28th ETH Nanoparticles Conference June 16–19, 2025, Zurich

Air Toxics Emissions and Potential Impacts from Industrial Complex and Port Operations in a Harbor City in Taiwan

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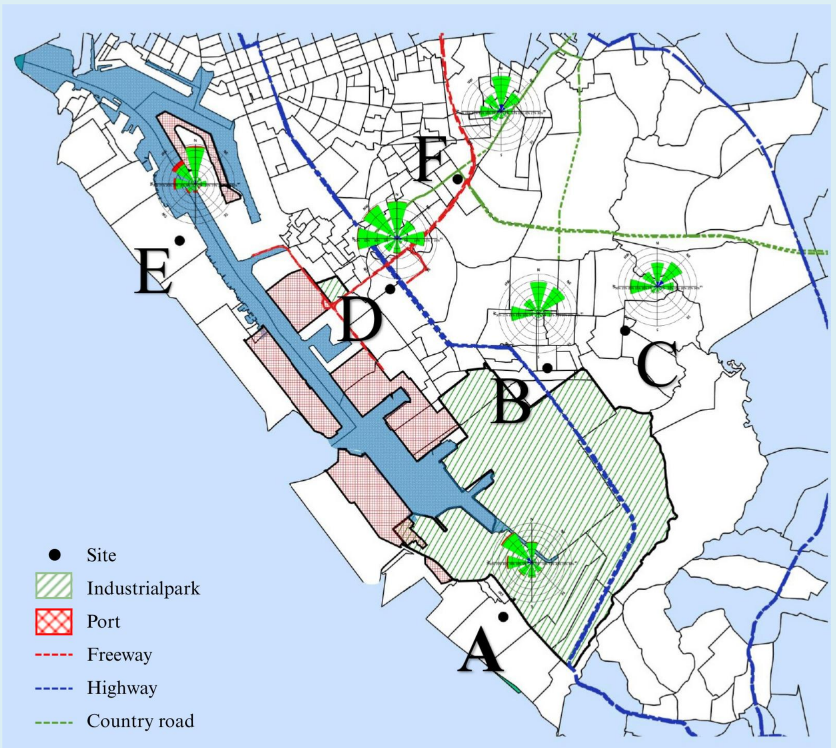
Introduction

The Linhai industrial complex and Kaohsiung port were important air toxics emission sources in the industrial city in southern Taiwan. Emissions from industrial processes, diesel truck and gasoline vehicle transportation, and activities in the port cause significant impacts on the air quality for decades. The potential health impact caused by air toxics on community in the vicinity of industrial complex and port has been concerned by the public in Taiwan. Several researches had been conducted in this area to monitor the ambient VOCs and particle-bound heavy metals in the region and presented a significant potential impact[1]. This research analyzed the monitoring data of toxic-VOCs and heavy metals, estimated the emissions of six species of air toxics from stationary sources, mobile sources, and port activities. Air quality modeling also applied to identify the potential hot spots in the nearby communities and evaluate the potential health impacts by air toxics from various sources in this region.

Methodology



The major emission sources and air monitoring sites were shown as Fig.1.

1. Estimation of air toxics emissions from stationary sources
   (1) Emissions estimation of heavy metal and VOCs were based on the database of The Ministry of Environment, Taiwan, ROC. [2]
   (2) Emissions from mobile sources were derived by fuel consumption method and MOVES model.
2. Air toxics concentration simulation were by applying the AERMOD model. The estimated emission grid size is 200m × 200m for simulation. Local meteorology parameters and geographical information were from official data bank.
3. Analysis of hot spot area were conducted by referring to the OEHHA risk assessment guidelines[3]. The model simulates the annual average concentration to estimate the inhalation cancer risk.

Fig.1 Major emission sources and air monitoring sites in the study region

Ambient Monitoring Data

- Annual average concentrations of target air toxics were shown as Fig. 2. Toluene concentrations at all sites were higher than the other species and followed by xylene and benzene. These results indicate that airborne VOCs in this region were dominantly contributed by mobile sources. However, the highest concentrations of each species at various sites were different.

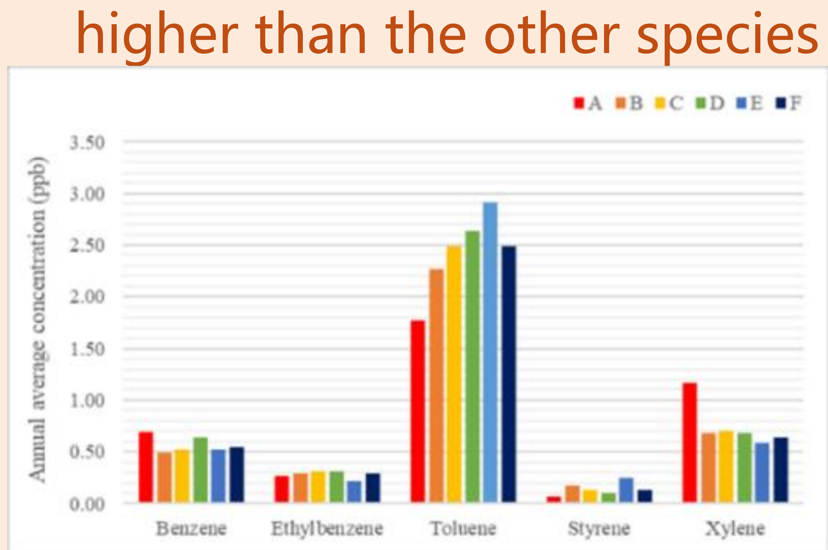


Fig. 2 Annual average concentrations of target air toxics at different monitoring sites

Emission Data

- Emissions of target air toxics are shown in Fig.3. Port activities were the dominant sources of benzene, formaldehyde, 1,3-butadiene,and DPM. The ocean-going ships operating in the port area, heavy duty vehicles, and port operation ships were the major sources of DPM. Vinyl chloride and arsenic (As) were emitted by stationary sources. The emission weighted by carcinogenic effect factor indicated that DPM accounted for 90% of total effect-weighted emission of these target air toxics in the study region.

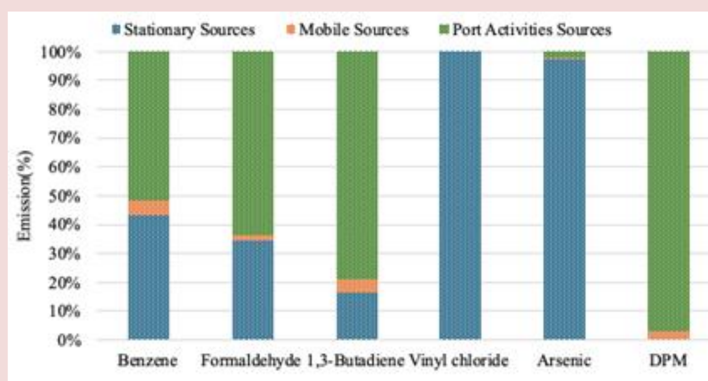
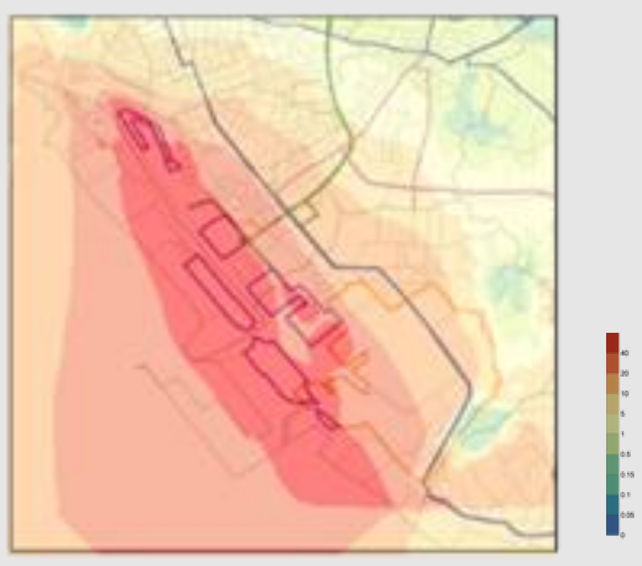


Fig. 3 Emissions of target air toxics from various sources

Spatial Distribution of Air Toxic Concentration

- Modeling results indicated that the average incremental concentration (calculated by averaging all grids) of benzene (1.9 μg/m^3) is 1.1 times of WHO reference value. The value of formaldehyde (7.6 μg/m^3) is 0.7 time of WHO reference value. The value of arsenic (0.7 ng/m^3) is 0.1 time of WHO reference value. The value of 1,3-butadiene (0.5 μg/m^3) and vinyl chloride (0.1 μg/m^3) are 0.2 and <0.1 times of Japanese reference value, respectively. The average incremental concentration of DPM from multiple sources is 6.0 μg/m^3.



- The overall results show that airborne concentration of benzene exceeded the environmental reference concentration which should be concerned.

Spatial distribution of DPM concentration is shown as Fig. 4. Higher concentration was observed in the port area.

Fig. 4 Spatial distribution of DPM concentration by modeling

Inhalation Risk Assessment and Hot Spot

- The results indicated that almost all grids in the study region were exposed the potential risk value > 10^{-4} caused by DPM. About 3% area is exposed the potential risk value > 10^{-4} caused by 1,3-butadiene.
- For both formaldehyde and benzene, about 1% area is exposed to the potential risk value > 10^{-4}. For vinyl chloride and arsenic, none of any grid were exposed the potential risk value >10^{-4}.
- Above all, DPM and 1,3-butadiene emitted by stationary sources, mobile sources, and port activities imposed significant potential health impacts on the neighborhood communities. It means that a significant reduction program on DPM and 1,3-butadiene should be implemented as soon as possible.

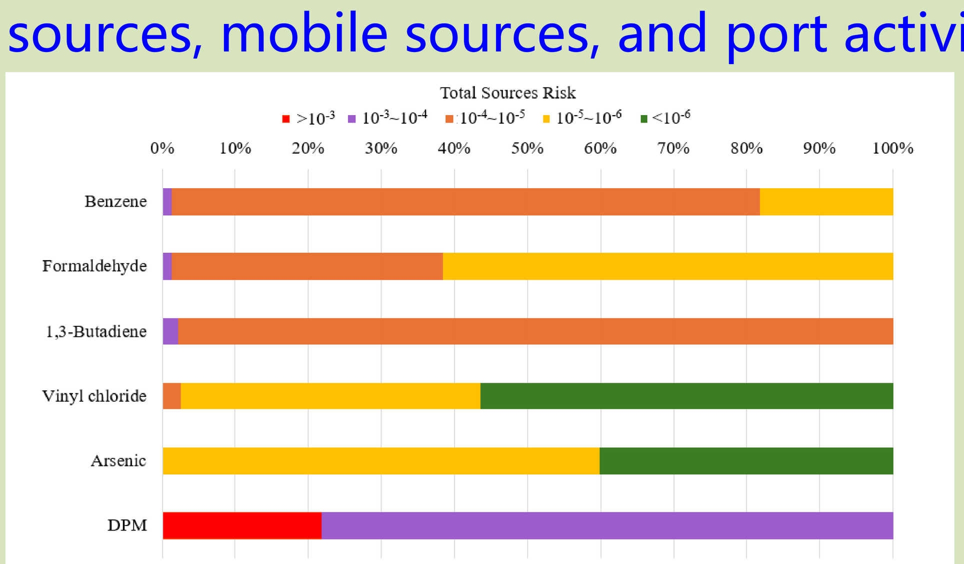


Fig.5 Potential impact of incremental concentration of composite source grid

Conclusion

The results derived from air monitoring data, model simulation, and risk assessment indicate that there are many communities, with distance < 1 km to the industrial complex or port, potentially under high risk and should be put on the hot spot list. The critical air toxics include DPM, benzene, and 1,3-butadiene which are emitted by stationary sources, mobile sources, and port activities. A reduction program targets on DPM, benzene, and 1,3-butadiene should be implemented as soon as possible for public health.

[References]

1. Taiwan EPA, Report No. EPA-109-FA1203-A163, 2020. (In Chinese)
2. TEPA, Taiwan HAP Emission Data, 2021. (In Chinese)
3. OEHHA, Consolidated Table of OEHHA / CARB Approved Risk Assessment Health Values. 2020.

[Acknowledgements]

This research was granted by NSTC, Executive Yuan, Republic of China under NSTC 111-2221-E-006-024-MY2.