REAL & PRESENT DANGER

The Underestimated Impact of Carcinogens in the Workplace

By Connie Muncy

WORLDWIDE, WORKPLACE CANCER PREVENTION has a significantly lower profile than workplace injury prevention despite a real and present need to elevate the profile of workplace cancer prevention globally. Many organizations worldwide attest to the high number of annual work-related cancers and cancer deaths, but then say that workplace cancer statistics are underestimated, that the problem is worse than statistics bear out, and that the profile of workplace cancer prevention must be elevated. This apparent consensus begs a few questions. Supported by reputable resources from around the globe, this article explores several questions:

- What is occupational cancer, how prevalent is it and what are its causes?
- Why does cancer prevention have a much lower profile than workplace injury prevention?
- Are current occupational exposure limits (OELs) for carcinogens adequate?
- What are the problems associated with cancer cluster investigations, how reliable are they and what must be done to improve them?
- What must be done to advance the cause of workplace cancer prevention?
- What are some valuable resources available to those who want to help advance the cause of workplace cancer prevention?

KEY TAKEAWAYS

- **Workplace cancer statistics from around the world reflect the seriousness of the global workplace cancer situation and reveal which worker groups are at greatest risk.**
- **This article discusses why workplace cancer prevention has a lower profile than workplace injury and what actions must be taken to elevate the profile of workplace cancer prevention.**
- **It also discusses important factors that influence workplace cancer cluster investigations.**

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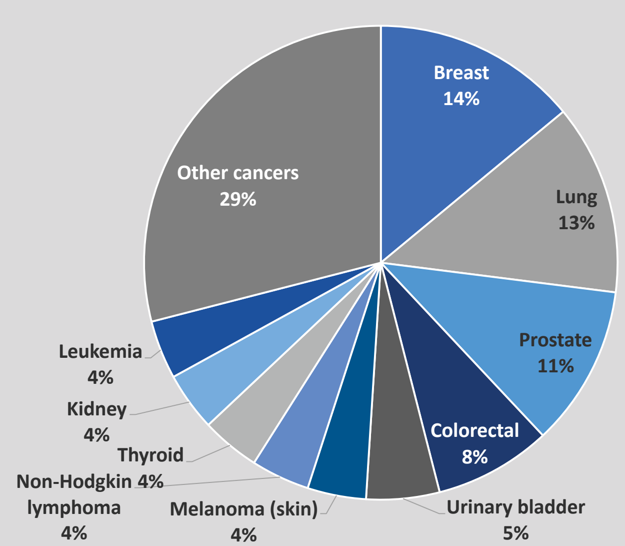
What Is Cancer & How Prevalent Is It?

According to the U.S. Department of Health and Human Services' 14th Report on Carcinogens, cancer affects almost everyone's life, either directly or indirectly; approximately one out of two men and one out of three women living in the U.S. will develop cancer at some point in his/her lifetime (NTP, 2016). According to American Cancer Society (ACS, 2017a), cancer is the second most common cause of death in the U.S. and accounts for nearly one of every four deaths. World Health Organization (WHO, 2017) estimates that worldwide in 2012 (the most recent data), 14 million new cancer cases and 8.2 million cancer-related deaths occurred, and that the number of new cancer cases is expected to rise by about 70% over the next 20 years.

FIGURE 1
MOST COMMON CANCERS IN THE U.S.



Note. Adapted from Report on Carcinogens, 14th Edition, by National Toxicology Program, 2016.

TABLE 1

PROPORTION OF THE WORKFORCE EXPOSED TO CARCINOGENS

Carcinogen	Agriculture	Mining	Manufacturing	Electrical	Construction	Trade	Transportation	Finance	Services
Lung carcinogens									
Silica	0.004	0.230	0.023	0.014	0.189	0.000	0.00476	0.000	0.001
Cadmium	0.000	0.000	0.005	0.003	0.003	0.000	0.00065	0.000	0.000
Nickel	0.000	0.020	0.017	0.004	0.000	0.000	0.00003	0.000	0.000
Arsenic	0.001	0.001	0.004	0.001	0.001	0.000	0.00000	0.000	0.000
Chromium	0.000	0.003	0.021	0.004	0.002	0.000	0.00370	0.000	0.002
Diesel fumes	0.006	0.220	0.011	0.034	0.058	0.005	0.13438	0.000	0.009
Beryllium	0.000	0.001	0.002	0.001	0.000	0.000	0.00011	0.000	0.000
Asbestos	0.012	0.102	0.006	0.017	0.052	0.003	0.00684	0.000	0.003
Leukaemogens									
Benzene	0.001	0.002	0.003	0.001	0.001	0.01	0.00500	0	0.02
Ionizing radiation	0	0.011	0	0.034	0	0	0.00400	0	0.0
Ethylene oxide	0.00012	0.00137	0.0006	0.00006	0.00027	0	0.00002	0	0.00057

Note. Proportion of the workforce exposed to carcinogens, by industry sector. Adapted from Occupational Carcinogens: Assessing the Environmental Burden of Disease at National and Local Levels, Table 4, by T. Driscoll, K. Steenland, A. Prüss-Üstün, et al, 2004, Geneva, Switzerland: World Health Organization.

ACS (2017b) defines cancer as "a group of diseases which cause cells in the body to change and grow out of control." This class of diseases is comprised of more than 200 different types of cancer; each is classified by the type of cell that is initially affected. Figure 1 (p. 41) depicts the 10 most common cancers in the U.S. and their prevalence.

Canada's Occupational Cancer Research Center provides similar pie charts that illustrate the distribution of workplace cancers by type for manufacturing, construction and government services industry in Ontario:

•Manufacturing: mesothelioma, 44%; lung cancer, 42%; cancer of the large intestine, 3%; esophageal cancer, 2%; leukemia, 1%; bladder cancer, 1%; other cancers, 7%.

•Construction: mesothelioma, 61%; lung cancer, 30%; esophageal cancer, 2%; cancer of the large intestine, 2%; leukemia, 1%; other cancers, 4%.

•Government services industry: cancer of the large intestine, 19%; mesothelioma, 18%; lung cancer, 11%; brain cancer, 11%; esophageal cancer, 9%; kidney(s) cancer, 8%; leukemia, 6%; bladder cancer, 5%; lymphoma, 4%; other cancers, 9% (Del Bianco & Demers, 2013).

Medical News Today (MNT, 2016) clarifies the damaging nature of cancer:

> Cancer is ultimately the result of cells that uncontrollably grow and do not die. Normal cells in the body follow an orderly path of growth, division and death. Programmed cell death is called apoptosis, and when this process breaks down, cancer begins to form. Unlike regular cells, cancer cells do not experience programmatic death and instead continue to grow and divide. This leads to a mass of abnormal cells that grows out of control.
>
> Cancer harms the body when altered cells divide uncontrollably to form lumps or masses of tissue called tumors (except in the case of leukemia where cancer prohibits normal blood function by abnormal cell division in the blood stream). Tumors can grow and interfere with the digestive, nervous and circulatory systems, and they can release hormones that alter body function.
>
> More dangerous, or malignant, tumors form when two things occur:
>
> 1) a cancerous cell manages to move throughout the body using the blood or lymphatic systems, destroying healthy tissue in a process called invasion;
>
> 2) that cell manages to divide and grow, making new blood vessels to feed itself in a process called angiogenesis.

So, what causes cells to uncontrollably grow and become cancerous? According to MNT (2016), cells can experience uncontrolled growth if mutations to DNA exist. Cancer occurs when a cell's gene mutations make the cell unable to correct DNA damage and unable to "commit suicide." Some causes of cancer include:

•Being born with certain genetic mutations.

•An increase in the number of possible cancer-causing mutations in our DNA that occurs with age (i.e., age is an important risk factor for cancer).

•Eight viruses, known as oncoviruses (e.g., Epstein-Barr virus, Hepatitis B and C, HIV, Kaposi sarcoma-associated herpesvirus) (AIHA, 2016; NTP, 2016).

•Certain bacteria (e.g., h pylori) and funguses (e.g., aflatoxins) (NTP, 2016).

•Carcinogens, a class of substances that are directly responsible for damaging DNA, promoting or aiding cancer. When a body is exposed to carcinogens, free radicals are formed that try to steal electrons from other molecules in the body. These free radicals damage cells and affect their ability to function normally.

•Ionizing radiation (e.g., gamma rays, X-rays).

•Ultraviolet radiation (A, B, C).

•Tobacco (smoke, smoking, smokeless).

•Alcoholic beverage consumption increases cancer risk in multiple ways:

a) metabolizing ethanol in alcoholic drinks to acetaldehyde, which is a toxic chemical and a probable human carcinogen; acetaldehyde can damage both DNA and proteins;

b) generating reactive oxygen species (chemically reactive molecules that contain oxygen), which can damage DNA, proteins and lipids (fats) through oxidation;

c) impairing the body's ability to break down and absorb various nutrients that may be associated with cancer risk, including vitamin A, nutrients in the vitamin B complex, vitamins C, D, E and carotenoids;

d) increasing blood levels of estrogen, a hormone linked to the risk of breast cancer;

e) alcoholic beverages may also contain various carcinogenic contaminants that are introduced during fermentation and production, such as nitrosamines, asbestos fibers, phenols and hydrocarbons (NCI, 2013).

•Shift work. In 2007, International Agency for Research on Cancer (IARC) concluded that shift work is "probably carcino-

TABLE 2
OCCUPATIONAL CAUSES OF CANCER

Cancer	Examples of principal carcinogenic occupational exposures
Lung cancer	Asbestos; silica; nickel; indoor radon; diesel fumes; environmental tobacco smoke at the workplace; production and refining of: arsenic, beryllium, cadmium, aluminum and chromium; mining of uranium; copper smelting; iron and steel founding; vineyard workers; roofers; asphalt workers; painters; welders
Bladder cancer	Diesel fumes; 2-naphtylamine; benzidine; 4-aminobipheyl; manufacturing of: magenta, auramine, p-chloro-o-toluidine, pigment chromate, and dyes; synthetic latex production; tire curing; calendar operatives; reclaim; cable makers; gas-retort workers; painters
Mesothelioma	Asbestos
Leukemia	External ionizing radiation; benzene; ethylene oxide; rubber industry; boot and shoe manufacturing and repair
Laryngeal cancer	Sulfuric acid; mineral oils and asbestos; pickling operations
Skin cancer	Intensive solar radiation; coal-tar pitches; coal tar; shale oils; arsenic; mineral oils; polycyclic-aromatic hydrocarbons; production of coke; vineyard workers; fishermen
Sinonasal and nasopharyngeal cancer	Wood dust; nickel compounds; hexavalent chromium; boot and shoe manufacturing and repair; manufacturing of isopropanol using strong acid process; furniture and cabinet making; carpenters; formaldehyde
Kidney cancer	Coke production
Liver cancer	Vinyl chloride; occupational infections with hepatitis B and C; healthcare workers

Note. Adapted from Cancer: What Causes It? by Victoria Trades Hall Council Australia, 2015.

genic to humans" (Straif, Baan, Grosse, et al., 2007). The evidence is strongest for breast cancer, although the risk of prostate and colorectal cancer may also be increased by shift work. Recently, 38 women with breast cancer who had previously worked night shifts for at least 20 years were compensated by the Danish National Board of Industrial Injuries (Moukangoe, Jansen van Rensburg, 2015). Possible mechanisms by which shift work increases the risk of cancer under study include:

a) Light at night suppresses the production of melatonin, which has direct and indirect anticancer effects.

b) Sleep disruption stimulates the hypothalamic-pituitary axis to release glucocorticoids, which results in depression of immune function.

c) Phase shift, in which the peripheral rhythms of functions such as digestion are out of phase with central sleep and wake rhythms. This may result in changes in the control of cell and tissue proliferation.

d) Shift work may result in changes in lifestyle factors such as smoking, diet, alcohol use or exercise.

e) Decreased production of vitamin D.

•Anything else that suppresses or weakens the immune system (i.e., inhibits the body's ability to fight infections and increases the chance of developing cancer).

Principal Carcinogenic Occupational Exposures

Occupational cancer is caused wholly or partly by exposure to a cancer-causing agent (carcinogen) at work, or by a particular set of circumstances at work (IOSH, 2017a). These agents may be chemical, biological or physical in nature.

Many factors play a role in the development of cancer. The importance of these factors varies depending on the type of cancer. A person's risk of developing a particular cancer is influenced by a combination of factors that interact in ways that are not fully understood. Some of the factors include:

•personal characteristics, such as age, sex, and race;
•family history of cancer;
•an individual's susceptibility to a substance;
•diet and personal habits, such as cigarette smoking and alcohol consumption;
•the presence of certain medical conditions or past medical treatments, including chemotherapy, radiation treatment or some immune-system suppressing drugs;
•exposure to cancer-causing agents in the environment (e.g., sunlight, radon gas, air pollution, infectious agents);
•the amount and duration of an exposure to cancer-causing agents in the workplace (NIOSH, 2015).

Although everyday exposures to chemicals are usually too low to cause harmful health problems, exposure in the workplace can be more serious. Chemical exposures in the workplace can happen at high levels and over long periods. That is why some jobs require that employees wear protective clothing, equipment or respirators. Companies are supposed to notify employees of a potential danger to their health (ASTDR, 2017).

OELs for carcinogens have been established by various agencies including OSHA, NIOSH and ACGIH; however, one problem with setting OELs for carcinogens, unlike other hazardous chemicals that have an identified "virtually safe dose," is that there is not always a threshold below which there is no adverse health effect. For example, carcinogens always cause a risk no matter how low the dose is. Thus, exposure to workplace carcinogens below an established OEL is no guarantee that cancer will not result.

Various agencies around the world publish lists of occupational carcinogens. For example, NIOSH (2018a) has published a list of substances considered to be potential occupational carcinogens and IARC lists more than 50 substances that are known or probable causes of workplace cancer, and more than 100 other possible substances (IOSH, 2017a).

WHO (Driscoll, Steenland, Prüss-Üstün, et al., 2004) published data indicating the proportion of the workforce exposed to carcinogens by industry sector (Table 1).

Victoria Trades Hall Council Australia (VTHCA, 2015a) compiled a list of examples of principal carcinogenic occupational exposures together with associated conditions (Table 2).

Canadian Center of Occupational Health and Safety (CCOHS, 2018b) reports the most common types of occupational cancer are lung cancer, bladder cancer and mesothelioma. The group has published an extensive list of examples of occupations and occupational groups that are more likely to have been exposed to carcinogens (CCOHS, 2018c), excerpted in Table 3 (p. 44).

Great Britain reports that almost half (48%) of occupational cancer deaths are in construction workers with the main carcinogens associated with those industries being asbestos, respirable crystalline silica, solar radiation (sun exposure) and diesel exhaust emissions (IOSH, 2018b).

TABLE 3

SOME OCCUPATIONS OR OCCUPATIONAL GROUPS ASSOCIATED WITH CARCINOGEN EXPOSURE

Occupations and occupational groups	Suspect substance
Aircraft and aerospace industries	Asbestos, beryllium and beryllium compounds; ionizing radiation
Boot and shoe manufacture/repair	Leather dust, benzene and other solvents
Ceramic production	Cobalt and cobalt compounds
Construction; insulation and maintenance workers	Asbestos; glass wool; silica (crystalline); toluene diisocyanates
Dry cleaning	Carbon tetrachloride; tetrachloroethylene; trichloroethylene
Hairdressers and barbers	Aerosols, dyes (aromatic amines, amino-phenols with hydrogen peroxide); propellants; solvents
Nickel refining and smelting; welding	Nickel and nickel compounds; welding fumes
Outdoor workers	Solar radiation
Plastics industries	Acetaldehyde; acetamide; acrylonitrile; ethyl acrylate; isoprene; special purpose glass fibers (respirable); styrene; vinyl acetate
Textile manufacturing/industries	Acrylonitrile; textile dust in manufacturing process; dyes and solvents in dyeing and printing operations; formaldehyde
Water and wastewater treatment	Acrylamide; chromium (VI) compounds

Note. Adapted from OSH Answers Fact Sheets: Occupations or Occupational Groups Associated With Carcinogen Exposures, by CCOHS, 2018.

Global Occupational Cancer Statistics

There is no disputing that statistics from around the world bear out the fact that occupational cancer is a prevalent and serious problem and, more importantly, that the total numbers are significantly underestimated.

NIOSH (2015) asserts that 3% to 6% of all cancers worldwide are caused by exposures to carcinogens in the workplace with estimated annual medical costs associated with occupational cancers to be $4.3 billion in the U.S. alone. Using cancer incidence numbers in the U.S., this means that in 2012 (the most recent year available), there may have been as many as 91,745 new cancer cases that were caused by past exposure in the workplace. NIOSH (2015) says "this is probably an underestimate."

Takala (2015) cites a 2009 study that found the proportion of cancer deaths attributable to occupational causes in Finland was 8.3% (13.2% among males) and in the U.K. it was 5.3% (8% among males).

In Australia, the scientific consensus is that on average, 8% of cancer deaths are work-related. For some cancers, such as bladder and lung cancer, the figure is well above 10% (VTHCA, 2015b). In fact, Fritschi and Driscoll (2006) found that one in 10 male workers and one in 50 female workers developed cancer every year due to workplace exposure to carcinogens.

International Labor Organization (ILO) estimates the human toll at over 600,000 deaths a year, one death every 52 seconds. ILO calculates that approximately 13% of all cancers in developed countries are the result of preventable, predictable workplace exposure (VTHCA, 2015a).

In a striking 2013 report, Occupational Cancer Research Center found that occupational cancer has become the leading cause of compensated work-related deaths in Canada, a phenomenon that appears to be the most notable in Ontario, where occupational cancer deaths surpass those for traumatic injury two to one (Nelson, 2013).

According to Takala (2015):

> Previous global estimates on occupational cancers by the ILO established that 32% of the deaths in the world related to work are associated with cancers. However, occupational cancers are quite rapidly globalized and in many industrializing countries, the percentage of occupational cancer deaths among all work-related deaths approaches that of the high-income countries; e.g. in the European Union occupational cancer deaths is already at 53% of all work-related deaths.

This phenomenon is further supported by Hämäläinen, Takala and Saarela (2007) who identify the top workplace killers as: 1) cancers (32%); 2) circulatory disease (26%); and 3) work incidents (17%). The authors conclude that occupational cancer "represents over half" of all occupational disease cases in established market economies.

Work-Related Cancer Cases Often Underestimated

Many sources openly acknowledge that occupational cancer statistics are, in reality, underestimated. To illustrate, in the U.S., Bureau of Labor Statistics workplace fatality data are obtained by cross-referencing source documents such as death certificates, workers' compensation records, and reports to federal and state agencies. This method ensures that counts are as complete as possible, but BLS acknowledges that long-term latent illnesses caused by exposure to carcinogens are often difficult to relate to the workplace and are not adequately recognized and reported (BLS, 1994).

Likewise, according to the U.K.'s Trades Union Congress, it is nearly always impossible to link a specific instance of cancer with a specific exposure to a cancer-causing substance (TUC, 2012). When a fatality occurs in the workplace it is visible, but most people who are killed by cancer will die either at home or in a hospital. Furthermore, many cancers develop decades after the initial exposure and often the person has retired from work before developing signs of cancer.

According to Takala (2015):

> There is an urgent need to harmonize the estimation methods by various bodies and to resolve these issues. However, experience shows that the more we'll study occupational carcinogens, mutagens and reprotoxic substances, the higher will be the estimates of negative outcomes. Further research cannot be an excuse for doing nothing, with today's solutions, most or all of such deaths and lost life years can be eliminated.

The Notable Lack of Action

While smoking cessation has become a major public health priority and has spurred an entire prevention industry, no similar campaign has been waged to address carcinogens encountered and inhaled by millions at work. A staggering number of factors appear to be to blame for the lack of action in preventing workplace cancers. Following is a sample of postulated factors.

- It has been postulated that because exposures cause cancers at least 2 decades later, the problem does not cause concern for corporate executives who answer to shareholders from one annual meeting to the next (Workers' Health International News, 2007).
- Nearly 100,000 chemicals are used in workplaces worldwide, yet only 1 in 100 has been thoroughly tested for health risks (Workers' Health International News, 2007).

•Tens of thousands of workers die before a workplace cancer problem is identified by scientific study.

> It can take a generation of exposures and a generation of deaths for traditional studies to spot an occupational cancer risk, unless the cancer is very rare in the general population. With the exception of the asbestos cancer mesothelioma, however, the most common occupational cancers are also common in the wider community. (Workers' Health International News, 2007)

•A misconception exists that better regulation has led to a fast decline of occupational cancer. However, this is not the case.

> Unlike the case of infectious diseases, where a response is frequently swift and draconian, there are typically long delays between the identification of a carcinogenic agent and adoption of adequate measures of prevention. Even then, measures are usually late and incomplete, and will leave a generation to await their fate as a result of prior exposures. (Workers' Health International News, 2007)

•Stirling University's Jim Brophy (as cited by Workers' Health International News, 2007) says, "The reaction of manufacturers that produce or employ products that might be deemed to be carcinogenic has at times been to suppress the damning research rather than to take steps to prevent harm to the exposed populations."

•Former head of the IARC program Lorenzo Tomatis (as cited by Workers' Health International News, 2007), says that industry is dictating terms.

> The prevailing assumption, also used as an improper justification, was that the production of certain goods is necessary and vital, even when it was only aimed at increasing consumption of inessential goods, and that the risks involved in their production are an unavoidable price that society must pay.

•Workers' Health International News (2007) says:

> This unequal risk of occupational cancer means a minority of the population are facing an enormously elevated, serious and preventable risk. That risk is not being taken seriously and those cancer cases are not, on the whole, being prevented. Work-related cancer is far more common in blue-collar workers—there is an undeniable correlation between employment in lower status jobs and an increased risk. (Infante, 1995)

Citing the carcinogenic exposure data for Great Britain, the group says that all workplace carcinogen exposures were restricted to one-fifth of the working population.

•The effective identification of workplace cancer risks has slowed. There is good reason to believe this is the result of a well-coordinated industry campaign to influence decisions of bodies including IARC and WHO, rather than any actual improvements at work.

> And as public funding for independent occupational health research is eroded, industry-funded research is swamping the literature, with occupational and environmental risks going underestimated or undetected as a result. A report in the October-December 2005 issue of the *International Journal of Occupational and Environmental Health* (Gennara & Tomatis, 2005), examining "business bias" in workplace studies, concludes, "in spite of claiming primary prevention as their aim, studies of potential occupational and environmental health hazards that are funded either directly or indirectly by industry are likely to have negative results." (Workers' Health International News, 2007)

It is noteworthy that some degree of bias is nearly always present in any published study, regardless of who funds it (Pannucci & Wilkins, 2010).

The Inadequacy of Current OELs for Carcinogens

One problem with setting OELs for carcinogens is that there is not always a threshold below which there is no adverse health effect. Carcinogens always cause a risk no matter how low the dose. So, setting OELs is not as straightforward a matter as one might think; because the cost of avoidance or treatment increases as the risk is reduced, society must accept some level of risk (Dartmouth College, 2017). This is where the process of risk management comes in to play.

Risk management is the process of selecting the most appropriate guidance or regulatory actions by integrating the results of risk assessment with engineering data and with social, economic and political concerns to reach a decision (Niemi, 2017). But the OELs reached through the risk management process are not always deemed acceptable by many, and even those organizations setting the OELs reflect this sentiment, as illustrated in the following cases discussing the setting of OELs for carcinogens by American Congress of Governmental Industrial Hygienists (ACGIH), NIOSH and OSHA.

Valente and Cavariani (2015) speak to the adequacy of current OELs for carcinogens:

> At the present there is no consensus on the levels of exposure to carcinogenic agents which can be considered "acceptable." Different countries and international agencies have proposed or have adopted different limits, on the basis of different criteria, for those exposed in the occupational setting and for the general population.

They mathematically illustrate the magnitude of additional risk to which occupationally exposed groups could undergo on the basis of the current TLVs for several carcinogenic substances. "The results show that the additional risk for the occupationally exposed groups at the current ACGIH TLVs-TWA is always higher than the risk considered "acceptable" for the general population (set by USA-EPA, at 1/100,000)" (Valente & Cavariani, 2015). The researchers conclude that despite the uncertainties in risk assessment, the excess cancer risk to workers estimated by the study shows that current prevention policies are ethically inequitable and require further study and novel solutions.

According to Mazzucco (2013):

> NIOSH uses a lifetime cancer risk increase of 1 in 1,000 as the acceptable regulatory threshold, while stating that "controlling exposure to lower concentrations is always warranted." NIOSH admits that "an excess risk of 1 in 1,000 is one or more orders of magnitude higher than what the U.S. permits for the general public." NIOSH justifies this questionable threshold with two arguments: The first is the historic "benzene decision" made by the U.S. Supreme Court in 1980, where a 1 in 1,000 risk was used in a seemingly rhetorical example. The second justification is that workers are a very small subset of the general population, and higher exposures for small numbers of people may be considered acceptable if they are comparable to the overall risks of employment itself.

Representing the Cancer Prevention and Treatment Fund of the National Center for Health Research, Mazzucco says the group disagrees "with these nonscientific justifications," and makes the following observations:

There is increasing evidence that occupational carcinogens spread into the greater environment. For example, trichloroethylene (TCE), an industrial solvent, is now present in approximately one-third of the U.S. water supply. The maximum risk threshold acceptable to the EPA is 10-fold less than the NIOSH threshold—and given the overlapping exposures, that does not make sense. The EPA considers 1 in 1,000,000 to be the target threshold for as many people as possible, but that is 1000 times lower than the NIOSH threshold. The bottom line is that there is no scientific basis for these differential safety standards, and we now know that occupational and environmental exposures frequently become indistinguishable. For that reason, the workforce should be afforded the same level of protection as the general public. (Mazzucco, 2013)

Perhaps recognizing this concern, on Dec. 27, 2016, NIOSH (2017b) published its Current Intelligence Bulletin 68: NIOSH Chemical Carcinogen Policy. About the policy, NIOSH (2018b) says:

Underlying this policy is the recognition that there is no safe level of exposure to a carcinogen, and therefore that reduction of worker exposure to chemical carcinogens as much as possible through elimination or substitution and engineering controls is the primary way to prevent occupational cancer. Accordingly, this policy no longer uses the term *recommended exposure limit (REL)* for chemical carcinogens; rather NIOSH will only recommend an initial starting point for control called the risk management limit for carcinogens (RML-CA). For each chemical identified as a carcinogen, this level corresponds to the 95% lower confidence limit of the risk estimate of one excess cancer case in 10,000 workers in a 45-year working lifetime. Keeping exposures within the risk level of 1 in 10,000 is the minimum level of protection and striving for lower levels of exposure is recommended. When measurement of the occupational carcinogen at the RML-CA is not analytically feasible at the 1 in 10,000 risk estimate, NIOSH will set the RML-CA at the limit of quantification of the analytical method. In addition, NIOSH will continue to evaluate available information on existing engineering controls and also make that information available when publishing the RML-CA.

Consider also OSHA's permissible exposure limit (PEL) for the carcinogen asbestos. Brayton Purcell (2018) opines:

Asbestos is extremely hazardous. According to NIOSH, "all levels of asbestos exposure studied to date have demonstrated asbestos-related disease" and "there is no level of [asbestos] exposure below which clinical effects do not occur. Therefore, all avoidable exposures to asbestos should be prevented whenever possible.

OSHA has set a PEL of 0.1 fiber per cubic centimeter (f/cc) for work in all industries, including construction, shipyards and asbestos abatement work. . . . OSHA is quick to add, however, that the asbestos PEL is a target guideline for regulatory purposes only, and does not establish any level of "safe" asbestos exposure. As OSHA writes in its asbestos final rule, "The 0.1 f/cc level leaves a remaining significant risk."

Closer examination of the asbestos rule raises some significant questions on the adequacy of the asbestos PEL. Following is an excerpt from the rule:

At the time of the proposal in 1990, the question of whether the proposed PEL reduction would reduce a still significant risk had already been given a tentative answer by the Court. The DC Circuit Court of Appeals, in remanding the issue of lowering the PEL to the agency, noted that based on the 1984 risk assessment, the excess risk stemming from average exposures of 0.1 f/cc "could well be found significant" (*BCTD v. Brock, 838 F.2nd* at 1266; 55 *FR* at 29714).

In the proposal, OSHA stated that it believes "that compliance with proposed amendments to reduce the PEL to 0.1 f/cc as a time-weighted average measured over 8 hours would further reduce a significant health risk which exists after imposing a 0.2 f/cc PEL" (55 *FR* 29714, July 20, 1990). OSHA's 1984 risk assessment showed that lowering the TWA PEL from 2 f/cc to 0.2 f/cc reduced the asbestos cancer mortality risk from lifetime exposure from 64 to 6.7 deaths per 1,000 workers. OSHA estimated that the incidence of asbestosis would be 5 cases per 1,000 workers exposed for a working lifetime under the TWA PEL of 0.2 f/cc. Counterpart risk figures for 20 years of exposure are excess cancer risks of 4.5 per 1,000 workers and an estimated asbestosis incidence of 2 cases per 1,000 workers.

OSHA's risk assessment also showed that reducing exposure to 0.1 f/cc would further reduce, but not eliminate, significant risk. The excess cancer risk at that level would be reduced to a lifetime risk of 3.4 per 1,000 workers and a 20-year exposure risk of 2.3 per 1,000 workers. Consequently, significant risk would be reduced substantially. However, OSHA concluded, therefore, that continued exposure to asbestos at the TWA permitted level and action level would still present residual risks to employees, which are significant. (OSHA, 1994)

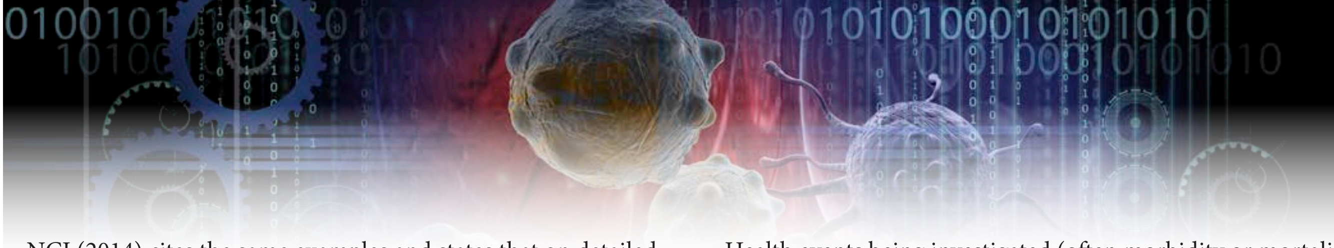
The likely inadequacy of present-day OELs begs the question of whether this might lead to the presence of various cancer clusters in industry.

Workplace Cancer Clusters

National Cancer Institute (NCI, 2014) defines *cancer cluster* as "the occurrence of a greater than expected number of cancer cases among a group of people in a defined geographic area over a specific time period." A workplace cancer cluster may be suspected when several coworkers are diagnosed with the same or related types of cancer.

According to Connecticut Department of Health (CTDPH, 2012), the study of cancer clusters has sometimes led to advances in epidemiology:

One of the first cancer cluster reports involved an epidemic of scrotal skin cancer among 18th century London chimney sweeps with high exposures to [polycyclic aromatic hydrocarbons] chemicals in chimney soot (Aldrich & Sinks 2002). More recent cancer cluster studies also have been successful in explaining higher cancer rates for certain occupations such as mesothelioma among asbestos workers and hepatic angiosarcoma (a rare liver cancer) among workers exposed to vinyl chloride during PVC plastics manufacturing (Benowitz 2008). . . . While there are indeed some examples of cancer cluster studies that have identified a common cause and have advanced scientific knowledge, the vast majority have not.



NCI (2014) cites the same examples and states that on detailed investigation, most suspected cancer clusters turn out not to be true clusters. "That is, no cause can be identified, and the clustering of cases turns out to be a random occurrence." This leads to the question of the effectiveness of the cancer cluster vetting process itself.

NCI (2014) explains how this process typically begins:

> Concerned individuals can contact their local or state health department to report a suspected cancer cluster or to find out if one is being investigated. Health departments provide the first response to questions about cancer clusters because they, together with state cancer registries, will have the most up-to-date data on cancer incidence in the area. If additional resources are needed to investigate a suspected cancer cluster, the state health department may request assistance from federal agencies, including the Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR), which is part of the CDC. . . . Health departments use established criteria to investigate reports of cancer clusters.

According to CTDPH (2012):

> Further investigation should only be considered [by health departments] when a cancer cluster report involves: 1) cancers of the same type (particularly if they are rare cancers); 2) cancers in numbers likely to reach statistical significance; 3) cancers diagnosed within a short time period; and 4) the presence of a possible common environmental exposure.

About occupational cancer clusters, NIOSH (2014) says:

> Because cancer is a common disease, cancer can be found among people at any workplace. In the U.S., over their lifetime, approximately one in two men and one in three women will develop or die from cancer (ACS, 2012). These statistics show the unfortunate reality that cancer occurs more often than many people realize.
>
> Cancer clusters related to a workplace exposure usually consist of the same types of cancer. When several cases of the same type of cancer occur and that type is not common in the general population, it is more likely that an occupational exposure is involved. When the cluster consists of multiple types of cancer, without one type predominating, an occupational cause of the cluster is less likely. When cancer in a workplace is described, learning whether the type of cancer is a primary cancer or a metastasis (spread of the primary cancer into other organs) is important. Only primary cancers are used to investigate a cancer cluster.

NIOSH also notes that exploring whether cancer cases are occurring among those working in certain jobs or workplace areas can help identify possible unrecognized exposures.

> The time between first exposure to a cancer-causing agent and clinical recognition of the disease is called the latency period. Latency periods vary by cancer type, but for some cancers may be 15 to 20 years or longer. Because of this, past exposures are more relevant than current exposures as potential causes of cancers occurring in workers today. Often, these exposures are hard to document.

Many other problems are encountered in the study of clusters, based on their diverse and complex nature (CDC, 1990; CTDPH, 2012):

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•Health events being investigated (often morbidity or mortality) are usually rare; increases of these events tend to be small and may occur over a long period.

•Some clusters occur by chance, much in the same way that five consecutive tosses of a coin, repeated several times, will eventually result in five tosses that come up all heads.

•Information on the at-risk population or on the expected rates often is not available.

•For methods using aggregated data, health events occur in space and time continua, thus yielding optimal and suboptimal units for displaying a pattern. The choice of a geographic area that is too small or too large, or of a period that is too short or too long, may result in insufficient statistical power to indicate a cluster.

•Most cancer clusters reported to public health agencies by citizens consist of many different cancers, with different etiologies that are unlikely to have a common cause.

•Our natural tendency is to notice cases first, then define a cluster boundary around the known cases, creating a potentially artificial cluster.

•Cancer has a long latency period. Unlike infections or acute toxic reactions, the effect of a carcinogen in a community typically will not be seen for many years.

•Cancer patients who appear to be clustered geographically may not have lived in the area long enough for their cancers to have a common cause.

•The development of cancer is a highly complex process. To produce a cancer cluster, a carcinogen must affect a huge number of cells in a huge number of people, over a long period. Even when people have received a heavy dose of a carcinogen and many cells have been damaged, not all will get cancer.

•Because of the diverse and complicated nature of clusters, there is no omnibus test for assessing them. Investigators must perform several related tests and report the results that are most consistent with validated assumptions.

In contemplating the many hurdles in evaluating potential occupational cancer clusters, one might naturally wonder how effective any evaluation can be. There is more work to be done in the evaluation of cancer clusters.

What Should Be Done

In addition to improving cancer cluster evaluation processes, additional action is urgently needed. Takala (2015) succinctly sums up the reasons that action must be taken:

> There is a need for clear priorities to prevent major work-related health risks and to identify solutions for action. Obviously, cancer at work is the biggest individual threat when looking at the number of deaths in the developed world and this serious and preventable disease is rapidly becoming the biggest killer at places of work in most countries in the world. We can and should have a more ambitious target: to eliminate occupational cancer.

To this end, following is a sample of actions recommended by various individuals and organizations to battle the occurrence of occupational cancers. These recommendations are targeted at physicians, researchers, epidemiologists, employers, governments, unions and individuals. It is hoped that each of these groups will take up the mantle and pursue many of these recommendations in the short term to stem the tide of human suffering and loss of life, as well as the impact and cost these occupational cancer cases and deaths have on society.

•Takala (2015) says:

> It is clear that cancers caused by work can be prevented by reducing or eliminating the exposures leading to the disease. In fact these cancers are the easiest ones to tackle, "such risks can be usually reduced or even eliminated" (Doll & Peto, 1981), and ethically the right way to go ahead.

Takala urges that we avoid exporting risks from developed countries to developing ones, and recommends taking the following actions:

> 1) Present unified scientific evidence of the magnitude of the problems, levels of exposures, number of workers exposed, and produce credible data on predicted negative outcomes.
>
> 2) Provide recommendations on evidence-based solutions that are adaptable to different kinds of circumstances, cultures, countries, sectors and sizes of workplaces.
>
> 3) Share findings via well-prepared reports and articles published in high-impact journals.
>
> 4) Mobilize institutions globally to act on elimination of work-related cancer and expand this action gradually through ILO and its Occupational Safety and Health Flagship program, and through WHO and its "collaboration centers" network, supporting IARC efforts in this field, and mobilizing global action through the national stakeholders. (Takala, 2015)

•A report by Canada's National Committee on Environmental and Occupational Exposures (2005, as cited by Workers' Health International News, 2007) identified seven priority areas for improving primary prevention of occupational cancers:

1) improved surveillance;
2) better information disclosure and labeling;
3) community education and action;
4) worker education and action;
5) nongovernmental organizations' involvement in cancer prevention;
6) employer/industry reductions in carcinogen use;
7) government intervention in the form of new regulations and policy.

•Researchers from Toronto's Occupational Cancer Research Center (as cited by Nelson, 2013) stress that:

> Physicians can play a key role in identifying individual cases and assisting their patients with compensation by being aware of their patients' hazardous exposures and being vigilant for early signs of work-related disease. By adopting a model in which physicians are more involved with the active surveillance of occupational cancers, and in which the current and projected burden of occupational cancer has been more systematically assessed, [countries] can be in a position where efforts are aimed at eliminating or minimizing occupational exposures and preventing these cancers from occurring.

•VTHCA (2015b) stresses that media involvement is needed. Popular media often cover cancer from the perspective of the individual and the challenges to the medical profession, and as it relates to poor dietary or lifestyle choices. But they typically do not cover cancer from an OSH perspective.

> Yet occupational cancer tops the ILO workplace diseases and accidents table with [more than] 600,000 dying of occupational cancers every year. More than 1 in 5 workers face a cancer risk from their work. Between 8% and 16% of all cancers result from occupational exposures. (VTHCA, 2015b)

•European Agency for Safety and Health at Work (EU-OSHA, 2014) opines that efforts are required at all levels:

a) improved application of legislation (especially concerning process-generated factors and nonchemical factors);
b) awareness-raising strategies to improve the risk perception of all stakeholders;
c) specifications of comprehensive preventive measures for all work processes that involve such risk factors;
d) improved implementation and enforcement;
e) lowering barriers to compensation.

•Canadian Strategy for Cancer Control is in favor of "primary prevention" of occupational cancer, calling for changes in Canadian law to better promote preventive measures. It called for strengthening the Canadian Environmental Protection Act as it is applied "in particular to IARC 1 and 2a designed human carcinogens." It also called for:

a) information bulletins addressing cancer prevention and toxic use exposure reduction;
b) investigation of the possibilities for introducing toxics use reduction legislation;
c) possible incentives for toxic use reduction programs (Workers' Health International News, 2007).

Many resources are available for those who want to get involved to help solve the workplace carcinogen exposure problem. Following is a brief sample of available materials.

•International Metalworkers' Foundation's "Occupational Cancer/Zero Cancer: A Union Guide to Prevention" (IMF, 2007).

•A publication developed by a group of U.K. organizations, "Cancer and Working: Guidelines for Employers, HR and Line Managers." The publication includes a template policy and provides practical advice for workplaces (CIPD, 2007).

•The Health and Safety Department of European Trade Union Institute (ETUI, 2017) provides infographics and campaign resources.

•Unifor (2018), a large Canadian manufacturing union, offers several resources for initiating its Prevent Cancer Campaign, including a cancer campaign book and a personal hazard exposure log.

•CCOHS (2018a) free e-course, "Occupational and Environmental Cancer: Recognition and Prevention."

•Table 3 of the EU-OSHA (2014) publication "Exposure to Carcinogens and Work-Related Cancer: A Review of Assessment Methods," offers extensive recommendations.

• "Reducing Environmental Cancer Risk: What We Can Do Now," from NCI (2010) provides recommendations on what individuals can do to reduce their own cancer risks.

Conclusion

What it is important to know about the occupational carcinogen problem is that it is taking a high toll on society; that there may be no safe limit of exposure to an occupational carcinogen; that all occupational cancers are avoidable; and that experts have proposed that certain steps be taken to prevent occupational cancers. It is up to the reader to decide how to get involved to help solve this serious problem. In the words of the Dalai Lama, "If you think you are too small to make a difference, try sleeping with a mosquito." **PSJ**

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