

Environmental Distribution of Air Pollutants and Environmental Risk Assessment in Regional Scale

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Abstract: We measured the concentrations of air pollutants at several residential sites, roadside sites and industrial sites in Iwate Prefecture, Japan. And the concentration distributions of air pollutants were estimated by atmospheric dispersion model using air emissions data. Based on those results, we calculated environmental risk of air pollutants emitted in Iwate Prefecture. As a result, it was found that the surround of factories with high emissions and highly toxic chemicals and the roadsides were high risk area, benzo(a)pyrene, formaldehyde and ozone exceeded the 10^{-5} risk level. Moreover, we tried to use "Loss of life expectancy: LLE" for an index to explain those risk to general public intelligibly. The total LLE of the carcinogenic chemicals was about 8.6 hours. Moreover, LLE of ozone was about 9.2 hours. Ozone has a big influence compared with the carcinogenic chemicals.

Keywords: air pollutants, concentration, distribution, environmental risk assessment, loss of life expectancy

1. Introduction

In recent years, there is increasing concern about environmental and health effects of airborne dust and chemicals. Many of volatile organic compounds (VOCs) including benzene are pointed out carcinogenic to humans [1]. In addition, VOCs are one of the major causes of photochemical ozone generation [2], and those emission controls have started in Japan. Moreover, in the atmosphere, there are the photochemicals by ultraviolet rays such as aldehydes etc[3]. Furthermore, airborne dust contains polycyclic aromatic hydrocarbons (PAHs) generated by auto emissions, fossil fuel burning, wood burning and smoking [4]. Many of PAHs including benzo[a]pyrene (B[a]P; belong to "Group1" in IARC Monographs [5]) are pointed out mutagenicity and carcinogenicity [6]. And various metals are contained in airborne dust, too. Especially, arsenic, nickel and so on are said high carcinogenicity [7].

In such a situation, Pollutant Release and Transfer Register (PRTR) was introduced, and the amount of the chemical emissions has been published every year since 2002 in Japan [8]. The concentrations of air pollutants have been measured at about 400 sites since 1998 [9].

However, concentration measurement sites are not still enough to understand the current state of air pollutants. And it is very difficult that general public know what affect their health by chemical emission.

In the advance studies, there are measurement examples of air pollution concentrations [9] and risk assessment examples of each chemical [10-13]. But, in regional scale, based on measurement results of many air pollutants, there is no study example for an index to explain those risk to general public intelligibly.

In this study, we measured the concentrations of airborne VOCs, aldehydes, PAHs, metals and ozone at several points in Iwate Prefecture, Japan. And the concentration distributions of VOCs were estimated by atmospheric dispersion model using air emissions data. Based on those results, we calculated environmental risk. And we attempted showing the results easy to understand for the general public.

2. Concentration Measurement

2.1 Sampling and Analysis

Atmospheric VOCs, aldehydes and PAHs were measured from April 2007 to March 2009 in several residential sites and roadside sites in Iwate Prefecture. Metals and ozone were measured in a part of their sites.

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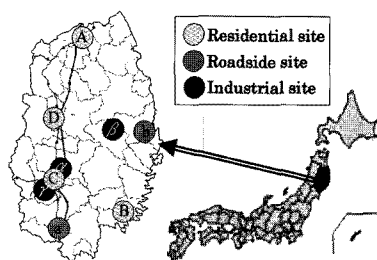


Fig. 1. Sampling points (Iwate prefecture, Japan).

In addition to those, VOCs were measured in three industrial sites selected by PRTR results. Sampling of them except ozone was carried out once a month in 24 hours. Ozone was continuously measured. Sampling sites were shown in Fig. 1. Analytical conditions were shown in Table 1.

2.1.1 VOCs

After we evacuated sampling canister (Silcosteel; Restek), it was connected with the passive canister sampler (PCS360; GL Science). And the air was sampled. The flow rate was 3.3 mL/min. As pretreatment for VOCs, after the sample was diluted pure nitrogen pressure and it was introduced into concentrators (Aero2100; GL Science). VOCs were analyzed by gas chromatograph mass spectrometry (GC/MS). The measuring targets were 52 chemicals including benzene.

2.1.2 Aldehydes

The portable gas-sampling pump (GSP-250FT; GASTEC) was used for the sampling. The flow rate was 100 mL/min. Air samples were drawn over a 2,4-dinitrophenylhydrazine (DNPH) -coated silica gel cartridge (GL-Pak mini AERO DNPH; GL Science) and were sampled to form the corresponding hydrazones derivatives. In front of the cartridge, the KI filter (GL-Pak mini AERO Ozone Scrubber; GL Science) was used during sampling to avoid ozone interference. And then aldehyde-DNPH derivatives are extracted with acetonitrile, and analyzed with a high-performance liquid chromatograph - ultraviolet detectors (HPLC-UV). The measuring targets were 16 chemicals including formaldehyde.

2.1.3 PAHs

PAHs were trapped on silica fiber paper (QR-100; ADVANTEC) by high volume air sampler (HV-700F; SIBATA). The flow rate was 700 L/min. As pretreatment, PAHs collected on the paper were extracted by ultrasonic extraction with dichloromethane. After the extract was

Table 1. Analytical condition of air pollutants

VOCs (GC/MS)

GC: Agilent 7890A, Column: Aquatic df= 1.0 μ m, 0.25 mm I.D. \times 60 m, Oven temp.: 35°C(6.5 min) \sim 5°C/min \sim 105°C \sim 18°C/min \sim 200°C(15 min), Carrier gas: He 210 kPa, Interface temp.: 200°C

MS: JMSQ1000GC K9 (JEOL), MS type: quadrupole, Ionization current 200 μ A, Ion source temp.: 200°C, Ionization energy: 70 eV

Aldehydes (HPLC-UV; Agilent1100 series)

Column: Wakosil DNPH 25 cm \times 4.6 cm ID, 5 μ m, Mobile Phase: A; Wakosil DNPH A, B; Wakosil DNPH B, Gradient program: 0-16 min A.Conc.90% hold, 16-35 min A.Conc.90-10 linear gradient, 35-45 min A.Conc.10% hold, Flow Rate: 0.6 mL/min, Column Temp.:40C, Detect.: UV 360 nm

PAHs (HPLC-FL; Agilent1100 series)

Column: LC-PAH 25 cm \times 4.6 cm ID, 5 μ m, Mobile Phase: A; Water: B; Acetonitrile, Gradient program: 0-2.5 min B.Conc.60%hold, 2.5-12 min B.Conc.60-90% linear-gradient, 12-20 min B.Conc. 0-100% linear-gradient, 20-37 min Conc.100%hold, Flow Rate: 1 mL/min, Column Temp.: 40C, Detect.: FL; Ex 295 nm Em 401 nm

CHeavy metals (ICP-MS; Agilent7500c)

RF power: 1500W, Carrier gas: 0.9 L/min, Mass number: m/z Be(9), Cr(53), Mn(55), Ni(60), As(75), (ISTD; Li(6), Ga(69), Ga(71))

Ozone (ultraviolet rays absorption; GUX-253)

centrifugation, it was almost volatilized and dissolved in the acetonitrile of 1ml again. PAHs were analyzed by HPLC - fluorescence detector (HPLC-FLD). The measuring targets were 8 chemicals from 4 to 6 rings including B[a]P.

2.1.4 Heavy metals

Heavy metals were trapped on silica fiber paper (QR-100; ADVANTEC) by HV-700F. The flow rate was 700 L/min. As pretreatment, metals collected on the paper were digested in closed vessels with HNO₃, HF and H₂O₂. It was decomposed by high-pressure microwave pretreatment system (ETHOS900; milestone). Next, the extract was almost volatilized and dissolved in the 2% nitric acid solution again. They were analyzed by inductively coupled plasma mass spectrometer (ICP-MS). The measuring targets were 5 materials including nickel.

2.1.5 Ozone

Ozone was measured by automatic ozone analyzer (GUX-253; TOADKK). The measurement principle was

an ultraviolet rays absorption method. The concentration was calculated according to the concentration ratio of the sample gas and the reference gas [14].

2.2 Measurement Results and Discussion

The average results of measured air pollutants concentrations were shown in Table 2. Benzene, 1,3-butadiene, aldehydes, and PAHs etc. were higher in the roadsides. It is thought that those were detected by the auto emissions [15]. Dichloromethane, chloroform and toluene, xylene etc. showed high concentrations in certain industrial sites. Emissions of dichloromethane were the highest in Iwate Prefecture, those of toluene were the highest in Japan, according to PRTR result [8]. Air emission of these chemicals was large, it was thought that high concentrations were contributed to emission conditions of a factory and wind directions. Moreover, halocarbons (CFC etc.; freon11, freon12 etc.) are known not only as ozone-depleting substances but also as about from 100 times to over 1000 times stronger greenhouse gases than CO₂. These concentrations were similar at all sites. Measured results at Ryori (Iwate Prefecture, Japan) by the Japan Meteorological Agency [16] were similar concentration, too. These results showed that after implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer [17] in 1989, there were not specific emission source after regulating halocarbons emission, and those were measured as the background concentrations at any sites.

3. concentration Distribution

3.1 Estimation Methods

In measurement of air pollutants at each site, we can get accurate information as concentrations. However, it is difficult only in it for the general public to know the status of those close to themselves. To understand the atmospheric diffusion conditions of VOCs throughout Iwate Prefecture, we tried to estimate the environmental distribution in air pollutants by National Institute of Advanced Industrial Science and Technology - Atmospheric Dispersion Model for Exposure and Risk Assessment Ver.2.5.0 (ADMER) [18]. It is a dispersion model used for the estimated concentration of airborne chemicals. This model is based on plume and puff models using uniform concentration in mixed layer as advection diffusion process. The spatial resolution is 5 km×5 km. It is reported that the estimates of this model were almost consistent with measurements [19]. However ADMER cannot use estimation of secondary alteration and product chemicals in the air. It was input

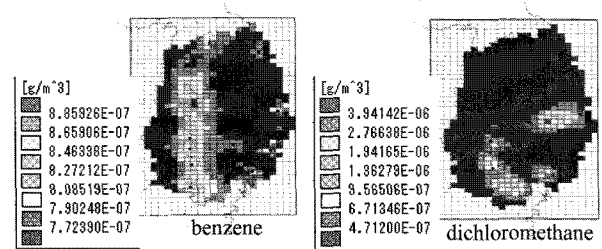


Fig. 2. Estimated results of concentration.

that the emission data (2007 PRTR), the meteorological data (average data from 2004 to 2006), the degradation factor and the background concentration (the lowest of all measurement points) for each chemical.

3.2 Estimation Results and Discussion

Some of the estimated results were shown in Fig. 2. We could get VOCs concentration distribution of each chemical throughout the prefecture. It was found that benzene etc. were higher along the main road and dichloromethane etc. were higher around the high emission factories etc.

4. Environmental risk Assessment

4.1 Risk Assessment of Each Chemical

We can know concentrations of air pollutants at the place near ourselves by the estimate. However, it is difficult only in it that the general public knows the health effects of air pollutants. Here, based on measured and estimated results, the environment and health effects of air pollutants (environmental risk) were calculated.

About carcinogenic air pollutant, we focused on “cancer” (The first cause of death in Japan). This risk was represented by Eq. (1). Carcinogenic by breathing (inhalation unit risk; UR) was input “Hazard”, the concentration of air pollutants was input “Exposure”.

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \quad (1)$$

About ozone, we assessed risk of increased non-accidental mortality [20]. This risk was represented by Eq. (2). Average non-accidental death toll of ozone seasons was input “y₀”. “RR-1” was relative risk when ozone concentration increased 10 ppb. The concentration differences between ozone seasons and the others was input “ΔC”. The population was input “P”.

$$\text{Risk} = (y_0 \times (\text{RR}-1) / 10 \times \Delta C) / P \quad (2)$$

The results of the calculated risk indicated the number

Table 2. Concentrations of air pollutants

Air pollutants	Residential				Roadside			Industrial		
	A	B	C	D	a	b	α	β	γ	
$\mu\text{g}/\text{m}^3$	VOCs									
freon134a	0.55	0.33	1.8	0.38	0.41	0.37	0.28	0.31	0.57	
freon22	0.78	1.1	0.81	0.94	0.90	1.0	0.82	0.79	0.85	
freon12	2.8	2.8	2.7	2.6	2.8	2.8	2.8	2.8	2.5	
freon142b	0.39	0.11	0.090	0.13	0.11	0.12	0.13	0.11	0.41	
chloromethane	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.1	
freon114	0.14	0.12	0.11	0.11	0.12	0.11	0.11	0.10	0.11	
vinyl chloride	0.0062	0.0059	0.0088	0.0062	0.0067	0.0039	0.0049	0.0038	0.0094	
1,3-butadiene	0.12	0.11	0.16	0.086	0.30	0.19	0.081	0.054	0.098	
bromo methane	0.23	0.15	0.045	0.048	0.053	0.26	0.047	0.046	0.040	
ethyl chloride	0.032	0.024	0.044	0.046	0.038	0.028	0.034	0.020	0.030	
freon123	0.0081	0.0069	0.0080	0.0073	0.011	0.0068	0.0095	0.0070	0.013	
freon11	1.5	1.5	1.4	1.4	1.5	1.5	1.5	1.5	1.3	
freon141b	0.87	0.24	0.21	0.35	0.16	0.15	0.41	0.16	0.40	
acrylonitril	0.050	0.057	0.059	0.023	0.066	0.064	0.16	0.052	0.19	
freon225ca	0.0068	0.010	0.016	0.013	0.017	0.0082	0.014	0.0070	0.016	
1,1-dichloroethane	0.020	0.017	0.012	0.028	0.030	0.020	0.012	0.012	0.017	
dichloromethane	0.67	3.1	1.3	1.8	1.0	1.2	15	11	1.7	
3chloropropane	0.015	0.019	0.14	0.011	0.10	0.045	0.0050	0.0050	0.077	
freon225cb	0.012	0.011	0.012	0.014	0.013	0.011	0.011	0.011	0.015	
freon113	0.62	0.65	0.60	0.61	0.61	0.63	0.61	0.61	0.54	
1,1-dichloroethane	0.0090	0.0071	0.0072	0.0083	0.0071	0.0071	0.0087	0.0076	0.011	
c-1,2dichloroethane	0.0078	0.0069	0.0079	0.0081	0.013	0.0073	0.020	0.0056	0.014	
chloroform	0.12	0.13	0.18	0.13	0.16	0.11	0.98	0.11	0.47	
1,2-dichloroethane	0.068	0.064	0.085	0.069	0.072	0.066	0.079	0.063	0.088	
1,1,1-trichloroethane	0.090	0.090	0.090	0.090	0.10	0.090	0.090	0.090	0.090	
benzene	1.1	0.82	1.8	1.1	1.6	1.3	0.92	0.71	1.3	
carbontetrachloride	0.74	0.73	0.67	0.71	0.70	0.75	0.68	0.69	0.62	
1,2-dichloropropane	0.021	0.021	0.022	0.035	0.024	0.050	0.025	0.017	0.039	
trichloroethane	0.031	0.16	0.076	0.068	0.10	0.056	0.36	0.028	0.092	
c-1,3-dichloropropane	0.0070	0.012	0.0047	0.0047	0.0068	0.0047	0.0053	0.0047	0.0070	
t-1,3-dichloropropane	0.0051	0.0049	0.0039	0.0052	0.0052	0.0039	0.0050	0.0045	0.0054	
1,1,2-trichloroethane	0.010	0.0074	0.0092	0.0093	0.012	0.0083	1.1	0.085	0.030	

toluene	3.4	2.3	11	2.8	5.7	5.2	6.4	1.2	7.7	
1,2-dibromoethane	0.022	0.032	0.020	0.023	0.023	0.024	0.37	0.39	0.57	
tetrachloroethene	0.038	0.028	0.038	0.031	0.038	0.042	0.025	0.020	0.048	
chlorobenzene	0.011	0.011	0.0070	0.011	0.0090	0.0080	0.48	0.068	0.029	
ethylbenzene	0.76	0.58	1.5	0.58	1.2	0.94	8.6	0.26	3.7	
m,p-xylene	4.8	3.6	12	3.8	9.2	6.8	28	1.3	24	
styrene	0.18	0.27	0.20	0.14	0.32	0.20	0.14	0.046	0.35	
1,1,2,2-tetrachloroethane	0.036	0.041	0.057	0.082	0.18	0.046	0.29	0.089	0.27	
o-xylene	0.46	0.35	1.2	0.39	0.92	0.65	1.9	0.12	2.0	
4-ethyltoluene	0.18	0.26	0.86	0.31	0.64	0.40	0.29	0.11	3.9	
1,3,5-trimethylbenzene	0.20	0.15	0.63	0.14	0.54	0.31	0.43	0.13	1.7	
1,2,4-trimethylbenzene	0.70	0.55	2.3	0.57	1.9	1.1	1.2	0.27	5.9	
benzylchloride	0.38	0.20	1.3	0.16	1.3	0.47	0.68	0.060	2.2	
m-dichlorobenzene	0.010	0.011	0.0090	0.010	0.0090	0.0080	0.046	0.019	0.54	
p-dichlorobenzene	0.57	0.53	0.51	0.27	0.55	0.68	0.16	0.13	0.23	
o-dichlorobenzene	0.029	0.022	0.022	0.020	0.039	0.018	0.018	0.015	0.057	
1,2,4-trichlorobenzene	0.013	0.014	0.014	0.012	0.012	0.011	0.011	0.010	0.019	
hexachlorobutadiene	0.014	0.015	0.015	0.014	0.016	0.011	0.010	0.0080	0.033	
ig/m^3	Aldehyde									
formaldehyde	0.70	1.7	0.55	-	2.2	1.8	-	-	-	
acetaldehyde	0.57	0.81	0.35	-	1.2	0.90	-	-	-	
propionaldehyde	0.055	0.055	0.055	-	0.055	0.055	-	-	-	
acrolein	0.073	0.073	0.073	-	0.073	0.073	-	-	-	
acetone	3.7	3.3	2.1	-	2.0	2.7	-	-	-	
isobutyraldehyde	0.056	0.084	0.056	-	0.056	0.056	-	-	-	
n-butyraldehyde	0.044	0.090	0.044	-	0.044	0.044	-	-	-	
isovaleraldehyde	0.059	0.059	0.059	-	0.059	0.059	-	-	-	
crotonaldehyde	0.48	0.64	0.55	-	0.85	1.0	-	-	-	
n-valeraldehyde	0.055	0.10	0.14	-	0.055	0.055	-	-	-	
benzaldehyde	0.056	0.10	0.044	-	0.044	0.044	-	-	-	
n-hexanal	0.60	0.061	0.097	-	0.12	0.061	-	-	-	
o-tolualdehyde	0.86	5.8	0.23	-	3.1	10	-	-	-	
m-tolualdehyde	0.26	4.1	0.18	-	1.4	1.6	-	-	-	
p-tolualdehyde	0.30	0.90	0.18	-	0.23	0.52	-	-	-	
2,5-dimethylbenzaldehyde	0.44	0.75	0.41	-	0.51	0.53	-	-	-	
ng/m^3	PAHs									
pyrene	0.79	0.44	0.31	-	0.70	0.95	-	-	-	
benzo[a]anthracene	0.35	0.17	0.14	-	0.25	0.40	-	-	-	
chrysene	0.57	0.30	0.29	-	0.52	0.69	-	-	-	
benzo[b]fluoranthene	0.93	0.72	0.55	-	0.94	0.98	-	-	-	

Table 2. Concentrations of air pollutants(Continued)

benzo[k]fluoranthene	0.22	0.15	0.12	-	0.19	0.23	-	-	-
benzo[a]pyrene	0.38	0.26	0.17	-	0.33	0.38	-	-	-
dibenzo[a,h]anthracene	0.038	0.026	0.024	-	0.031	0.037	-	-	-
benzo[g,h,i]perylene	0.42	0.38	0.26	-	0.34	0.53	-	-	-
ng/m ³	Heavy metals								
nickel	1.4	1.9	2.1	-	-	-	-	-	-
arsenic	1.1	0.74	1.0	-	-	-	-	-	-
beryllium	0.015	0.012	0.012	-	-	-	-	-	-
manganese	11	15	15	-	-	-	-	-	-
chromium	1.2	2.4	1.9	-	-	-	-	-	-
ppm	Ozone								
ozone	-	-	0.030	-	-	0.027	-	-	-

of people who die of cancer when we exposed throughout life on the current air pollutants level. The unit risks and calculated risks were shown in Table 3.

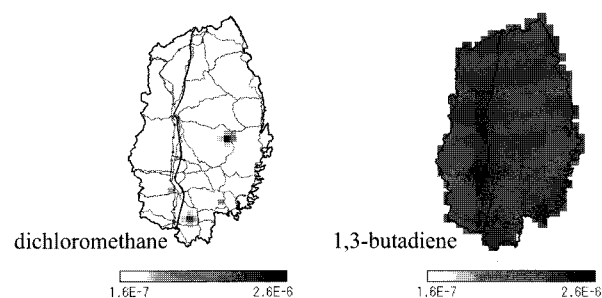
4.1.1 VOCs

We calculated the risks of 13 chemicals shown UR by United States Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS) [10]. The estimated concentration in 5km mesh by ADMER was input "Exposure". As a result (Table 3), the average and maximum risk of benzene was the highest, that of chloroform was higher secondly. However, the risk didn't exceed 1.0×10^{-5} (common acceptable level, 10^{-5} is a person per 100,000 persons). Moreover, it was found that the risk of dichloromethane (the highest air emission in Iwate Prefecture) was relatively low except some industrial zones, it was lower than the risk of 1,3-butadiene (relatively high UR) (Fig. 3). To think about the influence of all chemicals, the risk of VOCs was totaled with each mesh. As a result (Table 3), 10^{-5} risk level was exceeded even minimum value. At even Iwate Prefecture where air pollutant emission was relatively small in Japan, it was found that the risks of total VOCs were not negligible.

Next, we compared the risk ratios of chemicals in three characteristic meshes (Fig. 4), I was lowest risk mesh, II was highest risk mesh and III was heavy traffic and populous mesh. Overall, we found that the ratio of benzene is large. Compared with the other meshes, it was found that mesh II had large contribution of chloroform affected by specific emission source. Mesh III had relatively large contribution of benzene and 1,3-butadiene owing to heavy traffic. The ratio of

Table 3. Unit risks and calculated risks of air pollutants

Air pollutants	Unit Risk (/ $\mu\text{g}/\text{m}^3$)	Calculated Risks		
		Max	Min	Ave
VOCs				
benzene	7.8E-06	5.0E-06	3.9E-06	4.0E-06
acrylonitrile	6.8E-05	1.6E-06	1.6E-06	1.6E-06
trichloroethane	2.0E-06	1.3E-06	8.5E-09	2.3E-08
ethylbenzene	1.1E-06	1.9E-06	3.5E-07	3.9E-07
1,2-dichloroethane	2.6E-05	2.3E-06	1.6E-06	1.6E-06
tetrachloroethene	5.9E-06	2.6E-07	1.4E-07	1.4E-07
1,3-butadiene	3.0E-05	2.6E-06	1.8E-06	1.9E-06
dichloromethane	4.7E-07	2.7E-06	1.7E-07	2.3E-07
chloroform	2.3E-05	4.4E-06	2.2E-06	2.2E-06
Total (VOCs)		2.2E-05	1.2E-05	1.2E-05
Aldehydes				
formaldehyde	1.3E-05	2.8E-05	8.8E-06	1.9E-05
acetaldehyde	2.2E-06	2.6E-06	1.0E-06	1.7E-06
Total (Aldehydes)		3.1E-05	9.8E-06	2.1E-05
PAHs				
benzo[a]anthracene	3.95E-04	9.7E-08	3.0E-08	5.9E-08
chrysene	8.70E-04	4.1E-07	1.6E-07	2.6E-07
benzo[b]fluoranthene	1.02E-02	8.5E-06	4.5E-06	7.0E-06
benzo[k]fluoranthene	2.75E-03	4.8E-07	2.4E-07	3.7E-07
benzo[a]pyrene	8.70E-02	2.5E-05	9.0E-06	1.6E-05
dibenzo[a,h]anthracene	1.83E-01	4.8E-06	3.0E-06	3.8E-06
Total (PAHs)		3.9E-05	1.7E-05	2.7E-05
Heavy metals				
nickel	2.4E-04	5.0E-07	3.4E-07	4.3E-07
arsenic	4.3E-03	4.7E-06	3.2E-06	4.0E-06
beryllium	2.4E-03	3.5E-08	2.8E-08	3.1E-08
chromium	1.2E-02	2.1E-06	1.1E-06	1.6E-06
Total (Metals)		7.3E-06	4.6E-06	6.1E-06
Ozone		8.4E-04	6.6E-04	7.5E-04


Fig. 3. Risks of dichloromethane and 1,3-butadiene.

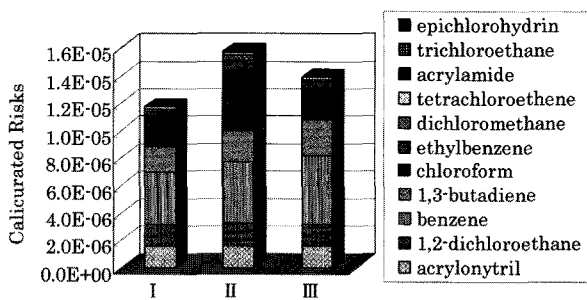


Fig. 4. Risk ratios of VOCs in three characteristic meshes.

dichloromethane with the highest emissions in Iwate Prefecture was relatively small.

4.1.2 Aldehydes

The risks of aldehydes were calculated two chemicals that the UR were shown by IRIS [10] in each measurement site. As a result (Table 3), it was found that the risk at the roadside sites was high because of the auto emissions, and formaldehyde exceeded 10^{-5} risk level. Moreover, at a part of the residential site, the risk was similar result. The total risk of aldehydes was exceeded 10^{-5} risk level at almost measurement sites including residential sites.

4.1.3 PAHs

The risks of PAHs were calculated six chemicals that the UR were shown by World Health Organization (WHO) [11] in each measurement site. As a result (Table 3), it was found that the risk at the roadside sites was high because of the auto emissions, and B[a]P exceeded 10^{-5} risk level. The total risk of PAHs was greatly exceeded 10^{-5} risk level at all roadside sites.

4.1.4 Heavy metals

The risks of metals were calculated four chemicals that the UR were shown by EPA IRIS [10] in each measurement site. Chrome was assessed that it was converted measured total chrome into hexad chrome using the ratio of total chrome to hexad chrome at the business district near the expressway [21]. As a result (Table 3), the arsenic risk was highest in the risks of metals. Nevertheless the risk is order of 10^{-6} . It was relatively small.

4.1.5 Ozone

Here, ozone seasons were configured from February to July. Average non-accidental death toll in the city at measurement sites was calculated from 2003 to 2007. And it was calculated that non-accidental death toll

increased 0.2% when eight-hour ozone concentration increased 10ppb [22]. As a result (Table 3), it was found that the risks in both sites were order of 10^{-4} , the risk levels were over 10 times greater than those of other pollutants calculated in this study.

4.2 Loss of Life Expectancy

We tried to use "Loss of life expectancy: LLE" for an index to explain those risk to general public intelligibly. LLE shows the shortened lifetime when a certain chemical substance is taken throughout the life. For instance, it is that the events induced a person per 100,000 persons are shared out among all population. LLE of 10^{-5} lifetime cancer risk was calculated 65.8 minutes by life table etc [23]. In this study, by summing of each pollutant, we attempted showing their health effects from air pollutants easy to understand for the general public.

LLE of VOCs was shown in Fig. 5. LLE of VOCs was calculated in the maximum for about 100 minutes around the factory in the prefecture central part. It was thought that exhaust gas from the factory greatly influenced. LLE along the main roads was relatively large for about 90 minutes. Next, LLE of each pollutant and total LLE at measurement sites (about VOCs, at meshes corresponding to each measurement site) were shown in Table 4. Maximum LLE of aldehydes was about 200 minutes at the roadside site, and that of PAHs was about 260 minutes at the roadside site. Considering the results of VOCs, we found to have a big impact on auto emissions. Maximum LLE of metals were about 40 minutes, those were smaller than the others. Total LLE of carcinogenic air pollutants were calculated from a minimum of 303 minutes (about 5.6 hours) to a maximum of 519 minutes (about 8.6 hours). Those had large contribution of aldehydes and PAHs. Finally, LLE of ozone assessed risk of increased non-accidental mortality was calculated a minimum of 550

Table 4. LLE of air pollutants (unit;minute)

	Residential				Roadside		Industrial		
	A	B	C	D	a	b	α	β	γ
VOCs	82	81	85	91	87	83	96	94	103
Aldehydes	75	155	65	-	203	179	-	-	-
PAHs	197	153	111	-	180	257	-	-	-
Metals	40	38	42	-	-	-	-	-	-
Total LLE of carcinogens	394	427	303	91	470	519	96	94	103
Ozone	-	-	432	-	-	550	-	-	-

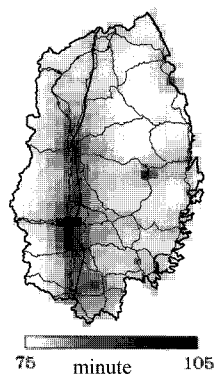


Fig. 5. LLE of VOCs.

minutes (about 9.2 hours), it was larger than total LLE of the carcinogens. However, we found that total LLE of all air pollutants calculated in this study was less than those of passive smoking (12 days due to lung cancer) [24], etc.

5. Conclusion

In this study, we measured the concentrations of airborne VOCs, aldehydes, PAHs, heavy metals and ozone at several points in Iwate Prefecture, Japan from 2007 to 2009. And the concentration distributions of VOCs were estimated by ADMER using PRTR. As a result, high concentration was observed around the factories with high emissions and the roadsides. Based on them, we calculated environmental risk. As a result, it was found that the surround of factories with high emissions and highly toxic chemicals and the roadsides were high risk area, B[a]P, formaldehyde and ozone exceeded 10^{-5} risk level, and benzene and chloroform contributed relatively large in VOCs. In addition, we calculated LLE for an index to explain those risk clarity. This time was calculated for about 8.6 hours in the area where total LLE of carcinogenic air pollutants was higher. We found that contribution of formaldehyde and PAHs was large. Moreover, LLE of ozone was calculated about 9.2 hours, it was larger than total LLE of the others.

However, the risk assessment of chemicals needs to take account of interactive effects (i.e. antagonism, synergy and additively) [25]. More detailed risk assessment is needed not only the diffusion estimate of VOCs but that of the airborne dust contain PAHs and secondary alteration and product chemicals contain aldehydes. We will continue measuring the air pollution concentration from now on, and we want to propose simple risk assessment technique for general public.

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