RESEARCH ARTICLE

# Geographic Distribution and Epidemiology of Lung Cancer During 2011 in Zhejiang Province of China

**Xia-Lu Lin[1&], Yan Chen[2&], Wei-Wei Gong[3], Zhao-Fan Wu[4], Bao-Bo Zou[1], Jin-Shun Zhao[1], Hua Gu[3]*, Jian-Min Jiang[3]***

## Abstract

**Background: To explore etiology for providing scientific clues for the prevention of lung cancer. Materials and Methods: Data for lung cancer incidence and meteorological geographic factors from 25 counties in Zhejiang province of China during 2011 were studied. Stepwise multiple regression and correlation analysis were performed to analyze the geographic distribution and epidemiology of lung cancer. Results: 8,291 new cases (5,998 in males and 2,293 females) of lung cancer during 2011 in Zhejiang province were reported in the 25 studied counties. Reported and standardized incidence rates for lung cancer were 58.0 and 47.0 per 100,000 population, respectively. The incidence of lung cancer increased with age. Geographic distribution analysis shows that the standardized incidence rates of lung cancer in northeastern Zhejiang province were higher than in the southwestern part, such as in Nanhu, Fuyang, Wuxing and Yuyao counties, where the rates were more than 50 per 100,000 population. In the southwestern Zhejiang province, for instance, in Yueqing, Xianju and Jiande counties, the standardized incidence rates of lung cancer were lower than 37 per 100,000 population. Spearman correlation tests showed that forest coverage rate, air quality index (AQI), and annual precipitation level are associated with the incidence of lung cancer. Conclusions: Lung cancer in Zhejiang province shows obvious regional differences. High incidence appears associated with low forest coverage rate, poor air quality and low annual precipitation. Therefore, increasing the forest coverage rate and controlling air pollution may play an important role in lung cancer prevention.**

**Keywords:** Lung cancer - geographic distribution - air quality index (AQI) - forest coverage rate - annual precipitation

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## Introduction

Lung cancer is the most common malignant tumor in the world, both in terms of incidence and mortality (Ahsan et al., 2004). In recent years, lung cancer incidence and mortality rates have been rising sharply worldwide, especially among the younger population (Zeng et al., 2008).

Although smoking, air pollution, exposure to carcinogens (such as asbestos), ionizing radiation etc., have been shown to be risk factors for lung cancer (Bhaskarapillai et al., 2012; Crawford et al., 2012; Zhang et al., 2012; Demirci et al., 2013; Babacan et al., 2014; Hajmanoochehri et al., 2014; Luqman et al., 2014), the pathogenic mechanism and the interactions between these risk factors are not entirely clear. Especially, the role of meteorological geographic factors in lung cancer is inconclusive. Geographic analysis is a useful method to determine the cluster of disease incidence and explore the association between the geographical factors and diseases (Ahari et al., 2013; Katayama et al., 2014; Shah et al., 2014). Research evidence shows that the incidence of lung cancer differs by geographic area, sex, and age, which reflects the complexity of lung cancer etiology (Alberg et al., 2003).

Research evidence has demonstrated that the incidence rate of lung cancer in Zhejiang province was higher than the national average in China (Mao et al., 2002 ). In the previous study, we found that the geographic distribution of lung cancer in Zhejiang province showed an obvious regional difference. To explore the etiology of lung cancer, we analyzed the association of meteorological geographic factors with lung cancer in Zhejiang province by using space geographic information system (GIS).

## Materials and Methods

In this study, meteorological geographic factors, including forest coverage, annual average temperature, annual sunshine, annual precipitation, relative humidity,

[1]*Medical School of Ningbo University, Zhejiang Provincial Key Laboratory of Pathological and Physiological Technology, Ningbo,* [2]*Public Health School of Zhejiang University, Hangzhou Red Cross Hospital,* [3]*Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou, Zhejiang Province,* [4]*School of Public Health, Fudan University, Shanghai, China* [&]*Equal contributors *For correspondence: hgu@cdc.zj.cn, jmjiangcdc@163.com*

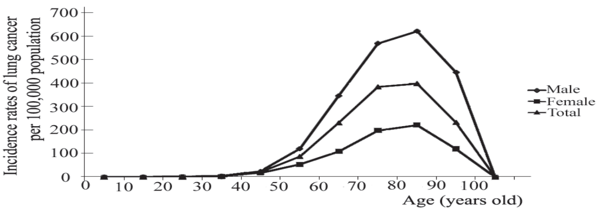


**Figure 1. Age Distribution of Lung Cancer**

and AQI, were studied. Data were obtained from the county Bureau of Meteorology, county Environmental Protection Agency, and Zhejiang Provincial Health Department. The digital map of Zhejiang province was obtained from the National Geographic Information Center. Digital map of county boundaries of digital maps (1:1 million) were used for the Zhejiang digital map database. Lung cancer incidence database during 2011 of 25 counties in Zhejiang province was provided by the Institute of Chronic Disease Control and Prevention of Zhejiang Provincial Center for Disease Control and Prevention.

*Spatial analysis*

Zhejiang counties' administrative boundaries digital maps developed by National Geographic Information Center of China were set as the background. Data of standardized incidence of lung cancer and the geographic factor were entered into the electronic digital maps at the approximate latitude and longitude as the center of the county in a point to point way by using Arcview 3.0 software. Under [Surface] menu, using the [Create Contours] and [Interpolate Grid] commands, the spatial distribution maps of lung cancer of Zhejiang province were created. For the no data counties, predicted data were speculated from the data of 12 closest points (counties) by using Inverse Distance Weighting (IDW) of the Arcview 3.0 software. Thereafter, the data were transferred to Excel table for further analysis.

*Statistical analysis: Stepwise multiple regression and correlation analysis*

The spatial prediction data were imported into SPSS software. The standardized incidence rate ($p$) of lung cancer (converted by ) was set as the dependent variable. Meteorological geographic factors were set as independent variables. Stepwise regression analysis was used to screen out the meteorological geographic factors which were significantly associated with lung cancer. Using SPSS software, association of standardized incidence of lung cancer with geographic factors was detected by correlation analysis. The spatial distribution of both standardized incidence rate of lung cancer and geographic factors on the maps was constructed using Arcview 3.0 of GeoProcessing Wizard model.

## Results

*Gender distribution of lung cancer*

8291 new cases of lung cancer including 5998 males (72.34%) and 2293females (27.66%) during 2011 in 25 counties of Zhejiang province were registered. The reported incidence rate and standardized incidence rate for lung cancer was 57.95 and 47.01 per 100, 000 population, respectively. The reported incidence rate in males (82.83 per 100, 000 population) was 2.55 times higher than females (32.45 per 100, 000 population). Compared with the lung cancer incidence rates (78.23 in males and 29.25 in females per 100, 000 population) during 2009 in Zhejiang province, the reported incidence rates during 2011 increased by 5.88% in males, and 10.95% in females.

**Table 1. Lung Cancer Incidence rate in 25 Counties in Zhejiang Province During 2011**

| County | Number of lung cancer cases | Total population | Reported incidence rate (/100, 000 population) | Standardized rate (/100, 000 population) |
|---|---|---|---|---|
| Yueqing | 379 | 1240544 | 30.55 | 28.77 |
| Yuecheng | 262 | 650351 | 40.29 | 30.63 |
| Xianju | 181 | 495279 | 36.55 | 33.53 |
| Putuo | 153 | 321285 | 47.62 | 35.57 |
| Jiande | 234 | 510194 | 45.86 | 36.29 |
| Lucheng | 356 | 713956 | 49.86 | 41.31 |
| Suichang | 117 | 231375 | 50.57 | 42.42 |
| Wenling | 695 | 1192880 | 58.62 | 47.57 |
| Dongyang | 490 | 820091 | 59.75 | 47.7 |
| Wuyi | 208 | 337391 | 61.65 | 47.88 |
| Fenghua | 298 | 483455 | 61.64 | 48.21 |
| Xinchang | 261 | 436505 | 59.79 | 49.38 |
| Yunhe | 58 | 112785 | 51.43 | 49.44 |
| Tongxiang | 449 | 674022 | 66.62 | 49.54 |
| Jiaojiang | 302 | 509184 | 59.31 | 49.59 |
| Anji | 354 | 457717 | 77.34 | 50.86 |
| Jiashan | 285 | 384095 | 74.2 | 51.63 |
| Shangyu | 540 | 776358 | 69.56 | 52.44 |
| Kecheng | 284 | 430374 | 65.99 | 52.45 |
| Yuyao | 577 | 833837 | 69.2 | 52.85 |
| Wuxing | 423 | 598488 | 70.68 | 53.24 |
| Wucheng | 400 | 620933 | 64.42 | 54.16 |
| Kaihua | 173 | 351996 | 49.15 | 54.35 |
| Fuyang | 421 | 650209 | 64.75 | 55.64 |
| Nanhu | 391 | 473567 | 82.38 | 59.69 |
| Total | 8291 | 14306871 | 58.7112 | 47.0056 |

*Age distribution of lung cancer*

During 2009, the average age of lung cancer in Zhejiang province was 63.78 years. Age-specific incidence rates of lung cancer patients are as follows: from a low level in 0-39 age group, slowly rising after the age of 35, then, rising sharply after age 55, reaches a peak at the age of 70-79, and decline after the age of 80. Comparison of lung cancer incidence rates between two genders are as follows: incidence rates among males in the 0-20 age group were lower than the females; after age 20, incidence rates in males were higher than females (Figure 1).

*Geographic distribution of lung cancer*

Nanhu county (reported incidence rate and standardized incidence rate were 82.38 and 59.69 per 100, 000 population, respectively) was the highest in Zhejiang province during 2011. The reported incidence rate and standardized incidence rate in Yueqing county were the lowest (30.55 and 28.77 per 100, 000 population, respectively) (Table1).

To further understand the characteristics of geographic

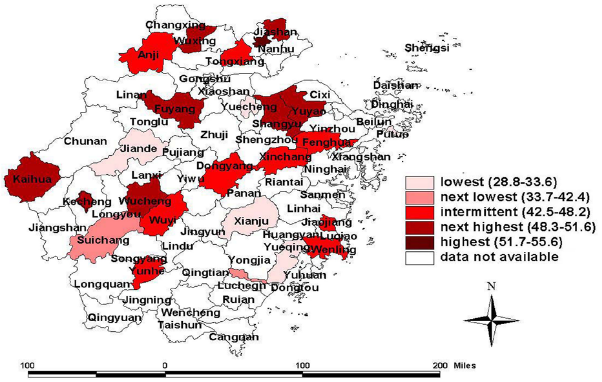


**Figure 2. Spatial Distribution of Lung Cancer.** Density of red color represents lung cancer incidence level

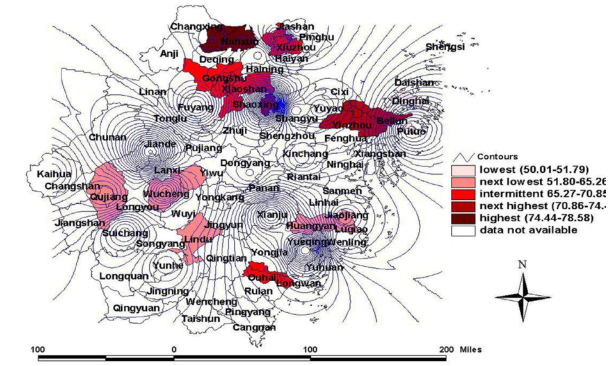


**Figure 4. Spatial Distribution of AQI.** Density of contours represents incidence level of lung cancer. Density of red color represents AQI values: 0-50 (air quality conditions-good); 50-100 (air quality conditions-moderate)

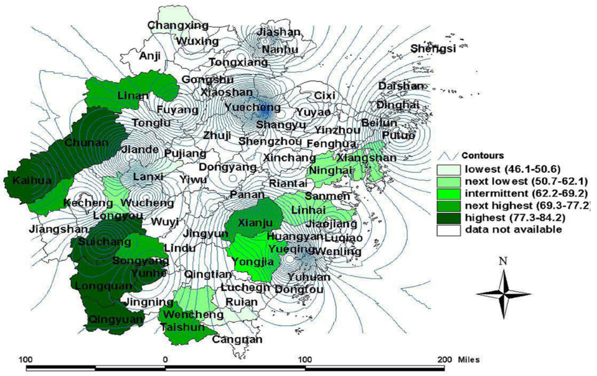


**Figure 3. Spatial Distribution of Forest Coverage rate.** Density of contours represents incidence level of lung cancer. Density of green color represents forest coverage rate level

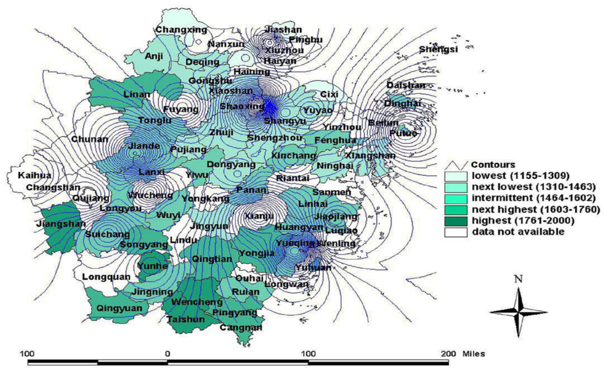


**Figure 5. Spatial Distribution of Annual Precipitation.** Density of contours represents incidence level of lung cancer. Density of green color represents annual precipitation level (cm/year)

distribution of lung cancer in Zhejiang province, GIS was utilized to analyze the spatial geographic distribution of standardized incidence rates of lung cancer on the map (Figure 2). Figure 2 shows: the standardized incidence rate of lung cancer in the northeastern Zhejiang province was higher than in the southwestern parts. Especially in the northern Zhejiang province, such as in Nanhu, Fuyang, Wuxing and Yuyao counties, the standardized incidence rates of lung cancer was more than 50 per 100, 000 population, but in the southwestern Zhejiang province, for instance in Yueqing, Xianju and Jiande counties, the standardized incidence rates of lung cancer was lower than 37 per 100, 000 population.

*Correlation and geographic overlay analysis on lung cancer and meteorological geographic factors*

The standardized incidence of lung cancer and Spearman rank correlation with meteorological geographic factors were calculated by SPSS software (Table 2). Forest coverage rate, and annual precipitation were negatively associated with the incidence of lung cancer ($p$<0.01). However, AQI was positively associated with the incidence of lung cancer ($p$<0.01). No significant association was found between lung cancer incidence and other meteorological geographic factors ($p$> 0.05).

*Stepwise multiple regression analysis on lung cancer incidence and meteorological geographic factors*

By setting three meteorological geographic factors as independent variables ($X_1$-forest coverage rate, $X_2$-AQI, and $X_3$-annual precipitation), stepwise multiple regression analysis shows that $X_1$ and $X_2$ can be selected into the regression equation ($p$<0.05; $R_2$=0.22; Y=21494.137-1.200$X_1$+11.961$X_2$). However, annual precipitation is automatically removed from the equation ($p$>0.05). Standard partial regression coefficients show that forest coverage rate and AQI have significant effects on the dependent variable ($p$<0.05). High forest coverage rate is a protective factor against lung cancer. However, high AQI is a risk factor for lung cancer. Results of stepwise multiple regression analysis is summarized in Table 3.

**Table 2. Rank Correlation Analysis on Standardized Incidence of Lung Cancer and Meteorological Geographic Factors**

| Meteorological geographic factors | r | t-test $p$ value | N (case number) |
|---|---|---|---|
| Forest coverage rate | -0.311** | 0.001 | 69 |
| Average annual temperature | -0.063 | 0.614 | 69 |
| Annual precipitation | -0.508** | 0.001 | 69 |
| Annual sunshine | -0.217 | 0.081 | 69 |
| Number of motor vehicles | 0.022 | 0.86 | 69 |
| Distance from the East China Sea | 0.176 | 0.148 | 69 |
| AQI | 0.428** | 0.001 | 69 |

**$p$<0.01; On the digital map of Zhejiang province, lung cancer standardized rate represented by contours were drawn on the background of the spatial distribution of forest coverage rate, AQI and annual precipitation (Figure 3, 4, 5). Results show that counties with low forest coverage rate, high AQI (poor air quality), and low annual precipitation had higher standardized incidence of lung cancer

## Discussion

Our results showed that the incidence of lung cancer during 2011 (57.95/per 100, 000 population) in Zhejiang province was higher than in 2009 (53.68/per 100, 000 population), which is in agreement with the conclusion of an upward trend of lung cancer incidence in Zhejiang province (Mao et al., 2006). The main reason for this upward trend might be due to rapid heavy industrialization in Zhejiang province, which inevitably causes heavier air pollution. Additionally, an increase in the proportion of older people due to the aging society in Zhejiang province also has played some role (Jemal et al., 2012).

In this study, we found that the reported incidence rates in males (82.83 per 100, 000 population) were 2.55 times higher than in females (32.45 per 100, 000 population) during 2011 in Zhejiang province. Compared with 2009, lung cancer incidence rates of Zhejiang province in 2011 increased by 5.88% in males, and 10.95% in females. Research evidence has demonstrated that worldwide lung cancer incidence is greater in men than women (Alberg et al., 2013). While cigarette smoking is normally considered to be the primary cause for the gender difference for lung cancer incidence, Besides cigarette smoking, greater exposure to other risk factors, such as work-related air pollution or carcinogens in men may also contribute to the increased susceptibility in men. Between woman and man, some difference may exist in the risk factors for lung cancer. For example, the passive smoking and the exposure of cooking oil emission were proved to be the important cause of females lung cancer (Phukan et al., 2014). The use of oral contraceptives in women is also suspected to be connected with the lung cancer (Wu et al., 2014). Due to the lack of availability of these risk factor exposure data, such as smoking, this study could not clarify the contribution of different risk factors for the differences among genders in Zhejiang province. In addition, compared to 2009, why the reported incidence rate of lung cancer incidence during 2011 increased in females much more than in males also needs further studying.

Zeng et al. (2013) reported that the age of onset of lung cancer has become younger and younger in recent years in China, especially in the population younger than 40 years old. In this study, we got the same conclusion. The reason for this upward trend is still unclear. Increasingly environmental pollution, indoor air contamination, or worked related stress might all contribute to it.

In this study, a significant difference in the incidence of lung cancer among different counties during 2011 in Zhejiang province was found. Higher lung cancer incidence data was gathered mainly in counties in the northeastern region of Zhejiang province. However, lower lung cancer incidence data was gathered mainly in the southwestern region of Zhejiang province. Mao et al (Mao et al. 2006) reported similar results in 2006 after they analyzed lung cancer incidence and mortality trends in the past 30 years in Zhejiang province. The regularities of distribution of lung cancer in Zhejiang province imply there might be some links between lung cancer and the geographical factors. Coincidentally, high-prevalence areas of lung cancer are seen in all regions with rapid industrialization and near heavy industrial zone, where air pollution is much more severe than other counties in Zhejiang province.

In correlation and geographical factor overlay analysis, we found that forest coverage rate and annual precipitation were negatively associated with the incidence of lung cancer. However, AQI was positively associated with the incidence of lung cancer. It is well known that high forest coverage rate and precipitation are both beneficial for changing the air quality and preventing air pollution. Our results show that meteorological geographic factors such as high forest cover rate and annual precipitation, especially high forest cover rate, are protective factors against lung cancer. While association between air pollution and lung cancer have been well documented (Lu et al., 2003; Shen et al., 2006; Cao et al., 2011; Raaschou-Nielsen et al., 2011), to our knowledge, this study is the first to analyze the association between forest cover rate and annual precipitation and lung cancer incidence.

Our results indicate that counties with a higher incidence of lung cancer are mostly located in the plains region with lower forest coverage rate. The forest coverage is important for keeping moisture under the ground and in the air, which in turn prevent air pollution. This phenomenon also indirectly proves that air quality can be changed by increasing forest coverage rate. Similar as forest coverage, high annual precipitation is also beneficial for cleaning the air. Fog and haze weather has been increasing in Zhejiang province in recent years. Precipitation can effectively clear the suspended particulate matter in the air, improve air quality, and thereby no doubt reduce the incidence of lung cancer.

It should be noted that the following inadequacies exist in this study. First, in this study, only a single AQI is analyzed. Interaction effects of AQI-related factors, such as smoking and air pollutants (nitrogen oxides, sulfides, PM2.5) were not analyzed because data was not available. Secondly, in this study we got only the lung cancer information during 2011 in Zhejiang province, therefore it is impossible to check the dynamic changes occurring between lung cancer incidence and geographical factors.

In conclusion, in this study we found that lung cancer incidence was higher in some of the northeastern counties where rapid industrialization is occurring. More forest coverage and precipitation are protective factors against lung cancer, whereas, poor air quality is a risk factor for lung cancer. Therefore, increasing forest coverage rate and controlling air pollution will be crucial in lung cancer prevention.

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