A MODEL FOR PRIORITISATION OF INDUSTRIAL AIR POLLUTANTS: PART II. APPLICATION

Puong Ling Law[1], Gracie S.C. Chong[2] and Chee Khoon Ng[1]

[1] *Department of Civil Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak*

[2] *Jabatan Kerja Raya Sarawak, Wisma Saberkas, Jalan Tun Abang Haji Openg, 93852 Kuching, Sarawak*

ABSTRACT

A model for prioritisation of industrial air pollutants was recently developed for use in Sama Jaya Free Industrial Zone (SJFIZ), Kuching based on the amount of toxic organic chemicals released into the atmosphere through stack and fugitive emissions. The Chemical Health Risk Index Number (CHRIN) rankings generated by this model indicate that xylene, among all chemicals emitted has the greatest health impact in terms of population and workers exposure with highest CHRIN of 4.246, followed by methyl ethyl ketone (3.153), trichloroethylene (2.244), ethylene glycol (2.214), methanol (1.697), toluene (1.479) and ethylbenzene (0.610). It is concluded that manufacturing facilities in SJFZ should devote its resources and research more effectively on xylene, followed by methylene ethyl ketone, trichloroethylene, ethylene glycol, methanol, toluene and theylbenzene on use reduction technologies and methods.

Keywords : *Chemical Health Risk Index Number (CHRIN), Ethylbenzene, Ethylene Glycol, Industrial Air Pollutant, Model, Methanol, Methylene Ethyl Ketone, Prioritisation, Health Impacts, Trichloroethylene, Xylene*

1 INTRODUCTION

The prioritisation model applied to industrial air pollutants recently developed takes into consideration the relative toxicity of a range of commonly used industrial chemicals, volume released into the air, contaminant transported in the plume, and atmospheric fate of chemicals [1]. The approach is to quantify in a relative sense, the potential health risks of nearby population and in-plant workers. The prioritisation model is applicable to a manufacturing facility that releases toxic chemicals into the air would produce a rank-ordered list of chemical health risk index number. The higher the chemical health risk index number, the more problematic is the chemical.

The model is intended to help the particular manufacturing facility devote its resources more effectively to research on toxic use reduction technologies and methods, or prioritise the facility's research agenda in toxics use reduction. The chemical health risk indices derived from the various algorithms in this model are intended as a reference in identification and prioritisation of chemicals for environmental management or toxics use reduction purposes. It is not meant to serve as an absolute measure for environmental control measure or toxics use reduction for any individual industrial facilities that emit toxic air pollutants.

Based on the program and developed area, the assumed quantity of chemical used in process line from the SJFIZ is shown in Table 1 [2]. Even though most of the industrial wastes generated from SJFIZ are in solid, semi-solid and liquid forms, e.g., solvent, oil, sludge, liquid and solid waste, a great majority of the solvents and liquids are volatile such as organic degreasing solvents [3]. The primary organic degreasing solvents air emissions from SJFIZ are ammonia, ethylbenzene, ethylene glycol, methanol, methyl ethyl ketone, toluene, trichloroethylene and xylene [3]. The estimated total air emissions SJFIZ industries are presented in Table 2, and estimated emission rates by engineering calculation methods for major chemicals are shown in Table 3 [4].

Table 1: Annual chemical utilisation at the facilities in SJFIZ

Year (m^3)	1996 (m^3)	1997 (m^3)	1998 (m^3)	1999 (m^3)	2000 (m^3)	2001 (m^3)
Solvents	100	135	170	200	240	350
Liquids	750	1230	1715	1770	1825	2620

Table 2: Estimated total emissions from facilities in SJFIZ

Year	Estimate 20% of solvents evaporated (g/s)	Estimate 5% of liquids evaporated (g/s)	Total emission rate (g/s)
1996	0.0028	0.0052	0.0080
1997	0.0038	0.0085	0.0123
1998	0.0047	0.0119	0.0166
1999	0.0056	0.0123	0.0179
2000	0.0067	0.0127	0.0194
2001	0.0097	0.0182	0.0279

Table 3: Calculated emissions for selected chemicals released from SJFIZ

Name	Formula	MW_x	T (R)	P_{vap} (psia)	Evaporation rate, W_x (g/s)
Ammonia	NH_3	17.03	351.74	6.11E+03	4.43E+02
Ethylbezene	C_8H_{10}	106.17	320.67	4.01E-03	1.08E-03
Ethylene glycol	$C_2H_6O_2$	62.07	468.27	2.48E-01	3.20E-02
Methanol	CH_4O	32.04	315.85	1.11E-01	1.37E-02
Methyl ethyl ketone	C_4H_8O	72.10	335.66	1.39E+00	2.77E-01
Toluene	C_7H_8	92.13	320.72	4.23E-02	1.04E-02
Trichloroethylene	C_2HCl_3	131.40	242.64	1.17E-01	4.79E-02
Xylene	$C_6H_4(CH_3)_2$	106.16	446.36	2.20E+01	4.25E+00

2 AREA OF STUDY AND METHODS

In this study, computer simulations were carried out using prioritisation model recently developed in an attempt to prioritise the toxic organic chemicals released from Sama Jaya Free Industrial Zone (SJFIZ), Kuching through stack and fugitive emissions. Most of the industrial wastes generated from SJFIZ are in solid, semi-solid and liquid forms, e.g., solvent, oil, sludge, liquid and solid wastes [3]. However, most of the solvents and liquids are volatile, like the organic degreasing solvents such as methyl ethyl ketone, toluene, xylene and methanol [3]. About 20% of the volatile solvents and 5% of liquids are evaporated before disposal as liquid wastes [5]. The estimated total emissions released into the atmosphere from SJFIZ industries are given in Table 2. To estimate the selected chemicals encountered in semiconductor manufacturing industries in SJFIZ, the estimated emission rates using engineering calculation methods for selected chemicals are shown in Table 3 [4].

The prioritisation model of air pollutants produces three specific indices: Population Exposure Index (PEI); Occupational Exposure Index (OEI); and Chemical Hazard Risk Index Number (CHRIN). Air pollutants prioritisation simulations using SJFIZ total organic air emission data were carried out to generation PEI, OEI and CHRIN. Identification and prioritisation of organic chemicals emitted from the industries would depend on CHRIN values for the individual organic chemicals. The model would produce a rank-ordered list of CHRIN for the individual organic chemicals emitted from SJFIZ - the higher the CHRIN numerical value, the more problematic is the chemical.

To prioritise the organic chemicals emitted from SJFIZ, the model simulated incremental ground level pollutant concentrations, that is, 365-day average and 24-hour average by using 2000 meteorological data over SJFIZ, and generated the PEI, OEI, and CHRIN indexes. The incremental ground level pollutant concentrations (C_i) for 365-day average concentrations and 24-hour average concentrations were simulated based on meteorological data for year 2000. To meaningfully estimate the nearby population exposure, the iso-concentration curves (isopleths) of the individual air pollutants are taken within a radius of 8 km are plotted corresponding to lowest concentration cut-off point of 0.002 µg/m^3 [6].

Population Exposure Index (PEI) numbers were generated providing a list of nearby population exposure indices ranked by potential exposure to organic chemicals released into the atmosphere from SJFIZ. The PEI values were dependent on the extent of population exposure in the proximity, size and contaminant levels contained in the plumes. The Occupational Exposure Index (OEI) numbers were generated giving a list of chemicals ranked by potential chemical risk to workers in the facilities SJFIZ. The algorithms that produce these indexes are intended to calculate the incremental risk posed by each of the chemicals to which workers in a facility are potentially exposed. Chemical Hazard Risk Index Number (CHRIN) Generation - Chemical Hazard Risk Index Number (CHRIN) could be finalised with the integration of Health Risk Index Number (HRIN) [7], Chemical Atmospheric Fate Index (CAFI) [6], Population Exposure Index (PEI), and Occupational Exposure Index (OEI). CHRIN are then used to prioritise and rank the given toxic chemicals emitted into the atmosphere.

3 RESULTS AND DISCUSSION

3.A Simulated Incremental Ground Level Pollutant Concentrations

The model simulated incremental ground level pollutant concentrations (µg/m^3) downwind and within 8 km radius from the source area (SJFIZ) for 365-day average concentrations and 24-hour average concentrations [6]. Table 4 shows the top ten maximum ground level incremental annual average concentrations in the vicinity of emission source for years 1996, 1997, 1998, 1999, 2000 and 2001. In year 1996, the maximum annual average concentration was 0.00758µg/m^3 occurred at 212.13m east and 212.13m north of the pollutant release source. The simulated second maximum average concentration was 0.00677 µg/m^3 occurred at 353.55m East and 353.55m north of the emission source. The maximum incremental ground level annual average concentrations were 0.01157 µg/m^3 for 1997, 0.01562 µg/m^3 for 1998, 0.01684 µg/m^3 for 1999, 0.01837 µg/m^3 for 2000, and 0.02625 µg/m^3 for 2001.

Table 4: Top ten maximum incremental 365-day average concentrations from year 1996 to 2001

	Concentration (µg/m^3) at receptor					
Rank	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
1	0.00758	0.01157	0.01562	0.01684	0.01837	0.02625
2	0.00677	0.01032	0.01393	0.01502	0.01641	0.02341
3	0.00666	0.01020	0.01377	0.01484	0.01616	0.02314
4	0.00630	0.00973	0.01313	0.01416	0.01528	0.02208
5	0.00603	0.00931	0.01257	0.01355	0.01462	0.02112
6	0.00568	0.00869	0.01173	0.01264	0.01379	0.01971
7	0.00547	0.00849	0.01146	0.01236	0.01325	0.01926
8	0.00540	0.00834	0.01125	0.01213	0.01310	0.01891
9	0.00520	0.00805	0.01086	0.01171	0.01262	0.01826
10	0.00486	0.00756	0.01020	0.01100	0.01179	0.01715

Table 5 provides the top ten maximum incremental 24-hour average concentrations (µg/m^3) at ground level in the vicinity of SJFIZ from year 1996 to 2001. The maximum 24-hour average concentration in year 1996 was estimated to be 0.05396 µg/m^3 occurred on 72nd day at 353.55m east and 353.55m north of emission source. In years 1997, 1998, 1999, 2000 and 2001, the maximum incremental average

Table 5: Top ten maximum incremental 24-hour average concentrations from year 1996 to 2001

	Concentration (µg/m^3)					
Rank	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
1	0.05396	0.07846	0.10589	0.11418	0.13085	0.17797
2	0.05338	0.07427	0.10024	0.10809	0.12944	0.16847
3	0.04831	0.07300	0.09852	0.10624	0.11714	0.16559
4	0.04773	0.07296	0.09847	0.10618	0.11575	0.16550
5	0.04746	0.07227	0.09753	0.10517	0.11508	0.16393
6	0.04700	0.07070c†	0.09541c†	0.10288c†	0.11399	0.16036c†
7	0.04550	0.06996	0.09442	0.10181	0.11034	0.15869
8	0.04529c†	0.06991	0.09435	0.10174	0.10984c†	0.15858
9	0.04524c†	0.06854	0.09250	0.09975	0.10970c†	0.15547
10	0.04501	0.06835c†	0.09225c†	0.09947c†	0.10915	0.15505c†

† Calms and missing values are tracked separately for the purpose of flagging the short-term averages. An average that includes a calm hour is flagged with a 'c'

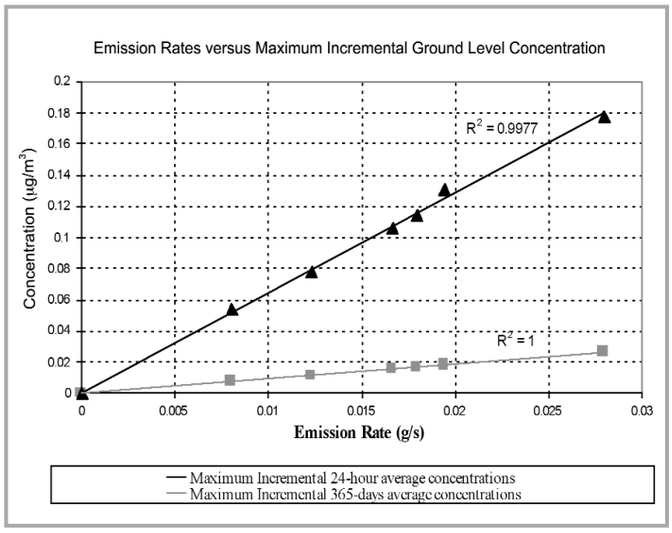

Figure 1: Maximum incremental 365-day average concentrations and 24-hour average concentrations for various emission rates from year 1996 to 2001

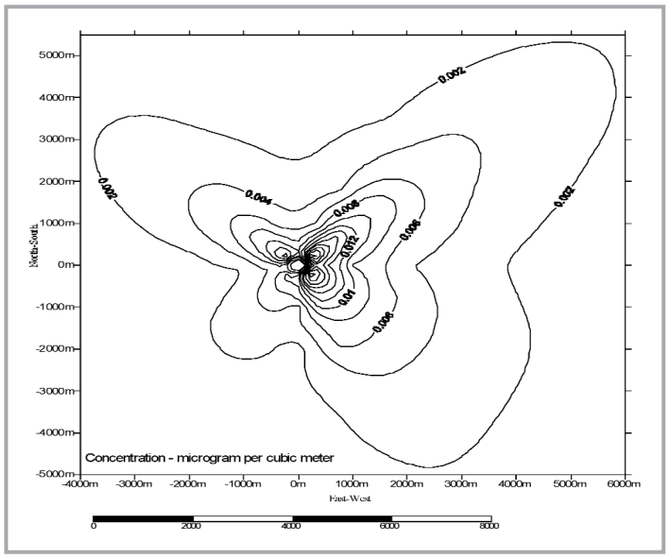

Figure 2: Concentration distribution of total emission rate in year 2001

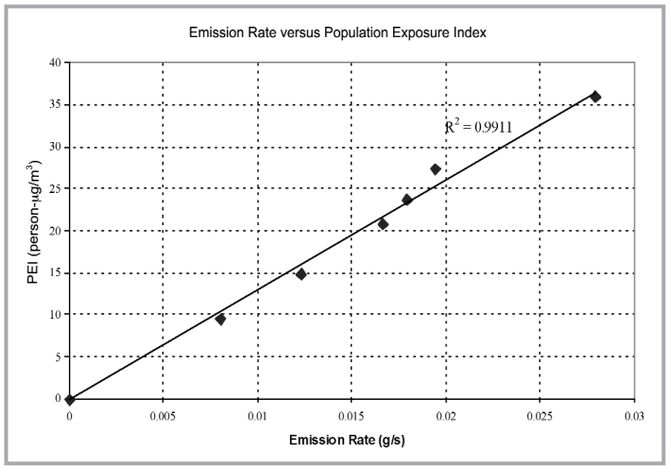

Figure 3: Emission rates versus PEI in SJFIZ from year 1996 to 2001

concentrations were predicted to be 0.07846 µg/m³, 0.10589 µg/m³, 0.11418 µg/m³, 0.13085 µg/m³ and 0.17797 µg/m³, respectively.

Figure 1 illustrates the summary of emission rates, the maximum incremental 365-day and 24-hour average ground level concentrations for year 1996 to 2001. The estimated total emission rates of the individual organic chemicals emitted from SJFIZ for year 1996 to 2001 ranged from 0.008 g/s to 0.028 g/s. Based on the simulated results, the incremental ground level concentrations increased tremendously from 1996 to 2001. The coefficients of correlation (R^2) between the emission rate versus maximum incremental 365-days, and emission rate versus 24-hour average ground level concentrations were found to be 1.0 and 0.9977, respectively. This indicates that the ground level concentrations are totally dependent on pollutant emission rates.

3.B Population Exposure Index (PEI)

The predicted incremental ground level pollutant concentrations (C_i) were simulated by the model based on meteorological data for year 2000. The iso-concentration curves (isopleths) of the individual air pollutants within a radius of 8 km were plotted corresponding to lowest concentration cut-off point of 0.002 µg/m³ and is shown in Figure 2. It is found that the simulated PEI values increased from 9.58 person-µg/m³ in 1996 to 36.03 person-µg/m³ in 2001, and the results are summarised in Table 6 and plotted in Figure 3. The population density used in this research study is based on 2001 census of 107 person/km² - an increase of approximately 23% as compared to 87 person/km² in 1996. However, in terms of the emission rates, it was estimated at 0.008 g/s in 1996 as compared to 0.0279 g/s in 2001 – approximately a 249% increase from 1991 to 2001 in PEI values, that is, from 9.58 to 36.03 person-µg/m³.

Table 6: Predicted PEI from year 1996 to 2001

Year	Emission rate (g/s, 10^{-1})	Population density (person/km²)	PEI (persons-µg/m³)
1996	0.0080	87	9.58
1997	0.0123	91	14.94
1998	0.0166	95	20.87
1999	0.0179	99	23.75
2000	0.0194	103	27.48
2001	0.0279	107	36.03

An appropriate air dispersion model, Industrial Source Complex Short-Term (ISCST) air dispersion model developed by USEPA [8] was integrated into the prioritisation model and was used to estimate the size of plumes covered and respective pollutant concentrations carried in the plume [9-10]. A coefficient of correlation between the emission rates and calculated PEI values was found to be 0.9911 (R^2 = 0.9911). The emission rate correlates well with PEI values indicating that the two variables have a high degree of positive correlation indicating that PEI values are dependent on emission rates of the pollutants released through stack.

As illustrated in Table 7, a total of 7 major organic chemical compounds were emitted into the atmosphere from SJFIZ [3]. To estimate nearby population exposure, isopleths or equal concentration curves were plotted so as to

Table 7: Annual average concentrations of air pollutants released in year 2000

No.	Hazardous air pollutant (HAP)	Emission rate (g/s, 10^{-})	Maximum incremental concentration (ppm)	PEI (person-ppm, 10^{4})
1	Ethylbenzene	0.001081	2.349E-07	0.0005
2	Ethylene glycol	0.03204	1.19E-05	0.0154
3	Methanol	0.01373	9.844E-06	0.0127
4	Methyl ethyl ketone	0.27661	8.817E-05	0.1183
5	Toluene	0.01038	2.601E-06	0.0046
6	Trichloroethylene	0.04787	8.383E-06	0.0171
7	Xylene	4.2535	0.0009	1.5905

calculate the products of annual average ground level concentrations and a specific area enveloped by the plume. From the modeled PEI values (person-ppm) for each of the chemicals, it is found that most PEI values (person-ppm) for hazardous air pollutant are negligibly small (usually below 10 persons-ppm). For instance, ethylbezene is 0.005 person-ppm, Ethyl glycol is 0.015 person-ppm, methanol is 0.013 person-ppm, methyl ethyl ketone is 0.12 person-ppm, phenol is 8.12 person-ppm, toluene is 0.005 person-ppm, trichloroethylene is 0.02 person-ppm and xylene is 1.59 person-ppm, respectively. The details of the calculations of the PEI values are summarised in Table 7.

Since an individual PEI value is the product of pollutant carried in the plume and population density enveloped, PEI would be higher if the lowest concentration cut-off point is chosen to be less than 0.002 µg/m^3 and a corresponding radius of greater than 8 km is considered. The nearby population exposure would be further underestimated by merely taking into account exposures via atmospheric inhalation, and neglecting other factors such as food and water consumption. It is predicted that the PEI values would be higher than the existing figures if a more comprehensive study of multiple-factor exposures were included in the model.

3.C Occupational Exposure Index (OEI)

Table 8 shows the predicted average in-plant pollutant concentrations and the computation of the Occupational Exposures Index (OEI) resulting from fugitive emissions within the facilities. Generally, it is estimated that 50% (poor control efficiency) of the chemicals are evaporated as fugitive emissions [6].

Table 8: Estimated workers exposure to in-plant emission for year 1996 to 2001

Year	Fugitive emission RATE (g/s)	In-plant concentration (mg/m^3)	Workers (estimate)	OEI (person-mg/m^3)
1996	0.0040	0.973	3000	2.06
1997	0.0062	1.497	2500	2.64
1998	0.0083	2.020	2500	3.56
1999	0.0090	2.178	3000	4.61
2000	0.0097	2.361	3500	5.82
2001	0.0140	3.395	3500	8.37

Results generated from the theoretical calculations show that the average in-plant concentrations are directly proportional to fugitive emission rate. The outcomes are illustrated in Table 8 and Figure 4. By considering 87.5% of the total employees in the facility are working fulltime [3], the predicted OEI values for year 1996 to 2001 ranged from 2.06 person-mg/m^3 in 1996 to 8.37 person-mg/m^3 in 2001 – approximately 306% increase (Table 8). The determination between the emission rates versus OEI values for year 1996 to 2001 are illustrated in Figure 5. The coefficient of correlation (R^2) between the OEI and emission rate was found to be 0.9458 (R^{2a} 1). This shows that OEI values are dependent on emission rate of pollutant released within the facility.

Table 9 shows the predicted Occupational Exposure Indices (OEI) resulting from estimated emissions for each chemical in the facilities that have 3500 workers (pen = 3500) and 87.5% of the workers are full time (P_f = 0.875) [3]. There are significant differences in OEI values among chemicals emitted from facilities from SJFIZ. For instance, the OEI values (person-ppm), for ethylbenzene is 9.093 person-ppm, ethylene glycol (461.01 person-ppm), methanol (382.68 person-ppm), methyl ethyl ketone (3426.22 person-ppm), toluene (100.62 person-ppm), trichloroethylene (325.35 person-ppm), and xylene (35782.28 person-ppm), respectively. As indicated, OEI value is a function of average pollutant concentration and number of workers. However, in terms of potential impacts on in-plant workers or prioritising the chemicals used in a facility by merely looking at the OEI values, the average contaminant concentration is primarily the determining factor as the number of workers is held constant.

3.D Comparison of Maximum Incremental Annual Average Ground Level and In-plant Concentrations versus ACGIH's Time-Weighted Average TLV-TWA

The maximum ground level incremental concentrations and in-plant concentrations of chemicals are shown in Table 10. The American Conference of Governmental Industrial Hygienists (ACGIH) has suggested threshold limit values (TLVs) time-weighted average (TWA) permissible air

Table 9: Predicted average in-plant pollutant concentrations in year 2000

No.	Chemical	Fugitive emission rate (g/s)	In-plant concentration (ppm)	OEI (person-ppm)
1.	Ethylbenzene	0.0005	0.0303	9.093
2.	Ethylene glycol	0.0160	1.5358	461.01
3.	Methanol	0.0069	1.2750	382.68
4.	Methyl ethyl ketone	0.1383	11.4100	3426.22
5.	Toluene	0.0052	0.3350	100.62
6.	Trichloroethylene	0.0239	1.0840	325.35
7.	Xylene	2.1268	119.2100	35782.28

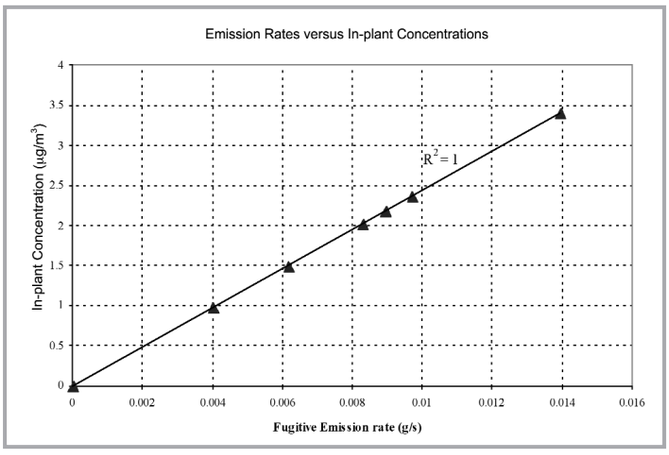

Figure 4: Emission rates versus in-plant concentrations for year 1996 to 2001

Table 10: Simulated ground level and in-plant concentrations versus ACGIH's TLV-TWA

No.	Chemical	Maximum incremental concentration (ppm)	In-plant concentration (ppm)	ACGIH TLV TWA (ppm)
1.	Ethylbenzene	2.349E-07	0.0303	100
2.	Ethylene glycol	1.190E-05	1.5358	50
3.	Methanol	9.844E-06	1.2750	200
4.	Methyl ethyl ketone	8.817E-05	11.4100	200
5.	Toluene	2.601E-06	0.3350	50
6.	Trichloroethylene	8.383E-06	1.0840	50
7.	Xylene	9.000 E-05	119.2100	100

concentrations of a given chemical to which an individual can be repeatedly exposed for 8 hours per day, 5 days per week [11-12]. It is found that the simulated results are much lower than their TWA values, except the in-plant concentration of xylene. The predicted in-plant concentration of xylene is 119.21 ppm as compared to ACGIH TLV-TWA of 100 ppm – approximately 19% higher than ACGIH recommended values. To protect in-plants workers from being exposed to excessive levels of xylene vapors, efficient ventilation system should be introduced or emission rate of xylene should be reduced so as to maintain the level below 100 ppm.

3.E Chemical Health Risk Index Number (CHRIN)

The prioritisation model, when applied to the facilities that releases the toxic chemicals into the air, would produce a rank-order list of chemical health risk index numbers, CHRIN. The higher the index number, the higher health risk the chemical is to the workers, public and environment. The calculated CHRIN values as shown in Table 11 indicate that xylene has the greatest health impact in terms of population and worker exposures, with the highest CHRIN (4.246), followed by methyl ethyl ketone (3.153). Ethylbenzene (0.610) is among the emitters of least concern based on available HRIN and CAFI data. As demonstrated in Table 11, the OEI values are generally higher than the PEI values indicating that CHRIN rankings are greatly influenced by the OEI.

Since the higher the CHRIN values, the higher health risk the chemical is to the nearby population and in-plant workers, the first emission control measures or technologies, or toxic use reduction researches or technologies should be targeted on xylene (CHRIN=4.246), followed by methyl ethyl ketone (CHRIN=3.153), trichloroethylene (CHRIN=2.244), ethylene glycol (CHRIN=2.214), methanol (CHRIN=1.697), toluene (CHRIN=1.479), and ethylbenzene (CHRIN=0.610). The results of the CHRIN rankings of the study showed that all the indices (PEI, OEI, CAFI and HRIN) are crucial and

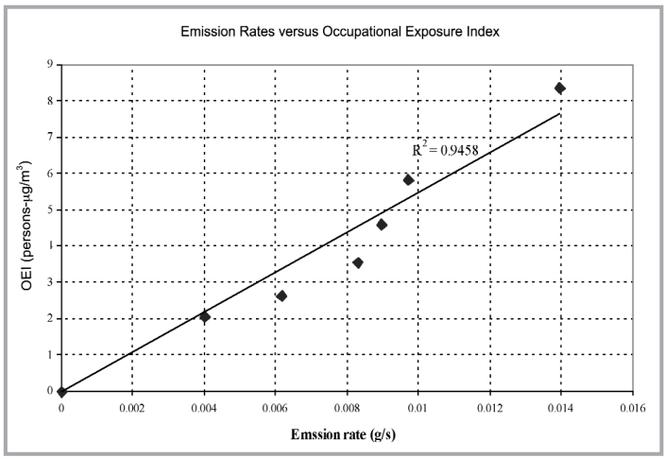

Figure 5: Emission rates versus OEI values for year 1996 to 2001

important elements while in assessing chemical releases and the subsequent human exposures. As shown in Table 11, the OEI values are generally orders of magnitude greater than the corresponding PEI resulting in relatively higher OEI values, that is, OEI being over-estimated while PEI could be greatly under-estimated. For a better comparison of CHRIN among chemicals emitted from the facilities, logarithms are taken on both the PEI and OEI as a way of narrowing the large differences between PEI and OEI to one significant figure (less than 10). As indicated since such a logarithmic method would lower the figures of PEI and OEI proportionally, it does not affect the extent of the bias for CHRIN rankings toward OEI. Generally, based on the nominal estimation, chemicals with relatively high OEI would predominantly rank among the top chemicals released from the faculties in SJFIZ.

4 CONCLUSIONS

Prioritisation of major organic air pollutants emitted from industrial facilities in SJFIZ from year 1996 to 2001 using the model indicates that Chemical Health Risk Index Number (CHRIN) ranking of xylene has the greatest health impact in terms of population and workers exposure with the highest CHRIN value of 4.246, followed by methyl ethyl ketone (3.153), trichloroethylene (2.2 44), ethylene glycol (2.214), methanol (1.697), toluene (1.479) and ethylbenzene (0.610). It is concluded that industrial manufacturing facilities in SJFZ should devote its resources and research more effectively on xylene, followed by methylene ethyl ketone, trichloroethylene, ethylene glycol, methanol, toluene and theylbenzene on use reduction technologies and methods. ■

Table 11: Summary of Calculations for PEI, OEI and CHRIN Values

Chemical	PEI (person -ppm)	OEI (person -ppm)	HRIN population	HRIN worker	CAFI	Nominal CHRIN	Nominal rank (based on CHRIN)
Xylene	1.5905	35782.28	0.368	2.067	1.5	4.246	1
Methyl ethyl ketone	0.1183	3426.22	0.412	1.743	2.5	3.153	2
Trichloroethylene	0.0171	325.35	0.811	2.262	2.5	2.244	3
Ethylene glycol	0.0154	461.01	0.152	1.492	1.0	2.214	4
Methanol	0.0127	382.68	0.000	0.546	2.5	1.697	5
Toluene	0.0046	100.62	0.000	1.257	2.5	1.479	6
Ethylbenzene	0.0005	9.09	0.412	1.880	1.0	0.610	7

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ANNOUNCEMENT

11th Asian Pacific Confederation of Chemical Engineering (APCChE) Congress 2006 - ChemTex 2006

The Chemical Engineering Technical Division is pleased to announce that IEM would be hosting the 11th Asian Pacific Confederation of Chemical Engineering (APCChE) Congress in 2006.

Aptly themed "Innovation Sustaining Future Business", the congress is scheduled from 27 to 30 August 2006 at the latest state-of-the-art convention centre, the Kuala Lumpur Convention Centre.

In conjunction with the congress, an exhibition entitled "ChemTex 2006" (to highlight the Malaysian Chemical Industry Achievement Showcase) would also be held. The showcase is aimed at highlighting the achievements of local R&D companies, institutions and universities that have won medals or awards in innovation, research and development.

IEM members from the Chemical Engineering discipline would have received the brochure on the event by now and the Organising Committee would like to take this opportunity to announce that local participants would be getting the rebates on the registration fee as follows:

Early Bird Registration (before 15 March 2006)	IEM Member	RM 1,600.00
	Rebate	RM 750.00
	Fee after Rebate	RM 850.00
Regular Registration (on or before 15 June 2006)	IEM Member	RM 1,900.00
	Rebate	RM 600.00
	Fee after Rebate	RM 1,300.00
Full Fee (after 15 June 2006)	IEM Member	RM 2,300.00

The Organising Committee looks forward to the support and participation of the IEM Members to make this event a success.