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Research article

STRUCTURE OF SOME DISEASES AND HEALTH RISKS FOR PEOPLE RESIDING IN SURROUNDING AREAS PREVIOUSLY CONTAINED HERBICIDES/DIOXIN

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During the war in Vietnam from 1961–1971, the US military used and sprayed nearly 80 million liters of herbicides in South Vietnam. Bien Hoa, Da Nang, and Phu Cat airports are herbicides repositories and hot spots for dioxin residues. The aim of this study was to examine the structure of some diseases and health risks of 1039 subjects residing around Da Nang, Bien Hoa, and Phu Cat airports (the ∑SG – study group) and 400 subjects residing in Son Tra district in Da Nang city – far from Da Nang airport (the ST – control group).

The analysis results show that the prevalence of some relevant diseases related to herbicides/dioxin in the ∑SG group has a high percentage such as hypertension: 23.0–33.6 % (mean: 29.6 %), diabetes: 3.50–13.0 % (mean: 9.62 %) and other diseases: stomach: 23.6–37 % (mean: 26.3 %), joints: 34.6–40.3 % (mean: 37.8 %), ear-nose and throat: 9.5–17.4 % (mean: 15.5 %), kidney-urinary system: 4.5–7.2 % (mean: 6 %). These values were 1.5 to 9 times higher in the ∑SG group than in the ST group. The subjects who resided and worked around airports had elevated risks of the foregoing diseases. The structure of these diseases in both the ∑SG and the ST groups depends on sex and age, but the decisive factor depends on herbicides/dioxin exposure status. Thus, exposure to herbicides/dioxin has changed the disease pattern and increased some aspects of disease in people residing near areas where herbicides/dioxin was previously stored.

Keywords: *herbicides, dioxin, hot spot, diseases, health risks, Da Nang, Bien Hoa, Phu Cat.*

During the war in Vietnam from 1961 to 1971, the US military used and sprayed nearly 80 million liters of herbicides including agent orange, agent white, agent green, agent pink, agent purple, agent green, etc. Among herbicides, Agent Orange was used most frequently (61 %) containing approximately 366 kg of dioxin [1, 2]. Herbicides were sprayed on an area of about 2.63 million hectares, accounting for 15.2 % of the entire area of Southern Vietnam. Bien Hoa, Da Nang, and Phu Cat airports were hosted by the US military for herbicides during the Vietnam War and were dioxin hot spots [3]. Agent Orange/dioxin causes diverse and complex damage to all parts of the human body such as cancer, damage to the skin, liver, thyroid, diabetes, and hypertension; affects the respiratory system, circulatory system, digestive system, endocrine system, and nervous system; induces mutations in genes and chromosomes, thereby causing birth defects and reproductive complications [4, 5].

Residents around Bien Hoa, Da Nang, and Phu Cat airports are at risk of dioxin exposure [3, 6]. Articles by M. Nishijo et al. [7] show that the dioxin concentration in milk of mothers residing in Thanh Khe and Son Tra in Da Nang city ranges within 3.73–72.3 pg toxic equivalent (TEQ)/g lipid and the average is 14.2 pg TEQ/g lipid. Dioxin concentrations in breast milk in areas where herbicides were stored, sprayed, and exposed to dioxin were

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higher than in non-exposed areas [8–10]. Average TEQ in milk of mothers residing near hot spots (Phu Cat, Thanh Khe, and Son Tra, 2008–2009), in sprayed areas (Cam Lo in Quang Tri province, 2002–2003), and in areas not sprayed (Cam Xuyen in Ha Tinh province, 2002–2003, and Kim Bang in Ha Nam province, 2008) were 14.1, 10.9 and 4.09 pg/g lipid, respectively, for first-borns and 11.5, 7.56 and 2.84 pg/g lipids for those giving birth to two or more children [11].

T.T. Tuyet-Hanh et al. [12] have estimated the average daily dose (ADD) values of dioxin through locally produced foods in Thanh Khe district in Da Nang city from 27.0 to 148 pg TEQ/kg BW/day, which is many times higher than the tolerable daily intake (TDI) level for dioxin (from 1 to 4 pg TEQ/kg BW/day) recommended by WHO [13]. Health risk assessment due to exposure to dioxin in ambient air for people residing around Da Nang airport and workers working in the dioxin treatment process at hot spots in the years 2013–2017 has shown the ADD values through inhalation in the area northeast of the airport were in the range of 0.007–0.052 pg TEQ/kg BW/day. In the north of the airport, ADD values reached 0.006–0.129 pg TEQ/kg BW/day. In the former Agent Orange mixing and loading area in Da Nang airport, the average ADD values were up to 0.16–0.21 pg TEQ/kg BW/day. It is worth noting that the maximum exposure level of up to 0.61–0.82 pg TEQ/kg BW/day is higher than 10 % of the TDI value (0.1–0.4 pg TEQ/kg BW/day) through inhalation [14].

The aim of this study is to investigate the structure of incidence and health risks of people residing around Da Nang, Bien Hoa, and Phu Cat airports (hereinafter referred to as the total study group – ∑SG) and residents in the Son Tra district – far from Da Nang airport (hereinafter referred to as the Son Tra control group – ST).

Materials and methods. The ∑SG group is made of people residing in three areas: Bien Hoa (BH), Thanh Khe-Da Nang (TK), and Phu Cat (PC) with a total of 1,039 persons currently residing around Bien Hoa Hoa, Da Nang, and Phu Cat airports and near sites where the US military previously stored herbicides/dioxin. The ST group includes 400 persons residing in Son Tra district, Da Nang city.

Research subjects were selected by household, representing each residential area, with a residence period of over five years. People selected to be interviewed were between the ages of 18 and 69 years. Women were given priority in the survey because they are the subject of reproductive health, and they can provide comprehensive answers about diseases of family members.

Location and time of the study:

– The BH area was surveyed in four wards: Tan Phong, Trung Dung, Quang Vinh, and Buu Long of Bien Hoa City, in July 2020;

– The TK area was surveyed in four wards: Hoa Khe, An Khe, Chinh Gian, and Thac Gian of Thanh Khe district, in March 2021;

– The PC area was surveyed in two wards: Cat Tan of Phu Cat district and Nhon Thanh of An Nhon town, Binh Dinh province, in April 2022;

– The ST area was surveyed in three wards: An Hai Dong, An Hai Tay, and Phuoc My of Son Tra district, in October 2021.

Research design. This study is cross-sectional, descriptive, and biomedical (current risk of dioxin exposure, health status, and some diseases and illnesses that may be related to dioxin exposure are assessed through questionnaires, face-to-face interviews). Conventional statistical methods were applied for data analysis.

A questionnaire of 85 questions was employed to collect general information, data on current health status, medical history, obstetric history, exposure to war toxins, food use, and risk factors that may be related to herbicides/dioxin exposure.

Data were analysed using Excel software and statistical analysis by IBM SPSS Statistics 20 software according to biomedical statistical methods. The results are presented as: mean (X), standard deviation (SD), percentage (%), and $p < 0.05$.

Figure 1 shows that residents aged 45–69 are similar and account for a high proportion

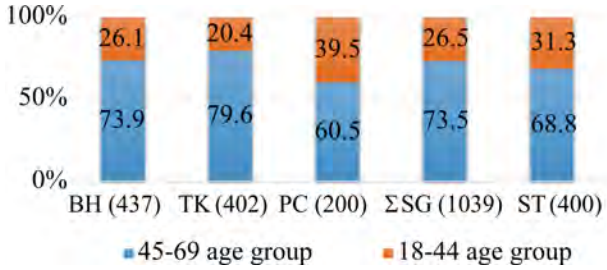

Figure 1. Age distribution (% contribution) of survey subjects

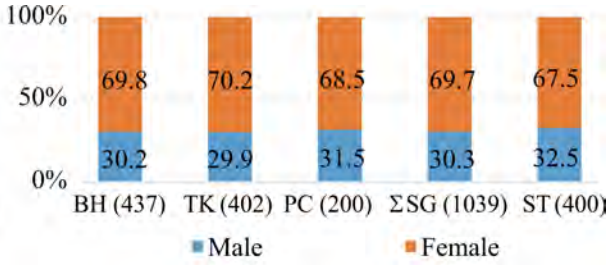

Figure 2. Sex distribution (% contribution) of surveyed subjects

of both ∑SG and ST groups (∑SG: 73.5 % and ST: 68.8 %), which is consistent with the criteria of selection standard. The proportion of subjects in the same age group (45–69 years or 18–44 years) did not have a statistically significant difference between the study groups. In addition, the average age of the ∑SG group (51.95 ± 11.58 years) and ST group (50.47 ± ± 12.21 years) is also similar and there is no statistically significant difference. Thus, the age distribution ensures similarity between the ∑SG and the ST groups.

According to the criteria for selecting research subjects, the sex ratio in Figure 2 is appropriate because females were given priority in the survey; hence, they accounted for a higher proportion than males. The proportion of females in each group (67.5–69.8 %) is statistically significantly higher than the proportion of males (30.2–32.5 %) with $p = 0.000$. There are similarities in the proportion of females in ∑SG and ST groups (∑SG: 69.7 %, ST: 67.5 %).

Previous studies have shown that some diseases are sex-related and age-related [15–17]. This study has surveyed and compared the structure of incidence by sex and age of both NC and ST groups, focusing on diseases related to several systems and organs in the human body that are affected by herbicides/dioxin such as the liver, nervous system, immune system, hormones, respiratory system and lungs, etc. [5, 18].

Hypertension and type 2 diabetes are key diseases caused by dioxin exposure as recommended by the National Academies of Sciences, Engineering, and Medicine, 2018.

Results and discussion. The analysis results in Figure 3 show that the proportion of diseases such as hypertension, stomach disease, joint diseases, ear-nose and throat (ENT), and other diseases (psoriasis, blood lipids, etc) account for a high proportion, and are almost statistically significantly higher compared to the remaining diseases. The rates of most diseases (except pancreas-thyroid-adrenal) in ∑SG were statistically significantly higher than in the ST group.

Figure 3 shows that the ∑SG group has a hypertension rate of 23.0–33.6 % (mean: 29.6 %) and diabetes: 3.50–13.0 % (average 9.62 %). The average rate of hypertension is 1.57 times higher and diabetes is 2.35 times higher than the rate in Vietnam (18.9 % and 4.1 %, respectively) [19]. In particular, all three study groups BH, TK, and PC have higher rates of hypertension and diabetes than the ST group (19 % and 6.0 %, respectively). The incidence of all diseases in the ∑SG group aged 18–69 years is 1.1–17.3 times higher than in the ST group. Thus, the results of this study show people's health risks due to exposure to herbicides/dioxin and/or residing and working near areas heavily contaminated with herbicides/dioxin.

Figure 4 shows that the rate of diabetes: 4.96–16.4 % (average: 12.3 %), hypertension: 28,9–40.9 % (average: 37.3 %), stomach: 25.1–38.8 % (average: 27.6 %), joints: 39.9–52.1 % (mean: 44.5 %), ENT: 7.44–16.7 % (mean: 13.0 %) and other diseases: 13.2–22.8 % (mean: 18.2 %) were all statistically significant higher in the ∑SG group aged 45–69 years compared to the ST group (8.36 %, 26.2 %, 14.6 %, 26.2 %, 1.82 %, and 1.09 %, respectively). The rate of these diseases in the age group 45–69 years in the ∑SG group is 1.4–16.7 times higher than in the ST group.

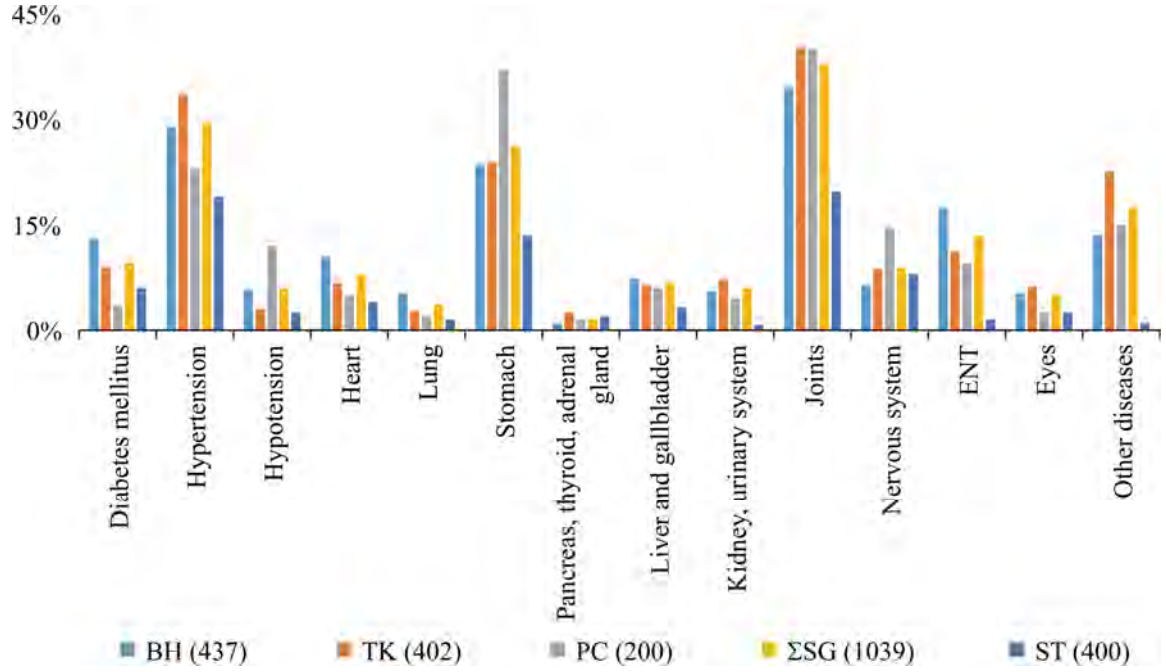

Figure 3. Incidence structure (% contribution) for all the groups

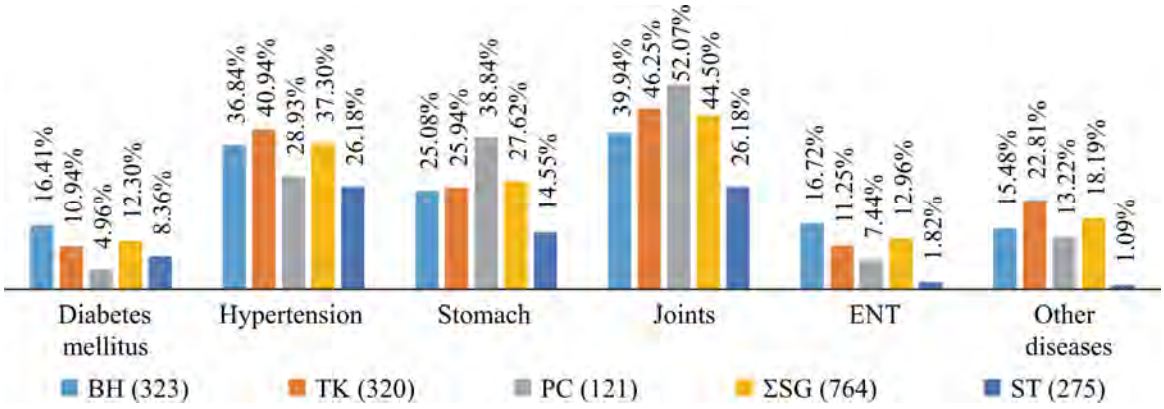

Figure 4. The incidence structure in the age 45–69 group

The incidence structure in the group aged 18–44 years in Figure 5 shows that the ∑SG group has a rate of diabetes: 1.22–3.51 % (mean: 2.18 %), hypertension: 4.88–13.9 % (mean: 8.0 %), stomach: 15.9–34.2 % (mean: 22.6 %), joints: 17.1–21.5 % (mean: 19.3 %), ENT: 11.0–19.3 % (mean: 14.9 %) and other diseases: 7.89–22.0 % (average: 14.9 %) that are all statistically significance higher than in the ST group (0.80 %, 3.20 %, 11.2 %, 5.60 %, 0.80 % and 0, 80 %, respectively). The rates of hypertension, stomach, joints, ENT, kidney-urinary system, eyes, and diabetes in the ∑SG group were 2.7–18.6 times higher than in the ST group.

Figure 6 shows that the prevalence of diabetes and hypertension that is higher in the group aged 45–69 years of the ∑SG group (12.3 % and 37.3 %, respectively) and the ST group (8.36 % and 26.2 %, respectively) than the rate in Vietnam in 2015 (4.1 % and 20.3 %, respectively) [19]. In contrast, the rate was lower for the group aged 18–44years, the ∑SG group (2.18 % and 8.0 %, respectively) and the ST group (0.8 % and 3.2 %, respectively) than the total Vietnam's rate. Thus, the results in Figures 3, 4, and 5 establish that the group aged 45–69 years with longer exposure to dioxin has an increased risk of diabetes and hypertension compared to groups aged 18–44 years.

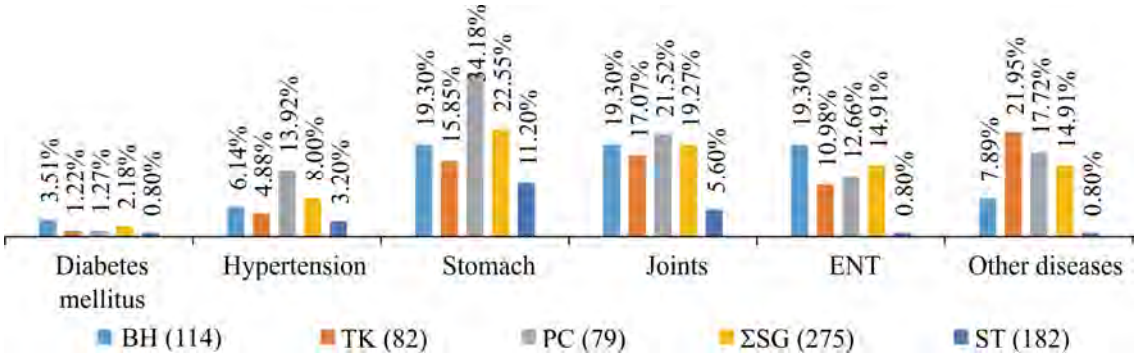

Figure 5. Incidence structure in the group aged 18–44 years

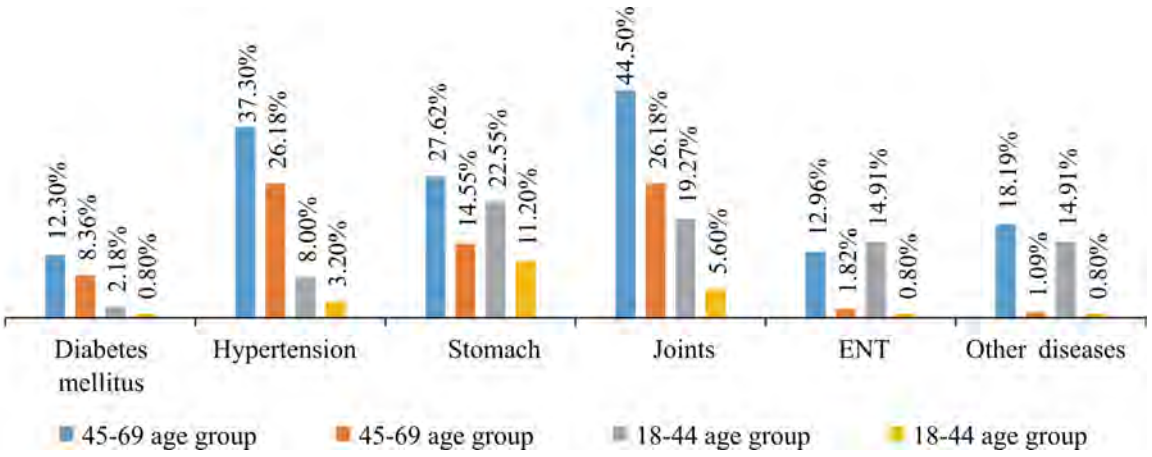

Figure 6. Comparative assessment of incidence structure in groups aged 18–44 and 45–69 years

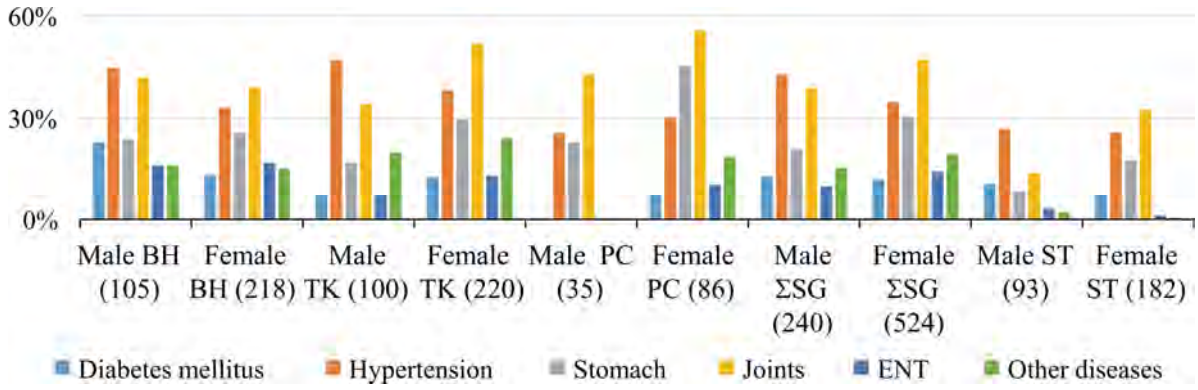

Figure 7. Comparative assessment of disease rates between males and females aged 45–69 years

The subjects in both ∑SG and ST group have diabetes, hypertension, and joint disease rates that were higher in the older group, and among those who lived closer to dioxin-contaminated areas. Specifically, the lowest rate of three diseases: diabetes – hypertension – and joints at the age of 18–44 years is for the ST group (only 0.8 % – 3.2 % – 5.6 %, respectively); then it increases 2.73 times – 2.50 times – 3.44 times at the same age group in ∑SG group (2.18 % – 8.0 % – 19.3 %, respectively); continues to increase 3.83 times, 3.27 times, 1.36 times at the group aged 45–69 years in ST group (8.36 % – 26.2 % – 26.2 %, respectively) and increases highest 1.47 times – 1.42 times – 1.70 times in group aged 45–69 years in ∑SG group (12.3 % – 37.3 % – 44.5 %, respectively).

Figure 7 shows that the ∑SG and the ST groups have similar characteristics as follows: in the same group, the proportion of males with the diseases of diabetes (12.9 % and 10.8 %) and

hypertension (42.9 % and 26.9 %) was higher than that of females in the same group (diabetes: 12.0 % and 7.14 %, hypertension: 34.7 % and 25.8 %, respectively). In contrast, females in both the ∑SG and ST groups had higher rates of the following diseases: stomach (30.5 % and 17.6 %) and joints (47.1 % and 32.4 %) compared to males (stomach: 20.8 %, 8.6 %; joints: 38.8 %, 14 %, respectively). Figure 7 also shows that six diseases in both males and females in the ∑SG group have higher rates than the ST group from 1.2 to 7.17 times for males and 1.34–35.4 times for females.

Figure 8 shows that both male and female aged 18–44 years in the ∑SG group have a higher rate of six typical diseases (diabetes: 5.48 % and 0.99 %, hypertension: 11 % and 6.93 %, stomach: 23.3 % and 22.3 %, joints: 16.4 % and 14.9 %, ENT: 15.1 % and 14.9 %, other diseases: 15.1 % and 14.9 %) than the ST group (diabetes: 2.7 % and 0 %, hypertension: 5.41 % and 2.27 %, stomach: 8,11 % and 12.5 %, joints: 5.41 % and 5.68 %, ENT: 2.7 % and 0 %, other diseases: 0 % and 1.14 %), from 2.03 to 5.58 times for males and 1.78–13.1 times for females.

In the ∑SG group, males aged 18–44 years had a higher incidence of these six diseases than females, from 1.01 to 5.53 times. In the ST group, the results were similar to those aged 45–69 years, proportions of males with diabetes (2.7 %), and hypertension (5.41 %) were higher than those of females (0 % and 2,27 %, respectively); proportions of males with stomach (8.11 %), and joints (5.41 %) issues were lower than those of females (12.5 % and 5.68 %, respectively).

Thus, the statistical analysis in Figures 7 and 8 shows that exposure to herbicides/dioxin due to residing and/or working around three airports of Bien Hoa, Da Nang, and Phu Cat was the main factor causing a higher risk of disease in the ∑SG groups.

To further clarify the impact of dioxin exposure on the incidence structure of the study groups, people exposed to herbicides/dioxin were separated into groups exposed to dioxin (dioxin exposure – DE group) and those not exposed to dioxin who were classified as dioxin non-exposure (DNE group). In addition, the DE group is mainly in the group aged 45–69 years, so people aged 45–69 years in the DNE group are also separated into the group DNE aged 45–69 years. These subgroups are compared in Table.

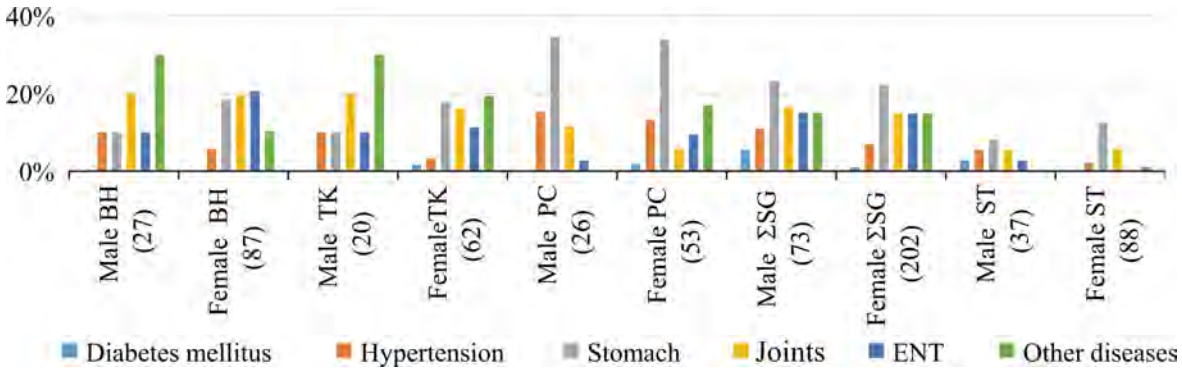

Figure 8. Comparative assessment of disease rates between males and females aged 18–44 years

Table

Disease structure according to dioxin exposure factors

Diseases	DE		DNE		DNE aged 45–69	
	∑SG (92)	ST (7)	∑SG (947)	ST (393)	∑SG (682)	ST (269)
Diabetes mellitus	22.8 %	42.9 %	8.34 %	5.34 %	10.7 %	7.43 %
Hypertension	48.9 %	42.9 %	27. 7 %	18.6 %	34.8 %	25.7 %
Stomach	27.2 %	42.9 %	26.2 %	13 %	27.4 %	13.8 %
Joints	59.8 %	57.1 %	35.7 %	19.1 %	41.2 %	25.3 %
Eyes	14.1 %	0 %	13.4 %	1.53 %	12.8 %	1.86 %
Other diseases	20.7 %	14.3 %	17.0 %	0.76 %	17.7 %	0.74 %

Table shows clear influence on health risks upon exposure to dioxin. Two diseases, namely, diabetes and hypertension are recommended by the National Academies of Sciences [20] to be related to Agent Orange/dioxin; and three diseases of stomach, joints, and other diseases all accounted for a statistically significant higher rate ($p < 0.05$) in the DE group than the DNE group and the DNE aged 45–69 years in both ∑SG and ST groups. For ENT diseases, there were no significant differences between the DE group and the DNE group.

In the ∑SG group, the rate of diabetes, hypertension, and joint diseases is from 1.67 to 2.74 times higher in the DE group than in the DNE group and is also higher by 1.45 to 2.13 times compared to the DNE group aged 45–69 years.

Similar comparisons in the ST group found that the rate of all six disease aspects was from 2.31–18.7 times higher in the DE group than in the DNE group, and was also higher than 1.67–19.2 times compared to the DNE group aged 45–69 years. Thus, exposure to herbicides/dioxin increased the rate of all diseases in the DE group.

To further clarify the impact of time spent living near areas previously containing herbicides/dioxin in the three airports of Da Nang, Bien Hoa, and Phu Cat, the subjects were again divided into three groups corresponding to three 20-year segments including 5–25 years, 25–45 years, and over 45 years.

Figure 9 shows that in all subgroups, the rates of all six diseases of ∑SG are statistically significantly higher than the ST group. Specifically, in the 5–25 year subgroup, it is higher by 2.0–23.5 times; in the 25–45 year subgroup, it is higher by 1.63–21.3 times; and in the subgroup over 45 years, it is higher by 1.14–11.9 times.

In the ∑SG group, the rate of three diseases of hypertension, stomach, and joint in the 25–45 year subgroup was 1.09–1.27 times higher compared to the 5–25 year subgroup; and it was higher by 1.23–1.79 times in the subgroup over 45 years.

Figure 10 shows that the rates of all six diseases in the ∑SG group are statistically

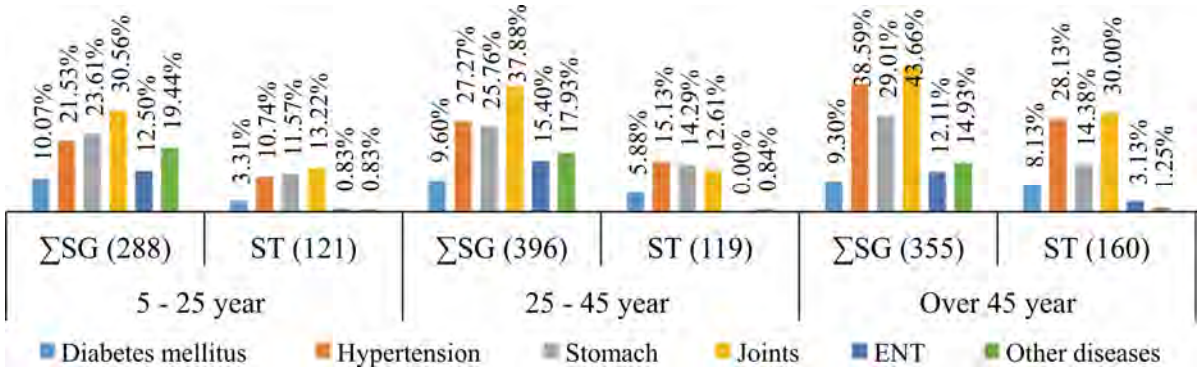

Figure 9. The incidence structure according to 20-year subgroups

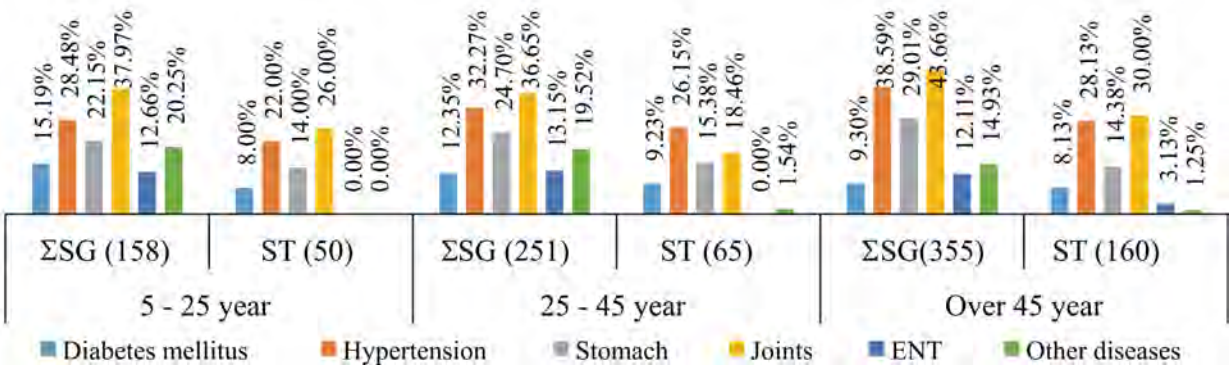

Figure 10. Incidence structure in the group aged 45–69 years according to 20-year subgroups

significantly higher than in the ST group. Specifically, in the 5–25-year subgroup, these rates are higher by 1.29–1.90 times; in the 25–45-year subgroup, by 1.23–12.7 times; and in the over 45-year subgroup, by 1.14–11.9 times. In the ∑SG group, the rates of hypertension, stomach, and joints are higher by 1.13 times in the 25–45-year subgroup and by 1.15–1.35 times in the over 45 year subgroup compared to the 5–25-year subgroup.

Conclusions. The rates of diseases in both the ∑SG group as well as in the two ages 18–44 years and 45–69 years were higher than in the ST group. In the study areas, the incidence of diabetes, hypertension, musculoskeletal, gastrointestinal, and ENT diseases is higher than other diseases.

The rate of six diseases in people who have been exposed to Agent Orange/dioxin is 1.1–2.7 times higher than in people who have not been exposed in the ∑SG group and is higher by 2.3–18,7 times than in the ST group.

The longer time of residence and work around three airports, the higher the risk of disease: the rate of diseases in the ∑SG group with a residence time of 25–45 years is higher from 1.1 to 1.3 times, and over 45 years is 1.2 to 1.8 times higher than the residence time of 5–25 years. During each period, the rate of diseases in the ∑SG group was 2.0 to 23.5 times higher than the ST group for the 5–25-year subgroup, from 1.6 to 21.3 times in the 25–45-year subgroup, and from 1.1 to 11.9 times in the subgroup over 45-years.

The incidence among people in the ∑SG and ST groups depends on the length of residence, sex, and age. However, the main factor determining the difference in disease structure is herbicides/dioxin exposure in a residence area. Exposure to herbicides/dioxin remaining in three airports for 50 years is one of the causes affecting the incidence structure of people in the ∑SG group as well as increasing the rate of some diseases.

Ethics approval and consent to participate. This study has been approved by the Ethics Council in Biomedical Research of the Joint Vietnam-Russia Tropical Science and Technology Research Center (Code: 18/2020/VREC, Certificate of Approval No. 1987/CN-TTNDVN dated July 1, 2020) and supervised during implementation.

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Consent to participate. All authors have read, approved, and accept responsibility for the manuscript.

Conflicts of interest. The authors declare no potential conflicts of interest concerning the research, authorship and/or publication of this article.

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