International Journal of Occupational Safety and Health

ISSN: 2091-0878 (Online) ISSN: 2738-9707 (Print)

Original Article

Carcinogenic chemicals used in key industries and agriculture in Tanzania: A descriptive study

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Date of submission: 22.08.2024
Date of acceptance: 26.03.2025
Date of publication: 01.04.2025

Conflicts of interest: None
Supporting agencies: NORHED-2

DOI:https://doi.org/10.3126/ijosh.v15i2.69022

ABSTRACT

Introduction: In Tanzania, about 50,000 cancer cases are reported annually, and this number is projected to double by 2030. Workplace exposure to carcinogens is a potential contributor to this rising cancer burden. Despite this, there is limited data on the presence and use of carcinogenic chemicals in workplaces, particularly in developing countries like sub-Saharan Africa. This study aimed to describe the presence of carcinogens in chemicals used in key industries and agriculture in Tanzania.

Methods: The study used secondary data on chemicals used in industries and agriculture in Tanzania. Data were obtained from the Government Chemist Laboratory Authority (GCLA) and the Tanzania Plant Health and Pesticide Authority (TPHPA). The chemicals reported were classified for carcinogenicity based on the International Agency for Research on Cancer (IARC). The carcinogens were classified into groups 1, 2A, and 2B. The proportion of carcinogens was obtained by dividing the total carcinogens (groups 1, 2A, and 2B) by the total chemical agents/mixtures assessed.

Results: The study assessed 1,332 chemical agents and 1,448 chemical mixtures from various industries. Carcinogenicity was evaluated for all chemical agents and for 1,356 (94%) of the chemical mixtures. Out of 1,332 chemical agents assessed, 7% contained carcinogens, and out of 1,356 chemical mixtures assessed, 4% contained carcinogens. Formaldehyde, a Group 1 carcinogen, was the most prevalent in 45% of the selected key industries. Additionally, out of the 1,855 pesticides assessed, 2% were found to contain carcinogens.

Conclusion: This study highlights the presence of carcinogens in chemicals used in key industries and agriculture in Tanzania, posing a potential risk to workers in these workplaces. These findings underscore the need for robust regulatory measures and further research to mitigate workplace exposure to carcinogens.

Keywords: Agriculture, Carcinogen, Industries, Workplace Exposure, Pesticides, Tanzania

Introduction

Cancer is a significant global health challenge, with an estimated 19.3 million new cancer cases and 10 million deaths reported in 2020.[1] In 2020, Europe had 4 million new cancer cases and 1.9 million cancer-related deaths, with cases projected to increase by 21% by 2040.[1] Africa experienced 1,109,209 new cancer cases in 2020, with a projected 70% increase by 2030.[1] In Tanzania, nearly 50,000 cancer cases are reported annually, with projections indicating a potential doubling of this number by 2030.[2]

Approximately 20% of the global population may develop cancer during their lifetime, with occupational exposure to carcinogens being a notable contributing factor.[1] For instance, in Italy, 4.2 million workers (24% of the workforce) are exposed to occupational carcinogens.[3] However, data on such exposures in African countries, including Tanzania, is scarce. It is noteworthy that most cancer programs in Africa are currently focused on treatment rather than prevention.

Occupational carcinogens account for an estimated 3.9% of global cancer deaths, though regional variations exist.[4] In Eastern sub-Saharan Africa, the burden is estimated at 0.8%, compared with 8.9% and 8.0% in Australia and Western Europe. Africa's lower cancer burden may reflect a younger population and underreporting.[4]Moreover, data on cancer in Africa are often derived from hospital-based sources, and the selection of these institutions might not fully represent the general population. However, specific information regarding the Population Attributable Fraction (PAF) for carcinogens in Tanzania is currently unavailable.

The International Agency for Research on Cancer (IARC) assesses the carcinogenicity of agents based on the strength of the available evidence. The assessment process follows systematic and scientific procedures, such as evidence review, analysis of human, animal, and mechanistic studies; evaluation by assessing the strength and consistency of the evidence; and classification of carcinogens into groups. As of July 2023, IARC had classified 127 agents as Group 1 (human carcinogens), 95 agents as Group 2A (probably carcinogenic to humans), and 323 agents as Group 2B (possibly carcinogenic to humans).[5]

Epidemiological studies consistently indicate that occupational exposure is often higher than exposure in the general environment. Unlike lifestyle-related risks such as diet and alcohol consumption, which are voluntary exposures, occupational exposures are involuntary and often result from inadequate workplace controls and awareness. Correct control measures can reduce workplace exposures.[6]

In Tanzania, where agriculture is a significant sector, employing over 62% of the working population,[7] and industrialization is expanding, workers face increasing exposure to chemicals. Despite Tanzanian government efforts to address chemical exposure issues in different workplaces, awareness of chemical hazards remains low, resulting in a higher risk of chemical exposure for many workers. This risk has increased due to industrialization, agricultural expansion, and greater use of chemicals.

Assessing the carcinogen status of the chemicals used in Tanzania is very important to understanding the proportionality of carcinogens. This can help the authorities make informed decisions when revising their list of hazardous chemicals in the future.

Therefore, this study aimed to address these gaps by identifying carcinogens in chemicals used in Tanzania's industrial and agricultural sectors. The findings will provide critical insights for exposure assessment and risk evaluation and help regulators make informed decisions to protect workers' health.

Methods

This cross-sectional study used secondary data from two government regulatory authorities: the Government Chemist Laboratory Authority (GCLA) and Tanzania Plant Health and Pesticide Authority (TPHPA). GCLA was established under the Government Chemist Laboratory Authority Act No. 8 of 2016[8] and TPHPA was established through the Parliament Act No. 4 of 2020.[9]

GCLA has established an online portal for handling chemical information in mainland Tanzania. The system comprises information about the name of the company/premises that imported chemicals, the date, the chemical name, the trade name, and the permit certificate.

The TPHPA registers and updates the list of pesticides registered in Tanzania yearly and publishes it on its website, which is free and

accessible to the public. The published data contain trade names, common names, internal registration numbers, usage, and registration categories. For the purpose of this study, we utilized three types of information- trade name, common name, and internal registration number to assess carcinogens.

In this study, assessments were conducted in eleven different types of industries. These industries were selected because they are major industries found in Tanzania and are significant users of chemicals. The chosen industries originated from the main sub-sectors of manufacturing, mining, and construction, which comprise the country's industrial sector and contribute significantly to the GDP, accounting for over 50%.[7]

Before requesting a list of chemicals from GCLA, we prepared a list of major industry types to focus on, identifying the presence of carcinogens with the support of the Occupational Safety and Health Administration (OSHA). The types of industries selected were based on the following criteria: current operating industry and employing more than 100 employees. Finally, eleven types of industries were selected: Textile, paints, leather, cement, plastics, mining, soap, breweries, steel, paper, and ceramic industries. This list of eleven types of industries was submitted to GCLA, requesting information about the chemicals imported by those industries from 2020 to 2022. TPHPA registers and publishes pesticide data on its website; the list of pesticide data is updated annually and is available for free access.

Data Analysis

The chemicals registered from the eleven types of industries were grouped by industry type, listed alphabetically, and cleaned to remove duplicates. To enhance clarity, the analysis and results for chemical agents and chemical mixtures were reported separately (Table 1). Chemical agents were defined as pure chemical compounds, while chemical mixtures were defined as chemicals of two or more different chemical agents (ingredients), where the ingredients might or might not contain carcinogens.

Chemical agents/mixtures & Pesticide Assessment

After obtaining clean lists of the chemical agents, the name of each chemical was searched for its carcinogen status in the most recent monograph published by the IARC. [5] The monograph provides the CAS number, name of chemicals, carcinogen status, and carcinogen group type. If the chemical agent was found in the monographs, its CAS number and the IARC carcinogen group were recorded in an Excel sheet. The IARC carcinogen group was categorized into Group 1, 2A, or 2B as carcinogens and Group 3 as non-carcinogens (Figure 1).

If a chemical agent's name was not found in IARC monographs, it was searched for its safety data sheets on the internet.[10] If the safety data sheet was available and the chemical agent was classified as a carcinogen according to IARC, it was classified as a carcinogen. In case the safety data sheet was available and the chemical agent was not classified as a carcinogen or classified as a carcinogen but not according to IARC, it was categorized as not a carcinogen. However, if the chemical agent's safety data sheet was not found online, it was classified as 'did not meet the criteria for carcinogen assessment'(Figure 1).

The safety data sheets of the chemical mixtures were searched on the internet[10] using the chemical mixtures' names. If the data sheets were available, the carcinogenicity of chemical mixtures was assessed based on their ingredients. If one or more ingredients were classified as carcinogens, the "Classification of chemical mixtures" criteria were used to evaluate the percentage weight of the carcinogen's components. If the percentage weight of the ingredients of the components was more or equal to 0.1%, it was considered a carcinogen, and those with a percentage weight below 0.1% were not considered carcinogens.[11] First, the pesticides were grouped into nine categories: Avicides, acaricides, fungicides, growth regulators, insecticides, nematodes,

herbicides, biological control agents, and restricted registrations. As per TPHPA classification, the restricted registrations group is defined as a group of pesticides sold in unique shops for specific purposes and can only be handled by well-trained personnel.

In assessing carcinogen status, first, we searched in the IARC Monographs to classify the pesticides as carcinogens or not.[5] Their carcinogen groups were recorded if the trade or common names were found in the Monographs. However, if information on pesticides was missing in the IARC Monographs, an internet[10] search was conducted for pesticide safety data sheets. If the trade or common name was found on data sheets, the carcinogenicity status of pesticides was assessed and recorded. However, if the pesticide safety data sheets were missing, it was classified as not carcinogenic (Figure 1).

Proportion of carcinogens

The total number of chemical agents and chemical mixtures was summed to calculate the proportion of carcinogens. Additionally, the number of carcinogens in the chemical agents and chemical mixtures was determined by summing the number of carcinogens in Groups 1, 2A, and 2B for each chemical agent and chemical mixture. The proportion of carcinogens for chemical agents and chemical mixtures was calculated by dividing the total number of carcinogens in Groups 1, 2A, and 2B by the total number of agents or chemical mixtures. The proportions of carcinogens for chemical agents and chemical mixtures were presented separately. The proportion of carcinogens among pesticides was obtained by adding Groups 1, 2A, and 2B carcinogens, then dividing by the total number of pesticides assessed.

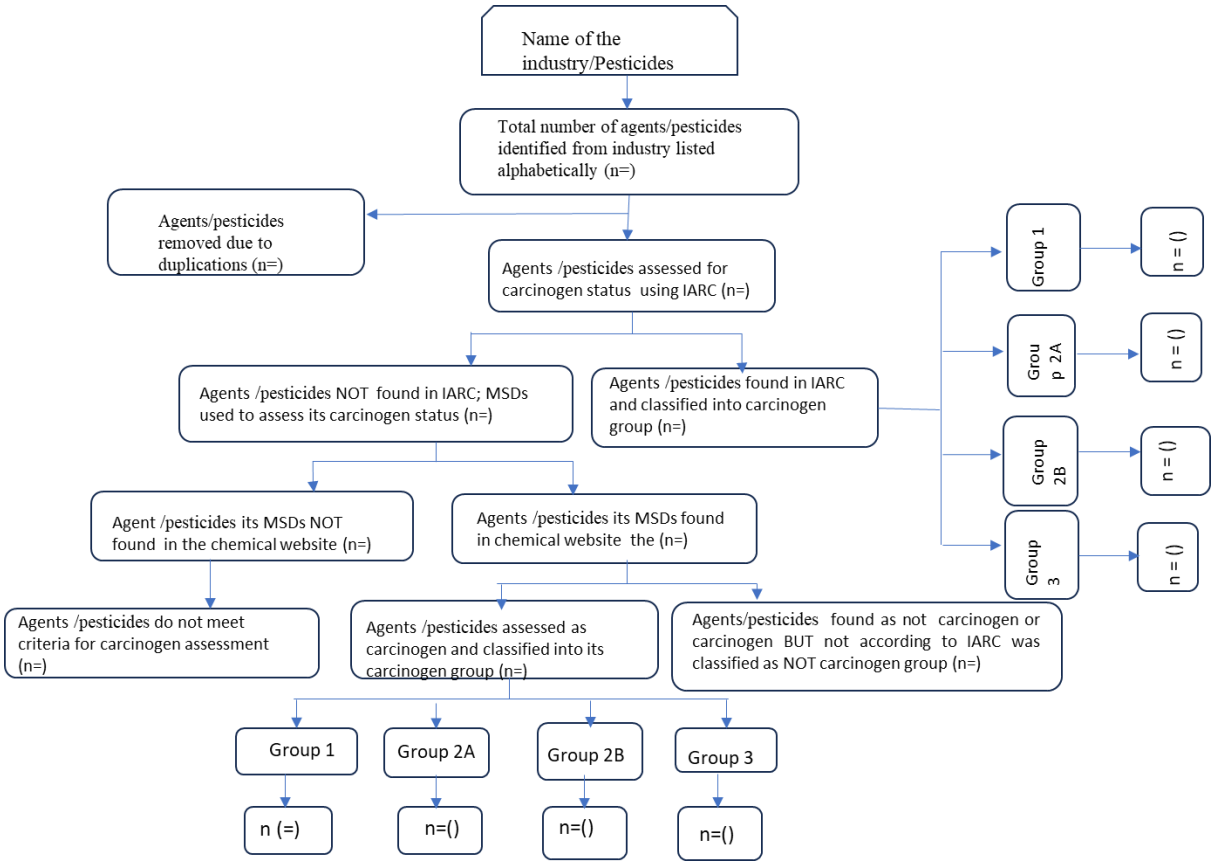

Figure 1: The flowchart showing the data analysis procedures for chemical agents, mixtures and pesticides

Ethical Clearance

Ethical clearance was obtained from the Senate Research and Publications Committee of Muhimbili University of Health and Allied Sciences (IRB #: MUHAS-REC-12-2021-914). We requested permission from the Authorities' management to use the data.

Results

Carcinogens in industries

This study assessed 1332 chemical agents and 1448 chemical mixtures from key industries. Carcinogenicity was evaluated for all 1,332 (100%) chemical agents and 1,356 (94%) of the mixtures (Table 1). The IARC classification system identified approximately 7% of the chemical agents and 4% of the mixtures as carcinogens (Groups 1, 2A, or 2B). Detailed information on specific carcinogens is provided in Table 2.

The number of chemical agents registered varied across industries, ranging from 23 in the mining sector to 365 in the leather industry. The proportion of carcinogenic agents also varied, from 2% in cement to 13% in paper. The leather industry recorded the highest number of carcinogens among the chemical agents (n=32), followed by the textile (n=15) and paint industries (n=10) (Table 1).

Formaldehyde was the most frequently identified Group 1 carcinogen found in 45% (n=11) of the studied industries. Carbon black, classified as a Group 2B carcinogen, was the most common across five industries (Table 2). Among the chemical mixtures, the paper industry showed the highest number of carcinogens (n=26), followed by breweries (n=8) and textiles (n=6) (Table 1). These findings emphasize the prominence of specific industries and substances in contributing to occupational carcinogen risks.

Table 1: Numbers and proportions of carcinogens in chemical agents and mixtures along with their IARC group registered from 11 key industries in Tanzania

		Chemical agents/ mixtures identified	Chemical agents /mixtures removed due to repetition	Chemical agents /mixtures assessed	Chemical agents /mixtures with available information on carcinogenicity	Chemical agents /mixtures classified as carcinogens.			
Industry	Chemical type	n	n	n	n	n (%)	Number of chemicals in IARC-groups*		
							Group 1	Group 2A	Group 2B
Textile	Chemical agents	143	2	141	141	14 (10)	4	1	9
	Mixtures	353	19	334	320	5 (2)	3	0	2
Paints	Chemical agents	96	11	85	85	11 (12)	4	2	5
	Mixtures	269	15	254	230	5 (2)	1	0	4
Leather	Chemical agents	354	6	348	348	32 (9)	9	11	12
	Mixtures	134	3	131	100	0 (0)			
Cement	Chemical agents	202	22	180	180	3 (2)	0	2	1
	Mixtures	87	9	78	60	4 (7)	3	1	0
Plastics	Chemical agents	69	0	69	69	5 (9)	1	2	2
	Mixtures	45	1	44	44	2 (5)	0	0	2
Mining	Chemical agents	16	0	16	16	2 (5)	0	1	1
	Mixtures	7	0	7	7	0 (0)			
Steel	Chemical agents	54	1	53	53	0 (0)			
	Mixtures	57	3	54	54	3 (6)	3	0	0
Paper	Chemical agents	17	2	15	15	4 (13)	1	0	3
	Mixtures	186	0	186	186	26 (14)	2	1	23
Soap	Chemical agents	65	6	59	59	2 (3)	1	0	1
	Mixtures	96	1	95	90	0(0)			
Breweries/ beer	Chemical agents	167	10	157	157	7 (5)	3	0	4
	Mixtures	147	1	146	146	8 (5)	4	0	4

Ceramic	Chemical agents	212	3	209	209	4 (2)	0	0	4
	Mixtures	131	12	119	119	5 (4)	0	0	5
All industries	Chemical agents	1395	63	1332	1332	87 (7)	24	20	42
	Mixtures	1512	64	1448	1356	57 (4)	14	1	41
	All	2907	127	2780	2688	144 (5)	38	21	83

Group 1: Carcinogenic to humans, Group 2A: Probably carcinogenic to humans, Group 2B: Possibly carcinogenic to humans

Table 2: List of carcinogens along with CAS numbers and IARC group among chemical agents registered from 11 key industries in Tanzania

Industry Type	Name of Carcinogens	CAS No	IARC Carcinogens Group
Textile	Formaldehyde	50-00-0	1
	Chromium (VI) compounds	18540-29-9	1
	Nitric acid	7697-37-2	1
	Ethylene oxide	75-21-8	1
	Tetrabromobisphenol A	79-94-7	2A
	1,3-Dichloro-2-propanol	96-23-1	2B
	Titanium dioxide	13463-67-7	2B
	Carbon black	1333-86-4	2B
	2,4-Dinitrotoluene	121-14-2	2B
	Nitrobenzene	98-95-3	2B
	Methylazoxymethanol acetate	592-62-1	2B
	1-Bromopropane	106-94-5	2B
	Chloronitrobenzene	100-00-5	2B
Paints	Isopropyl Alcohol	67-63-0	1
	Trichloroethylene	79-01-6	1
	UreaFormaldehyde Precondensate/	9011-05-6	1
	Formaldehyde	50-00-0	1
	Methylene chloride	75-09-2	2A
	Styrene-7,8-oxide	96-09-3	2A
	Carbon black	1333-86-4	2B
	Titanium dioxide	13463-67-7	2B
	Dihydrosafrole	94-58-6	2B
	Vinyl acetate	108-05-4	2B
	2,4-Dinitrotoluene	121-14-2	2B
Leather	Etoposide	33419-42-0	1
	Cadmium	7440-43-9	1
	3,4,5,3′,4′-Pentachlorobiphenyl (PCB-126)	57465-28-8	1
	Benzene	71-43-2	1
	Methoxsalen	298-81-7	1
	Polychlorinated biphenyls	1336-36-3	1
	Chromium (VI) compounds	18540-29-9	1
	Acid mists	7664-93-9	1
	Isopropyl alcohol	67-63-0	1
	Dieldrin	309-00-2	2A
	Ortho-Anisidine hydrochloride	134-29-2	2A
	4,4'-dichlorodiphenyltrichloroethane	50-29-3	2A
	Chloramphenicol	56-75-7	2A
	Cobalt metal	7440-48-4	2A
	Diazinon	333-41-5	2A
	Glyphosate	1071-83-6	2A

Industry Type	Name of Carcinogens	CAS No	IARC Carcinogens Group
	Malathion	121-75-5	2A
	N, N-Dimethylformamide	68-12-2	2A
	2-Bromopropane	75-26-3	2A
	Dichloromethane	75-09-2	2A
	2,4-dichloro phenoxy acetic acid	94-75-7	2B
	Anthraquinone	84-65-1	2B
	Phenazopyridine hydrochloride	36-40-3	2B
	Beta-Butyrolactone	3068-88-0	2B
	Heptachlor	76-44-8	2B
	Hexachlorobenzene	118-74-1	2B
	Melamine	108-78-1	2B
	Nitrilotriacetic acid	139-13-9	2B
	Phenolphthalein	77-09-8	2B
	Streptozotocin	18883-66-4	2B
	Tetrahydrofuran	109-99-9	2B
	Dichlorvos	62-73-7	2B
Cement	Hydrazine	302-01-2	2A
	Nitrogen mustard	51-75-2	2A
	Nitrobenzene	98-95-3	2B
Plastics	Cadmium	7440-43-9	1
	Tyrene-7,8-oxide	96-09-3	2A
	Lead compounds, inorganic	7439-92-1	2A
	benzophenone	90-94-8	2B
	Potassium bromate	7758-01-2	2B
Mining	Lead compounds, inorganic	7439-92-1	2A
	Carbon black	1333-86-4	2B
Soap	Formaldehyde	50-00-0	1
	Titanium dioxide	13463-67-7	2B
Breweries	Chromic Acid	1333-82-0	1
	Formaldehyde	50-00-0	1
	Ethanol	64-17-5	1
	Polychlorophenols	87-86-5	2B
	Acetaldehyde	75-07-0	2B
	Dichlorophenol	120-83-2	2B
	Isobutyl nitrite	542-56-3	2B
Paper	Formaldehyde	50-00-0	1
	Melamine	108-78-1	2B
	Carbon black	1333-86-4	2B
	Titanium dioxide	13463-67-7	2B
Ceramic	Bitumens (Asphalt)	8052-42-4	2B
	Carbon black	1333-86-4	2B
	Silicon carbide, fibrous	308076-74-6	2B
	Refractory ceramic fibres	1302-76-7	2B

In assessing the chemical mixtures from eleven key of industries, crystalline silica was the most frequently identified Group 1 carcinogen, found in chemical mixtures across six of the eleven industries (Table 3). Carbon black and titanium oxide were the most frequently identified Group 2B carcinogens in chemical mixtures in seven industries (Table 3).

Table 3: List of carcinogens in chemical mixtures used across 11 key industries in Tanzania

Industry	**Mixture**	**Number of ingredients**	**Number of carcinogen**	**CAS no**	Name of **carcinogens**	**IARC carcinogen group**	**Weight %**
Textile	Cartridge	4	1	1333-86-4	Carbon black	2B	5-10
	Clear varnish	6	1	71-43-2	Benzene	1	1.0 - 10
	COD solution	5	1		Sulfuric Acid	1	65–87
	Disperse black RLS	2	1	1333-86-4	Carbon black	2B	30 - 40
	Fire Clay	2	1	14808-60-7	Crystalline Silica	1	10-30
	Penetrol-sf	2	1	111-42-2	Diethanolamine	2B	1 - 5
	Barytes	4	1	14808-60-7	Quartz (silica)	1	10-12
	Dowsil rsn-0805 resin	4	1	100-41-4	Ethylbenzene	2B	11 - 12
	Gasket Maker	3	1	1333-86-4	Carbon black	2B	0.1 – 1.0
	Styrenated Alkyd Resin	10	1	13463-67-7	Titanium Dioxide	2B	5 – 15
Cement				14464-46-1	Cristobalite	1	10-20
	Castable Refractory Cement	3	2	14808-60-7	Quartz	1	5-10
	Steam Seal Jointing Paste.	5	1	14808-60-7	Quartz	1	5-10
	Formazin-Various NTU	3	1	302-01-2	Hydrazine	2A	0.5
Plastics	Blue Tube	2	1	13463-67-7	Titanium Dioxide	2B	10 - 25
	Masterseal	9	1	13463-67-7	Titanium Dioxide	2B	10 - 25
Breweries	Digestion solution for COD 20-1500mg/l high-range	4	1	7664-93-9	Sulfuric Acid	1	80 - 90
	Digestion solution for COD3-150mg/l Range	4	1	7664-93-9	Sulfuric Acid	1	80 - 90
	Ink Cartridge	4	1	1333-86-4	Carbon black	2B	2-8
	Isotal	2	0	14808-60-7	Quartz (silica)	1	5-10
	Phosphate Acid Reagent Vials	2	1	7664-93-9	Sulfuric Acid		3 - 7
	Ribbon Cartridge	4	1	1333-86-4	Carbon black	2B	2-8
	Touch Up Paint	4	1	100-41-4	Ethylbenzene	2B	2.5-10
Steel	Mapelastic Smart Part A	2	1	14808-60-7	Silica Sand	1	50-75
	Mapelastic Smart Part B	2	1	14808-60-7	Silica Sand	1	50-75
	Portland Cement	5	1	14808-60-7	Crystalline silica	1	5
Ceramic	Canon Black Cartridge	4	1	1333-86-4	Carbon black	2B	5-10
	Cartridge	4	1	1333-86-4	Carbon black	2B	5-10
	Cartridge (Cyan)	4	1	1333-86-4	Carbon black	2B	5-10
	Cartridge Magenta	4	1	1333-86-4	Carbon black	2B	5-10
	Cartridge(For Ink)	4	1	1333-86-4	Carbon black	2B	5-10
Paper				75-09-2	Dichloromethane	2A	65-85
	Blanket Saver	7	2	75-56-9	Propylene oxide	2B	1-2%
	Developer Dv 315 Black	8	1	1333-86-4	Carbon black	2B	< 1
	Developer Dv 411	7	1	1333-86-4	Carbon black	2B	< 1
	Dv214k Dev	7	1	1333-86-4	Carbon black	2B	< 1
	Dv614k Black	7	1	1333-86-4	Carbon black	2B	< 1
	Dv616k Dev Black	7	1	1333-86-4	Carbon black	2B	< 1
	Refractory Cement	6	1	1408-60-7	Crystalline silica	1	15
	Tn 321k Toner Black	8	1	13463-67-7	Titanium dioxide	2B	<1
	Tn 324b Toner Black	7	1	13463-67-7	Titanium dioxide	2B	<1
	Tn 324c Toner Cyan	7	1	13463-67-7	Titanium dioxide	2B	<1
	Tn 324m Toner Magenta	7	1	13463-67-7	Titanium dioxide	2B	0.1-1
	Tn118	6	1	13463-67-7	Titanium dioxide	2B	0.1-1
	Tnp46	6	1	13463-67-7	Titanium dioxide	2B	0.1-1
	Tnp48k Toner	6	1	13463-67-7	Titanium dioxide	2B	<1
	Toner 619 Black	8	1	13463-67-7	Titanium dioxide	2B	<1
	Toner 619 Cyan	8	1	13463-67-7	Titanium dioxide	2B	<1
	Toner 619 Magenta	7	1	13463-67-7	Titanium dioxide		<1

Industry	Mixture	Number of ingredients	Number of carcinogen	CAS no	Name of carcinogens	IARC carcinogen group	Weight %
						2B	
	Toner 619 Yellow	7	1	13463-67-7	Titanium dioxide	2B	<1
				1333-86-4	Carbon black	2B	10
	Toner Tn 622 Black	6	2	13463-67-7	Titanium dioxide	2B	<1
	Toner Tn 622 Cyan	5	1	13463-67-7	Titanium dioxide	2B	<1
	Toner Tn 622 Magenta	5	1	13463-67-7	Titanium dioxide	2B	<1
	Toner Tn 622 Yellow	5	1	13463-67-7	Titanium dioxide	2B	<1
	Urea Formaldehyde	3	1	50-00-0	Formaldehyde	1	0.3
	Uv Ink Black 220ml Ver4	8	1	1333-86-4	Carbon black	2B	1.5

Carcinogens in Pesticides

Only four out of ten pesticide types contained one or more carcinogens (Table 4). The number of pesticides evaluated for carcinogenicity varied, ranging from 101 in the restricted registration group (according to TPHPA classification, restricted registration refers to pesticides sold in specialized shops for specific purposes and handled only by well-trained personnel) to 822 for insecticides (Table 4). The proportion of pesticides containing carcinogens ranged from 1% among herbicides to 3% among insecticides. Malathion was the most frequently identified carcinogen in 13 out of 23 insecticides. Chlorothalonil was the most commonly identified Group 2B carcinogen, found in all ten registered fungicides. This study also provides the details of carcinogens by pesticide types (Table 5).

Table 4: Number, proportion and IARC group of carcinogens in the four pesticide groups in Tanzania

S/N	Pesticides class	Total number of pesticides assessed	Agents classified as carcinogens			
			n (%)	Group 1	Group 2A	Group 2B
1.	Fungicides	487	10 (2)	0	0	10
2.	Insecticides	822	23 (3)	0	19	4
3.	Herbicides	445	4 (1)	0	4	0
4.	Restricted registration	101	2 (2)	1	1	0
	Total	1855	39 (2)	1	24	14

Table 5: List of carcinogens categorized by pesticide types including their IARC groups

Type of pesticides	Registration number	Common name	Trade name	Carcinogen group
Fungicides	F.U./0091	Daconil 720 SC	Chlorothalonil 720g/L	2B
	FU/0144	Rav 500SC	Chlorothalonil 500g/L	2B
	FU/0315	Twigathalonil 500SC	Chlorothalonil 720g/l	2B
	FU/0332	Bachloronil 720SC	Chlorothalonil 720g/L	2B
	FU/0340	Green 720 SC	Chlorothalonil 720g/L	2B
	FU/0454	Siconil 500 SC	chlorothalonil 500 g/L	2B
	FU/0368	Bestonil 50% SC	Chlorothalonil 500 g/L	2B
	FU/0456	Chloroforce 72SC	Chlorothalonil 720 g/L	2B
	FU/0455	Dachlor 720SC	Cholorothalonil 720g/l	2B
	FU/0055	Clortocaffa ro 54 FLW	Chlorothalonil	2B
Insecticides	IN/0762	Hit Aerosol	Tetramethrin 0.325%	2A
	IN/0846	Maxi Aerosol	Tetramethrin 0.325%	2A
	IN/0847	Rungu Aerosol	Tetramethrin 0.325%	2A
	IN/0880	Goodnight Aerosol	Tetramethrin 0.17% + D-transalethrin	2A

	IN/0197	Black Jack	Tetramethrin	2A
	IN/0382	Agro-Zinon 60EC	Diazinon 600g/L	2A
	IN/0510	Magic 50 EC.	Malathion 500g/L	2A
	IN/0057	Fyfanon 500g/l	Malathion 500g/L	2A
	IN/0318	Skana Super Dust	Malathion 20g/Kg + Permethrin0.4g/Kg	2A
	IN/0508	Severe 50	Malathion 50g/L	2A
	IN/0509	Tanzamalt 50EC	Malathion 500g/L	2A
	IN/0522	Mupathion 50EC	Malathion 500g/L	2A
	IN/0800	Reserve Dust 1.13% DP	Malathion 2% + Permethrin 0.3%	2A
	IN/0690	Snowthion 50EC	Malathion 500g/L	2A
	IN/0800	Tallic Dust	Malathion 2% + Permethrin 0.3%	2A
	IN/0848	Dera Blue Cross 20 Dusts	Malathion 20g/Kg	2A
	IN/0873	Malper Dust 2%	Malathion 16g/Kg + Permethrin 4g/Kg	2A
	IN/0874	Dera Malathion 500E	Malathion 500g/L	2A
	IN/0690	Snowthion 50EC	Malathion 500g/L	2A
	IN/0830	Hangthoate 400 EC	Dimethoate 400 g/l	2B
	IN/0540	Dimate 40 EC.	Dimethoate 400g/L	2B
	IN/0754	Dimeforce 40EC	Dimethoate 400g/L	2B
	IN/0720	Fezmet 40EC	Dimethoate 400g/L	2B
Herbicides	HE/0395	Fuhasate 75 SG	Glyphosate 757g/kg	2A
	HE/0396	Fuhasate Super 48 SL	Glyphosate 480g/l	2A
	HE/0249	Dizron Super 380WP	Clomazone 240g/kg+	2A
	HE/0095	Mamba 360 SL	Glyphosate 360g/L	2A
Restricted registration	RE/0172	Permacure oxide Liquor	Chromium Trioxide 298g/kg Arsenic Pentoxide 204g/kg (CCA)	I
	RE/0004	Ethylene Dibromide	Ethylene Dibromide	2A

Discussion

Approximately 5% of the assessed chemical agents and mixtures contained carcinogens, although this proportion varied significantly across the eleven key industries. The leather industry had the highest number of identified carcinogens, followed by the paper industry, which also exhibited the highest fraction of chemicals containing carcinogens. Formaldehyde was the most frequently identified Group 1 carcinogen in nearly half of the key industries assessed. Among the pesticides, the mean fraction containing carcinogens was 2%, with the highest proportion observed in the insecticides. Malathion was the most frequently identified carcinogen in 13 out of 23 insecticides assessed.

Over the last 54 years, IARC has classified approximately 1,000 agents, many of which are occupational chemicals or complex mixtures.[12] The lack of data on specific locations of carcinogenic exposures remains a significant challenge to preventing occupational cancer.[13] According to IARC evaluations, nearly 50% of these agents are classified as carcinogenic, likely carcinogenic, or possibly carcinogenic to humans. The European Union (EU) reported generating and consuming more than 34 million tons of carcinogenic, mutagenic, and reprotoxic chemicals in 2020,[14] with 17% of workers in Europe exposed to these chemicals for at least 25% of their working hours in 2015.[13] Similarly, a Canadian study estimated workers were exposed to 44 known, probable, and suspected carcinogens, including night shift work, solar ultraviolet radiation, and diesel engine exhaust.[14]

This study highlighted the presence of carcinogens in agents and mixtures used in Tanzanian industries. It identified the leather industry as having the highest number of carcinogens, including cadmium, polychlorinated biphenyls, benzene, and chromium (VI) compounds. These findings align with a short review from India, which also reported a significant number of carcinogens present in leather tanning workplaces, such as chromium, formaldehyde, and benzene, though arsenic noted in the India study was not registered in Tanzania.[15] These discrepancies may reflect differences in exposure levels or study methodologies, as the Indian study drew from global literature without a defined time frame. In contrast, the present study exclusively focused on Tanzania, with data from 2020 to 2022.[16]

The textile industry was the second highest contributor to carcinogen presence, consistent with global studies identifying carcinogenic dyes and chemicals in textile production.[17] In Tanzania, formaldehyde, benzene, sulfuric acid, and crystalline were among the carcinogens identified in textile industries, though direct comparison to global reviews is limited by the lack of specificity in chemical identification.[15]

Formaldehyde emerged as the most frequently identified Group 1 carcinogen in Tanzanian industries due to its extensive use in manufacturing resins, leather, textiles, cement, plastic, and rubber.[18] It is also widely used as a preservative and disinfectant in healthcare facilities. Its versatility and widespread application in various sectors explain its high prevalence in the study.[19]

Pesticide analysis revealed the presence of carcinogens in some products used in Tanzania, suggesting potential exposure risks for agricultural workers. Identified carcinogens included chlorothalonil, glyphosate, parathion, malathion, diazinon, hexachlorobenzene, aldrin, dieldrin, and chlordane, aligning with previously studies.[20,21] Identifying carcinogens used in the country is crucial in preventing cancer related to pesticide exposure, as current evidence indicates the presence of carcinogens in some pesticides. Despite the relatively low proportion of pesticides containing carcinogens, caution is warranted because even small exposures to carcinogens can have effect. Studies conducted in Tanzania and Nepal have shown that farmers have poor practice and often mix several pesticides during the application, and most pesticides have not yet been evaluated for their carcinogenicity. [22–25]

Exposure to carcinogens identified in this study poses significant health risks to workers. For instance chromium (VI) compounds can increase risk of lung, sinus, stomach, and laryngeal cancers through inhalation.[26] Formaldehyde is associated with lung cancer, nasopharyngeal cancer, leukemia, and non-Hodgkin's lymphoma. [19] Cadmium exposure may increase the risk of lung and pancreatic cancers.[20] Benzene exposure is strongly linked to leukemia and other blood cancers.[21]

This study provides valuable insights into carcinogenic chemicals used in Tanzanian workplaces, making it the first comprehensive of its kind. However, the study has some limitations. The use of secondary data not specifically designed to assess carcinogens may have resulted in missing information. Additionally, the absence of detailed information on the composition of chemical mixtures required reliance on online safety data sheets for chemicals that were missing in IARC, which may vary in quality and reliability. Furthermore, the study only considered imported chemicals, excluding raw materials and by-products that may also pose carcinogenic risks. Also, knowledge in this area is under continuous development, and more chemicals might be classified as carcinogens in the future.

Despite these limitation they study's strengths include its comprehensive assessment of chemicals imported by key industries over a two-year period, covering over 2,706 agents and involving sectors that employ a substantial number of the Tanzanian workforce. The inclusion of over 2,000 pesticides further enhances the

study's scope and relevance. The industries and pesticides selected represent sectors that collectively employ more than 70% of the working-age population in Tanzania. This extensive coverage enhances the representativeness of the study and contributes to a more comprehensive understanding of the potential exposure to carcinogens in these important sectors.

The findings of this study suggest a potential risk of workplace exposure to carcinogens in various industries and in agriculture, posing a concern for future cancer incidence among workers. To mitigate the risk of cancer among workers, the responsible authority should:

1. Establish legislation to regulate the use of carcinogenic agents and enforce exposure limits in workplaces.

2. Use substitution methods by replacing carcinogens with less hazardous alternatives wherever feasible.

3. Implement stringent measures to minimize exposure when substitution is not possible.

4. Raise awareness about the risk of carcinogenic chemicals and promote safe handling practices through worker education.

Conclusions

This study highlights the presence of carcinogens in chemical agents, mixtures and pesticides used in key industries and agriculture in Tanzania. This implies potential exposure to carcinogens among workers in these workplaces. Furthermore, risk assessment is needed to evaluate carcinogens exposure associated with industrial processes and agriculture. These findings underscore the need for robust regulatory measures and further research to mitigate workplace exposure to carcinogens.

Acknowledgements

The authors acknowledge the management of the cement, textile, paint, and plastic factories and workers' readiness to participate in this study. Also, we thank the Government Chemist Laboratory Authority (GCLA) for assisting us in using their data on chemicals and Tanzania Plant Health and Pesticide Authority (TPHPA) for making data public available.

Funding

This project was financially supported by the Norwegian Programme for Capacity Development in Higher Education and Research for Development (NORHED-2), Safe Work Conditions by Innovative Research and Education / SAFEWORKERS (69181).

Author Contributions

All five authors have access to the manuscript's supporting data. All five authors have reviewed and accepted the manuscript. All of the authors concur on the manuscript's contents. LPM conceived the study, collected data, conducted data analysis, and wrote the first draft of the manuscript. SHDM, MB, and BEM were involved in project conceptualization, methodology, and validation, and they conceived and reviewed the manuscript. IPN reviewed the manuscript.

Conflicts of interest

All authors declare that they have no conflict of interest.

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