WATER RESEARCH 79 (2015) 26–38

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Global and local health burden trade-off through the hybridisation of quantitative microbial risk assessment and life cycle assessment to aid water management

Yumi Kobayashi [a], Greg M. Peters [a,b], Nicholas J. Ashbolt [a,c], Sara Heimersson [b], Magdalena Svanström [b], Stuart J. Khan [a,*]

[a] School of Civil & Environmental Engineering, University of New South Wales, 2052 NSW, Australia
[b] Department of Chemistry and Chemical Engineering, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden
[c] School of Public Health, University of Alberta, Edmonton, Alberta T6G 2G7, Canada

ARTICLE INFO

Article history:
Received 26 September 2014
Received in revised form
27 February 2015
Accepted 15 March 2015
Available online 25 March 2015

Keywords:
Environmental impact
Water recycling
Water treatment
Carbon footprint

ABSTRACT

Life cycle assessment (LCA) and quantitative risk assessment (QRA) are commonly used to evaluate potential human health impacts associated with proposed or existing infrastructure and products. Each approach has a distinct objective and, consequently, their conclusions may be inconsistent or contradictory. It is proposed that the integration of elements of QRA and LCA may provide a more holistic approach to health impact assessment. Here we examine the possibility of merging LCA assessed human health impacts with quantitative microbial risk assessment (QMRA) for waterborne pathogen impacts, expressed with the common health metric, disability adjusted life years (DALYs). The example of a recent large-scale water recycling project in Sydney, Australia was used to identify and demonstrate the potential advantages and current limitations of this approach. A comparative analysis of two scenarios – with and without the development of this project - was undertaken for this purpose.

LCA and QMRA were carried out independently for the two scenarios to compare human health impacts, as measured by DALYs lost per year. LCA results suggested that construction of the project would lead to an increased number of DALYs lost per year, while estimated disease burden resulting from microbial exposures indicated that it would result in the loss of fewer DALYs per year than the alternative scenario. By merging the results of the LCA and QMRA, we demonstrate the advantages in providing a more comprehensive assessment of human disease burden for the two scenarios, in particular, the importance of considering the results of both LCA and QRA in a comparative assessment of decision alternatives to avoid problem shifting. The application of DALYs as a common measure between the two approaches was found to be useful for this purpose.

© 2015 Elsevier Ltd. All rights reserved.

* *Corresponding author*. Tel.: +61 2 93855070.
E-mail address: s.khan@unsw.edu.au (S.J. Khan).

http://dx.doi.org/10.1016/j.watres.2015.03.015
0043-1354/© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Human health can be affected by various types of environmental emissions. While some emissions such as effluents from sewage treatment plants (STPs) may affect the health of local population, others, including carbon emissions due to electricity usage at STPs, could cause global warming and hence contribute to global population impact. In some cases, local and global impacts can be in a trade-off relationship. For instance, STP effluent qualities can be improved to reduce local impacts by applying additional water treatment processes that are energy intensive, resulting additional global impacts. Therefore, consideration of local and global impacts simultaneously is required to avoid problem shifting. As such, the ability to directly compare different sources or types of health impacts on a common quantitative scale would be advantageous for achieving more holistic environmental health impact assessments.

Environmental impacts on human health can be evaluated by various environmental assessment methods. Life cycle assessment (LCA) is one of the tools frequently used (Loiseau et al., 2012). LCA incorporates various environmental impacts throughout the entire life cycle of a product or service. Quantitative risk assessment (QRA) is another common approach, but framed very differently (Loiseau et al., 2012). QRA is used to assess the potential health impacts on a population following exposure to particular hazardous substances including pathogens and chemicals. Typically QRA focuses only on specific impacts on a local population, while LCA measures impacts at regional or global scales and may overlook some specific local details. As QRA and LCA have different foci, the results of the two may be contradictory, leading to more complex decision making (Saouter and Feijtel, 2000).

To facilitate decision making, others have suggested that there may be benefits from combining results from QRA and LCA (Askham, 2012; Cowell et al., 2002; De Haes et al., 2006; Flemström, 2004; Olsen et al., 2001). For this integration, the use of disability adjusted life years (DALYs) appears advantageous to amalgamate a diverse range of human health impacts. DALYs not only include the number of cases of health impacts, but also the number of years of life lost (YLL) and years lived with disability (YLD) in an internationally used health metric. As such, DALYs are commonly expressed as per Equation (1) (Prüss-Üstün et al., 2003).

$$\text{DALYs} = \text{YLL} + \text{YLD} \tag{1}$$

YLL are determined by the number of deaths and the standard life expectancy at the age of death. YLD are a function of the number of incidences, disability weight and duration of the disability. Disability weights are estimated mainly by health professionals depending on the severity of disability scaled between zero (no impact to health) and one (worst possible health state) (Devleesschauwer et al., 2014; Mathers et al., 2007). DALYs are also capable of taking social weighting such as age-weighting and future discounting into account. Age-weighting is applied when the value of one life year differs depending on a person's age, and future discounting is used when present health is preferable to that in the future.

There are number of other health metrics to measure human burden of disease. Similar to DALYs, quality adjusted life years (QALYs), health adjusted life expectancy (HALE) and healthy life years (HeaLYs) also take mortality and morbidity into account (Gold et al., 2002; Manuel et al., 2000; Prüss-Üstün et al., 2003).

HALE has advantages such as use of meaningful units (expected years of life) and provides readily understood concepts for non-experts. However, it does not distinguish contributions of different diseases to the overall outcome while other metrics may do so (Mathers et al., 2000; WHO, 2000). The major difference between QALYs and DALYs is that the former measures health gains whereas the latter measures health loss (Mathers et al., 2007). Also, while DALYs are used globally, QALYs are mostly used in high-income countries (Mangen et al., 2013). HeaLYs are similar to DALYs; with the main differences being how age-weighting and future discounting are applied (Hyder et al., 1998).

The major limitation with all of these health metrics is that they are restricted to health measures, and hence are unable to incorporate other types of environmental impacts (Olsen et al., 1999). Monetary units such as willingness-to-pay have an advantage in this regard and have been applied in some LCAs (Itsubo et al., 2004; Steen, 1999). However, monetisation of environmental impacts requires multiplication of quantified impacts by predetermined economic values per unit impacts. This extra step adds further uncertainty (Olsen et al., 1999), but has also been applied to DALYs (Tariq et al., 2011).

DALYs have been chosen in this study as they have been widely used to quantify human burden of disease and have already been applied in QRA and LCA more commonly than other metrics (Boulay et al., 2011; Goedkoop et al., 2013; Harder et al., 2014; Heimersson et al., 2014; Schoen et al., 2014; Xiao et al., 2012).

Therefore, to examine the possibility of specifically including waterborne pathogens, which are not addressed by LCA, we examined the advantages and limitations in using DALYs to compare outputs from quantitative microbial risk assessment (QMRA) and LCA using a recent large-scale water recycling project in Sydney. This project, constructed by Sydney Water Corporation (SWC) was known as the "Replacement Flows Project" (RFP) (SWC, 2006). Prior to 2010, a significant volume of water from Lake Burragorang (behind Warragamba Dam that supplies most of Sydney's drinking water) was released annually to the Hawkesbury-Nepean River to maintain the health of the downstream river system. The RFP was proposed to replace some of these environmental flows with recycled water to secure Sydney's drinking water needs. To provide the recycled water, an advanced water treatment plant (AWTP) was constructed at St Marys (north western Sydney) for further treatment of effluent from three tertiary wastewater treatment plants in north western Sydney. These were the Penrith, St Marys and Quakers Hill STPs. The St Marys AWTP has a capacity to produce up to about 18 billion litres (GL) per year of recycled water which can be released to the Hawkesbury-Nepean River at Penrith.

As an additional means of drinking water supply augmentation, the Sydney Desalination Plant (SDP) was constructed and commenced its operation in 2010 (SWC, 2010). In this study, it was hypothetically assumed that drinking water

Download English Version:

https://daneshyari.com/en/article/4481149

Download Persian Version:

https://daneshyari.com/article/4481149

Daneshyari.com