ARTICLE IN PRESS

Journal of Environmental Management xxx (2016) 1–7

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Economic implications of mercury exposure in the context of the global mercury treaty: Hair mercury levels and estimated lost economic productivity in selected developing countries

Leonardo Trasande [a,b,c,d,e,*], Joseph DiGangi [f], David C. Evers [g], Jindrich Petrlik [h], David G. Buck [g], Jan Šamánek [h], Bjorn Beeler [f], Madeline A. Turnquist [g], Kevin Regan [g]

[a] Department of Environmental Medicine, University School of Medicine, New York, NY, 10016, USA
[b] Department of Pediatrics, University School of Medicine, New York, NY, 10016, USA
[c] Department of Population Health, University School of Medicine, New York, NY, 10016, USA
[d] NYU Wagner School of Public Service, New York, NY, 10012, USA
[e] NYU Steinhardt School of Culture, Education and Human Development, Department of Nutrition, Food & Public Health, New York, NY, 10013, USA
[f] IPEN, Första Långgatan 18, 413 28, Göteborg, Sweden
[g] Biodiversity Research Institute, 276 Canco Road, Portland, ME, 04103, USA
[h] Arnika Association, Chlumova 17, Prague 3, 130 00, Czech Republic

ARTICLE INFO

Article history:
Received 11 December 2015
Received in revised form
23 August 2016
Accepted 24 August 2016
Available online xxx

Keywords:
Mercury
Global mercury treaty
Developing countries
Intellectual disability
DALYs
Lost economic productivity

ABSTRACT

Several developing countries have limited or no information about exposures near anthropogenic mercury sources and no studies have quantified costs of mercury pollution or economic benefits to mercury pollution prevention in these countries. In this study, we present data on mercury concentrations in human hair from subpopulations in developing countries most likely to benefit from the implementation of the Minamata Convention on Mercury. These data are then used to estimate economic costs of mercury exposure in these communities. Hair samples were collected from sites located in 15 countries. We used a linear dose-response relationship that previously identified a 0.18 IQ point decrement per part per million (ppm) increase in hair mercury, and modeled a base case scenario assuming a reference level of 1 ppm, and a second scenario assuming no reference level. We then estimated the corresponding increases in intellectual disability and lost Disability-Adjusted Life Years (DALY). A total of 236 participants provided hair samples for analysis, with an estimated population at risk of mercury exposure near the 15 sites of 11,302,582. Average mercury levels were in the range of 0.48 ppm–4.60 ppm, and 61% of all participants had hair mercury concentrations greater than 1 ppm, the level that approximately corresponds to the USA EPA reference dose. An additional 1310 cases of intellectual disability attributable to mercury exposure were identified annually (4110 assuming no reference level), resulting in 16,501 lost DALYs (51,809 assuming no reference level). A total of $77.4 million in lost economic productivity was estimated assuming a 1 ppm reference level and $130 million if no reference level was used. We conclude that significant mercury exposures occur in developing and transition country communities near sources named in the Minamata Convention, and our estimates suggest that a large economic burden could be avoided by timely implementation of measures to prevent mercury exposures.

1. Introduction

Industrialization and increases in energy demand have produced rapid increases in anthropogenic mercury (Hg) emissions. Coal-fired power plants and artisanal and small scale gold mining (ASGM) are leading sources of Hg emissions, accounting for more than 50% of all global emissions to the atmosphere (Global Mercury Assessment, 2013). In addition to emissions into the atmosphere,

Abbreviations: ASGM, Artisanal small-scale gold mining; DALY, Disability-Adjusted Life Years; EPA, Environmental Protection Agency; GDP, Gross Domestic Product; IQ, intellectual quotient; LMICs, Low- and middle-income countries; Hg, Mercury; PPP, Purchasing power parity; UNEP, United Nations Environment Programme.

* Corresponding author. Department of Pediatrics, New York University School of Medicine, 403 East 340th Street, 1st floor, New York, NY, 10016, USA.
E-mail addresses: Leonardo.Trasande@nyumc.org (L. Trasande), joe@ipen.org (J. DiGangi), david.evers@briloon.org (D.C. Evers), jindrich.petrlik@arnika.org (J. Petrlik), david.buck@briloon.org (D.G. Buck), jan.samanek@arnika.org (J. Šamánek), bjornbeeler@ipen.org (B. Beeler), madeline.turnquist@briloon.org (M.A. Turnquist), kevin.regan@briloon.org (K. Regan).

http://dx.doi.org/10.1016/j.jenvman.2016.08.058
0301-4797/

significant releases of Hg directly into the environment occur from a variety of sources including ASGM, chlor-alkali facilities and other industrial sites. Elemental Hg is converted to inorganic forms in the atmosphere and eventually deposited onto land and in water. Once Hg enters aquatic ecosystems, it can be transformed to an organic form, methylmercury (MeHg) (Guimaraes et al., 2000), a potent neurotoxicant (National Research Council, 2000), especially to the developing brain. It biomagnifies in the aquatic food chains, especially in marine predatory fish at the top of the food chain such as swordfish, tuna, and king mackerel (Dietz et al., 2000; Neumann and Ward, 1999; Trasande et al., 2010). Human exposure to mercury occurs primarily via the consumption of contaminated fish (Trasande et al., 2005), although rice (Feng et al., 2008; Zhang et al., 2010) and even direct exposure to mercury vapor (Global Mercury Assessment, 2013) can be locally significant pathways. There is a robust literature on the human health effects of mercury exposure.

In multiple longitudinal studies prenatal exposure to methylmercury has been documented to produce extreme fetal abnormalities and significant decrements in neurological and cognitive outcomes, independent of confounding factors, including fish consumption (Grandjean et al., 1997; Kjellstrom et al., 1986, 1989; Oken et al., 2005). Available data suggests that moderate exposure to Hg can be associated with decrements in memory, attention, language development, and visual motor skills (National Research Council, 2000). Recent research also suggests that low levels of Hg exposure can impact the cardiovascular and immune systems in both children and adults (Karagas et al., 2012). Increased awareness about the negative impacts of Hg exposure on both human health and the environment motivated the international community to develop a new global, legally binding treaty on mercury, the Minamata Convention on Mercury (United Nations Environment Programme, 2013a). The treaty represents a global consensus that mercury poses a threat to human health and environment and that global action is required. Key anthropogenic sources of mercury air emissions covered by the treaty include ASGM, coal combustion, production of non-ferrous metals, cement manufacturing, large-scale gold mining, consumer product waste, contaminated sites, and chlor-alkali plants (United Nations Environment Programme, 2013a).

Knowledge of pollution sources, accompanying exposures, and information on the cost of inaction can be key drivers for promoting chemicals management and treaty implementation into national policies (United Nations Environment Programme, 2013b). However, many developing countries and countries with economies in transition have limited or no information about exposures near anthropogenic mercury sources or estimates of the economic impacts of mercury pollution.

Previous estimates of economic impacts of mercury exposure in developed countries show substantial economic costs, especially in terms of lost economic productivity. In the United States, these costs totaled $5.1 billion in 2008 (Trasande and Liu, 2011), while in the European Union losses of up to €9 billion ($11.9 billion) have been identified (Bellanger et al., 2013). Pacyna et al. have estimated that global lost economic productivity from mercury pollution could reach $29.4 billion in 2020 (Pacyna et al., 2008). Studies have also suggested substantial economic benefits to mercury pollution prevention in the US and globally (Sundseth et al., 2010; Trasande et al., 2006). Yet, no studies have quantified costs of mercury pollution or economic benefits to mercury pollution prevention in developing and transition countries, which would inform implementation of the global mercury treaty.

In this study, we analyzed hair samples from exposed subpopulations in developing countries most likely to benefit from treaty implementation, and estimated economic costs related to mercury exposure in these communities.

2. Methods

2.1. Site selection

Mercury sources listed in the Minamata Convention provided a guide to the selection of sites. Listed sources in this study include chlor-alkali plants (Article 5); artisanal small-scale gold mining (ASGM) (Article 7); coal-fired power plants, waste incineration, non-ferrous metal smelting, and cement plants (Article 8); wastes (Article 11); and contaminated sites (Article 12). The United Nations Environment Programme (UNEP) inventory of mercury sources includes large-scale gold mining as a source of global mercury emissions to air. Several sites with mixed sources were included in the study since these represent the reality of emission sources encountered in most countries. Finally, one Small Island Developing State without industrial sources was included to reflect mercury sources from global deposition.

2.2. ASGM sites

ASGM sites are primary contributing mercury sources at sites in Indonesia, Kenya, and Tanzania. In Indonesia, samples were collected near two ASGM sites. Sekotong is a large site with more than 35,000 miners and more than 200 ball mill plants. Poboya contains approximately 5000 miners and 100 ball mill plants. Miners at both sites amalgamate gold using mercury, then burn off the mercury to leave the gold. Processing occurs in the backyards of residences or near rice fields. The miners process contaminated tailings further using cyanide leaching or dump wastes directly into rivers. In Kenya, the ASGM sites are located in Masara in the Mogori District. At peak mining times, more than 20,000 miners work in the area using mercury to amalgamate gold and then wastes are dumped in rivers that serve as main food sources for the surrounding communities. The Tanzanian ASGM sites are in Matundasi and Makongolosi. Mercury is used to amalgamate gold, and then burned off. The wastes along with water used for sluicing end up in the Lupa River which flows into Lake Rukwa, an important support for livelihoods in southern Tanzania and located on the border of an Ugandan game reserve.

2.3. Chlor-alkali plant sites

Current or former chlor-alkali plants are a primary contributing mercury source at study sites located in Albania, India, Russia, and Uruguay. In Albania, a currently abandoned chlor-alkali and PVC plant operated from 1967 to 1992 using mercury-cell technology. The factory discharged mercury-containing waste directly into Vlora Bay and dumped polluted sludge by the seashore. Vlora Bay is an important fishing area and fish from the area are distributed to all cities in Albania. The former Vlora Bay facility is currently a contaminated site. The chlor-alkali plant in India is located in Ganjam Province in the state of Orissa. The plant utilized mercury cell technology from 1967 to 2011 and discharged wastes into the nearby estuary which supplies fish to the surrounding communities. The chlor-alkali plant in Volgograd, Russia uses both mercury cell technology and diaphragm processes. Mercury-containing wastes are discharged into local waterways and also stored in drums outside the plant. Mercury is also released during incineration of mercury-containing lamps. In Uruguay, the chlor-alkali plant using mercury cell technology is located in San Jose province near the mouth of the Santa Lucia River. The river is a principal waterway in Uruguay that feeds into the large Rio de la Plata which runs between Argentina and Uruguay and serves as an important fishing area.

Please cite this article in press as: Trasande, L., et al., Economic implications of mercury exposure in the context of the global mercury treaty: Hair mercury levels and estimated lost economic productivity in selected developing countries, Journal of Environmental Management (2016), http://dx.doi.org/10.1016/j.jenvman.2016.08.058