The Okinawa Study: Effects of Chronic Aircraft Noise Exposure on Daily Lives and the Health of Residents near the U.S. Bases.

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1. Introduction

In accordance with the Treaty of Mutual Co-operation and Security between Japan and the United States of America (Treaty No. 6 of 1960), and the Agreement under ARTICLE VI of the Treaty of Mutual Co-operation and Security between Japan and the United States of America, Regarding Facilities and Areas and the Status of United States Armed Forces in Japan (Treaty No. 7 of 1960), Kadena Air Base and Futenma Air Station are provided to the U.S. Forces as the "Facilities and Areas" for aircraft service and other such activities in addition to operating and managing the bases.

The negative impact of military activities on surrounding communities of the U.S. bases and facilities is extensive among which the chronic aircraft noise exposure around Kadena Air Base and Futenma Air Station situated in the midst of cities has caused serious disturbance to local residents due to incessant jet noise and helicopters as well as frequent engine tunings. Extremely intense aircraft noise occasionally exceeding 120 dB occurs in the area of the residences below the flight path of the U.S. Forces' aircraft that land and take off on the runways of the bases. In the air space over Kadena Air Base, touch-and-go flights and manoeuvres by the U.S. military aircraft have been conducted regularly as well as frequent engine tunings. At Futenma Air Station, individuals residing around the airfield have been exposed to intense noise generated by landings and departures during flight exercise and helicopter flight manoeuvres conducted in the air space over the base as well as over the surrounding residential areas.

The aircraft noise around the airfields in Okinawa had been recognized so tremendous that the noise has often been expressed "murderous" or "lethal" and that it has also been said that the residents suffer from various kinds of damages due to the noise exposure. In fact among scientists are accepted that noise does not only interfere with speech/conversation and sleep but also disrupts classes, jams TV/radio broadcasts, and is considered to cause physical and mental strains such as loss of hearing, fatigue and neurosis. The number of individuals affected by the aircraft noise exceeding the environmental standard for aircraft noise set by the Environment Agency, Japan, in 11 municipalities in Okinawa is estimated to be about 480,000, 38% of the prefectural population. However, there had not been comprehensive surveys undertaken on the effects of the aircraft noise in Okinawa.

Under the circumstance, the prefectural government undertook a study survey on the state of noise exposure and the possibly adverse effects of noise on the health of residents near Kadena and Futenma airfields from 1995 to1999 under the supervision of the Research Study Committee of Aircraft Noise Influences to Health which consisted of 18 medical scientists, environmental engineers, medical doctors and epidemiologists.

2. An overview of Okinawa and the U.S. bases

Okinawa Prefecture is one of the smallest in Japan, 44th in area and 35th in population among 47 prefectures. The total land area of Okinawa consisting of 160 islands, among which about 50 are inhabited islands, is only about 0.6% of the land area of Japan and Okinawa is made up of 1.25 million individuals, 1.1% of the Japanese population. The population density is 9th after metropolitan areas such as Tokyo, Osaka, Nagoya and some others. The biggest island in the prefecture is Okinawa Island, the land area of which is about a half of the prefecture land area and one third of which 1.14 million individuals reside in. Moreover, for the historical, geographical and military strategic reasons, there exist 39 facilities of the U.S. Forces as of March 1998 which account for about 75% in area of the U.S. Bases and Facilities in Japan, and, particularly in Okinawa Island, 20 % of the small island area is used by the U.S. Forces. This results in high population density in the residential district in Okinawa and that is the case for even the area in the nearest vicinity of bases.

During World War II, Okinawa was the land of Japan where the only and most tragic land war in Japanese history unfolded, and then non-combatant individuals were involved and about 160,000 Okinawans were killed in the war.

The U.S. Forces, after landing in Okinawa, occupied military bases the former Japanese Imperial Army had built. After the war, the U.S. Forces' administrative authorities governed over Okinawa and took in surrounding land of the bases with the background of military power and further expanded and strengthened the bases.

In the situation where there was no place or home for the residents to live in and the U.S. Forces interned them in concentration camps, the U.S. Forces took over one tract of land after another. When the residents were removed from the camps they found their land was in the bases. For example, the residents of Sunabe were released from the camp after one year or so, but part of their land was released after 10 years and the rest of their land is still within the fence of Kadena Base.

The sites of the both bases are on the fertile and flat land positioned in the heartland of Okinawa, and therefore, the place of residential and farm land owned and used by the residents until World War II. Kadena Air Base and Futenma Air Station were certainly built in the middle of highly cultivated part of the island. Thus Okinawa was transformed into an "island of bases."

The reversion of the administrative authority of Okinawa from the U.S. to Japan in 1972 did not change the situation basically.

An overview of Kadena Air Base:

Kadena Air Base is spreading over the three municipalities of Chatan Town, Kadena Town and Okinawa City. The Base has two runways with accompanying taxiways, tarmacs, engine tuning shops, hangars, and equipment as well as the headquarters, barracks, telecommunication facilities, homes, schools, clinics and other such facilities.
It was set up as "Central Airfield" in September 1944 by the former Japanese Imperial Army. In April 1945 the U.S. Forces that landed on the Okinawa Island occupied this airfield. Thereafter the base was reconstructed, expanded and became more functional through the requisition of immense amounts of surrounding private land etc. During the

Vietnam War in 1967 two runways were completed and the base played an important role for the bombers to make sorties and as a supply relay depot. From 1968 to 1970, B52 Stratofortress strategic bombers were stationed at the Base. In 1991, with the close of the Clark Base in the Philippines, the 353rd Special Operations Group and Air Transport C-12 aircraft were moved to Kadena Base. Presently, many aircraft such as F-15 Eagle fighters, KC-135 Tanker Transport, E3A Airborne Early Warning Aircraft, P-3C Orion Anti Submarine Warfare Aircraft, HC-130 Hercules rescue transports, and HH-3 rescue helicopters are in fact permanently stationed at Kadena Base.

An overview of Futenma Air Station:

Futenma Air Station was constructed immediately after the occupation of Okinawa by the U.S. Forces and is positioned in the centre of Ginowan City. In 1953 the runway was extended to 2,700m and now the base has a 2,800m × 46m runway. In 1960 the management of the base was transferred from the U.S. Air Force to the U.S. Marine Corps, and today Futenma is home to the Marine Aircraft Wing, 3rd Marine Expeditionary Force, which is prominent for helicopters. The base has many support facilities such as hangars, maintenance and repair facilities, storage facilities, a communication facility, parts warehouses, offices, PX, clubs, bars, health clinics, a .re station etc.

3. Noise exposure

3.1 Past noise exposure

A few measurements at the residential areas in the vicinity of Kadena Air Base in 1968 and 1972 during the Vietnam War are available to estimate the state of past noise exposure

The estimation of noise exposure based on the record tells WECPNL was around 105 which is by 5 to 15 higher than the WECPNL the Defense Facilities Administration Agency (DFAA) now designates, and *L*Aeq,24h came up to 85 dB which is as high as the permissible criteria for hearing conservation for eight working hours a day recommended by the Japan Society for Occupational Health. In 1977 the DFAA made noise measurement of an extensive scale around Kadena Air Base and Futenma Air Station. The maximum sound level recorded by the DFAA in 1972 was 127 dB at Yara and 124 dB at Sunabe, both in front of residences, while engine tuning was carried out. The values of the noise indices WECPNL and *L*Aeq calculated using the record in November are in the range of 97 to 109 and 77 to 89, respectively, which are extremely high.

3.2 Present noise exposure

Okinawa Prefectural Government set up a remote monitoring system for aircraft noise exposure surrounding three military and civil airfield, two U.S. military bases and one Japanese airport, which is used by both civil and military aviation. It has 19 observation stations as of April 1998, around the three airports.

The maximum value of WECPNL is as high as over 100 at a monitoring station located in a residential area in the vicinity of Kadena Air Base, and the differences between the maximum and the mean values are remarkable suggesting the daily noise exposure

varies one day after another. The maximum sound levels recorded are over 110 dB at 6 among 19 observation points. Even in the nighttime, they exceed 100 dB at 6 observation points. The maximum number of daily noise events occurred at the point where maximum WECPNL observed is over 500 and the maximum number of flights having occurred in the nighttime at the point is 58.

Judging from the analysis of the acquired data in the monitoring system of aircraft noise, it can be said that the state of noise exposure observed in the communities around the two military airfields are still high over the extended area in the middle part of Okinawa Island.

4. Community responses with respect to the effects on daily lives

A survey was conducted around Kadena Air Base and Futenma Air Station on the effect of aircraft noise on residents' daily activities and quality of life. The questionnaire consists of 98 questions asking about the neighborhood satisfaction, the regional and life environment, the base and aircraft noise, and sleep disorders. Respondents were randomly sampled, by a stratified sub-sampling method, from the areas with different levels of aircraft noise exposure expressed in WECPNL, from 75 to 95 or more, and from the area without noise exposure. The total sample size is 7,894 and the number of valid answers is 5,693.

The residents answer that the most disturbing time is basically daytime, but even in the midnight and very early in the morning over 40% of the population living in the areas of WECPNL of 90 and over 95 in the Kadena Air Base's surroundings complain disturbed.

Very clear dose-response relationships are found in the annoyance and its related reaction. The percentage of the "highly annoyed" starts increasing from the value of WECPNL of 75, becomes higher as the level of noise exposure is high and reaches about 70% at WECPNL of over 95. The tendency is the same for the other items such as anxieties of crash, drop of objects, explosion, involvement in war, fear of war memory and so on.

The rates of the disturbed in TV/radio listening, speech communication and telephone use increase as a function of WECPNL. The percentage of those complaining TV listening are always disturbed by aircraft noise, for example, begins to increase at WECPNL of 70 or 75 and becomes higher as the level of noise exposure increases reaching over 60% at WECPNL of over 95. The dose-response relationships between the rates and WECPNL are quite clear. The response rates regarding the disturbance of daily activities and rest are not high in the area with WECPNL below 85 but they increase with WECPNL in the region of over 90.

Two types of scores indicating the degree of sleep disorder are calculated based on the answers to four questions on sleep disorder. The questions did not specify the sleep disorder as caused by the aircraft noise. The rate of respondents with high score increases as WECPNL is higher, thus the clear dose-response relationships between the scores of sleep disorder and the level of noise exposure are found. Logistic regression analysis with the independent variables of WECPNL, age, sex, occupation and the interaction of age and sex shows that odds ratio regarding relatively frequent sleep disorder, more than once a week, is 3.4 in the group with WECPNL of over 95, so as to suggest that the residents

exposed to high level of aircraft noise suffer from serious sleep disorder. Odds ratios regarding relatively scarce sleep disorder, more than once a month, are significantly higher than the control in all the exposed groups WECPNL of over 75 inclusive. The fact suggests that sleep disturbance occurs even in the areas with lower level of noise exposure.

The questionnaire contains the items with respect to the quality of residential environment evaluated by the individuals living around the base. The respondents answer the questions asking if they are satisfied with their lives, if they are happy with their places of residence, and if they wish to live in the present places permanently. Logistic regression analysis shows the odds ratios regarding life dissatisfaction are significantly higher in the areas of WECPNL of 90 and 95 than those of other level of aircraft noise and the control. The odds ratio regarding the lower neighborhood satisfaction increases as the level of noise exposure gets higher and the difference in odds ratios from that of the control are significant over 85 of WECPNL. The odds ratio regarding the intention of permanent residence decreases as the level of noise exposure gets higher. The significant difference is found in the odds ratio the noise exposed groups and the control group.

5. Residential sound insulation and community response

In the communities surrounding Kadena Air Base and Futenma Air Station, the Japanese government has undertaken sound-insulation programme to mitigate aircraft noise in compliance with an act pertaining to improvements of residential environments adjacent to defense facilities. Homes located in areas where noise contours designated by the DFAA are 75 or higher are eligible for sound insulation under this act. Sound insulation measures to be executed on demand of the residents include sound-proofing of windows and doors, ceiling and wall insulation, and air conditioning. The number of rooms to be sound insulated in a home depends upon the condition of household such as the number of family members.

The questionnaire contains some items on the sound insulation of the residences of the respondents. They answered questions asking if sound insulation had been implemented for their homes by the DFAA and if the performance was satisfactory. Difference in the responses to the questions on reported annoyance, interference with communication, sleep disorders and neighborhood satisfaction are analysed between the residents of homes sound insulated and not insulated.

The results show that independently of WECPNL groups, the implementation rate is around 60%. Although the negative evaluation of sound insulation is relatively low (20%) among those in the group with WECPNL of 75, the rate increases to about 70% among residents with WECPNL of over 95. The percentage of the response on the dissatisfaction with sound insulation is as low as about 10% in the group of WECPNL of 75, but it increases with WECPNL and reaches about 60% in the group of WECPNL of over 95.

The dose-response relationships of reported annoyance, interference with conversation, sleep disorders and neighborhood satisfaction of the residents of homes with and without sound insulation show surprisingly good agreement with each other. The result of logistic regression analysis shows no difference between the two populations in odds

ratios, either.

It is clear that the implementation of sound insulation has not led to the responses toward desirable direction regarding both sleep disturbance and interference with television and telephone use regardless of WECPNL grouping. It can be concluded that the sound insulation implemented by the DFAA does not, in actual context, mitigate the effects of noise in the daily lives of residents the aforementioned positive responses reflecting its physical reduction notwithstanding.

Undisturbed sleep is essential for health and is closely related to the quality of life. Taking into account the serious noise exposure around Kadena Air Base, it is strongly recommended that more radical measures, such as the restriction of night landings and alternations in established flight paths, be introduced to provide relief to residents adjacent to the base.

6. Effects on children

Children in their nature demonstrate misbehaviours more or less. But some factors in their living environment can raise the frequency of misbehaviours. Hattori *et al.* (1986) pointed out aircraft noise was one of the factors reporting that the children around Komatsu Airport in Ishikawa Prefecture showed significantly higher rate of misbehaviours than those of the control.

A questionnaire survey on children's misbehavior was conducted in nursery schools and kindergartens around Kadena Air Base and Futenma Air Station. The areas were divided into four groups according to WECPNL values of under75, 75, 80, and over 85. The subjects were male and female preschool children (3 6y ears old), whose parents, caregivers, and teachers answered the questions. The numbers of valid answers were 1,580 from the noise-exposed area (915 around Kadena Air Base, 665 around Futenma Air Station), and 308 from the control area.

The responses are analysed by means of the method of multiple logistic regression taking the number of misbehaviours concerning "biological function," "social standard," "physical constitution," "movement habit," "character," "all the misbehaviours," "reaction to noise" or "TV etc." as the dependent variables and "dose of noise exposure," "age," "sex," "size of family," "birth order," "mother's age at birth," "father's job," and "mother's job" as independent variables. Linear relationships with positive slope are found between the logarithm of odds ratio and WECPNL in the categories of "all the misbehaviours," "physical constitution," "character," "reaction to noise" and "TV etc." around Kadena Air Base and "social standard," "physical constitution" and "reaction to noise" around Futenma Air Station.

Multiple logistic regression analysis is conducted with the same independent variables as above and with the dependent variable of the cluster score of each of 17 clusters obtained by means of cluster analysis. It is found that the clusters showing the linear relation with positive slope between the logarithm of odds ratio and WECPNL are "cold symptoms," "headache-stomachache," "eating problem," "passive inclination" and "emotional instability" around Kadena Air Base, and "cold symptoms," "eating problem" and "passive inclination" around Futenma Air Station.

From the results it would be safe to say that the aircraft noise exposure is a factor of increasing the number of the preschool children's physical and mental misbehaviours. To put it tersely, children exposed to aircraft noise are likely to have the following inclinations: they easily catch cold, have a poor appetite, and take a long time to make friends.

7. General health questionnaire survey: Todai Health Index

Health management is the basis of public health. Collecting precise and minute information on the individuals' health conditions and conducting health management of the individuals might be considered most desirable, but in the realistic conditions it is virtually impossible to carry out health examinations of all the population. It is for this reason that surveys on perceived wellness or subjective health of groups of individuals are widely undertaken by means of personal interview and/or questionnaire survey for the sake of health management.

A survey on health effects of aircraft noise on people residing around Kadena Air Base and Futenma Air Station was conducted using the Todai Health Index (THI) (Suzuki et al.; 1991). THI was developed for the purpose of supplementing the Cornell Medical Index (CMI), which consists of 130 questions regarding subjective symptoms, mental health, habits and so forth. In this paper, 12 scale scores, VCOM (vague complaints), RESP (respiratory), EYSK (eye and skin), MOUT (mouth and anal), DIGE (digestive), IMPU (irritability), LISC (lie scale), MENT (mental instability), DEPR (depression), AGGR (aggression), NERV (nervousness) and LIFE (irregularity of life), are calculated and analysed in relation to the aircraft noise exposure. As a noise-exposed group, residents living around the airfield were stratified into five groups according to the level of noise exposure expressed in WECPNL from 75 80, 80 85, 85 90, 90 95 and over 95. Questionnaires were distributed to 7,053 residents sampled from the poll book of each group by stratified random sampling. Including 1,031 samples from the control, total sample size comes to be 8,084. The 615 answers of the previous survey conducted in the same area in 1992 were also used for the analysis (Hiramatsu et al.; 1997).

Twelve scale scores are converted to dichotomous variables based on scale scores of 90 percentile value or 10 percentile value in the control group. Multiple logistic regression analysis taking twelve scores converted as the dependent variable and WECPNL, age, sex, occupation and the interaction of age and sex as the independent variables is conducted. Significant dose-response relationships are found around Kadena Air Base in the scale scores of VCOM ($p = 0.0009$), RESP ($p < 0.0001$), DIGE ($p = 0.0004$), MENT ($p = 0.0085$), AGGR ($p = 0.0124$) and NERV ($p = 0.0005$), where p denotes significance probability of trend test. Around Futenma significant dose-response relationships are found in the scale scores of EYSK ($p = 0.0201$) and NERV ($p = 0.0014$). The discriminant function (DF) value for psychosomatics and neurosis are calculated and logistic regression analysis is conducted with the independent variables of WECPNL, age, sex, occupation and the interaction of age and sex. The result shows that odds ratio of DF value of psychosomatics represents clear dose-response relationship and that of neurosis is significantly high in the area of WECPNL of 95.

Factor analysis was carried out using the 12 scale scores obtained as above and 2 factors are extracted which may be called "somatic factor" and "mental factor." The factor scores of the 90 percentile of the subjects in the control group are used as the thresholds to carry out the logistic regression analysis. The results of the analysis indicate that the odds ratio of the somatic factor increases in the lower noise exposure area of WECPNL of 75 and gets higher as WECPNL increases. The dose-response relationship is highly significant. As to the odds ratio of mental factor, the dose-response relationship is less clear than that of the somatic factor, but the test of the increasing tendency shows it is significant with the significance level of 5%.

As a non-specific biological stressor, noise can influence the entire body system via both autonomic nervous system and neuroendocrine system (Morrell *et al.*; 1997). In this sense, it would be reasonable to consider that pro-longed and repeated exposure of aircraft noise may adversely affect health and well-being of individuals around Kadena Air Base, making allowance for the serious noise exposure level in the residential area and the high community responses regarding sleep disturbance, disturbance of rest, fear of possible danger as well as annoyance. In addition, it was denied that sound insulation as a measure against aircraft noise and air conditioning which reduces ventilation might cause the spread of air borne infections and thus increase the complaints regarding respiratory organs (RESP). Finally, it should always be borne in mind that physical health effects of noise may manifest in susceptible subgroup within a population and the sites where various symptoms appear are different among individuals even in the same conditions of noise exposure.

8. Analysis of the data obtained in general health examination

Some physiological indices obtained by health examinations were investigated to find relationships with aircraft noise exposure. The examinations were conducted by the local authorities in the fiscal years of 1994 and 1995, which were suggested by Japanese government for senior citizens over 40 years of age to undergo on the basis of Health and Medical Service Act for the Elderly.

The data were analysed with respect to systolic blood pressure and diastolic blood pressure (28,781 cases), the numbers of red blood cells (28,692 cases), white blood cells (13,404 cases) and the concentration of uric acid (8,449 cases) adjusted for creatinine. The Multiple logistic regression analysis was applied to analyse the data acquired.

The rates of those with systolic blood pressure and diastolic blood pressure exceeding the thresholds determined for age groups were taken as the response, and clear dose-response relationships were found in terms of the aircraft noise exposure expressed by WECPNL. The odds ratio of 90 percentile of those of the noise exposed group with WECPNL over 85 was 1.3 reference to that of the control. This implies the number of persons with the blood pressure exceeding the threshold increase by about 30 % in the noise exposed group. The increase of odds ratio was also found in the noise exposed group with WECPNL from 75 to 80 compared with the control.

No significant dose-response relationship was found as to the numbers of white blood cells and red blood cells. Clear trend was found that the concentration of uric acid (creatinine adjusted) decreases as WECPNL is higher. The odds ratio of those exceeding

the threshold corresponding 90 percentile of the population is 0.6 in the noise exposed group with WECPNL of 80.

9. Higher rate of low birth-weight infants

It is generally recognized that the mental stress possibly causes through the endocrine and nervous systems various physical impact upon human beings.
Noise can be a stressor to cause such stress reactions as many mental stresses might do to human bodies. Many papers have been published to report the results of animal experiments and epidemiological researches suggesting the effect of noise on pregnancy; that is the noise exposure is a factor reducing birth weight and/or shortening the term of pregnancy. For example, it is reported that the rate of low birth weight of infants was found higher in the vicinity of Osaka International Airport (Ando & Hattori; 1973) than the average rate of non-noise exposed area in Japan and that the aircraft noise exposure could be a factor of raising the rate. Taking the high level of noise exposure around the U.S. airfields in Okinawa, particularly in the vicinity of Kadena Air Base, into account, there would be a good reason to investigate whether the higher rate of low birth weight infants are observed.

The birth weight of infants were analysed using the birth records from 1974 to 1993 in Okinawa Prefecture. The birth records including the information on year of birth, address, sex, birth-weight, mother's age, single or multiple pregnancy, legitimacy of the infant, the period of pregnancy, live birth order, experience of stillbirth, occupation of householder, etc. The number of births in Okinawa Prefecture recorded for the 20 years was 356,549 among which 164,028 records of 15 municipalities around Kadena Air Base and Futenma Air Station are used for the analysis in the present investigation. The municipalities are classified according to the population weighted average WECPNL. In the following analysis the 8 municipalities with WECPNL under 75 are treated as the control, the 5 municipalities with WECPNL from 75 to 80 are treated as "lower noise exposed group." Chatan Town and Kadena Town are independent groups.

The birth rate of low birth-weight infants of Kadena Town is 8.3% which is by about 2% higher than the rate 6.4% of the control and the ratio of the rate of Kadena to that of the control is about 1.3. Chatan Town and the 5 municipalities of lower noise exposure have nearly the same birth rates of low birth-weight infants as each other.

The odds ratio with respect to the birth rate of infants with low birth weight (under 2,500 grams) was tested by means of the multiple logistic regression method. The primary factors that would be related to infants' weights such as sex, mother's age, live birth order, occupation of householder, legitimacy of the infant, year of birth and interaction of mother's age and live birth order are applied as the independent variables in the logistic regression analysis. Significant increasing trend of the rate of low birth weight is found with the increase of the dose of noise exposure.

Higher birth rates of preterm births are found in the municipalities with higher noise exposure. The preterm birth rate of Kadena Town is by about 2% higher than the rate of the control and the ratio of the rate of Kadena to that of the control is about 1.2. Chatan Town and the 5 municipalities of lower noise exposure have by about 0.5% higher rates of

preterm birth than the control. As was found in the case of low birth-weight, the trend of increase of odds ratio regarding preterm birth with the increase of WECPNL is clear and significant according to the trend test.

It is very unlikely for possibly higher rate of smoking habit among females in Kadena Town, which is unknown actually, might raise the birth rate of low birth-weight infants. Thus the aircraft noise exposure is considered to be the most likely factor raising the rate of low birth weight around Kadena Air Base.

10. Hearing loss

10.1 TTS and NIPTS calculated based on the past noise exposure

Some areas adjacent to Kadena Air Base have for the last 40 years been exposed to intense ground noise from the airfield as well as over-flight noise. The noise exposure during the Vietnam War was so intense that it is hypothesized that it could have caused hearing loss among the local residents. The possibility of hearing loss occurred among people living in the vicinity of the airfield was estimated. The time history of sound level during 24 h was estimated from the measurement conducted in 1968, and the sound level was converted into the spectrum level at the center frequency of the critical band of temporary threshold shifts (TTS) using the results of spectrum analysis of aircraft noise. With the information of spectrum level and its time history, TTS was calculated as a function of time and level change (Takagi et al.; 1988).

Results of calculation indicate the noise exposure around Kadena Air Base causes TTS in excess of 20 dB. Noise induced permanent threshold shift (NIPTS) was also calculated by means of Robinson's method (Robinson; 1971) for 90 percentile of NIPTS to be about 20 dB.

The results indicate the noise exposure around Kadena Air Base was hazardous to hearing and is likely to have caused hearing loss to people living in its vicinity.

10.2 Hearing test

Hearing test was conducted at three wards A, B and C, in two towns neighbouring Kadena Air Base. The noise exposures expressed in WECPNL are over 95 inclusive in the ward A, 85 to 95 in the ward B, and 85 to 90 in the ward C. The subjects to receive the test were limited to the individuals aged between 25 and 69 years inclusive, whose numbers were 2,035. Three hundred and forty three individuals received the test. They were 137 males and 206 females. Among them, 40 individuals who were judged to have possible noise induced hearing loss were sent to Okinawa Chubu Hospital as subjects for the secondary test. In the secondary examination the external and middle ears were first checked by visual inspection of tympanic membrane and by tympanometry and then air-bone gap of hearing acuity was investigated in order to omit the subjects with conductive hearing loss. Thirdly, SISI test was conducted to detect the subjects showing recruitment phenomena. Positive recruitment phenomena are considered that the hearing loss is not retrocochlear but cochlear hearing loss.

Thus twelve subjects are selected whose hearing loss is very likely noise induced hearing loss. The examiners interviewed selected subjects as above to confirm that they had

not experienced habitual or repeated intense noise exposure at their residential or working life other than aircraft noise exposure in their home place. The geographical locations of the subjects' residences are concentrated to the very vicinity of the air base, which strongly supports one to draw a conclusion that the cause of their hearing loss is most likely their exposure to the intense noise of aircraft take-offs, landings and tune-ups at Kadena Air Base.

Causation between hearing loss and aircraft noise :

The result of hearing test alone cannot specifically determine that aircraft noise is the direct cause of their hearing loss. The following 7 reasons can be raised why their hearing losses are likely to be due to the aircraft noise from Kadena Air Base.

1) Audiogram

As a typical pattern of audiogram of noise induced hearing loss c5-dip and its progressive pattern are observed. Recruitment positive is another symptom to support the diagnosis.

2) Geographical concentration

The individual judged noise induced hearing loss are concentrated the vicinal area of the base. The 12 subjects dwell in the closest part in the ward to either of the runways of Kadena Air Base. In Figure 9.5 are plotted the locations of the residences of the subjects living in Sunabe relative to the base. In the map circles indicate the individuals who went through the hearing test, and among them 9 individuals over 40 years of age were judged to suffer from noise induced hearing loss. There resided 6individuals in the area of WECPNL over 95, 2 in WECPNL 90 95 and 1 in WECPNL 85 90. Statistical test tells that the increasing trend of the number of individuals having NIPTS with the increase of WECPNL is significant ($p = 0.0402$, one-tailed Mantel extension method with exact test).

3) Intense noise exposure

Noise exposure past and present is extremely intense so as to be comparable to damage risk criteria for occupational noise exposure.

4) Estimated NITTS/NIPTS

The NITTS at 4 kHz estimated on the basis of the past noise exposure reaches about 20 dB on average and the NIPTS at 4 kHz of one chance in ten individuals is calculated to be about 20 dB.

5) Occupational noise exposure

The examiners interviewed the subjects to confirm that they had not experienced repeated intense noise exposure at their residence or workplace other than aircraft noise that might have caused their hearing loss.

6) Long term of residence

The individuals had resided in the area for 19 to 43 years.

7) High odds ratio for subjective hard of hearing

In the THI questionnaire besides the 130 THI questions was included a question asking if she/he had hard of hearing. Result of the analysis by means of logistic regression model is presented in Figure 9.6. Open circles indicate the odds ratios adjusted by age, sex, occupation and interaction of age and sex with 95% confidence intervals. It is clearly shown that the residents living in the area with WECPNL over 95 appeals hard of hearing

and the increase of odds ratio is statistically significant. These seven reasons strongly supports one to draw a conclusion that the cause of the individuals' hearing losses are most likely the exposure from the past to the present or a certain period in the past to the intense noise from aircraft take-off, landing and tune-up on Kadena Air Base.

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