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Original Research Article

Investigation on Ratios of Some Common Diseases and Health Risks Relating to Dioxin Exposure in Da Nang, Vietnam

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ABSTRACT

Agent Orange (AO)/dioxin has potent, long-term, and serious effects on human health. It is capable of all parts of the body, causing cancer and diabetes; damaging the skin, liver, thyroid, immune system, respiratory system, circulatory system, digestive system, endocrine system, nervous system, cardiovascular system, and lungs; and causing mutations in genes and chromosomes, thereby causing birth defects and reproductive complications. This study aimed to analyze the status of disease patterns and health risks of people in Thanh Khe district (TK group) residing near areas where AO/dioxin was stored in Da Nang airport, compared with people in Son Tra district (ST control group), Da Nang city. This is a survey of 402 families residing in the TK group and 400 families residing in the ST group. Individuals in the age group 45–69 years accounted for a high proportion, of whom women accounted for the majority; the duration of residency was stable and long, typically more than 15 years in both groups. People in the TK group who had direct and indirect exposure to AO/dioxin accounted for a higher proportion than in the ST group. The incidence of some diseases that are thought to be related to AO/dioxin exposure, were hypertension (33.6%), diabetes mellitus (8.96%), and other diseases such as those of the stomach (23.0 %), joints (40.3%), ear/nose/throat (11.2%), and urinary system (7.21%) compared with the ST group. Exposure to AO/dioxin has changed the disease pattern and increased some diseases in people residing near areas where AO/dioxin was previously stored.

Keywords: Diseases, Health risks, AO/dioxin, Hot spot, Thanh Khe, Son Tra.

Introduction

During the Viet Nam war, from May 1964 to March 1972 at Da Nang airport, the US army stored and used 52.700 barrels of Agent Orange (AO), 29.000 barrels of Agent White, and 5.000 barrels of Agent Blue for the spraying campaign "Ranch Hand" and the recovery campaign "Pacer Ivy".[1] Da Nang airport is one of the three most serious hotspots for dioxin contamination in Viet Nam.[2] The highest dioxin concentration recorded at the Da Nang airport reached 365.000 pg toxic equivalent (TEQ)/g in the soil in the former AO mixing and loading area.[3]The Da Nang dioxin-contaminated sites were located north of the Da Nang airport in central Viet Nam. Approximately 94.000 m^3 of heavily dioxin-contaminated soil and sediment was treated between 2013 and 2017 by the environmental remediation project;[4] however, there is still 68.000 m^3 of material with a concentration of less than 1.000 pg TEQ/g being landfilled in the southwest of the airport. People residing around Da Nang airport are at risk of dioxin exposure through ingestion, skin contact, and inhalation.[5]

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During the implementation of the dioxin remediation project, residents living near the Da Nang airport were at low risk of being expose to dioxin with an average daily dose through inhalation ranging from 0.006 to 0.129 pg TEQ/kg body weight/day, whereas residents living close to the former AO mixing and loading area faced elevated risks with an average daily dose from 0.017 to 0.820 pg TEQ/kg body weight/day.[6] Tuyet Hanh et al. estimated that the daily intake of people living in four wards (An Khe, Hoa Khe, Chinh Gian, and Thac Gian) around Da Nang airport due to local high-risk food consumption was very large (from 27.0 to 148 pg TEQ/kg body weight/day), much higher than the World Health Organization (WHO) recommended tolerable daily intake (1–4 pg TEQ/kg body weight/day).[7] Recent studies have also shown that dioxin concentrations in the milk of mothers living in dioxin-exposed areas were higher than those of mothers living in non-dioxin-exposed areas.[8] The mean dioxin concentrations in breast milk collected between 2008 and 2009 from mothers living around the former Da Nang hotspot were 12.8–14.3 pg TEQ/g lipid.[9]

AO/dioxin has potent, long-term, and serious effects on human health.[10] It is capable of causing diverse and complex damage to all parts of the body, causing cancer and diabetes; damaging the skin, liver, thyroid, immune system, respiratory system, circulatory system, digestive system, endocrine system, nervous system, cardiovascular system, and lungs; and causing mutations in genes and chromosomes, thereby causing birth defects and reproductive complications.[11] The risk of dioxin exposure for people living near hotspots many years ago is very high. Therefore, this study investigated and compared the disease pattern and health risks of people in Thanh Khe district (TK group) living around previously heavily polluted areas with dioxin and those residing in Son Tra district (ST control group) far from Da Nang

airport.

Material and Methods

Study area

Da Nang is situated in the center of Viet Nam. Its mainland latitude and longitude are 15°55' to 16°14' N and 107°18' to 108°20' E. Da Nang city has a total area of 1.283 km^2 and had a population of 1.134.310 in 2019. The population density of Da Nang is about 883 people/km^2. Thanh Khe district has an area of only 9.36 km^2, a population of 178.447 people, and the highest population density in the city at 19.065 people/km^2. Son Tra district has an area of 59.32 km^2, a population of 132.944 people, and population density of 2.241 people/km^2 .[12] The TK group consisted of 402 households residing in four wards: An Khe, Hoa Khe, Chinh Gian, and Thac Gian (Figure 1). This area has a very high risk of dioxin exposure because people live near areas previously heavily contaminated with AO/dioxin.[7] The ST group consisted of 400 households residing in three wards: An Hai Tay, An Hai Dong, and Phuoc My (Figure 1). The ST group was similar to the TK group in terms of socioeconomic conditions and population characteristics; however, it was not directly affected by AO/dioxin residues inside Da Nang airport. The ST group is located about 5 km east of Da Nang airport and across the Han River, and is unaffected by industrial activities.

Figure 1. Map points out the study sites of Thanh Khe and Son Tra groups.

Selection criteria

The individuals selected for the investigation were adults, of both sexes, aged between 18 and 69 years, representing each household, who had resided continuously in the locality for at least 5 years. During the survey, women were prioritized for interview because they were indicators of reproductive health, often did housework, rarely had to work far away from home, and therefore, had a more stable and longer-term duration at the research location than men. Also, women had less exposure to toxins from occupations in industry, and typically drank less alcohol and smoked less compared to men.

Study design and data collection

This is a cross-sectional descriptive biomedical study on the risk of dioxin exposure, health status, and diseases and illnesses that may be related to dioxin exposure through questionnaires, face-to-face interviews, and statistical data. General information, health status, risk factors for food consumption, history of exposure to AO/dioxin and toxic factors, medical history, and obstetric history related to dioxin exposure were investigated through an investigation consisting of 85 questions in the form of a face-to-face interview. The interviewer had experience in the research field as well as clinical experience related to the investigated diseases. People who were considered to have diseases were those who had had a confirmed test, had been treated in a hospital, were taking medication, or were receiving local outpatient treatment. The experimental protocols have been approved by Vietnam-Russia Tropical Center Ethics Committee (operation number: IRB-VN02017 issued by Ministry of Health) with code number 18/2020/VREC and *in compliance* with international guidelines on data collection and survey design.

Investigation time

The survey was conducted in March 2021 for the TK group and October 2021 for the ST group.

Data analysis

Research data were processed by a computer using Microsoft Excel 2013, IBM SPSS Statistics 20, and Statav4 software according to biomedical statistical methods. The results were presented as:

- Mean (X), percentage (%), and *p* value.
- Comparison of ratios with a χ^2 test; The difference was considered statistically significant at $p < 0.05$.

Results and Discussion

Age distribution, residence time and sex distribution of individuals

The mean age (mean ± 2SD) of the TK group was 53.83 ± 22.52 and of the ST group was 50.47 ± 24.42. In both groups, the age group 45–69 years accounted for a high rate (TK group, 79.60%; ST group, 68.75%) and was statistically significantly higher than in the age group 18–44 (TK group, 20.4%; ST group, 31.25%) (Table 1); however, within the same age group (18–44 or 45–69 years) there was no difference between the two groups ($p > 0.05$). This result showed that the TK group and the ST group were similar in age, consistent with the requirements for selecting participants. Table 1 also shows that the majority of households and people had a long-term residence period of >15 years in the two research locations (TK group, 89.30%; ST group, 90.75%). People with a residence period of 5–15 years accounted for a low percentage (TK group, 10.70%; ST group, 9.25%) and there was no difference between the two groups ($p > 0.05$). In both groups, women who were prioritized for interview made up the majority of participants (TK group, 70.15%; ST group, 67.50%) and there was a statistically significant difference ($p < 0.05$) between the percentages of men and women in each group but no difference in sex ratio between the two groups ($p > 0.05$) (Table 1).

Toxic elements and AO/dioxin exposure

The statistics in Table 2 show that the proportion of people exposed to toxic elements in industry and agriculture in the ST group and the TK group accounted for a very low percentage (<0.75%) and there was no significant difference ($p > 0.05$) between the two groups.

In the TK group, the proportion of people directly and indirectly exposed to dioxins was 3.48% and 9.45%, respectively. These rates were statistically significantly higher ($p < 0.05$) than the ST group (0% and 1.75%, respectively). The ST group was far from the airport and no one in this group had ever worked in a hotspot or heavily contaminated area with dioxin, so there was no direct contact with dioxin (Table 2).

Status of living, alcohol, beer, and tobacco use

Table 3 shows that 100% of people in both groups used tap water for domestic use. The TK group had a self-sufficiency rate (growing more vegetables and raising poultry) of 13.7%, which was significantly higher ($p < 0.05$) than the ST group (3.75%). The use of some foods that were self-sufficient in areas at risk of dioxin exposure around Da Nang airport may be the reason why food poisoning in the TK group (13.7%) was higher and reached statistical significance compared to the ST group (7.25%). Although there was no significant difference ($p > 0.05$) in the status of alcohol/beer and tobacco use of residents in the two groups, the rates of using alcohol/beer and tobacco by residents in the TK group (17.91% and 19.15%, respectively) were higher than in the ST group (12.0% and 17.0%) (Table 3).

Disease pattern of individuals in the research location

The results of the analysis of the disease pattern of the residents in the two groups in Table 4 show that most of the diseases surveyed in this study in the TK group accounted for a statistically significant higher

percentage ($p < 0.05$) compared with the ST group. This shows that people's health risks due to dioxin exposure around Da Nang airport were present and related to AO/dioxin residues. Dioxin exposure in the TK group increased the incidence of diseases: hypertension, stomach,

Table 1. Age distribution, residence period, and sex distribution.

Age group, residence period, and sex		TK group (n = 402)		ST group (n = 400)		p
		Number of people	Rate (%)	Number of people	Rate (%)	
Age group (years)	45–69	320	79.60	275	68.75	> 0.05
	18–44	82	20.40	125	31.25	
Residence period	5–15 years	43	10.70	37	9.25	
	>15 years	359	89.30	363	90.75	
Sex	Men	120	29.85	130	32.50	
	Women	282	70.15	270	67.50	

Table 2. Exposure to toxic elements and AO/dioxin exposure.

Toxic elements and type of exposure		TK group (n = 402)		ST group (n = 400)		p
		Number of people	Rate (%)	Number of people	Rate (%)	
Toxic elements	Chemical fertilizers	3	0.75	3	0.75	> 0.05
	Pesticides, herbicides	3	0.75	3	0.75	
	Pesticide poisoning	0	0	1	0.25	
	Latex processing	0	0	3	0.75	
	Wood processing	0	0	2	0.50	
	Waste treatment/ incineration	1	0.25	2	0.50	
	Cement	1	0.25	0	0	
	Metallurgical	0	0	0	0	
Types of exposure	Direct	14	3.48	0	0	< 0.05

Table 3. Status of living, alcohol, beer, and tobacco use.

Factors and stimulants		TK group (n = 402)		ST group (n = 400)		p
		Number of people	Rate (%)	Number of people	Rate (%)	
Factors	Self-sufficient	55	13.68	15	3.75	> 0.05
	Using tap water	402	100	400	100	
Stimulants	Food poisoning	55	13.68	29	7.25	< 0.05
	Alcohol/beer	72	17.91	48	12.00	
	Tobacco	77	19.15	68	17.00	

joints, ear/nose/throat (ENT), liver-gallbladder, kidney-urinary system, and eye diseases (33.58%, 23.88%, 40.3%, 11.19%, 6.47%, 7.21%, and 6.22%, respectively), which was statistically significant ($p < 0.05$) at between 1.8–7.5-times higher than in the ST group. Diseases such as diabetes and heart and lung diseases in the TK group (8.96%, 6.72%, and 2.74%, respectively) were also 1.2–1.8-times higher than that of the ST group, but they did not reach statistical significance ($p > 0.05$). In particular, in the TK group, the rates of 33.58% hypertension and 8.96% diabetes mellitus were higher than the general rates of 19.00% and 6.00, respectively of Vietnamese people.[13]

Disease pattern of participants in the research location by age

People with diseases surveyed in this study concentrated in the age group 45–69 years in both TK and ST groups. People aged 45–69 years in the TK group had a 1.1–12-times higher prevalence of diseases in Table 5 than the ST group except for hypotension. People aged 18–44 years in the TK group had statistically significantly higher rates of diseases: hypertension, stomach, joints, ENT, eye, and diabetes ($p < 0.05$) from 1.4–13.7-times higher compared with the ST group. This indicates that there are many health risks for all residents

living near the areas where AO/dioxin was stored in the Da Nang airport.

Table 4. Disease pattern of individuals in the groups.

Diseases	TK group (n = 402)		ST group (n = 400)		p
	Number of people	Rate (%)	Number of people	Rate (%)	
Hypertension	135	33.58	76	19.00	
Stomach	96	23.88	54	13.50	
Joints	162	40.30	79	19.75	
Ear/nose/throat	45	11.19	6	1.50	< 0.05
Liver and gallbladder	26	6.47	13	3.25	
Kidney, urinary system	29	7.21	3	0.75	
Eyes	25	6.22	10	2.50	
Diabetes mellitus	36	8.96	24	6.00	
Hypotension	12	2.99	10	2.50	
Heart	27	6.72	16	4.00	
Lung	11	2.74	6	1.50	< 0.05
Pancreas, thyroid, adrenal gland	10	2.49	8	2.00	
Nervous system	35	8.71	32	8.00	

Disease pattern of Individuals in the research location by sex

The results of the analysis of disease patterns by sex in Table 6 show that the disease pattern depended on sex. Most of the diseases surveyed in this study in both sexes of the TK group accounted for a statistically significant higher rate ($p < 0.05$) than the ST group from 1.1–17.3-times higher for women and 1.1–3.6-times higher for men. Men tended to have hypertension and lung and eye diseases more than women. In contrast, women tended to have diseases of the stomach, joints, and nervous system at a higher rate than men. The disease pattern of people in the TK group residing in areas at high risk of dioxin exposure was different compared with the ST group residing far from the airport. The rate of ENT, liver–gallbladder, and kidney–urinary system diseases, diabetes, and heart disease in the TK group was higher than that of the ST group.

Disease rates between men and women aged 45–69 years

Table 7 shows that people aged 45–69 years in both TK and ST groups had higher rates of hypertension and eye diseases in men than in women. In contrast, diseases of the stomach, joints, and pancreas–thyroid–adrenal glands in women account for a higher rate. In the TK group, both men and women had a prevalence of most diseases that was 1.2–12-times higher than that of the ST group.

Disease rates between men and women aged 18–44 years

Table 8 shows that among people aged 18–44 years in both TK and ST groups, men tended to have hypertension, liver–gallbladder diseases, and heart disease more than women. In contrast, women had higher rates of diseases of the stomach, kidney-urinary system, and nervous system than men. In the TK group, both men and women had 1.2–5.0-times higher rates of hypertension/hypotension, and diseases of the stomach, joints, ENT system, eyes, and lungs than those in the ST group.

Rates of women with menstrual disorders and risks of birth defects

Dioxin is known to cause menstrual disorders, changes in the average age of puberty, birth defects, and reproductive complications in women.[14] Table 9 shows that there was no significant difference ($p > 0.05$) in the proportion of women with menstrual disorders between the TK group and the ST group in both ages. Women aged 45–69 years in the TK group had menstrual disorders at a rate of 11.82%, which was higher than that of the ST group (9.89%). But in the age group of 18–44 years, the ST group had a higher rate of menstrual disorders (14.77%) than the TK group (9.68%). Table 9 also shows that the TK group had two types of risks: delayed physical development (0.45%) and mental retardation (1.82%) and both belonged to women aged 45–69 years but there was no significant difference between the two groups.

Rates of reproductive complications

As Table 9 shows, there was no difference in the mean age of puberty as well as the prevalence of menstrual disorders in women between the TK and ST groups; however, Table 10 shows that there was a clear difference in the rate of reproductive complications between the two groups. In the TK group, women encountered five types of reproductive complications more than in the ST group, in which the factor of preterm birth reached statistical significance ($p < 0.05$) compared with the ST group.The rates of premature birth, dead malformed birth, living malformed birth, and postnatal death in the TK group (3.64%, 0.45%, 1.36%, and 0.45%, respectively) were higher than in the ST group (1.65%, 0%, 0%, and 0%, respectively). Health risks were evident for women in the TK group between the ages of 45–69 years, as their longer residence period around the hotspot means they also had a longer exposure to AO/dioxin and thus experienced all five types of complications, whereas women aged 18–44 years in this group only encountered one type of complication (preterm birth). In the same age group of 45–69 years, the ST group lived far from the airport, so they only encountered two types of complications (premature birth and stillbirth). In particular, the rate of premature birth in the TK group for each age group (6.45% and 3.64%) was significantly higher ($p < 0.05$) than in the ST group (0% and 1.65%). The distribution of people's age and residence period of the two groups were similar, consistent with the selection criteria and prioritizing survey of individuals with a long, stable residence period in two areas TK and ST to eliminate the confounding factor of time. Residents aged 45–69 years were most frequent in both groups (TK group, 79.60% ; ST group, 68.75%) (Table 1). The majority of residents resided in the area for more than 15 years (TK group, 89.30%; ST group, 90.75%) (Table 1). As such, these people had settled down, had long-term exposure to AO/dioxin, and bore many health risks due to daily exposure to the surroundings of the hotspot,[3] and local high-risk air and food use.[6,7] In this study, women were prioritized for interviews in both groups (Table 1), because women were representative of reproductive health and could answer extensively about diseases and illnesses of family members; therefore,

they accounted for the majority of participants (TK group, 70.15%; ST group, 67.50%). Women also often did housework, so they spent more time working at home in each group. Women also worked in jobs with low exposure to toxic elements related to industrial and residential activities. Women were also less likely to drink alcohol/beer and smoke tobacco than men; therefore, this study limited confounding factors and

Table 5. Disease pattern in age groups 45–69 and 18–44 years.

Diseases	TK group (*n* = 402)				ST group (*n* = 400)				*p*
	45–69 years of age (*n* = 320)	Rate (%)	18–44 years of age (*n* = 82)	Rate (%)	45–69 years of age (*n* = 275)	Rate (%)	18–44 years of age (*n* = 125)	Rate (%)	
Hypertension	131	40.94	4	4.88	72	26.18	4	3.20	
Stomach	83	25.9	13	15.85	40	14.55	14	11.20	
Joints	148	46.25	14	17.07	72	26.18	7	5.60	< 0.05
Ear/nose/throat	36	11.25	9	10.98	5	1.82	1	0.80	
Liver and gallbladder	24	7.50	2	2.44	9	3.27	4	3.20	> 0.05
Kidney, urinary system	28	8.75	1	1.22	2	0.73	1	0.80	
Eyes	21	6.56	4	4.88	8	2.91	2	1.60	< 0.05
Diabetes mellitus	35	10.94	1	1.22	23	8.36	1	0.80	
Hypotension	4	1.25	8	9.76	7	2.55	3	2.40	
Heart	26	8.13	1	1.22	14	5.09	2	1.60	
Lung	8	2.50	3	3.66	6	2.18	0	0.00	> 0.05
Pancreas, thyroid, adrenal glands	9	2.81	1	1.22	4	1.45	4	3.20	
Nervous system	33	10.31	2	2.44	24	8.73	8	6.40	

Table 6. Comparison of disease rates between men and women aged 18–69 years.

Diseases	TK group (*n* = 402)				ST group (*n* = 400)				*p*
	Men (*n* = 120)	Rate (%)	Women (*n* = 282)	Rate (%)	Men (*n* = 130)	Rate (%)	Women (*n* = 270)	Rate (%)	
Hypertension	49	40.83	86	30.50	27	20.77	49	18.15	
Stomach	19	15.83	76	26.95	11	8.46	43	15.93	
Joints	38	31.67	124	43.97	15	11.54	64	23.70	< 0.05
Eae/nose/throat	9	7.50	36	12.77	4	3.08	2	0.74	

Liver and gallbladder	10	8.33	16	5.67	3	2.31	10	3.70	
Kidney, urinary system	12	10.00	16	5.67	0	0	3	1.11	
Eyes	11	9.17	14	4.96	4	3.08	6	2.22	
Diabetes mellitus	7	5.83	29	10.28	11	8.46	13	4.81	
Hypotension	2	1.67	10	3.55	2	1.54	8	2.96	
Heart	12	10.00	15	5.32	5	3.85	11	4.07	
Lung	9	7.50	2	0.71	4	3.08	2	0.74	> 0.05
Pancreas, thyroid, adrenal glands	3	2.50	7	2.48	2	1.54	6	2.22	
Nervous system	3	2.50	32	11.35	6	4.62	26	9.63	

Table 7. Comparison of disease rates between men and women aged 45–69 years

Diseases	**TK group (*n* = 320)**				**ST group (*n* = 285)**				***p***
	Men (*n* = 100)	**Rate (%)**	**Women (*n* = 220)**	**Rate (%)**	**Men (*n* = 93)**	**Rate (%)**	**Women (*n* = 182)**	**Rate (%)**	
Hypertension	47	47.00	84	38.18	25	26.88	47	25.82	
Stomach	17	17.00	65	29.55	8	8.60	32	17.58	< 0.05
Joints	34	34.00	114	51.82	13	13.98	59	32.42	
Ear/nose/throat	7	7.00	29	13.18	3	3.23	2	1.10	> 0.05
Liver and gallbladder	9	9.00	15	6.82	1	1.08	8	4.40	
Kidney, urinary system	12	12.00	15	6.82	0	0	2	1.10	< 0.05
Eyes	9	9.00	12	5.45	4	4.30	4	2.20	
Diabetes mellitus	7	7.00	28	12.73	10	10.75	13	7.14	
Hypotension	1	1.00	3	1.36	1	1.08	6	3.30	
Heart	11	11.00	15	6.82	4	4.30	10	5.49	
Lung	8	8.00	0	0.00	4	4.30	2	1.10	> 0.05
Pancreas, thyroid, adrenal glands	2	2.00	7	3.18	1	1.08	3	1.65	
Nervous system	3	3.00	30	13.64	5	5.38	19	10.44	

. excluded health risks, not due to dioxin exposure. Exposure to risk

factors for diseases such as foodstuffs, waste treatment, waste incineration, pesticides, chemical fertilizers, cement, metallurgy, rubber and wood processing may also increase the risks of diseases.[15] Table 2 shows that the proportion of people exposed to toxic factors not related to dioxin in both TK and ST groups was very low at 0–0.75%; therefore, in the assessment of results, interference from industrial and residential activities can be excluded. The proportion of people who had been directly and indirectly exposed to AO/dioxin during the war and from the storage at Da Nang airport of the TK group was 3.48% and 9.45%, respectively, which was higher than that of the ST group (0% and 1.75% respectively) (Table 2). But the greatest health risk and highest risk of AO/dioxin exposure was in people in the TK group due to their frequent and long-term residence around former hotspot locations. This was the main cause of the difference in disease patterns between the TK and ST groups. There were approximately 13.7% of households in the TK group that were self-sufficient, growing vegetables, and raising fish and poultry around the airport and using it as food, which was the cause of food poisoning with a rate of 13.7% and higher than that of the ST group (Table 3). This shows that the risk of AO/dioxin exposure and health risks in the TK group were present and that people in the TK group suffered from many diseases at a higher rate than in the ST group. This is also consistent with previous results.[8]

Table 8. Comparison of disease rates between men and women in the age group 18–44 years.

Diseases	TK group (n = 82)				ST group (n = 125)				p
	Men (n = 20)	Rate (%)	Women (n = 62)	Rate (%)	Men (n = 37)	Rate (%)	Women (n = 88)	Rate (%)	
Hypertension	2	10.00	2	3.23	2	5.41	2	2.27	
Stomach	2	10.00	11	17.74	3	8.11	11	12.50	< 0.05
Joints	4	20.00	10	16.13	2	5.41	5	5.68	
Ear/nose/throat	2	10.00	7	11.29	1	2.70	0	0	
Liver and gallbladder	1	5.00	1	1.61	2	5.41	2	2.27	
Kidney, urinary system	0	0	1	1.61	0	0	1	1.14	> 0.05
Eyes	2	10.00	2	3.23	0	0	2	2.27	
Diabetes mellitus	0	0	1	1.61	1	2.70	0	0	
Hypotension	1	5.00	7	11.29	1	2.70	2	2.27	< 0.05
Heart	1	5.00	0	0	1	2.70	1	1.14	
Lung	1	5.00	2	3.23	0	0	0	0	> 0.05
Pancreas, thyroid, adrenal glands	1	5.00	0	0	1	2.70	3	3.41	
Nervous system	0	0	2	3.23	1	2.70	7	7.95	

Previous studies have shown that disease properties are related to sex and age.[16,17] This study investigated and compared the disease pattern according to age and sex of both TK and ST groups, focusing on the diseases related to a number of systems and organs in the body that are sensitive to AO/dioxin. Dioxin exposure damages a number of organ systems in the human body, such as the liver, nervous system, immune system, hormones, respiratory system, and lungs.[11] Tables 4–7 indicate that dioxin exposure by residents near the hotspot increased the prevalence of multiple diseases. The prevalence of diseases in the TK group aged 18–69 years was 1.1–9.6-times higher than that of the ST group (Table 4); those aged 45–69 years were 1.1–12-times higher than the ST group (Table 5). Between the ages of 18–44 years, the prevalence of hypertension/hypotension and diabetes as well as diseases of the stomach, joints, ENT system kidney–urinary system, and eyes was 1.4–13.7-times higher in the TK group than in the ST group. The disease pattern depends on sex, but dioxin exposure due to residence near the hotspot was still the main factor in creating the difference in disease pattern between the TK and ST groups (Table 6). Health risks and disease risks were higher for both sexes in the TK group. Women in the TK group had a 1.1–17.3-times higher rate of all diseases than in the ST group, and for men, this was 1.1–3.6-times higher (except for diabetes and diseases of the nervous system). Compared with the ST group by the two age groups in Tables 7 and 8, it was found that the prevalence of most diseases in men in the TK group was 1.7–8.4-times higher in the age group 45–69 years and 1.2–3.7-times higher in the age group of 18–44 years; the rates in women of the TK group were 1.2–12-times higher and 1.4–5-times higher in the two age groups, respectively. The dioxin concentrations in breast milk collected between 2008 and 2009 from mothers in the TK group

were high and ranged 12.8–14.3 pg TEQ/g lipid.[9] Dioxin exposure from the milk of mothers living near the Da Nang hotspot in the TK group had a negative impact on the physical, nervous system, cognitive, language, autistic traits, and motor development of their children.[18] The results of this study on the effects of AO/dioxin on reproductive health also noted the state of reproductive complications in women as well as the risk of birth defects in young children; [14] however, no difference was found in the mean age of puberty and the proportion of women with menstrual disorders. Table 10 shows that women in the TK group residing around Da Nang airport were at risk of a higher number and a higher rate of reproductive complications than the ST group, who resided far from the airport. In the TK group, women aged 45–69 years had a longer exposure to AO/dioxin than women aged 18–44 years, so they suffered many reproductive complications, such as dead malformed birth, living malformed birth, stillbirth, and postnatal death. Also, women between the ages of 45–69 years had children born with delayed physical development and mental retardation.[19]

Table 9. Rates of women with menstrual disorders and risks of birth defects.

Menstrual disorders and risks of birth defects		TK group (aged 18–69, *n* = 282)				ST group (aged 18–69, n = 270)				*p*
		Aged 18–44 (*n* = 62)		Aged 45–69 (*n* = 220)		Aged 18–44 (*n* = 88)		Aged 45–69 (*n* = 182)		
		Rate (%)	Number	Rate (%)	Number	Rate (%)	Number	Rate (%)	Number	
Menstrual disorders		9.68	6	11.82	26	14.77	13	9.89	18	
Risks	Delayed physical development	0	0	0.45	1	0	0	0	0	> 0.05
	Mental retardation	0	0	1.82	4	0	0	2.20	4	

Table 10 Rates of reproductive complications

Complications	TK group (*n* = 282)				ST group (*n* = 270)				*p*
	Aged 18–44 (*n* = 62)		Aged 45–69 (*n* = 220)		Aged 18–44 (*n* = 88)		Aged 45–69 (n = 182)		
	Rate (%)	Number	Rate (%)	Number	Rate (%)	Number	Rate (%)	Number	
Premature birth	6.45	4	3.64	8	0	0	3	1.65	< 0.05
Hydatidiform mole	0	0	0	0	0	0	0	0	
Hydatidiform mole with complications	0	0	0	0	0	0	0	0	
Dead malformed birth	0	0	0.45	1	0	0	0	0	> 0.05
Living malformed birth	0	0	1.36	3	1	1.14	0	0	
Stillbirth	0	0	0.45	1	0	0	1	0	
Postnatal death	0	0	0.45	1	0	0	0	0	

Conclusion

The TK group was exposed to many health risks due to their residence near areas that were formerly AO/dioxin hotspots within Da Nang airport. The diseases identified by WHO as related to AO/dioxin exposure accounted for a higher proportion in the TK group than the ST group. The prevalence of diseases in the people in the two groups depended on the residence time, sex, and age, but the main factor determining the difference in disease pattern was the local AO/dioxin exposure. Exposure to AO/dioxin for 50 years at Da Nang airport was one of the causes affecting the disease pattern of people in the TK group as well as increasing the incidence of certain diseases and reproductive complications.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

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