

Sex Ratio at Birth Associated with Petrochemical Air Pollution in Taiwan

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Only a few studies have examined the relationship between exposure to petrochemical emissions and its health effects on surrounding communities. The findings from these studies have also been inconclusive. Some studies have observed associations between residence in petroleum and chemical manufacturing areas and cancer mortality rates (Hoover and Fraumeni 1975, Blot and Fraumeni 1976, Blot et al. 1977, Kaldor et al. 1984), while another study provided findings that place of residence near petrochemical industries is not associated with increased cancer risk (Hearey et al. 1980).

The petrochemical industry is considered to be the main source of industrial air pollution in Taiwan (EPA/ROC 1992). Our recent studies have found that exposure to petrochemical air pollution may be associated with increased rates of acute irritative symptoms in adults (Yang et al. 1997a) and upper respiratory symptoms and asthma in school children (Yang et al. 1998). In addition, we have found that petrochemical air pollution may increase male liver cancer risk (Yang et al. 1997b) and female lung cancer risk (Yang et al. 1999).

The mechanism by which pollution could affect the sex ratios at birth is not clear. Williams et al. (1992,1995) suggested a biological model: the metabolism of the rapidly dividing cells of the gonadal and fetal tissues appears to be particularly vulnerable to the influences of pollutants. Nonetheless, sex ratio at birth has been suggested as a crude but routine index of the quality of public health which can provide early warning of cryptic health hazards from environmental pollution (Lyster 1973, Hytten 1982).

The objective of the present study was to explore the hypothesis that abnormal sex ratio of births would be found in municipalities with residential exposure to petrochemical air pollution. This report is one in a series of studies evaluating the health hazards from petrochemical air pollution.

MATERIALS AND METHODS

Taiwan is divided into 361 administrative municipalities. According to the 1989 census of manufactures, a total of 218 municipalities had plants engaged in

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petrochemical manufacturing, although there were less than 50 employees in about 30% of these municipalities (MOE/ROC 1989). In this study, an individual municipality was classified as a “petrochemical industrial municipality” (PIM) if the number of workers in the petroleum and petrochemical industry comprised at least 2 per cent of the municipality’s total population. This proportion was used as an indicator of a resident’s exposure to air emissions from petrochemical plants. In all, 16 municipalities satisfied these criteria. Their details have already been described in an earlier publication (Yang et al. 1997b).

In 1994, the Environmental Protection Administration organized a network of 66 air-quality monitoring stations in 66 municipalities. Among these, only 5 stations were located in our 16 study municipalities. For each station, we obtained information on daily PM_{10} and SO_2 levels and calculated the mean yearly concentration for 1994. The average levels of PM_{10} and SO_2 at the 5 stations located in study municipalities were $84.6 \mu g/m^3$ and 18.3 ppb respectively. The corresponding average values in the rest of Taiwan were $68.8 \mu g/m^3$ and 7.2 ppb respectively. The study municipalities had higher concentrations of PM_{10} and SO_2 than the rest of Taiwan.

Since it is obligatory to register any birth, death, marriage and divorce, and migration in the household registration office, the population statistics in Taiwan are highly accurate and complete. The annual numbers of male and female births in study municipalities in 1987-1996 were obtained from the Taiwan-Fukien Demographic Fact Book printed by Republic of China Ministry of Interior. The annual sex ratios at birth were calculated first for the individual PIMs. The mean sex ratios at birth in all PIMs were then calculated. The null hypothesis tested was that the ratio of boys to girls in PIMs would not be higher than that for the rest of Taiwan. The statistical significance of the sex ratios were assessed by using the Z test. When Z exceeds ± 1.96 , $P < 0.05$.

RESULTS AND DISCUSSION

The sex ratio at birth is defined as (number of male births/number of female births) $\times 100$. The sex ratio at birth in the PIMs for the period of 1987-1991 and 1992-1996 were 109.2 (52,399/47,804) and 109.0 (56,490/51,808), respectively. Statistically significant high sex ratios at birth were found for 1987-1992, the ratio was also high (but not quite significant, $P=0.064$) in 1992-1996. The mean sex ratios at birth for the combined period 1987- 1996 in PIMs were again highly significant compared to national live birth sex ratios.

Perinatal and infant mortality had been previously used as indicators of quality of public health. However, with improvements in obstetrical care, these variables have become less discriminating (Williams et al. 1995). It has also been suggested that the sex ratio of births might be used to reflect deaths at much earlier stages and therefore might be used to monitor the quality of public Health (Hytten, 1982, Williams et al. 1995). Furthermore, given the large

populations involved, sex ratios has also been suggested as a sentinel indicator of avoidable health exposures (Davis et al. 1998).

The completeness and accuracy of the birth registration system should be evaluated before any conclusion can be made. In Taiwan, infant births have to be registered by the parents or the family concerned within 15 days. It is required to obtain a birth certificate from the hospital or clinics, which then must be submitted to the household registration office in order to register birth. Since most deliveries in Taiwan took place in either a hospital or clinic (98.8%) (Wu and Young 1986), and the birth certificates are completed by physicians and it is mandatory to register all births at local household registration offices, the birth registration is very complete.

Workers exposure to certain chemicals has been found to be associated with abnormal sex ratios at birth in their children. Significantly low sex ratios have been found in the offspring of male workers exposed to nematocide DBCP (1,2-dibromo-3-chloro-propane) (Goldsmith et al. 1984, Potashnik and Yanai-Inbar 1987), borates (James 1995), dioxin (James 1997a, Dimich-Ward et al. 1996), and vinclozolin (James 1997b). Several other occupations also have been reported to be associated with low sex ratios including male carbon setters (Milham 1993), and men that work in high-voltage installations (James 1997c).

If exposure to pollutants within industries can cause an imbalance of the sex ratios in the worker's offspring, it is reasonable to believe that pollutants from those industries might also cause abnormal sex ratios in the offspring of residents exposed to those pollutants (Williams et al. 1995). There is sparse data, however, regarding the possible association between sex ratio at birth and air pollution. One study reported a lower sex ratio at birth in residential areas at risk from air pollution from incinerators (Williams et al. 1992). Two studies reported higher sex ratios at birth in areas exposed to polluted air from a local steel foundry (Lloyd et al. 1984, 1985). A recent study conducted in Scotland, however, found no convincing evidence that exposure to generalized airborne pollution was associated with abnormal sex ratios (Williams et al. 1995). Here we report a high sex ratio at birth in PIMs. One hypothesis is that different pollutants affect the sex ratios in different ways and may cause both abnormally high or abnormally low sex ratios (Williams et al. 1995). The pollutants released by the petrochemical industries in Taiwan include vinyl chloride monomer, polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) (EPA/ROC 1992); while the pollutants found in other studies were polycyclic hydrocarbons (PCHs) (Williams et al. 1992), iron, manganese, nickel, cadmium and copper (Lloyd et al. 1984, 1985). In the present study, we lacked data to permit estimates of levels of pollutants (environmental estrogens) which could affect sex ratios between PIMs and the rest of Taiwan. However, we believed that the concentrations of environmental estrogens are positively correlated with the criteria pollutants such as PM₁₀ and SO₂. In this study, the study municipalities had higher concentrations of PM₁₀ and SO₂, than the rest of Taiwan. Therefore, it is believed that the study

municipalities also had higher concentrations of environmental estrogens than the rest of Taiwan.

James (1996) has hypothesized that the sex ratio of mammalian (including human) offspring is partially controlled by the hormone levels of both parents at the time of conception, girls being favored by high levels of gonadotropin and low levels of testosterone. Our findings may suggest that petrochemicals may either decrease the gonadotropin levels or elevate testosterone levels in the residents living in PIMs. The observed associations in these data warrant further investigation of the role of petrochemicals on the offspring's gender. We suggested that future studies perform endocrine challenge test, i.e., gonadotropin and testosterone measurements, to provide a better assessment of the possible petrochemicals-related effects on sex ratios.

Younger paternal age (Ruder 1985), younger maternal age (Hyttén and Leitch 1971), high socio-economic class of population (Teitelbaum and Mantel 1971), and exposure to diseases such as hepatitis (Drew et al. 1978) has been shown to increase the sex ratios in communities. There is unfortunately no information available on these variables for individual PIMs and they could not be adjusted for directly in the analysis. Although there is no reason to believe that there would be any difference between the PIMs and the rest Taiwan regarding these variables, the association found in this study could not rule out the role of chance. In our study, however, if sex ratios are affected via residential exposure to petrochemical air pollution, the detection of such abnormalities would constitute an early indication of a cryptic health hazard (Williams et al. 1992).

Table 1. Sex ratio at birth in petrochemical industrial municipalities (PIMs) in Taiwan 1987-1996

Year	Male birtsh	Female births	Sex ratio	Z statistic
1987-1991	52,399	47,804	109.2	2.48 (P =0.012)
1992-1996	56,490	51,808	109.0	1.85 (P =0.064)
1987-1996	108,889	99,612	109.3	2.96 (P =0.003)

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