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Economic status as a determinant of national PCDD/PCDF releases and implications for PCDD/PCDF reduction

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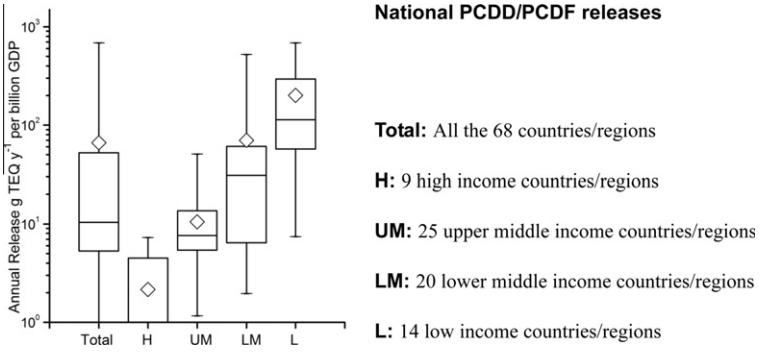
HIGHLIGHTS

- PCDD/PCDF inventories of 68 countries/regions were developed.
- Economic status was found to be a determinant of PCDD/PCDF release.
- Economic growth can reduce PCDD/PCDF release intensity per GDP effectively.
- Open burning is dominating PCDD/PCDF source for lower income countries.
- A methodology to assess International PCDD/PCDF Reduction Burden is proposed.

GRAPHICAL ABSTRACT



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ABSTRACT

The annual releases of polychlorinated dibenzo-*para*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) from 68 countries/regions were investigated by correlating quantitative emissions with economic status of the nations. The national dioxin/furan inventories were developed using the PCDD/PCDF Standardized Toolkit, which presents the quantitative releases from ten major source groups to five release vectors. The correlation between intensity of PCDD/PCDF release and economic status was discussed and the influence of economic status on composition of five release vectors and ten source groups was studied. As PCDD/PCDF are mainly released from human activities to environmental matrices, release per person (RpP) and release per unit area (RpA) are defined to reflect release burden (Donor) and contamination burden (Receptor), respectively. Based on these two concepts, International PCDD/PCDF Reduction Burden is characterized by burden quotient (BQ) and a calculation model is established. The numbers of countries/regions with high, moderate and low International PCDD/PCDF Reduction Burden were 19, 31 and 18, respectively. The information in this paper can be used for politicians to develop legislations to improve International PCDD/PCDF Reduction.

1. Introduction

Polychlorinated dibenzo-*para*-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) have never been produced for any purpose other than laboratory experiments. They are unintentionally formed in industrial-chemical processes, such as chemical manufacture, and thermal processes, such as waste incineration or forest fires, and released to the environment. The predominant mechanism or pathway to generate PCDD/PCDF can vary from process to process resulting in a wide range of source-specific emission factors that also take into account different factors, such as reduction and abatement technologies, to reduce the releases (Dyke et al., 1997; Finocchio et al., 2006; Wang et al., 2006; Holtzer et al.,

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2007; Lee et al., 2008; Wielgosinski, 2010; Cavaliere et al., 2011). It is generally accepted that the main sources of PCDD/PCDF are human activities.

Sine the early 1990s, researchers and governments have undertaken attempts to estimate the total releases of PCDD/PCDF at national or sector scales (Fiedler et al., 1990; MITI, 1998; US-EPA, 1998; UNEP, 1999). With the entry into force of the Stockholm Convention on Persistent Organic Pollutants (POPs), the obligation to develop and report PCDD/PCDF releases as required by article 5 or article 15 of the convention, national inventories have gained importance. In order to assist countries in the development of these inventories and to allow comparison between countries and changes with time, the United Nations Environment Programme (UNEP) has developed the "Standardised Toolkit for Identification and Quantification of Dioxin and Furan Release" (UNEP, 2005). Through its structure for reporting, i.e., ten source groups and five release vectors, it is possible to gain some further insight into the global situation as to the sources of PCDD/PCDF releases, and information has been drawn from, e.g., submissions of parties to the Stockholm Convention according to national reporting under article 15 or from national implementation plans prepared according to article 7.

At Dioxin'90, Fiedler and coworkers published the paper entitled "Dioxin Emissions to Air: Mass Balance for Germany Today and in the Year 2000". The results were mainly based on measured emission data and had a total annual emission of 928.5 g I-TEQ to air from sources in Germany (former Federal Republic of Germany) (Fiedler et al., 1990). Although releases in solid residues such as slags, fly ashes, sludges have been quantified, a systematic approach for estimating these releases had not been undertaken. In 1999, UNEP published a report presenting the results of 15 emission inventories; the reference year was around 1995 (UNEP, 1999). In the early 2000s, 23 national release inventories were available that have been made with the UNEP Toolkit methodology (Fiedler, 2007). In 2011, 68 national inventories with reference years between 1999 and 2009 have been assessed and the quantitative releases have been correlated to geographic, demographic and source-specific information, exploring the release patterns of PCDD/PCDF influenced by economic status and methodology that is fair, accurate and objective enough to assess International PCDD/PCDF Reduction Burden.

2. Methods and materials

2.1. Inventory methodology

PCDD/PCDF release inventories from countries that had applied the UNEP Standardised Toolkit have been assessed. The reporting scheme of the UNEP Toolkit is comprised of ten source groups and reports releases to five vectors (UNEP, 2005). The annual re-

Table 1
Total and annual release of PCDD/PCDF in 68 countries/regions by reference year.

Total PCDD/PCDF releases (g TEQ y^{-1})								
Air		Water		Land		Product		Residue
26400		1200		6000		5300		19800
45.0%		2.1%		10.2%		9.0%		33.7%
Grand total				58700				
	Country/region				Country/region			
	Full name	ISO-3 code	Annual Release (g TEQ y^{-1})	Reference year	Full name	ISO-3 code	Annual Release (g TEQ y^{-1})	Reference year
H	Australia	AUS	1780	2002	Germany	DEU	116	2004
	Brunei	BRN	1.40	2001	New Zealand	NZL	89.4	2008
	CHN HKG	HKG	20.8	2003	Portugal	POR	95.2	2006
	Croatia	HRV	169	2001	Slovenia	SVN	30.5	2005
	Estonia	EST	29.2	2000				
UM	Albania	ALB	143	2004	Lithuania	LTU	56.9	2005
	Argentina	ARG	2111	2003	FYR Macedonia	MKD	175	2001
	Azerbaijan	AZE	128	2003	Mauritius	MUS	30.4	2003
	Belarus	BLR	101	2006	Niue	NIU	0.56	2004
	Chile	CHL	85.6	2003	Panama	PAN	99.6	2005
	China	CHN	10237	2004	Peru	PER	424	2003
	Colombia	COL	790	2002	Romania	ROU	590	2004
	Cuba	CUB	225	2002	Serbia	SRB	398	2006
	Ecuador	ECU	97.6	2002	Seychelles	SYC	5.41	2003
	Gabon	GAB	173	2005	Thailand	THA	1070	2005
	Iran	IRN	1568	2005	Tunisia	TUN	209	2004
	Jordan	JOR	81.6	2003	Uruguay	URY	46.9	2003
	Lebanon	LBN	166	2004				
LM	Armenia	ARM	52.0	2001	Nicaragua	NIC	684	2004
	Côte d'Ivoire	CIV	432	2002	Nigeria	NGA	5340	2004
	Djibouti	DJI	119	2003	Paraguay	PRY	156	2002
	Fiji	FJI	19.2	2002	Philippines	PHL	534	1999
	Ghana	GHA	668	2002	Samoa	WSM	1.38	2004
	India	IND	8658	2009	Sri Lanka	LKA	258	2002
	Indonesia	IDN	7352	2003	Sudan	SDN	992	2004
	Lao PDR	LAO	104	2005	Syria	SYR	623	2006
	Moldova	MDA	776	2001	Vietnam	VNM	68.8	2002
	Morocco	MAR	236	2003	Zambia	ZMB	483	2004
L	Benin	BEN	379	2002	Liberia	LBR	315	2004
	Burkina Faso	BFA	785	2002	Madagascar	MDG	334	2002
	Burundi	BDI	195	2004	Mali	MLI	39.5	2005
	Cambodia	KHM	607	2004	Nepal	NPL	332	2003
	Ethiopia	ETH	215	2003	Tajikistan	TJK	173	2003
	Gambia	GMB	177	2000	Tanzania	TZA	964	2007
	Kenya	KEN	4738	2005	Togo	TGO	519	2002