Bull. Environ. Contam. Toxicol. (1992) 48:795–802

Environmental Contamination and Toxicology

Regional Relationships between Toxic Releases, and Environmental and Human Exposure to Toxic Substances

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Human and environmental exposures to toxic substances may be evaluated by direct measurement (i.e., monitoring data), or by using surrogate measures (i.e., release data). The usefulness of surrogate measures is dependant upon their reliability as indicators of actual human exposure. The release of toxic substances into the environment may result in human and environmental exposures. Therefore, the recent creation of the Toxic Release Inventory (TRI) data base may provide suitable surrogate measures of regional human and environmental exposure. However, the reliability of these data as indicators of regional exposure has not been adequately tested.

Previous studies using existing national monitoring data from the National Human Adipose Tissue Survey (NHATS) and the Environmental Protection Agency (EPA) STORET data base have demonstrated that regional differences in human and environmental exposures exist (Phillips and Birchard 1991a, 1991b). Regional correlations between NHATS and STORET data have also been observed (Phillips, 1991). In this study, regional relationships between the quantity of toxic substances released into the environment, and the magnitude of human and environmental exposures were evaluated using TRI data in conjunction with NHATS and STORET data. The results of this study provide: 1) a comprehensive assessment of regional correlations between the amount of toxics released via various emission pathways, and the levels of human exposure and environmental contamination; and 2) an evaluation of the reliability of toxic release data for predicting exposures.

MATERIALS AND METHODS

The relationships between regional toxic releases, and environmental contamination and human exposure were tested using data from three existing EPA data bases which were sorted according to U.S. census divisions (Table 1). The data sets included: 1) TRI data for the 322 TRI chemicals reported in 1988 (USEPA 1990); 2) STORET data for 43 chemicals retrieved for the years 1978-1987 (Table 2); and 3) data from 54 toxics retrieved from the 1982 NHATS (Table 2).

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Table 1. Census divisions used to sort TRI, STORET, and NHATS data.

New England (NE)	Mid Atlantic (MA)	South Atlantic (SA)
Maine	New Jersey	Delaware
New Hampshire	New York	Maryland
Vermont	Pennsylvania	D.C.
Massachusetts		Virginia
Rhode Island		West Virginia
Connecticut		North Carolina
		South Carolina
		Georgia
		Florida
East North Central (EN)	**East South Central (ES)**	**West North Central (WN)**
Ohio	Kentucky	Minnesota
Indiana	Tennessee	Iowa
Illinois	Alabama	Missouri
Michigan	Mississippi	Nebraska
Wisconsin		Kansas
		North Dakota
		South Dakota
West South	**Mountain (MO)**	**Pacific (PA)**
Arkansas	Montana	California
Louisiana	Wyoming	Hawaii
Oklahoma	Colorado	Washington
Texas	Utah	Oregon
	Arizona	Alaska
	Nevada	
	Idaho	
	New Mexico	

TRI is a national database containing information on the emissions of toxic chemicals into the environment by manufacturing industries (USEPA 1990). TRI was mandated by Congress in 1986 under Title III of the Superfund Amendments (Emergency Planning and Community Right-to-Know Act -EPCRA). TRI contains annual information on 322 chemicals which are released via air, surface water, land, underground injection, and sewage (USEPA 1990). Total direct releases are also tabulated. TRI release data (pounds/year), which are tabulated by individual states (USEPA 1990), were sorted according to census division by totaling the releases for each of the states assigned to a region for each of the emission pathways (air, surface water, land, underground injection, sewage, and total direct releases). The density of releases (pounds/mile^2-year)

Table 2. Data selected from the National Human Adipose Tissue Survey and from STORET for analysis.

Pesticides	Polychlorinated biphenyls[1]
Beta benzene hexachloride	Total PCBs
P,P'DDE	Trichlorobiphenyls
P,P'DDT	Tetrachlorobiphenyls
Mirex	Pentachlorobiphenyls
Dieldrin	Hexachlorobiphenyls
Hexachlorobenzene	Heptachlorobiphenyls
Trans nonachlor	Octachlorobiphenyls
	Nonachlorobiphenyls
Semi-volatiles	Decachlorobiphenyls
1,2,4-Trichlorobenzene	Volatiles
Triphenyl phosphate	
Tributyl phosphate	Chloroform
Tris(2-chloroethyl)phosphate	1,1,1-Trichloroethane
Diethyl phthalate	Bromodichloroethane
Di-n-butyl phthalate	Benzene
Di-n-octyl phthalate	Tetrachloroethene
Butyl benzyl phthalate	Dibromochloromethane
Naphthalene	1,1,2-Trichloroethane
Phenanthrene	Toluene
	Chlorobenzene
Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzo-p-furans[2]	Ethyl benzene
	Bromoform
	Styrene
	1,1,2,2-Tetrachloroethane
	1,2-Dichlorobenzene
Tetrachlorodibenzo-p-dioxin	1,4-Dichlorobenzene
Pentachlorodibenzo-p-dioxin	Ethyl phenol
Hexachlorodibenzo-p-dioxin	Xylene
Heptachlorodibenzo-p-dioxin	
Octachlorodibenzo-p-dioxin	
Tetrachlorodibenzofuran	
Pentachlorodibenzofuran	
Hexachlorodibenzofuran	
Heptachlorodibenzofuran	
Octachlorodibenzofuran	

[1] Slightly different PCB classifications were used for STORET than those listed.
[2] Dioxin and furan data were retrieved from NHATS only.

for each region was calculated by dividing total releases (pounds/year) by the total land area (mile^2) in each region. Ranks were assigned to each region based on the total density of releases. Regions with the highest releases were ranked number-one, and regions with the lowest releases were ranked number-nine (Table 3).

STORET is a computerized data base maintained for the storage and retrieval of water quality data within the United States (USEPA n.d.). It serves as a repository for water quality data, sediment, fish tissue residue analysis, groundwater data, and other related data which have been collected by the EPA, federal agencies, state and local governments, industry, and a variety of other organizations. STORET data for sediment, fish tissue, and groundwater were sorted by U.S. census division (Table 1). A ten-year time period was selected to maximize the number of observations and regions represented for each toxic substance evaluated. Ranks were assigned to each census division based on the mean concentration of the 43 toxics (Table 2) in sediment, fish, and groundwater. Pooled ranks were calculated for each type of environmental media by totaling the individual ranks for each compound. Regions were re-ranked based on the total ranks of all 43 compounds (Table 4).

NHATS is conducted annually by the EPA, Office of Toxic Substances (OTS). Its objective is to detect and quantify the prevalences of toxic compounds in the general population of the United States (USEPA 1986a, 1986b, 1986c). Fiscal-year 1982 NHATS was used for this project because it is the most recent and comprehensive survey that has been conducted on a regional basis, and has been summarized and published by the EPA. NHATS data for three age groups (0-14 years, 15-44 years, and 45 years and older) were sorted by census divisions. Ranks were assigned to each of the nine census divisions according to the mean concentration of toxic in adipose tissue, according to age group. Pooled ranks were calculated by totaling the individual ranks for each compound for all ages of adipose tissue. Regions were re-ranked based on the total ranks for all 54 toxic substances combined (Table 4).

In this study, the relationships between regional TRI, and STORET and NHATS ranks were tested using computerized Spearman rank correlation matrices. Correlation analyses were based on the regional ranks of TRI total direct releases, air releases, surface water releases, land releases, underground releases, and public sewage releases versus: 1) regional NHATS ranks; and 2) regional STORET sediment, fish tissue, and groundwater ranks. The following Spearman test statistic was used (Hays 1981).

d = difference between ranks
n = number of regions

$$C = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$$

Table 3. TRI releases (lbs/sq mi) and ranks according to census division.

CENSUS DIVISION	NE	MA	SA	EN	ES	WN	WS	MO	PA
TOTAL DIRECT RELEASES									
Releases	1492.80	2331.66	2539.39	3021.55	2547.52	635.77	3101.61	394.89	220.71
Rank	6	5	4	2	3	7	1	8	9
AIR RELEASES									
Releases	1289.09	2057.83	1650.37	1976.48	1569.86	361.13	870.25	179.01	164.92
Rank	5	1	3	2	4	7	6	8	9
SURFACE WATER RELEASES									
Releases	141.39	73.79	329.25	107.67	93.38	18.40	387.14	0.95	31.60
Rank	3	6	2	4	5	8	1	9	7
LAND RELEASES									
Releases	62.24	200.00	435.00	517.54	178.88	80.81	83.58	180.49	22.02
Rank	8	3	2	1	5	7	6	4	9
UNDERGROUND RELEASES									
Releases	0.06	0.04	124.78	421.30	705.41	175.41	1890.64	31.39	2.17
Rank	8	9	5	3	2	4	1	6	7
PUBLIC SEWAGE RELEASES									
Releases	370.25	929.58	397.49	529.77	162.53	183.26	104.08	9.13	62.40
Rank	4	1	3	2	6	5	7	9	8

A perfect agreement between ranks is indicated by a value of 1, whereas disagreement of ranks is indicated by a negative value. A correlation coefficient of zero indicates no particular relationship between ranks of the two variables (Hays 1981). Due to the low number of paired observations (9 regions) used in this study, correlation coefficients at or above 0.5 were believed to indicate significant correlations. Probability factors for these correlation coefficients were also calculated to indicate the significance of the observed relationships. For the purposes of this study, probabilities at or below 0.2 were considered to be indicative of significant correlations between data sets. This type of analysis was used in previous studies in which the relationships between human exposure and environmental contamination were evaluated (Phillips, 1991).

RESULTS AND DISCUSSION

When correlation analyses were performed using regional TRI ranks for the various emission pathways and regional NHATS ranks, significant correlations

Table 4. NHATS and STORET ranks (based on the total ranks of all toxics and all ages of adipose tissue; and on the total of all toxics in sediment, fish tissue, and groundwater.

CENSUS DIVISION	NE	MA	SA	EN	ES	WN	WS	MO	PA
NHATS	8	5	1	4	2	6	3	7	9
STORET sediment	9	3	4	5	2	1	8	7	5
STORET fish tissue	9	6	4	7	8	2	5	1	3
STORET groundwater	9	5	2	8	3	6	1	4	7

See Phillips and Birchard 1991a, 1991b for an explanation of these rankings.

were observed for all pathways except releases via sewage disposal (Table 5). A strong correlation (0.8) was observed for TRI total direct releases and NHATS data. Little relationship appeared to exist between regional TRI ranks and regional STORET sediment, fish tissue, and groundwater ranks (Table 5). The strongest correlations for TRI and STORET data were observed for ranks based on toxic releases via underground injection, and ranks based on the concentration of toxics in groundwater (0.5). Negative correlations between TRI air, water, and sewage ranks, and STORET fish tissue ranks are difficult to explain.

The results of this study indicate that TRI data may be a suitable predictor of relative regional human exposure to toxic substances, but may not be as good a predictor of regional environmental contamination. However, the strength of the observed relationships may have been weakened by the low numbers of paired observations (9 census divisions), missing data for some toxics for some regions in STORET, and/or sampling biases. Although the toxics substances retrieved from NHATS and STORET included a sampling of substances from various classes of chemical compounds, the correlations may have been weakened by the relatively limited number of toxics used, compared to the number included in the TRI data set.

This type of analysis was used to evaluate semi-qualitative relationships between toxic releases and human and environmental exposures. It was not intended to quantitatively assess risk to discrete populations from toxic releases. Further comparisons of TRI, and NHATS and STORET data on an individual chemical basis would be useful in further assessing the semi-quali-tative

Table 5. Correlation coefficients and corresponding probabilities for TRI ranks vs NHATS and STORET ranks.

	NHATS	STORET Sediment	STORET Fish Tissue	STORET Groundwater
TRI Total Direct Releases	0.80000 (0.0096)	-0.04184 (0.9149)	-0.55000 (0.1250)	0.41667 (0.2646)
TRI Air Releases	0.60000 (0.0876)	0.24268 (0.5292)	-0.61667 (0.0769)	0.03333 (0.9322)
TRI Surface Water Releases	0.56667 (0.1116)	-0.37657 (0.3178)	-0.58333 (0.0992)	0.28333 (0.4600)
TRI Land Releases	0.65000 (0.0581)	0.20084 (0.6044)	-0.08333 (0.8312)	0.26667 (0.4879)
TRI Underground Releases	0.61667 (0.0769)	0.11716 (0.7640)	-0.03333 (0.9322)	0.50000 (0.1705)
TRI Sewage Releases	0.35000 (0.3558)	0.28452 (0.4581)	-0.51667 (0.1544)	-0.25000 (0.5165)

Note: Values in parentheses indicate probabilities.

relationships observed in this study, and in evaluating quantitative relationships between toxic releases, and human exposure and environmental deposition.

Acknowledgments. The assistance of G. Birchard and J. Remmers is sincerely appreciated.

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Received November 1, 1991; accepted January 4, 1992.