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Occupational Exposures to Carcinogens in an Industry: Identifying and Communicating Chemical Risk

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Abstract

In the 45 years since the creation of the U.S. Environmental Protection Agency and Occupational Safety and Health Administration, the United States has not made sufficient progress in protecting workers from environmental exposures to known and suspected human carcinogens. A principal obstacle to progress is limited information on the extent and identity of carcinogenic exposures in the workplace. The aim of this study was to develop a method for identifying such exposures. Using publicly available EPA data sets, we examined the potential for exposure to carcinogens at one large aerospace manufacturing facility in the U.S. A total of 394 unique chemicals were identified. This number included 131 unique chemicals or chemical categories (33%) associated with malignant and benign neoplasms, including 78 chemicals categorized as "known human carcinogens" by one or more authoritative bodies. These findings disclose a problem of national significance.

Keywords: Carcinogens; occupation; National Emissions Inventory; Toxic Release Inventory; Safety Data Sheets

Introduction

Cancer incidence rates have increased in most countries since 1990 [1]. In the United States the Division of Cancer Prevention and Control of the Centers for Disease Control and Prevention has projected that death from cancer will exceed death from cardiovascular disease by 2020, if it has not done so already [2]. While it is good news that deaths from cardiovascular disease are declining, it is not such good news that deaths from cancer are not declining as rapidly. Cancer is due to several different factors, including genetics, inflammation, infection and exposure to carcinogenic substances ranging from radiation to chemicals [3-5].

The President's Cancer Panel [6] stated "There is a lack of emphasis on environmental research as a route to primary cancer prevention." Our goal in this report is to demonstrate that publicly available data can be used to document the number of known human chemical carcinogens that workers in one plant and residents in the nearby community are potentially exposed to.

The U.S. Occupational Safety And Health Administration (OSHA) and the National Institute Of Occupational Safety And Health (NIOSH) are responsible for regulating and supporting the necessary research to assure safe and healthful working conditions in the U.S. Included as Title III of the Superfund Amendments And Reauthorization Act (SARA Title III or SARA) passed by Congress in 1986 is the Emergency Planning And Community Right-To-Know Act (EPCRA), which requires that facilities inform workers of all hazardous substances to which may result in exposure. This is to be communicated by training and by Safety Data Sheets. (SDS). The law requires that an SDS for every product used at a facility that lists its chemical ingredients must be made available to all employees. The assumption is not that every employee is exposed but rather that there is a potential for every employee to be exposed.

Another major goal of EPCRA was to report the use, storage, production or release of hazardous chemicals to state and local governments, emergency responders and the public. This is because toxic chemicals used at the facility may affect not only the employees, but also individuals living near to the plant. The starting point of this process is a facility's submission of a Title II form as required under Section 312 of the Act. As stated by EPA, "The purpose of this form is to provide State, local officials, and the public with specific information on potential hazards. This includes the locations, as well as the amount, of hazardous chemicals present at your facility during the previous calendar year." Thus, the Act was designed to serve two related purposes: to meet a requirement that both the employee and the local community have a right-to-know of potential hazards and to provide for emergency planning within the local environment should there be releases of toxic substances.

The Toxic Release Inventory (TRI) is a federal program for tracking industrial emissions. At present, the system collects data from large industrial facilities for 696 chemicals released on-site (air, water, land, underground injection) or transferred off-site (for various types of disposal or recycling). While the data sets and analytical tools available to the general public are inadequate for the purposes of epidemiological research, detailed TRI data for the years 1987 to 2012 supplied by EPA have been used to create a Structured Query Language (SQL)-compliant database that makes it possible to identify facilities using and releasing TRI chemicals by zip code and address. The National Emissions Inventory (NEI), mandated by the 1990 Clean Air Act, is yet another EPA dataset that systematically collects data on some 300 airborne criteria and hazardous air pollutants from industrial sources. This data has also been converted into a SQL compliant database by the authors. All releases can be analyzed at the country level, but only point sources can also be identified by address or geocoordinates. It is often the case that employees live relatively near to their workplace. Exposure to carcinogens is certainly not limited to occupational exposure. While it is not possible to obtain information on all sources of exposure to carcinogens from food, personal care products and personal habits, such as smoking, we have used the information in the TRI and NEI on county-level releases of carcinogens from industrial sources. Together this information provides one indication of carcinogenic chemicals in the local ambient environment.

The goal of the present study was to use SDS and other federally mandated environmental reports for a single large aerospace manufacturing facility to determine the number of carcinogenic chemicals that are used at and/or released from the plant. In addition, we have determined the total releases from the plant and from other industrial facilities in that county, using data from the TRI and NEI, to approximate carcinogenic risks from these sources at the local level.

This information is important for several reasons. Although they must be available, SDS are rarely accessed by employees. Furthermore, SDS only present information of the chemical or chemicals in a single product. However, both in occupational settings and elsewhere individuals are exposed to mixtures of multiple chemicals, many of which are known carcinogens. Some SDS lists chemical mixtures (e.g. nickel compounds) as well as individual chemicals (e.g. metallic nickel.).

Mixtures of chemicals may have additive, less-than-additive, or more than additive (Synergistic) actions [7], and these are rarely identified or considered by employers or by regulatory agencies.

Neither employees, managers or union safety and health personnel are likely to know the number of chemical carcinogens at their workplace, the quantity of releases or their known or suspected health effects. (Upon reviewing a draft of this paper, this statement was confirmed by an executive vice president of the union representing this work site.).

Documenting the presence and/or use of a carcinogenic chemical through information from the SDS does not necessarily indicate employee exposure, but it does indicate the possibility of exposure. Other datasets, however, document releases of chemicals into air, water or soil from a facility, and when a carcinogenic chemical is released from a plant there is almost certainly a risk of exposure of employees. We examine the potential exposure of workers and local residents using data from these multiple sources. To the authors' knowledge, there are no published studies that have attempted to inventory all chemicals found at a work site and their associated health effects in general and cancer in particular.

Materials and Methods

Study Site

The site studied is a major jet engine production and repair facility in the U.S. Its primary NAICS is 33641 -- Aerospace Product and Parts Manufacturing. (Nationally 235 unique facilities with this NAICS reported point air pollution releases to EPA in 2014). The workforce at this and two similar company sites in the study site numbered slightly above 19,000 in the not too distant past. The workforce is now down to approximately 3,000. The workers at this plant are represented by the International Association of Machinists and Aerospace Workers (IAMAW) which has approximately 800,000 active and retired members in the U.S. and Canada.

Documenting Potential Chemical Exposures

Data documenting chemicals found on site or released from the plant were obtained from 4 sources: facility safety data sheets (SDS), U.S. EPA TIER-II reports for 3 specific years (1998, 2008, 2014), U.S. EPA Toxic Release Inventory (TRI) data for a 27-year period (1987-2010), and EPA National Emission Inventory (NEI) data for 1998, 2011 and 2014. The company's "Tool & Supply Sheets" (April 2016) lists 4,677 individual SDS. It was not possible to examine all these sheets. However, with the cooperation of the president of the local union, safety and health staff provided physical copies of 404 SDS or 8.6% of all 2016 SDS. The majority of SDS were for products currently used on site. Seventy-five SDS (18.6%) included in this study found in the union's archive were in use in the 1980s and 1990s. Most list chemicals are also found in current SDS. There are, however, a small number of chemicals which may not be in current use. (These older SDS available in the union's archive were included in our sample because a significant percentage of the current work force were hired in the late 1970s-early 1980s and were potentially exposed to the chemicals contained in these products Most of these chemicals continue to be used at the facility).

Federal legislation found in EPA TIER-II statues requires that facilities documents the presence and locations of specific chemicals on site. Submission of Tier II forms are required under Section 312 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). At the time of its passage, EPCRA stated that this information would be available to those responsible for emergency response such as fire departments as well as the public. For the public and scientific researchers, obtaining this data is increasingly difficult. In years past, there was little difficulty in obtaining TIER-II data for an entire state, and in 2000 we obtained a printed copy of the state's full 1998 TIER-II report which included submissions by all sites with all pertinent chemical information, relevant portions of which are included in this study. However, a decade later we could only obtain data for our study site and only for two additional years (2011 and 2014). This required a written request to the relevant state agency. Permission was granted to review this material on site in paper form. (Though the agency maintains TIER-II data in digital form, it would not provide it to the authors.) TRI data for the 23-year period 1987-2010 were used to determine point sources of known carcinogens included in TRI that were released at the study site as well as from other industrial sources in the county. TRI data is in the public domain. (https://www.epa.gov/toxics-release-inventorytri-program) NEI data for the three most recent reporting years (2008, 2011 and 2014) was used to document NEI known carcinogens released at the study site as well as all countywide releases. NEI data is in the public domain. (https://www.epa.gov/air-emissions-inventories/national-emissions-inventorynei). Thus, we have TRI data for the period 1997-2010 and NEI data for three years (1998; 2011, 2014) for the county in which this particular plant was located for the purpose of determining the particular carcinogenic chemicals in this dataset that are known to be released and in what volume. While the data is clearly not complete, they provide a picture of the range of carcinogens to which employees are potentially exposed and at least a lower bound of the quantity.

Determining Carcinogenicity of Chemicals

We searched national and international authoritative bodies for identification of chemicals used or released from this one site that have been identified as known human carcinogens.

A total of 119 chemicals have been listed by the International Agency for Research on Cancer (IARC), a body of the World Health Organization, has identified as being Group1,"carcinogenic to humans".Most but not all are individual chemicals. (http://monographs.iarc.fr/ENG/Classification/).U.S.NationalToxicology Program, Report on Carcinogens, 13th edition, lists all chemicals considered known or reasonably anticipated carcinogens that they have evaluated. For this study we are only including NTP"known" carcinogens (https://ntp.niehs.nih.gov/annualreport/2015/glance/roc/index.html). U.S. EPA IRIS List of Known Human Carcinogens ("known" carcinogens) and EPA TRI carcinogens. U.S. NIOSH Immediately Dangerous to Life or Health Concentrations (IDLH) and the NIOSH Pocket Guide to Chemicals were used to identify "potential occupational carcinogens". NIOSH does not have the authority to list a chemical as a known workplace carcinogen. This responsibility is solely that of OSHA. A review of the NIOSH literature shows that the Agency considers many more chemicals "potential occupational carcinogens" than are regulated by OSHA as "known carcinogens". U.S. Occupational Safety and Health Administration's current list of substances that the Agency regulates as known carcinogens can be found at: (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=24730&p_table=INTERPRETA TIONS).

Information was also obtained from the California Proposition 65 (CA P65).(oehha.ca.gov/proposition65/proposition-65-list). (https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword=human+carcinogens%2C+known). Any chemical documented as being present or released from the site that was identified by a unique CAS number in at least one of these datasets as being carcinogenic to humans was identified.

Not all chemicals at the study site have been evaluated by all agencies. In addition, different agencies have drawn different conclusions about the potential of any given substance's potential to cause cancer. Of the agencies considered "authorities", IARC undertakes the most rigorous evaluation. For this reason, chemicals IARC considers "probable human carcinogens" (Group 2A) or "possible human carcinogens" (Group 2B) were not included in this report unless another agency considers it a "known" carcinogen (NTP, CA P65, OSHA) or "potential occupational carcinogen" (NIOSH).

Results

Of the 119 individual substances identified by IARC as "known (Group 1) human carcinogens, 29 are present at the site.

The National Toxicology Program has identified 62 substances as being "known human carcinogens". Of these 35 are individual chemicals and 17 are present at the site.

EPA lists 10 chemicals and two mixtures as being "known human carcinogens" and 11 are at the site.

NIOSH lists 132 chemicals or mixtures as being "potential human carcinogens", and 31 individual chemicals are found at the site. OSHA lists 26 chemicals as "recognized human carcinogens" and 10 are present at the site.

CA P65 lists 592 chemicals, of which all but 55 are single chemicals, "known to the State to cause cancer" and 63 are found at the site.

(Table 1) lists chemicals found at the site as identified by SDS, EPA TIER-II, TRI or NEI reports that are included in one or more of the above national or international listings as being carcinogenic. Having a SDS indicates that the chemical is present at the facility but does not provide detailed information on degree of use and/or exposure. The TRI contains facility reported releases into air, land, waste and underground injection. TIER-II indicates the presence and location of the chemical and NEI air releases.

s.no	Chemical name	ARC	U.S. EPA	U.S. NIOSH	U.S. NTP	U.S. OSHA	CA P65
1	Acetaldehyde			√			√
2	Acrylonitrile			√		√	√
3	A-alpha-C						√
4	Antimony						
5	Antimony oxide						√
6	Aroclor 1260	√					
7	Arsenic	√	√	√	√	√	√
8	Asbestos	√	√	√	√	√	√
9	Benz(a)anthracene						√
10	Benzene	√	√	√	√	√	√
11	Benzo(a)pyrene	√		√			√
12	Benzo(b)fluoranthene						√
13	Benzo(k)fluoranthene						√
14	Beryllium	√	√	√	√		√
15	Beryllium compounds	√		√	√		√
16	Butadiene, 1,3-	√	√	√	√	√	√
17	CI Pig. Yellow 36, as Cr6+	√					
18	Cadmium	√		√	√	√	√
19	Cadmium oxide	√					
20	Carbon black						√
21	Carbon tetrachloride			√			√
22	Cesium-137	√					
23	Chloroethane						√
24	Chloroform			√			√
25	Chloromethane			√			√
26	Chromium (VI) & inorganic Cr6+ cmp's	√	√		√		√
27	Chrysene						√
28	Coal tar	√	√		√		
29	Cobalt						√
30	Cobalt (II) sulfate						√
31	Cumene [Styrofoam]						√

32	Dibenz(a,h)anthracene						√
33	Dichlorobenzene			√			√
34	Dichloroethane, 1,1-						√
35	Dichloropropane, 1,2-	√		√			
36	Dichloropropene, 1,3-		√				√
37	Dimethylbenz(a)anthracene, 7,12-						√
38	Dioxane, 1,4-			√			√
39	Di-(2-ethylhexyl)phthalate [DEHP]			√			√
40	Ethyl acrylate			√			√
41	Ethylbenzene						√
42	Ethylene dibromide			√			√
43	Ethylene dichloride			√			√
44	Formaldehyde	√		√	√	√	√
45	Hexachloroethane						√
46	Indeno(1,2,3-cd)pyrene						√
47	Lead						√
48	Methane dichloride			√		√	√
49	Methyl iodide			√			√
50	Methylcholanthrene, 3-						√
51	Methylchrysene, 5–						√
52	Methylenedianiline			√		√	√
53	Naphthalene						√
54	Nickel		√	√			√
55	Nickel compounds	√					
56	Nickel chloride	√					
57	Nickel monoxide	√			√		√
58	Nickel sulfamate	√			√		√
59	Nickel sulfate	√			√		
60	Nickel sulfate hexahydrate	√					
61	Perchloroethylene			√			√
62	Polychlorinated biphenyls	√					√
63	Polycyclic aromatic hydrocarbons	√			√		
64	Potassium chromate, as Cr6+	√					
65	Propylene oxide			√			√
66	Silicon dioxide						√
67	Sodium dichromate, as Cr6+	√					
68	Styrene						√
69	Sulfuric acid				√		√
70	Talc (containing Asbestos)	√					√
71	Tetrachloroethane, 1,1,2,2-			√			√

72	Toluene diisocyanate (mixed isomers)			√			√
73	Toluene diisocyanate, 2,4-						√
74	Trichloroethane, 1,1,2-			√			√
75	Trichloroethylene	√	√	√	√		√
76	Urethane						√
77	Vinyl chloride	√	√		√	√	√

Table 1: 77 Known Carcinogens at Study Site by Authority and On-Site TRI Releases.

(Table 2) lists shows the evidence of carcinogenicity and volume of releases for eight TRI-regulated known human carcinogens at the site: cobalt, Di-(2-Ethylhexyl) Phthalate [DEHP], naphthalene, nickel, nickel compounds, perchloroethylene, polycyclic aromatic hydrocarbons and sulfuric acid. The chemical with the greatest reported release by far is perchloroethylene (1.45 million pounds). Of the total releases of 1.5 million pounds, the large portion were fugitive (non-stack) releases (1.3 million pounds). There were also reported releases of metals (cobalt and nickel) and organics (di-2-ethylhexyl) phthalate or DEHP, naphthalene, polyromantic hydrocarbons) and acids.

s.no	Chemical name	Authorities						TRI On-Site Releases						
		IARC	U.S. EPA	U.S. NIOSH	U.S. NTP	U.S. OSHA	CA P65	Air Fugitive	Air Stack	Air Total	Land	Water	Under-ground inj.	On-Site Total
8	**Totals**	**2**	**2**	**3**	**2**	**0**	**6**	**1,277,972**	**210,222**	**1,488,194**	**1,287**	**6,754**	**0**	
29	Cobalt						√	985	5,856	6,841	0	1,076	0	**7,917**
32	Di-(2-ethylhexyl)phthalate [DEHP]			√			√	0	2,040	2,040	0	74	0	**2,114**
53	Naphthalene						√	22	33	55	2	0	0	**57**
54	Nickel		√	√			√	3,118	9,570	12,688	0	3,029	0	**15,717**
55	Nickel compounds	√						1,126	8,821	9,947	0	2,280	0	**12,227**
61	Perchloroethylene			√			√	1,272,260	176,522	1,448,782	0	295	0	**1,449,077**
63	Polycyclic aromatic hydrocarbons	√			√			0	0.10	0.10	1,285	0	0	**1,285**
69	Sulfuric acid				√		√	461	7,380	7,841	0	0	0	**7,841**

Table 2: 8 Known TRI On-Site Carcinogens at Study Site.

(Table 3) lists county-level releases (in pounds) of known carcinogens as reported from the TRI and NEI. This table shows that in the 23-year period 1987 to 2010, 9.85 million pounds of known carcinogen were reported by TRI, and 171,811 pounds were reported by NEI for the years 2008, 2011 and 2014. Over a typical work life of thirty or more years at this work site, residence in the county for a similar length of time and the ubiquity of these chemicals as ambient pollutants, it is not unreasonable to assume that workers at the study site have the potential of being exposed.

s.no	Chemical name	Known Human Carcinogens										Documented Exposure Sources																				
		Authorities										On-Site								County Ambient Air									Other	Pr		
												US EPA							P & W	US EPA												
												NEI					T-II	TRI		NEI							U.S. EPA TRI					
		ACCGIH	CA Proposition 65	DFG	EPA	IARC	IRRST	NIOSH	New Jersey	NTP	OSHA	All On-Site	Safety data sheets	NEI 2008	NEI-2011	NEI 2014	TIER-II	TRI 1987-2010	Groundwater	Soil	Other	All County	EPA NEI 2008	EPA NEI-2011	EPA NEI 2014	EPA NEI Lbs.	EPA TRI 1987-2010	TRI Lbs.	Indoor Air Pollution	Used in pesticides	Dietary contamination	High prd >1 mill. lbs.
		12	64	17	11	28	3	31	15	16	10	64	32	11	36	35	32	5	3	1	1	55	29	45	47	171,884.21	33	3,476,016.57	50	23	12	44
1	Acetaldehyde		√					√				√		√	√	√						√	√	√	√	18,989.20	√	8,900.00	√		√	√
2	Acrylonitrile		√					√			√											√		√	√	1,647.40	√	500.00	√	√		√
3	A-alpha-C		√									√	√				√															
4	Antimony								√			√			√	√						√	√	√	√	27.79	√	1,400.00	√			
5	Antimony oxide		√									√					√															√
6	Aroclor 1260					√						√					√														√	
7	Arsenic	√	√	√	√	√		√	√	√	√	√	√	√	√	√						√	√	√	√	45.47			√			
8	Asbestos	√	√	√	√	√		√	√	√	√	√									√	√					√	1,555.00	√	√		
9	Benz(a)anthracene		√	√								√			√	√						√	√	√	√	3.17						
10	Benzene	√	√	√	√	√	√	√	√	√	√		√																			
11	Benzo(a)pyrene		√			√		√				√			√	√						√	√	√	√	3.50			√		√	
12	Benzo(b)fluoranthene		√									√			√	√						√	√	√	√	3.72			√		√	

13	Benzo(k)fluoranthene		√									√			√	√						√	√	√	√	3.71			√		√	
14	Beryllium		√	√	√	√		√	√	√		√	√		√	√				√		√	√	√	√							
15	Beryllium compounds		√	√		√		√	√	√					√	√						√		√	√	.64						
16	Butadiene, 1,3-		√	√	√	√		√		√	√	√			√	√						√	√	√	√	7,472	√	263,269.00	√		√	√
17	CI Pig. Yellow 36, as Cr6+	√				√	√		√			√	√				√															
18	Cadmium		√	√		√		√	√	√	√	√	√	√	√	√	√					√	√	√	√	85.49	√	7,967.00	√		√	√
19	Cadmium oxide					√			√			√	√				√															
20	Carbon black		√									√	√				√												√			√
21	Carbon tetrachloride		√					√				√			√	√						√		√	√	7.29	√	1,970.00	√	√		√
22	Cesium-137					√						√																				
23	Chloroethane		√									√					√					√	√	√	√	70.86	√	1,380.00	√			√
24	Chloroform		√					√				√			√	√						√		√	√	43.07	√	152,390.00	√	√	√	√
25	Chloromethane		√					√									√					√	√	√	√	55.66	√	1,132,296.00	√			√
26	Chromium (VI) & inorg. Cr6+ cmp	√	√	√	√	√				√		√		√	√	√	√					√	√	√	√	45.29						
27	Chrysene		√									√		√	√	√						√	√	√	√	3.12			√			
28	Coal tar	√			√	√				√		√	√				√												√	√		√
29	Cobalt		√									√		√	√	√		√				√	√	√	√	61.67	√	7,917.00	√			
30	Cobalt (II) sulfate		√									√	√																			

31	Cumene [Styrofoam]		√																			√	√	√	√	10.24	√	504.50	√		√	√
32	DEHP		√					√				√				√		√				√	√	√	√	24.47	√	2,114.00	√			√
33	Dibenz(a,h)anthracene		√									√			√	√						√		√	√	.03						
34	Dichlorobenzene		√					√														√	√	√	√	30.74			√	√	√	√
35	Dichloroethane, 1,1-		√									√			√	√						√		√	√	190.65			√			√
36	Dichloropropane, 1,2-					√		√				√			√	√						√		√	√	16.67				√		√
37	Dichloropropene, 1,3-		√		√							√			√	√						√		√	√	.01			√	√		√
38	Dimethylbenz(a)anthracene, 7,12-		√												√	√						√		√	√	.05						
39	Dioxane, 1,4-		√					√				√	√				√					√					√	125.00	√			√
40	Ethyl acrylate		√					√														√			√	255	√	3,940.00	√			√
41	Ethylbenzene		√									√		√	√	√	√					√	√	√	√	2,203.96	√	8,712.00	√			√
42	Ethylene dibromide		√					√				√			√	√						√		√	√	.16			√	√	√	√
43	Ethylene dichloride		√					√				√			√	√						√		√	√	33.29	√	25,700.00	√	√		√
44	Formaldehyde		√			√		√	√	√	√	√	√	√	√		√					√	√	√		35,851.52	√	36,161.00	√	√		√
45	Hexachloroethane		√									√	√				√												√			√
46	Indeno(1,2,3-cd)pyrene		√									√			√	√						√		√	√	2.49			√			
47	Lead		√									√	√				√					√	√				√	11.889	√			√
48	Methane dichloride		√					√			√	√	√		√	√	√					√	√	√	√	81,248	√	125,43	√	√		√

																												7. 00				
49	Methyl iodide		√					√														√	√			.78	√	50 0. 00				
50	Methylchol anthrene, 3-		√									√			√	√						√		√	√	.01						
51	Methylchr ysene, 5–		√																													
52	Methylene dianiline		√					√			√	√	√				√					√					√	9, 05 0. 00				√
53	Naphthalen e		√									√	√	√	√	√	√	√				√	√	√	√	5,7 16	√	11 .0 0	√	√		√
54	Nickel		√	√	√			√				√	√	√	√	√	√	√				√	√	√	√	882 .38	√	13 .0 0	√			
55	Nickel compound s											√						√				√					√					
56	Nickel chloride			√		√						√	√																			
57	Nickel monoxide	√	√	√		√			√	√							√															
58	Nickel sulfamate	√	√			√				√		√	√				√															
59	Nickel sulfate			√		√				√		√	√																			
60	Nickel sulfate hexahydrat e					√						√	√																	√		
61	Perchloroet hylene		√					√				√	√				√	√	√			√	√	√	√	515 .21	√	1, 44 9, 07 7. 00	√	√		√
62	PM10-Primarily diesel engines		√			√																√			√	1,2 00. 36						
63	Polychlori nated biphenyls		√			√						√	√				√		√	√		√		√	√	.07	√	0. 18	√			
64	Polycyclic aromatic hydrocarbo ns	√				√			√	√		√						√														
65	Potassium chromate, as Cr6+	√		√		√			√								√													√		
66	Propylene oxide		√					√				√	√		√							√	√	√	√	258 .68	√	18 1,	√	√		√

																												935.00				
67	Silicon dioxide		√									√					√												√	√		
68	Sodium dichromate, as Cr6+	√		√		√			√			√	√																	√		√
69	Styrene		√									√	√		√	√	√					√	√	√	√	1,936.54			√			√
70	Sulfuric acid		√							√		√	√				√	√				√					√	26,236.00	√	√		√
71	Talc (containing Asbestos)	√	√			√						√	√				√												√			√
72	Tetrachloroethane, 1,1,2,2-		√					√				√			√	√						√		√	√	152.73	√	12,300.00	√	√		√
73	Toluene diisocyanate (mixed isomers)		√					√				√	√				√					√			√	.03	√	594.00	√			√
74	Toluene diisocyanate, 2,4-		√																			√					√	1,500.00	√			√
75	Trichloroethane, 1,1,2-		√					√				√			√	√						√		√	√	.01			√			√
76	Trichloroethylene		√	√	√	√		√		√		√					√		√			√		√	√	312.11	√	11,314.00	√	√		√
77	Urethane		√						√			√	√				√												√			
78	Vinyl chloride	√	√	√	√	√	√		√	√	√	√	√		√	√			√			√		√	√	1,022.33			√			√

Table 3: 76 Chemicals classified as known carcinogens by one or more authorities found at study site (64) or county ambient air (55).

Discussion

Between September 2008 and January 2009, the President's Cancer Panel (USDHHS 2010) convened four national meetings "to assess the state of environmental cancer research, policy and programs addressing known and potential effects of environmental exposure on cancer." The Panel's report was released in 2010. "Research on environmental causes of cancer has been limited by low priority and inadequate funding. There is a lack of emphasis on environmental research as a route to primary cancer prevention. Cancer prevention efforts have focused narrowly on smoking, other lifestyle behaviors and chemo-preventive interventions. Scientific evidence on individual and multiple environmental exposure effects on disease initiation and outcomes, and consequent health system and societal costs, are not being adequately integrated into national policy decisions and strategies for disease prevention, health care access and health system reform."

The results of our study, considering these comments from the President's Cancer Panel, raise three significant questions. First, what percentage of cancers are a likely consequence of exposure to chemical carcinogens? Secondly, what is the impact of occupational as compared to non-occupational exposures? Finally, how adequate are policies that both inform people of hazards and act to reduce exposure to chemical carcinogens?

There is considerable debate on the question of what percentage of cancers are due to exposure to chemical carcinogens, both in the workplace and elsewhere. Doll and Peto (1981) [8] "provisionally estimated" that 4% of cancer was due to occupational exposures but attributed most of this to lung cancer. Mokdad et al. (2004) [9] ascribed only 2.3% of causes of death in the US to "toxic agents", but then attributed 18.1% to tobacco and 16.6% to poor diet and physical inactivity, not distinguishing the degree to which either was due to chemicals in tobacco or food. Schottenfeld et al. (2013) [10] list tobacco, alcohol, ionizing radiation, solar radiation, infectious agents and obesity as risk factors for cancer, but totally ignore exposures to chemical carcinogens other than those related to occupation. Pruss-Ustun and colleagues from the World Health Organization (2016) [11] attribute 19% of all cancer to environmental factors, which includes 2-8% due to exposure in occupational exposures. Their report does not consider smoking, alcohol, diet or genetic factors. In discussing specific cancers, they attributed colon and rectum cancer to low physical activity, radiation and asbestos, but do not mention other chemical carcinogens in food. Chemical exposure is identified as a risk factor for breast, lymphoma, multiple myeloma, leukemia, larynx, bladder and melanoma cancers. Clapp et al. (2008) [12] note that while overall cancer rates are declining (especially lung among men and colorectal in both sexes), some are rising (esophagus, liver, thyroid, melanoma, non-Hodgkin's, multiple myeloma, testicular, bladder, brain, and lung in women). Childhood cancers (leukemia and brain) are also rising. They and Belpomme et al. (2007) [13] provide strong evidence that exposure to carcinogenic chemicals plays a major role in risk of all these cancers. Christiani (2011) [14] has suggested that 85-95% of cancer arise because of exposure to specific carcinogenic agents.

In addition to exposure to chemical carcinogens, cancer can be caused by genetics, infection and inflammation. Lichtenstein et al. (2000) [15] reported an analysis of mono- and di-zygotic twins in Scandinavia in an effort to distinguish genetic from environmental factors in causation of cancer. They concluded that most cancers were due to environmental factors. Genetic factors were relatively unimportant in most cancers, although were significant in prostate (42%), colorectal (35%) and breast cancer (27%). Wu et al. (2016) [16] examined intrinsic and extrinsic risk factors for cancer and concluded that intrinsic factors contribute only modestly (less than 10-30%) to risk. This is not to imply that individual genetic differences are unimportant, because polymorphisms of drug metabolizing enzymes serve as modulators of cancer susceptibility [17] and chemically-induced epigenetic changes may be of greater importance [18].

These reports indicate that we do not have good understanding of the relative role of exposure to chemical carcinogens in overall cancer incidence beyond general knowledge that many chemicals to which humans are exposed cause cancer. Clearly carcinogenic chemicals are found in both the occupational and non-occupational environment. While the chemical exposure in an occupational setting differs from that of the general population, there are many carcinogens found in food, tobacco, personal care products, and indoor and outdoor air. Many use terms such as "life-style" to encompass such behaviors, without considering that exposure to carcinogenic chemicals occurs from these sources. Workers at this particular facility will, of course, have all of these non-occupational exposures as well as those specific to the workplace.

Sources of Exposure: Our data are from two quite different sources. The information in the SDS implies potential exposure, while information from the TRI and NEI reporting quantifiable emissions is stronger evidence of exposure both at the facility and in the surrounding area. As emphasized by De Vocht et al. (2013) [19], use of ecologic data such as that from the SDS should not be over-interpreted but also should not be ignored. When used in conjunction with reported releases of known carcinogens from the facility this information provides a more comprehensive picture of uses and releases of carcinogens than has previously been reported for any such facility, to our knowledge.

Federal legislation makes SDS central to providing both workers and communities with information about chemical hazards. An employer's responsibility to make SDS available to workers is established in 29 CFR 1900.1200 Hazard Communication, Toxic and Hazardous Substances. A corporation's responsibility to provide state and local emergency coordination committees with SDS in order to detail the hazards of the chemicals they handle is established by the Emergency Response and Community Right-to-Know Act of 1986 and subsequent amendments.

However, there are few comprehensive evaluations of the accuracy of SDS\MSDS. Noteworthy is a literature review by Nicol et al. (2008) [20] which concluded: "Despite the fact that these studies varied in methodology and spanned a period of more than 15 years, a number of common themes emerged regarding inaccuracies, incompleteness, incomprehensibility and overall low use of MSDSs. The results of the literature review suggest that there are serious problems with the use of MSDSs as hazard communication tools."

Another major limitation of the SDS is that there is no consideration of the hazard of multiple chemical exposures. The SDS paradigm is centered on the idea that risk to workers, consumers and communities can accurately be communicated by describing the potential health risks of a single chemical. It is also not uncommon for a manufacturer's SDS\MSDS to fail to list one or more hazardous ingredients [21-23]. The content may also be vague and presented in language not clearly understood by employees and may not present recent information on the chemical under consideration.

All evidence would suggest that industrial workers are exposed to more carcinogenic chemicals than the general population simply because of the chemicals used at the site. What is striking to us is that neither the national or local union leadership at this facility, to say nothing of individual employees, were aware of the extent of potential exposure to carcinogens before being presented with the above results. There is little or no incentive for employers to provide more information on potential exposure to carcinogens beyond what is required by law, which is in practice only to have the information on the SDS available for interested employees. At the local site the union and safety personnel are those that should be pushing for additional health and safety measures. But at this facility, as in many, concerns about maintaining jobs often stifles enthusiasm even by union officials for systematically determining potential exposure to dangerous substances and pushing for greater safety for employees.

While national standards for releases of many individual chemicals in the workplace exist, these consider individual chemicals one at a time without consideration of the numbers of different chemicals to which workers are potentially exposed and the possible interactions resulting. When a person accepts employment at a facility such as this they are basically agreeing to working with potential exposure to chemicals listed in the SDS. However, workers rarely take the effort to inform themselves of chemical hazards and the consequent health effects Leigh JP (2011). For various reasons, national and state government agencies responsible for worker health and safety as well as national and local unions have not made reducing potential exposure to [24] carcinogens a priority.

The goal of this study was to show how a more meaningful right-to-know inventory could be created.

OSHA Hazard Communication Standard (29 CFR 1910.1200) mandates that private-sector employers must provide chemical information to their workers, and many states have their own right-to-know laws that cover public-sector workers. OSHA Hazard Communication Standard has four principal requirements: (1) Employers must maintain a list of all hazardous products known to be in the workplace. (2) Chemical containers must have labels. (3) Material Safety Data Sheets (MSDS) that describe the dangers of a chemical and how to prevent exposure must be provided. (4) Workers must be trained about chemical hazards.

This Study Directly Relates to 3 of These 4 Requirements

Employers Must Maintain a List of All Hazardous Products Known to Be in The Workplace

Union health and safety personnel at this plant could not provide the authors with a list of all hazardous products known to be in the workplace. If they chose, they could print some 10,500 individual SDS sheets, but this isn't equivalent to a list of all known potential chemical exposures nor would it analyze the potential adverse health effects of those chemicals. In a review of our findings a Vice President of the national union wrote:

"Chemical hazards are of great concern to both active members and retirees and while Safety Data Sheets (SDS) explain how to use the chemical they are vastly unable to address possible long-term health effects of exposures.This is the difficulty the union and its locals have in identifying the effects of chemicals workers are exposed to and their specific potential health risks.

We were therefore pleasantly surprised when the Institute provide us with a preliminary analysis of the chemical [25] hazards they documented at an aerospace facility represented by the IAMAW. At the same time, we were also distressed: The Institute clearly documented what we had suspected-that our members are exposed to hundreds of chemicals each with numerous health risks.

The Institute's proposal to create a site-specific hazard communication report that (1) documents all chemicals found at a work site and (2) to list the specific potential illness associated with each chemical along with the relevant scientific sources is something that would be a significant improvement over the long-term data found in most Safety Data Sheets. We believe he information that will come out of these investigations will allow us to significantly improve our efforts to improve worker health and safety. (IAMAW 2015)

Material Safety Data Sheets (MSDS) That Describe the Dangers of a Chemical and How to Prevent Exposure Must Be Provided

The deficiencies of SDS are well documented. One critical concern is their lack of specificity: they will indicate that a substance is considered a carcinogen by an authoritative agency, but not the specific cancers associated with the chemical. Surely this information is of great relevance to a company's employees, but it is not information found in an SDS.

Workers Must Be Trained About Chemical Hazards

By providing a comprehensive list of all chemicals and a detailed description of their effects (as well as the relevant scientific references) can only make the task of worker training about chemical hazards more meaningful, with the additional benefit of making the work of union health and safety personnel more focused.

The principle of right-to-know does not require a discussion of RELs, PELs or TWAs. This is true whether one is considering an employee's right-to-know as covered by the OSHA standard, a community's right-to-know about industrial pollution as mandated by EPA Toxic Release Inventory (TRI), the use and storage of chemical hazards as regulated by the right-to-know provision of the Tier II program or exposure to pesticides mandated under the Restricted Use Products (RUP) Report, Title 42 U.S.C. Section 7412 (which identifies the list of environmental pollutants), or Title

42 U.S.C. Section 7413 (which contains the reporting requirement for environmental pollutants).

In conclusion at this one aerospace facility we documented potential exposure to 78 known human carcinogens from SDS and on-site release of 1,496,235 pounds of carcinogens in and from the facility. In addition, using federal data sources there has been at least a total release of 3,647,900 pounds of carcinogens in the county in which this facility is located between 1987 and 2014. This ambient release increases the possibility of exposure to employees who live there.

If the first step to understanding a problem is accurately defining its nature and extent, the methods and materials used in this analysis can be applied to any workplace. Placing this information in the hands of workers and their representatives provides those at greatest risk from chemical hazards the ability to advance measures to protect their own health by reducing carcinogenic exposures.

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