 burden of disease when subtracting the unavoidable burden and the otherwise attributable burden (i.e. attributed to specified risk factors by the GBD study or as part of our analysis of the unavoidable burden). It should be noted that this implies a rather broad definition of "health care system" including also – and maybe in particular – preventive activities. Also, a part of the DALY attributed by the GBD study to specific risk factors we refer back to and include in 'Insufficient health care' (see the sections "Undernutrition" and "Unsafe sexual practices" below). Nevertheless, we

expect that future identification of additional risk factors will mean that a part of the residual currently attributed to 'Insufficient health care' will later be attributed to more specific human activities, for example a part of food-borne infections not yet attributed in the official GBD [2].

The resulting burden that we attribute to an 'Insufficient health care system' is 851 million DALY globally or 35.6% of the total GBD. This burden varies a lot between countries, especially for low-income countries; see Figure 1.

Figure 1 shows that above a Purchasing-Power corrected GDP of 10,000 USD per person an increase in GDP does not necessarily lead to a more efficient health care system. It can be argued that this should lead us to place the cut-off for "unavoidable" disease burden higher than the 1st decile across countries. However, even the richest countries have a large income inequality that is known to reflect itself in health inequalities [3], which would be visible if we subdivided the country data into income groups. Under the current conditions of within-country income inequality, it would not be reasonable to expect the curve in Figure 1 to reach zero at the right end, since also the richer countries should be able to improve their health care systems for the poorer parts of their population.

In Figure 1, a power fitted line has been added for illustration. It is not intended for extrapolation purposes, since actual values are available for each country of the world. The relatively large variation is expected, since GDP is not a direct driver for the efficiency of the health care system. We have also compared to other welfare-related indicators, such as GNI per person, health expenditure per person, and total DALY per person, all giving very similar fits.

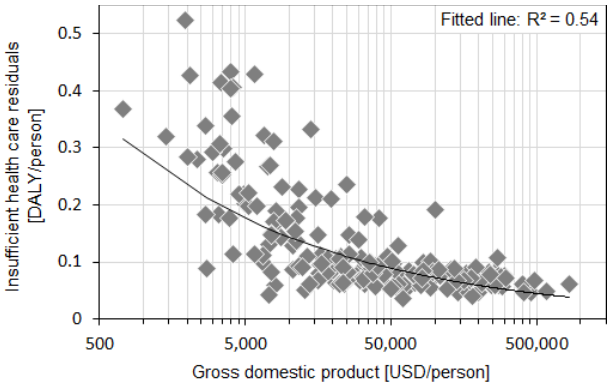

Figure 1. Insufficient health care in DALY/person-year versus country Purchasing-Power-corrected Gross Domestic Product (GDP) per person-year, calculated as residual by subtracting the "unavoidable burden" of disease and the otherwise attributable share from the total burden of disease. Each point represents one country.

3.2. Insufficient clean water supply and sanitation

A large part (94-96%) of the diarrheal diseases, typhoid fever, and paratyphoid fever, as well as 14% of lower respiratory infections, are attributed to the GBD risk factor 'Unsafe water, sanitation, and handwashing'. We also include here the faeces-borne nematode infections ascariasis and trichuriasis. The GDB for this risk factor is 80 million DALY (3.4% of the GBD).

Insufficient clean water supply and sanitation includes also insufficient wastewater treatment and use of untreated human excreta as fertiliser.

3.3. Undernutrition

We attribute all child and maternal malnutrition in the GDB study, as well as all neural tube defects, to 'Undernutrition'. The avoidable GDB for undernutrition amounts to 109 million DALY (4.6% of overall GBD). The risk factor 'Suboptimal breastfeeding' of the GBD study can partly be related back to the workplace environment (based on the relatively scarce studies we have been able to find in this field [4,5], we estimate that 50% can be related to the early return to work after giving birth and 10% can be avoided by providing paid breaks for breastfeeding; in combination 55%) and partly to insufficient health care advice, the latter (i.e. the remaining 45%) thus included in the above burden attributed to an 'Insufficient health care system'. With the current data availability, we cannot distinguish the remaining causes of undernutrition, but relate all to poverty-related 'Food insecurity', except for a small part (7.5%) that can be related to 'Household gender discrimination', for which we use 'Intimate partner violence' as the only available proximate risk factor (see below section "Violence"). Beyond the direct health effects covered by these impact pathway descriptions, there is also influence on intelligence (reduced cognitive skills), which is not quantified here.

4. Disabilities attributable to specific activities

Besides the poverty-related disease burden described in the previous section, we detail in the present section how we relate the remaining attributable GBD (attributed to specified risk factors by the GBD study or as part of our above analysis of the unavoidable burden) to specific human activities and their pressure indicators.

In the following descriptions of the attributable disabilities, some will already be covered by existing LCI pressure indicators, while many are not. We further evaluate the extent to which these burdens are adequately covered in existing LCI databases and LCIA methods. For burdens currently not considered in LCA, new LCIA data and impact categories are needed.

The structure of this section follows the large groups of risk factors from the GBD study, in order of decreasing global importance (decreasing numbers of DALY).

4.1. Dietary risks

The GBD study attributes 229 million DALY (9.6% of total GBD) to dietary risks from an unbalanced diet, more specifically a diet low in fruits, vegetables, whole grains, nuts and seeds, milk, fibre, calcium, polyunsaturated fatty acids, and omega-3 fatty acids or precursors, high in red meat, processed meat, sugar-sweetened beverages, trans fatty acids, and sodium. These health effects can be related to the marginal influence of the individual food items on the diet, as

a result of the dietary choices made in the food preparation and consumption stages of the food life cycles.

4.2. Particulate matter exposure

Particulate matter exposure includes exposure to ambient air emissions (106 million DALY), occupational exposure (9.4 million DALY), and household exposure from combustion (77 million DALY), in total 192 million DALY (8% of total GBD). The resulting disease burden is attributed to pneumoconiosis (occupational), lower respiratory infections, stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer; for household exposure also cataract. The GBD study rests on a large amount of exposure data. A relation to sources is made using PM composition. Health impacts from particulate matter exposure are already relatively well covered in LCI databases.

4.3. Smoking

The GBD study attributes 177 million DALY (7.4% of total GBD) to smoking, mainly of tobacco. 13.4% of this is due to second-hand smoke, mainly in households. The GBD study uses a dichotomous measure of exposure defined as current daily use of smoked tobacco (and prevalence of second-hand smoke in household and in occupational settings). In an LCI context, it would potentially be more logical to relate this disease burden to the quantity of tobacco consumed.

4.4. Misuse of drugs (including alcohol)

The GBD study attributes 131 million DALY (5.5% of total GBD) to drug use, out of which 99 million DALY (4.2% of total GBD) are from alcohol misuse and the majority of the rest is from misuse of opioids. 30 million DALY are caused by injuries related to misuse of alcohol (included in the aforementioned value). The attribution of misuse to human activities may be controversial, where some may regard the substance itself – and thus its production – as decisive, while others argue that the majority of misuse is related to social exclusion and can therefore be traced back to social LCI pressure indicators, such as 'Unemployment' and 'Discrimination'.

4.5. Transport injuries

Transport injuries amount to 84 million DALY (3.5% of total GBD), of which the GBD study attributes 36% to alcohol use and 3% to tobacco use, while 45% are in GBD attributed to occupational transport injuries. In some LCA studies, data on fatal and non-fatal injuries per million vehicle-km have already been included. It should hence be generally possible to include transport-related injuries in LCI and to characterize their related health impacts, while accounting for variations depending on e.g. driving habits, traffic enforcement, and road conditions.

4.6. Unsafe sexual practices

A burden of 55 million DALY (2.3% of total GBD) of sexually transmitted diseases, including cervical cancer and HIV/AIDS, can be attributed to unsafe sexual practices (household activities typically unrelated to any product life cycles), except for 5% attributed to violence. In some countries, a part of the unsafe sexual practices may be traced back to a lack of access to condoms or police harassment of sex workers, and thus can be included in our 'Insufficient health care' category. Statistics on the prevalence of condom accessibility and usage by country and for specific population groups is very patchy. The only systematic, annual data are prevalence data for 'Unmet need for family planning' and 'Demand for family planning satisfied with modern methods' among 15-49 year old women living with a partner [16]. It is a reasonable assumption that sufficient access to condoms in general is at least not higher than the unsatisfied demand for family planning with modern methods (of which condoms is one), and we therefore use these data as a (best-case) proxy for insufficient access to condoms as risk factor, and thus for the share of the unsafe sexual practices included under 'Insufficient health care' per country.

4.7. Lack of physical activity

The GBD study attributes 24 million DALY (1% of total GBD) to 'low physical activity', divided among ischemic heart disease, diabetes, stroke, colon cancer, and breast cancer. This corresponds to a burden for activity levels below the WHO minimum recommendation of 600 metabolic equivalent-minutes (MET-minutes) per week. Relative changes in risk per MET-minute/week are provided by [11], which could be converted into a DALY value per MET-minute/hour. A related LCI pressure indicator could potentially be defined for every hour of activity deviating positively or negatively from the average MET-level. MET-levels for many activities are included in [12]. Data on sedentary work per industry, occupation, and skill level are available from Australia [13].

4.8. Ergonomics

Ergonomically inappropriate equipment can lead to physical strain and discomfort. While the potential damages may obviously be of very diverse nature, and also have impacts on productivity at below-clinical levels, the quantification in the GBD study is limited to 20 million DALY (0.8% of total GDB), of which 71% of all cases are attributed to low back pain. The GBD values can be related to the industries in LCI based on occupational health statistics.

4.9. Non-transport related occupational injuries and noise

Occupational injuries amount in the GBD study to 4% of all injuries or 11 million DALY (0.5% of total GBD). Hearing loss from occupational noise exposure amounts to 7.1 million DALY (0.3% of total GBD). The GBD study provides data on occupational exposure per economic activity that can be used to relate the GBD values to the industries in LCI. More

detailed statistics for some countries may be used for extrapolation to countries with no or insufficiently detailed statistics, while considering differences in technologies and safety standards enforcement.

4.10. Emission-related cancers

Of 213 million DALY (9% of GBD) for cancers (malignant neoplasms), 40% or 85 million DALY are currently attributed to specific risk factors by the GBD study, out of which only a smaller part (17 million DALY or 8% of all cancers) is emissions-related (attributed to particulates, radon and specific occupational exposures). Clearly, there are more potentially carcinogenic substances than the ones accounted for in the GDB study, but a few substances in current LCI databases typically dominate LCA results (notably arsenic, cadmium, dioxins, formaldehyde, lead, mercury, nickel and PAHs emitted to air, and cadmium, lead and nickel emitted to soil) summing to a potential burden of less than 1 million DALY globally when using USEtox normalisation reference and health impact factors. This can be compared to the 7.2 million DALY attributed to occupational risk factors by the GBD study. For chemical substances, exposure is dominated by worker and consumer exposure to articles, sprays, foods, etc. [6], not currently included in LCAs, except for some indoor air emissions.

4.11. Lead exposure

The GBD study attributes 14 million DALY to lead exposure (0.6% of GBD), distributed on cardiovascular diseases (74%), idiopathic developmental intellectual disability (21%), and chronic kidney disease (5%). The GBD estimate covers both outdoor and indoor exposure. According to [10], for sources and speciation of Pb emissions from intentional use from 1930 onwards to 3.6E+6 kg total emissions in 2010, intentional use accounts for more than 50% of total emissions. The EXIOBASE 2011 LCI database appears to overestimate emissions from steel manufacture and shows a total of lead emissions to air of 150E+6 kg, i.e. 50 times the total loss of lead reported by [10], but with the USEtox characterisation factors this still only amounts to 6.6 million DALY. The most important human exposure pathway is ingestion of contaminated foods.

4.12. Exposure to other toxic emissions

The USEtox global normalisation reference updated with the EXIOBASE 2011 global emissions and combined with the USEtox characterisation factors give a total potential human health impact related to exposure to non-carcinogenic human toxic chemical emissions of 4 million DALY (0.2% of GBD). While this is likely to be only part of the full picture, it does not immediately appear as an area of concern. The main need for improving LCA, however, is the inclusion of currently missing but potentially dominating exposure environments for toxic chemicals, namely worker and consumer exposure.

4.13. Violence

The GBD study attributes 8.2 million DALY (0.34% of total GBD) to intimate partner violence and childhood sexual abuse. In an LCI context, this could be included as separate activities, not related to any product life cycles. Besides the direct effects of interpersonal violence, intimate partner violence is also the only available proximate risk factor for 'Household gender discrimination', to which we attribute 7.5% of 'Undernutrition' not otherwise attributed, based on [14] finding an odds ratio of 1.48 (95% confidence interval 1.23-1.79) for women with lifetime experience of physical intimate partner violence to have a stunted child (under 5 years). The total number of such women in poor households with lifetime exposure to violence is 620 million or 17% of all women (calculated from [15]).

4.14. Photochemical ozone exposure

The GBD study attributes 3.8 million DALY (0.16% of GBD) from chronic obstructive pulmonary disease to emissions of chemicals with photochemical ozone formation potential. The ReCiPe, ILCD and ImpactWorld+ LCIA methods all use the atmospheric chemistry model LOTOS-EUROS [7], which is based on the same method as the model used by the GDB study, but give only approximately 60% of the GBD results.

4.15. Asthmagens exposure

For occupational exposure to asthmagens, the GBD study attributes 2.3 million DALY, which is only 10% of all asthma cases, since causal relationships between individual risk factors and asthma are still poorly understood. Asthma accounts for 1% of the global disease burden. The AOEC exposure code lookup tool (http://www.aoecdata.org/ExpCodeLookup.aspx) provides a list of 518 asthmagens, but specific emission and exposure data for these are not readily available to build a related impact pathway.

4.16. Food-borne trematodiases

All cases of food-borne trematodiases (1.8 million DALY; 0.07% of total GBD) could be related to a new LCI pressure indicator for 'Insufficient freezing of fish before raw consumption'.

4.17. Ionising radiation

Residential radon exposure is the largest source of ionising radiation exposure for humans, and the only one included in the GBD risk attributions with 1.3 million DALY (0.05% of GBD) from tracheal, bronchus, and lung cancer. UNSCEAR estimate 42,000 Man-Sv from occupational expose (specified by industry), i.e. 49,000 DALY or 3.5% of the GBD radon value, mainly from coal mining (16,000 Man-Sv) and other mining (14,000 Man-Sv); the next important source is medical use [8]. Current LCI databases appear to include only

industrial emissions and are dominated by C-14 from nuclear power plants [9], and hence should be extended.

5. Conclusion

Figure 2 provides an overview of the suggested impact pathways linking an avoidable 81% of the global disease burden either to the pressure indicator of underpayment of labour and taxes or to specific human activities (non-income-related inventory items).

Underpayment of labour and taxes can be measured relative to a reference level sufficient to eliminate the residual avoidable GDB, as suggested in [17]. The relationship between this pressure indicator and disposable private and public income depends also on income redistribution, which has not been included in our current model.

Insufficient health care can be caused both directly by insufficient private income and indirectly by insufficient public income for funding of the health care system.

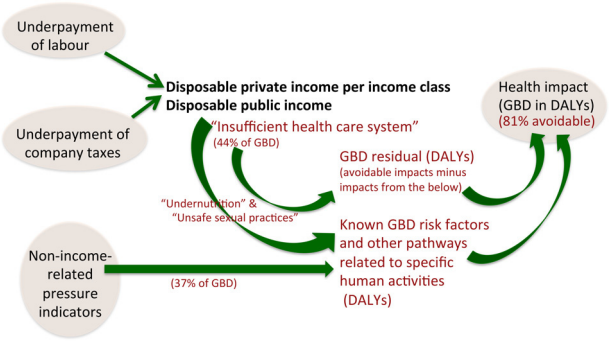

Figure 2. Impact pathways from human activities to the avoidable GDB 2016.

6. Outlook

Our analysis is a preliminary proof-of-concept for linking the Global Burden of Disease to human activities and thus to product life cycles. The analysis can be improved as follows:

- In general, uncertainty should be added to all health data presented above, using the confidence intervals from all relative risk models used to calculate the GBD.
- For diseases that have several causes, the total DALYs reported above may be overestimated when adding the DALYs from each separate cause. It would be possible to avoid such overestimations by applying a more detailed analysis using the same models of co-variance as used for the GBD study. Such detailed analyses, however, were beyond our resources for this initial analysis.
- Additional risk factors should be identified and incorporated in our analysis as quantified, e.g., for food-borne infections [2], to reduce the part of GBD that is currently attributed to the more generic 'insufficient health care'.
- DALYs finally attributable to insufficient health care should be systematically linked either to the financing and efficiency of public health services or to personal income equality, taking into account also the effect of income redistribution.

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References

[1] Forouzanfar MH, Afshin A, Alexander LT, Anderson HR, Bhutta ZA, Biryukov S, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: A systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016;388:1659-724.

[2] Hald T, Aspinall W, Devleesschauwer B, Cooke R, Corrigan T, Havelaar AH, et al. World Health Organization estimates of the relative contributions of food to the Burden of Disease due to selected foodborne hazards: A structured expert elicitation. PLoS ONE 2016;11:e0145839.

[3] Pickett KE, Wilkinson RG. Income inequality and health: A causal review. Soc Sci Med 2015;128:316-26.

[4] Ogbuanu C, Glover S, Probst J, Liu J, Hussey J. The effect of maternity leave length and time of return to work on breastfeeding. Pediatrics 2011;127:e1414-27.

[5] Heymann J, Raub A, Earle A. Breastfeeding policy: A globally comparative analysis. B World Health Organ 2013;91:398-406.

[6] Fantke P, Ernstoff AS, Huang L, Csiszar SA, Jolliet O. Coupled near-field and far-field exposure assessment framework for chemicals in consumer products. Environ Int 2016;94:508-18.

[7] van Zelm R, Huijbregts MAJ, den Hollander HA, van Jaarsveld HA, Sauter FJ, Struijs J, et al. European characterization factors for human health damage of PM_{10} and ozone in life cycle impact assessment. Atmos Environ 2008;42:441-53.

[8] UNSCEAR. Sources and effects of ionizing radiation. Official Records of the General Assembly, 63rd Session, Suppl 46. New York: United Nations; 2008.

[9] Benini L, Mancini L, Sala S, Manfredi S, Schau EM, Pant R. Normalisation method and data for Environmental Footprints. European Commission, JRC, Institute for Environment and Sustainability. Luxembourg: Publications Office of the European Union; 2014..

[10] Liang J, Mao J. Source analysis of global anthropogenic lead emissions: Their quantities and species. Environ Sci Pollut Res 2015;22:7129-38.

[11] Kyu HH, Bachman VF, Alexander LT, Mumford JE, Afshin A, Estep K, et al. Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: Systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. Brit Med J 2016;354:i3857.

[12] Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: An update of activity codes and MET intensities. Med Sci Sports Exercise 2000;32:S498-S516.

[13] Kyaw-Myint S M, de Crespigny F. National hazard exposure worker surveillance: Exposure to biomechanical demands, pain and fatigue symptoms and the provision of controls in Australian workplaces. Canberra: Safe Work Australia; 2011.

[14] Ziaei S, Naved RT, Ekström E-C. Women's exposure to intimate partner violence and child malnutrition: Findings from demographic and health surveys in Bangladesh. Matern Child Nutr 2014;10:347-59.

[15] United Nations. The World's Women 2015: Trends and Statistics. New York: United Nations; 2015.

[16] United Nations. World Contraceptive Use 2016 (POP/DB/CP/Rev2016). New York: UN Department of Economic and Social Affairs; 2016.

[17] Weidema B P. The social footprint – a practical approach to comprehensive and consistent social LCA. Int J Life Cycle Assessment, first on-line 2016 August 08.