A Study on Geographical Interpolation Analysis of Korean Asbestos Factories

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Abstract

While asbestos issues becoming a major social problem, it is important to grasp exposure concentrations around past asbestos factories. But it is difficult to estimate exposure concentrations because the records for asbestos factories are few and all factories don't manufacture asbestos goods the present day.

This study aimed to identify the relative degree of asbestos exposure for the surrounding areas of past asbestos factories to be based on accumulative output during a given period of time.

Exposure concentration for the exposure period was calculated as the sum of the annual quantities of product and the exposure period was set up from 1981 to 2000 to consider 10 to 30 years as latency of malignant mesothelioma and lung cancer.

GIS interpolation methods used to estimate distribution of exposure concentrations. Prior to interpolation, 2 kilometers radius concentric circle to center of each asbestos factory in Busan were drawn through Buffer Analysis. According to the drawing, it is estimated that past asbestos concentrations in Yeonje, Yeongdo, Saha and Sasang ward were higher than other ward. And GIS interpolation was performed. As the result of comparing Buffer Analysis with GIS interpolation, it was found that interpolation by the quantities of product rather than the measured concentration could have possibility to distort fact. An interpolation method which set up virtual exposure sources is suggested for the improvement of it.

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I. Introduction

Recently, various social activities to prevent and manage asbestos-damage make steady headway In Korea.
Asbestos-related legislations are in force or scheduled in 2012 in good order of prohibition of new use, compensation for victims and management of existing construction or facilities.
Manufacture, import, transfer, delivery and use for all kinds of asbestos was banned in 2009 and Asbestos Damage Relief Act to compensate for asbestos victims has been in operation since 2011 and Asbestos Safety Management Act to institutionalize prevention and safety management from existing equipped asbestos will come into force after April 29, 2012
Social interest and activity are also heightened and results of asbestos monitoring for whole range of society such as sports facilities in school, cosmetics, professional baseball stadium are reported.

The estimated year of peak incidence for malignant mesothelioma in Korea is 2045 for long latency of Asbestos-Related Diseases (ARD) and early detection of the diseases is very important because the treatment for ARD is very difficult.
Thus preventive medical examination for high-risk population and information of sources of asbestos exposure are required.

Since the records for asbestos factories are few and all factories don't manufacture asbestos goods at the present day, although air concentrations of asbestos were sometimes measured and asbestos maps were drawn against the areas asbestos factories located, the effectiveness of it can be placed low value.

This study aimed to identify the relative degree of asbestos exposure for the surrounding areas of past asbestos factories to be based on accumulative output during a given period and to select high-risk area where a medical examination have to be preferentially performed to contribute to early detection of ARD victims.

For this purpose, spatial analysis was used.
Generally, exposure concentrations (EC) in an area surrogate ambient air concentrations and are proportioned to exposure power but are in inverse proportion to distance from exposure source.
The distribution of EC also extends in the direction of main stream of wind.
In other words, exposure concentrations can be expressed as a function to be composed of exposure quantities, exposure duration, distance from source, density of exposure material and carrier and so on.
In case of asbestos exposure, the regions with a significantly elevated standardized mortality ratio reached 2,200 meters from the plant in the same direction in which the wind predominantly blew.

The interpolation for some of the sample can be utilized in order to determine the spatial distribution of concentration.
A method about Linear function, regression analysis, Fourier series, spline, moving average and kriging or The Inverse Distance Weighted (IDW) of Geographical Information System (GIS) are also useful to estimate values of a point with EC not measured.
Furthermore spatial distribution for a particular variation can be estimated using these.

In this study, spatial exposure concentrations were drawn to be based on two variables such as location and size of annual permitted production of past factories.

II. Survey of the distribution of the past asbestos factories in Korea

In Korea, Asbestos factories started operation in 1920s and were activated in 1970s. Since 2007, asbestos factories seem to stop asbestos related work.
Asbestos mines were developed across the country since the mid-1930s and had produced 4,815 tons to 1944. Since 1976 when Korea's high economic growth period, raw asbestos materials were imported by approximately 63,000 tons per year from Canada, China, Zimbabwe, etc. and total imported amount of it by 2005 reached 1,222,981 tons.
The early representative asbestos factory in Korea is Korea Slate Industrial Co., Ltd. established by Japanese in front of Yongsan station in 1929. After that time,

asbestos manufacturer in Korea can be classified as companies to manufacture or sell goods related with products of asbestos mines or Japanese asbestos-related companies to enter Busan. The former representative company is Gwangcheon asbestos industry which grew up a company listed on the stock exchange in the early 1970s, the latter is Jeil chemistry. All of them were operated in Busan.
The factories to be newly licensed to manufacture asbestos-containing product amounted to 81 from 1991 to 2006 and has shown continuous decline after 1997.
The past distribution of asbestos factories and asbestos mines in South Korea is shown in Figure 1.

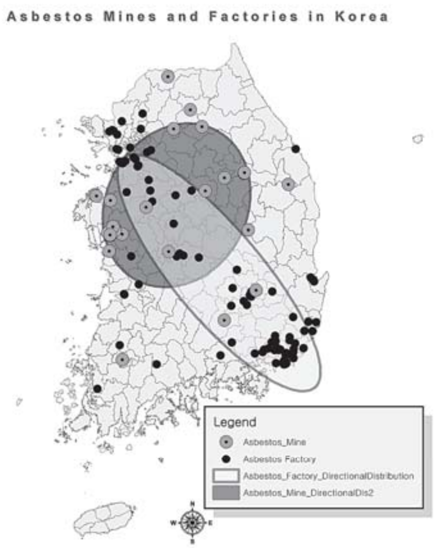

Fig. 1 The past distribution of asbestos factories and mines in Korea

The distribution of asbestos mines spread out west-east of the central region and asbestos factories spread out south-north to concentrated into Busan and Seoul.
Initially, asbestos factories started operation in Busan to be adjacent to Japan but were mainly activated in the capital region in the economic boom.
Most asbestos textile factories were located in Busan and Kyoung-Nam province and asbestos brake lining factories were concentrated in the capital region.

III. Data and methods

Korea Research Center for Asbestos Related Diseases (KRCARD) has accumulated information of Korean asbestos factories as computer database.
The initial data sources originated from Occupational Environmental Medicine in Pusan National University and School of Public Health in Seoul National University. The information collected from asbestos-related associations, Korea Occupational Safety and Health Agency's report, Soonchunhyang Hospital Asbestos Environmental Health Center were supplemented.
When a data was difficult to confirm by available literature, advice from the past asbestos distribution experts were reflected.
Table 1 shows counted records of various asbestos exposure sources in Korea.

Table. 1. Asbestos exposure sources in Korea

Type of source	records of database
Asbestos factories	178
Asbestos mines	84
Repair Shipyard	500

To collect past asbestos exposure sources is very difficult because literature of asbestos exposure sources hardly remained and almost plant were closed. Verification for the collected data was carried out through literature review, expert consultation and a spot inspection.
The main columns of the database contain factory name, address, established date, closed date, sum of the worker, size of annual permitted production and position as latitude and longitude and almost data are read through the below website as based on google map Application Programming Interface (API).
http://www.krcard.org/information/asbestos5.php?menu=3&menu_sub=3

This study was performed only at the asbestos factories in Busan.
Originally in the database, all of the asbestos factories in Busan are 31 records.
Among them, 9 duplication records caused by name change or closing were excepted and 8 factories to be deficient in the data of production or operation period also expected. Table. 2 show remaining 14 factories.

Table. 2 Asbestos Factories in Busan

Company	Exposure term	Total labor	Annual Production	Accumulative production	Ward	Product item
N Indus	1992~1996	4	50	200	Saha	Asbestos Textile
J Chem	1981~2000	300	2,803	53,257	Yeonje	Asbestos Textile
H Asb	1993~2000	4	24	168	Saha	Asbestos Textile
H Chem	1981~1993	30	96	1,152	Saha	Asbestos Textile
D Lining	1992~2000	52	312	5,616	Saha	Brake Lining
TY Asb	1981~2000	9	300	5,700	Sasang	Brake Lining
S Brake	2000	31	140	140	Saha	Brake Lining
AJ Chem	1990~2000	6	0.6	6	Geejang	Brake Lining
U Brake	1981~2000	40	25	475	Saha	Brake Lining
H Brake	1999~2000	31	140	140	Saha	Brake Lining
K Packing	1995~2000	7	180	2,700	Saha	Packing, Gasket
T S&G	1991~2000	9	150	1,350	Sasang	Packing, Gasket
T Seal	1981~2000	20	300	5,700	Gandseo	Gasket
J Slate	1981~1996	30	813	12,195	Yeongdo	Asbestos Slate

Exposure concentration for the exposure period was calculated as the sum of the annual quantities of product and the exposure period was set up from 1981 to 2000 to consider 10 to 30 years as latency of malignant mesothelioma and lung cancer.

The Asbestos product item divided into, textiles, brake linings, packing and gaskets, asbestos slate.

Longitude and latitude coordinates were automatically calculated by Google API program.

Interpolation can estimate values for unmeasured cells of a raster with a limited number of sample data points.

It can be used to estimate unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on.

Inverse Distance Weighted (IDW) and kriging which are well-known interpolation method in GIS are applied as research method.

IDW uses a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process.

Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values.

ARCGIS ver.9.3 is used as GIS software in this study.

IV. Results and Discussion

Buffer Analysis

Buffer analysis creates buffer polygons to a specified distance around the input features. An optional dissolve can be performed to remove overlapping buffers and the Multiple Ring Buffer tool allows the user to input several distances at once to create multiple buffers.

The 2km radius concentric circle to center of each asbestos factory in Busan was drawn through Buffer Analysis and the concentrations of the circle which depend on the size of production were classified as shown in the Fig.2. The figure shows that past asbestos concentrations in Yeonje, Yeongdo, Saha and Sasang ward were higher than other ward.

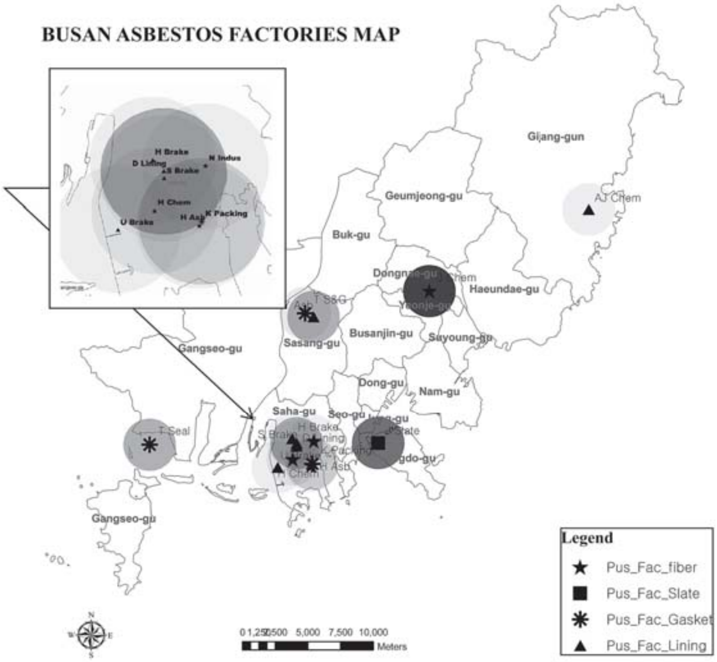

Fig. 2 Asbestos Concentrations Map by Buffer Analysis

Spatial Interpolation

The input data and parameters of IDW and Kriging model are shown in table. 3. The value to multiply quantities of product per year by operation time was used as Z Value.

As a result of the experiment, It was observed that power and maximum distance have an effect on distribution of contour in the IDW method and Semivariogram mode is effective in kriging method.

There was no difference between fixed and variable search radius except contour was slightly extended in variable search radius. The width of contour in kriging was wider than the IDW but contour group not to be seen in the IDW was formed. However, there was no big difference between two methods because the distance between samples was far away and the processing speed of the IDW was faster than kriging

Table. 3 Parameters of IDW and Kriging model

Method	Search Radius	power	Number of point	Maximum distance
IDW	Variable	2	12 (Default)	500
		2	12 (Default)	1,000
		5	12	500
		5	12	1,000
	Fixed	2	12	500
		2	12	1,000
		5	12	500
		5	12	1,000
Method	Search Radius	Semivariogram mode	Number of point	Maximum distance
Kriging	Fixed	Spherical	12	500
		Circular	12	500
		Exponential	12	500
		Gaussian	12	500
		Linear	12	500

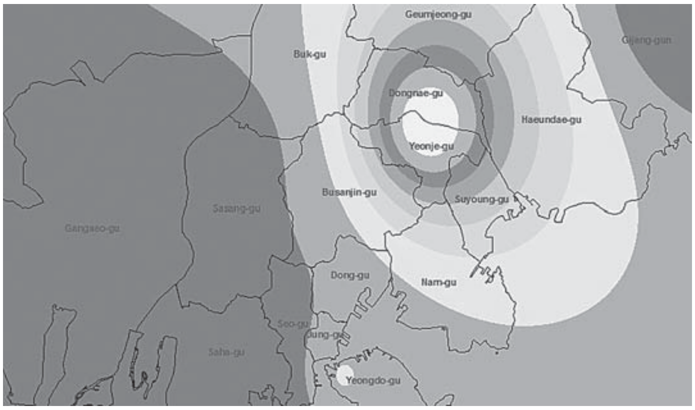

Fig. 3 spatial exposure concentrations by IDW method (Fixed search radius)

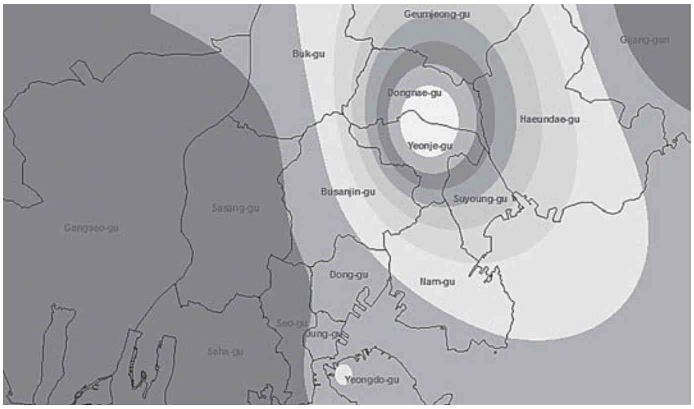

Fig. 4 spatial exposure concentrations by IDW method (Variable search radius)

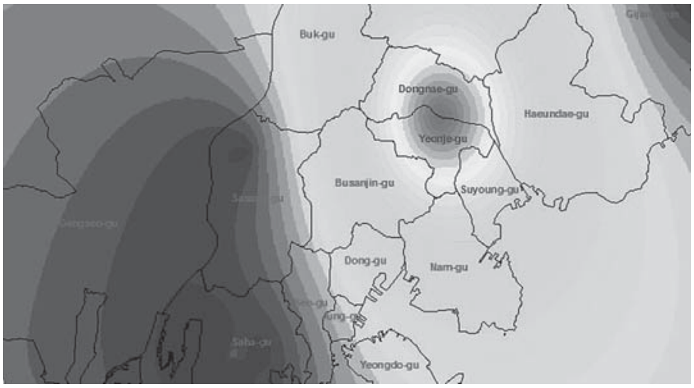

Fig. 5 spatial exposure concentrations by Kriging method (Circular Model)

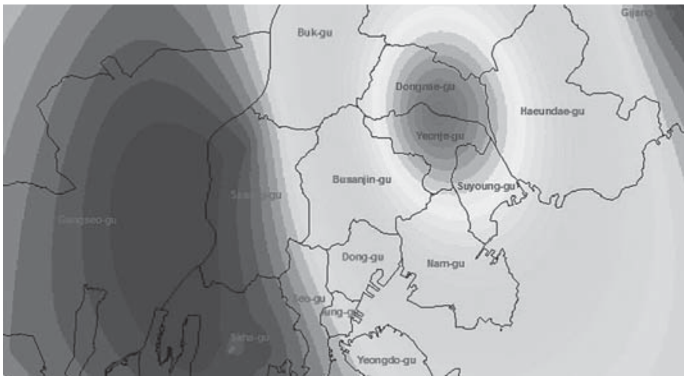

Fig. 6 spatial exposure concentrations by Kriging method (Spherical Model)

To evaluate the relative risk of exposure by region, Buffer analysis and spatial interpolation method were used and the results were similar to each other. To overlay the distribution of each plant's production by the IDW method makes the relative risk of asbestos exposure assessed more easily. However, in spatial interpolation, the expression of concentrations for other areas except Yeonje has a limitation because the production of Yeonje significantly overwhelmed it of other ward and spreading in the south-north direction also seems to be excessive.

Spatial interpolation can be applied to interpolate when samples measured but can have a severe distortion in case of concentration distribution by the production, which is governed by artificially factors.

In order to overcome these shortcomings, an interpolation method can be suggested, which set up virtual exposure sources after whole area is divided into uniform grid.

V. Conclusion

When exposure sources of hazardous substances located in densely populated areas, seriousness for exposure problem is amplified.

Fig.7 is a map to overlay asbestos exposure concentrations from this study with the location of elementary, middle, high and special school in Busan. From this map, it is assumed that many students had been exposed to asbestos.

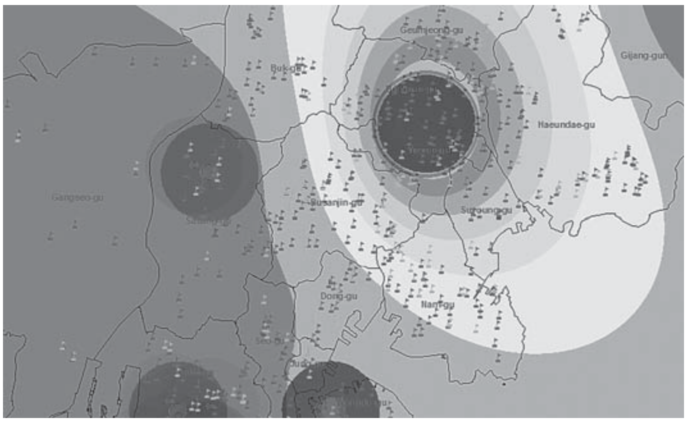

Fig. 7. A map of exposure sources and schools

As the results of this study, it is certain that the relative exposure concentration for asbestos was higher in Yeonje, Yeongdo, Saha and Sasang ward.
In recent years, the Ministry of Environment, Ministry of Labor and local governments have carried out a medical examination for residents around the past asbestos factories in Yeonje, Saha and Sasang ward except Yeongdo ward. Therefore, a medical examination for Yeongdo residents is needed.
The slope of the terrain, Land use and weather information are not reflected in this study.
I will try to invent improved interpolation model for estimation of unmeasured concentrations and combine the layer of spatial exposure concentrations with Digital Evaluation Model (DEM) and weather information at that time in order to obtain exposure contours in Busan.

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