Title: Trends of accidental carbon monoxide poisoning in the Republic of Korea, 1951-2018

Running title: Trend of carbon monoxide poisoning in Korea

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ABSTRACT

Objectives: Carbon monoxide (CO) poisoning from coal briquette combustion has been a significant public health problem of the South Korea in the past decades. This study estimated the time trend of the consumption of anthracite coal and the number of victims from CO poisoning due to changes in heating facilities over seven decades.

Methods: Using Population and Housing Census data and energy statistics, we estimated the number of houses using briquette as heating fuel over seven decades. After estimating the incidence of CO poisoning in a housing unit by type of heating facility, we determined the ratio of members of the household who experienced CO poisoning. Finally, the distribution of the victims was estimated according to the severity of the CO poisoning, excluding victims of intentional exposure.

Results: We estimated that total over 26 million people experienced CO poisoning from 1951 to 2018. The household consumption of anthracite peaked in 1986, but the number of victims from CO poisoning reached a peak of about 1 million people in 1980. From 1951 to 2018, a cumulative number of victims of CO poisoning comprised approximately 22,830,000 mild cases, 3,570,000 severe cases, and 65,000 deaths.

Conclusions: The peak number of victims from CO poisoning occurred 6 years earlier than when the number of people using briquettes for heating peaked. This time gap is caused by an improvement in the briquette heating system. This finding provides a quantitative basis for the epidemiological studies on the health outcome of CO poisoning in the population.

Key words: Carbon monoxide poisoning; Briquette gas poisoning; Coal; Time trend; Mortality; Morbidity
INTRODUCTION

Carbon monoxide (CO) poisoning, called as 'the silent killer', is caused by inhaling CO, a colorless, odorless gas formed from incomplete combustion of coal and other hydrocarbon product [1]. CO binds more strongly to hemoglobin in the blood than oxygen, making it challenging to supply oxygen to human tissues [2]. CO poisoning causes symptoms such as headaches, dizziness, nausea, and vomiting. In severe cases, it may cause unconsciousness or even death [3].

Before the 1960s, traditional residences in the South Republic of Korea (South Korea) used wood as a main fuel for heating and cooking. As the government began to regulate logging in the mountains to protect forests that were destroyed during the Korean War, coal replaced firewood in the private sector [4-6]. In the 1960s, coal briquettes began to be used as house fuel in South Korea, and CO poisoning became a serious social and public health problem [4]. The problem of CO poisoning, which has lasted for more than 40 years, had gradually disappeared since the 1990s, when home heating and cooking fuels were replaced with petroleum and liquefied natural gas (LNG). Korean traditional house heating uses an 'ondol' heating method, in which hot smoke warms the floor of a room [7]. Due to the structural characteristics of 'ondol' rooms, which inevitably has small leakages, gases from combustion could seep through the gaps in the floor [8]. According to a survey of the leading causes of CO poisoning accidents between 1965 and 1976, gas leaking from 'ondol' structures accounted for 54.2%, while gas leaking from a fireplace such as a coal fuel hole accounted for 26.3%. Overall, in about 80% of the CO poisoning case, causes were related to 'ondol' heating facilities [9]. At that time, CO poisoning became a significant social problem due to the combination of traditional heating methods and poor residential housing created by rapid urbanization. According to police data from this time, 85% of CO poisoning cases occurred in slums on the outskirts of the city [4]. Not only did the slums have poor housing conditions, but the residents were more vulnerable to CO poisoning because of the high prevalence of anemia due to malnutrition [4].

There have been epidemiologic studies on the CO poisoning since 1980s in parallel with the widespread supply of the hyperbaric oxygen tank. However, most of the studies were based on the
limited data source or a direct survey in a metropolitan area. In the past, data on deaths from CO poisoning were often missing, but registry statistics were maintained by the police. However, patients with CO poisoning who received hospital treatment were not managed by the public health sector [9]. Therefore, the nationwide number of victims of CO poisoning has not been systematically investigated. Since the 2000s, briquette usage has been drastically reduced, and the number of victims caused by CO poisoning has also been continuously reduced. However, in the 2010s, coal briquettes were still used among the energy-poor class in the South Korean society and have not entirely disappeared. Moreover, studies of the extent of health damage due to CO poisoning, which is understandable in this context, have been insufficient. Consequently, there is not available estimation of the incidence of CO poisoning across overall period of briquette use.

Assessing the overall scale of carbon monoxide poisoning provides an estimate of the rates of mild, severe, and death. Especially in severe cases with CO poisoning, it leaves neurological sequelae, which is known to last for life. Therefore, understanding the scale of past carbon monoxide poisoning in the present viable age group can be an essential data source in conducting follow-up studies related to sequelae. Therefore, the purpose of this study was to investigate the amount of briquette consumption and estimate the incidence of CO poisoning in the South Korea from 1951 to 2018.

METHODS

In the 1960s and 1970s, data were insufficient to estimate the health effects of CO poisoning. In the 1980s and 1990s, data on the causes of death existed, but many cases were missing, and many errors were included because the death registration system was not yet systematic and complete. Therefore, we performed the following procedure to estimate the injury consequences of CO poisoning from the use of briquettes. First of all, Population and Housing Census data and yearbook of energy statistics were used to determine the scale of use of briquettes as heating fuel over a long time. Next, to estimate the incidence of the health outcome of CO poisoning, previous
epidemiological studies were investigated. We, therefore, attempted to investigate cases using previous research and official secondary data to estimate the health consequences of CO poisoning.

Data sources

A questionnaire on household heating fuel was conducted every 5 to 10 years as part of the Population and Housing Census (1960, 1970, 1975, 1980, 1985, 1990, 2000, 2005, 2010, 2015) [10]. From the census data, we acquired information on variables such as the numbers of houses using briquettes as heating fuel and the number of persons per household (Table 1). Population and Housing Census data used in this study are 2% sampling data. Since the data is a complex design, a stratified sampling method was applied according to the type of residence by the administrative district and the number of household members, and weights were given for post-stratification. In the estimation of the number of houses using briquette for heating, the confidence interval was calculated by applying the relative standard error and design factors. More detailed calculation methods can be found in the Population and Housing Census user guide. Intervening years without census data were extrapolated from data for the nearest preceding and subsequent years when the census was conducted. In South Korea, heating fuel has significantly changed between 1990 and 2000. However, the Population and Housing Census data only existed in 1990 and 2000, making it challenging to identify fluctuations during the remaining ten years. To solve this problem, we acquired data on the number of houses using briquettes from a yearbook of energy statistics provided by the Korea Energy Statistical Information System (Supplementary Table 1). These data were used to supplement the data on the number of people using briquettes from 1990 to 2000 [11]. To compare the consumption of briquettes and the number of victims from CO poisoning, we used anthracite demand in residential and commercial domains from the 1951 to 2018 data provided by the Korea Coal Association [12]. Data on the incidence of CO poisoning from heating facilities and the distribution of victims according to severity of CO poisoning were obtained from previous epidemiological studies [13,14]. To verify the validity of the estimated number of deaths from CO poisoning, we compared our findings against the
police statistical yearbook and annual cause of death statistics based on the International Statistical Classification of Diseases and Related Health Problems (ICD) code published by the National Statistical Office (Supplementary Figure 1) [15].

Data analysis

The procedure for estimating the number of victims from accidental CO poisoning in South Korea was as follows: first, Population and Housing Census data and yearbook of energy statistics data were used to estimate the number of houses using coal briquettes as heating fuel from 1951 to 2018 (Figure 1). Second, the total number of houses at risk was calculated by applying the incidence of CO poisoning in house units based on the type of heating facilities to the number of houses that used briquettes as heating fuel. Third, among the houses at risk of CO poisoning, we calculated the ratio of members who experienced actual CO poisoning to all household members. Fourth, we used the distribution of victims by severity level of CO poisoning to estimate the number of victims in mild, severe, and death cases in each year. Fifth, since CO poisoning cases include cases of intentional exposure for suicide, we excluded the proportion of CO poisoning due to intentional exposure and only calculated the number of victims of unintentional briquette gas exposure. Finally, we compared the amounts of annual anthracite consumption in residential and commercial domains to the trends of victims of unintentional CO poisoning. We also validated our results by comparing them with statistical police yearbook data and cause of death statistics.

RESULTS

In 1960, the proportion of houses using briquette as heating fuel was 24.1%, which continued to rise to a peak of 69.5% in 1980. In 1985, the proportion of houses using briquette as a heating fuel was still high (67.7%), but there was a significant change in heating systems. In 1980, the old system of a coal briquette fuel hole represented approximately 50% of heating systems, but by 1985, the more improved pipe briquette boiler system represented approximately 50% of heating systems. Since 1990,
the proportion of briquettes has decreased to 62.0% due to increases in other heating fuel usage. In addition, between 1990 and 2000, a drastic change in heating systems occurred. As a result, the proportion of houses using briquette as a heating fuel in 2000 decreased to only 1.8% (Table 1).

The number of people using briquettes, calculated by multiplying the number of houses using briquettes by the number of members per household, was about 17,214 in 1951 (Supplementary Table 2). Since then, the number of people using briquettes has steadily increased to over 1 million in 1953 and over 10 million in 1965. It exceeded 20 million in 1974 and reached a peak of approximately 27 million in 1988. These results were similar in pattern to the consumption of civilian anthracite coal, which increased to its peak level in 1986 (Figure 2).

The trend in the number of people experiencing actual CO poisoning was somewhat different from the patterns of civilian anthracite coal consumption or the number of people using briquettes (Figure 2). The estimated number of people who experienced CO poisoning peaked at approximately 1 million in 1980. This peak occurred approximately 6 to 8 years earlier than the peak in the number of people using briquettes as heating fuel and the peak in the consumption of civilian briquettes.

The number of mild, severe, and death cases followed the same trend, as the proportions were based on the population estimated to be at risk from CO poisoning. The number of mild cases peaked in 1980 at approximately 0.86 million cases, while severe cases numbered approximately 134,000. The number of death cases first exceeded 1,000 in 1964, and it was estimated that more 1,000 deaths continued during the subsequent 30 years, until 1993. The number of deaths peaked in 1980, with approximately 2,400 cases (Supplementary Table 2).

**DISCUSSION**

In South Korea, briquette use became widespread following the Korean War in the 1950s [5,6]. As a result, 24.1% of all houses used briquettes as a heating fuel in the 1960 Population and Housing Census. In 1988, the number of people using briquettes as heating fuel peaked, and since then, it has
gradually declined due to the proliferation of other heating schemes. In the 1990s, in particular, heating fuel choice rapidly changed to oil and LNG, due to increased apartment availability and a change in government energy policy.

The incidence of CO poisoning has fluctuated with the changes in heating facilities and subsequent improvements to residential environments and with changes in the number of briquettes consumed per day. In particular, although briquettes were used as a heating fuel in most houses in the 1980s, the incidence of CO poisoning was different according to heating facilities. In the briquette fuel hole system, the annual probability of CO poisoning was 11.1%, while the piped coal briquette boiler system as a more improved system had a probability of 6.6% [13]. The briquette fuel hole system, which has been in use since the 1960s, is particularly vulnerable to briquette gas leaks because it relies on combusted hot air passing underneath the 'ondol' floor. By contrast, the piped coal briquette boiler system, which has been in use since the mid-1970s, is a hot water radiant floor heating system. Therefore, the thermal energy efficiency of the piped coal briquette boiler system was high, and the risk of briquette gas leakage was relatively low compared with the fuel hole system [7]. In houses using briquette fuel hole systems, briquettes used from evening to morning tended to use fewer air holes to extend the length of briquette usability [5]. It increased the amount of incomplete combustion, leading to increased CO generation and a rise in the incidence of CO poisoning. Based on the duration of usage for a single-use-briquette, the briquettes were likely replaced 2-3 times a day. In most South Korean houses, briquettes were generally replaced just before sleep, shortly after waking, and afternoon [16]. Since CO concentrations were known to reach their peak levels 2-3 hours after starting briquettes burned, many people who changed to new briquettes before going to sleep were at risk for CO poisoning during deep sleep [9]. For the reasons already discussed, although annual anthracite consumption in residential and commercial domains peaked in 1986, briquette gas poisoning cases occurred most frequently in the late 1970s and early 1980s, despite briquette usage in this period is lower than in the mid-1980s.
Symptoms caused by CO poisoning differ in severity depending on the concentration of inhaled CO and the exposure time. Therefore, to estimate the number of victims from CO poisoning, measuring the incidence by severity is required. The severity of CO poisoning symptoms can be classified as mild, severe, and death. In this study, cases with headache, nausea, and vomiting symptoms were classified as mild, and cases with temporary loss of consciousness were classified as severe. In the past, national statistical surveys on CO poisoning cases were not conducted in South Korea, so large-scale surveys of more than 100,000 people have only been conducted by individual researchers. In the 1970s and 1980s, two population surveys of more than 100,000 people on CO poisoning experiences in South Korea were published (Table 2). In a 1974 survey of about 530,000 people living in Seoul, 244 people experienced mild symptoms per 10,000 people using briquettes as heating fuel, 45 suffered severe symptoms such as loss of consciousness, and one individual died as a result of CO poisoning [17]. In addition, a study conducted in 1984 estimated that 320 people per 10,000 people using briquettes annually suffered mild symptoms, 50 people experienced severe symptoms, and one person died from CO poisoning [14].

In South Korea, causes of death were first classified in 1979. However, the cause of death statistics in the 1980s and 1990s had many problems [18]. In 1980, only 45% of deaths were classified by cause, and only 24% of registered deaths were certificated by doctors [19]. The rate of death certificates written by doctors also remained low at 36%, 57%, and 60% in 1985, 1994, and 1997, respectively. Besides, there were many errors in the causes of death [18-20]. Some surveys in 1991 found errors in the cause of death in 56.1% of all cases [20]. Also, there were continuous reports of missing or distorted death registries until the mid-1990s. For example, in the case of suicide deaths, there was a difference of approximately 3,000 people between police statistics and the cause of death statistics [20]. For these reasons, a portion of the deaths due to CO poisoning in the 1980s and early 1990s may have been misclassified as death from unknown causes. Therefore, it is likely that the official annual cause of death statistics on CO poisoning was underestimated. Nevertheless, in 1985 approximately 1,600 people had their cause of death classified as 'accidental poisoning by gas and steam' [21]. These findings helped us interpret and explain our results on the estimated number of
deaths from CO poisoning in South Korea over the past 70 years. From 1985 to 1999, our estimates were about 2 to 3 times greater than the official data of the National Statistical Office. Based on these results, we estimate that many deaths from CO poisoning were missing or misclassified in the official death registry data before the 2000s. These shortcomings began to improve in the 2000s. One study reported that reported causes of death beginning in the 2000s were at least 90% accurate [22]. In our study, the estimated number of deaths from CO poisoning since 2000 was similar to that of the official death registry.

In the past, CO poisoning was classified as an accident, so it was not reported separately from accidents. Statistics produced by the police included only cases that were found and identified as dead at the site of CO poisoning, meaning that cases who died during hospital treatment were not included in the statistics [18]. According to the police statistical yearbook of 1976, 1,013 people died from CO poisoning [9]. However, in a study in the same period, the number of people who died due to worsening symptoms while being treated for CO poisoning at a hospital was 1.6-fold higher than those who died at the scene [13]. Therefore, the number of deaths from CO poisoning reported by the National Police Agency in 1976 was likely underestimated [8]. Based on the factors leading to these underestimated statistics, we estimate that the number of deaths from CO poisoning in the mid-1970s may have exceeded 2,000. By combining sources of data from the past, we can conclude the causes of death that agree with our research, which was inferred based on the number of people who used briquettes as heating fuel.

Cases of CO poisoning are typically combined from cases of intentional exposure for suicide and unintentional poisoning caused by accidental exposure. Therefore, we used epidemiological data on the cause of death statistics to distinguish these two options. Before 2007, most of the CO poisoning deaths in South Korea were unintentional poisoning deaths caused by exposure to briquettes, and intentional poisoning deaths were very rare [23]. The death registry from 1990 to 1999 shows that proportion of suicide in cases of CO poisoning were about 8.9% (Supplementary Figure 2).
these figures were almost constant, we used them to estimate the number of deaths from accidental CO poisoning.

The limitations of this study are as follows. First, in South Korea, there are very few epidemiological papers on the incidence of CO poisoning. In this study, we applied the average value of the incidence calculated in four domestic cities. However, since our analyses were performed only for a single year, our results may not accurately reflect the incidence of CO poisoning because of improvements in housing and changes in heating facilities. Second, in estimating the number of houses using briquettes, we used data from the Population and Housing Census. However, since the Census was conducted at five or ten-year intervals, data for the remaining years were extrapolated, which can cause instability in the estimates. Third, since the 2000s, the use of LNG has spread, and cases of CO poisoning from gas boiler exhaust emissions have occurred. In addition, the use of an instantaneous gas water heater has caused accidents from incomplete combustion to occur. As outdoor camping has gained popularity, CO poisoning from the heating device has begun to occur during bedtime. Thus, it is challenging to establish cases of CO poisoning since the 2000s as victims of complete CO poisoning. However, since the 2000s, the number of people using briquettes as a heating fuel has declined significantly, and no significant errors have occurred. Finally, effect of hyperbaric oxygen therapy was not included in this study. Hyperbaric oxygen therapy has been a main therapeutic option in South Korea since 1970s, but there are few longitudinal data on its usage. There is a consensus on the effect of hyperbaric oxygen therapy in reducing neurologic sequelae, but its effect on the mortality need to be established [25].

Despite these limitations, this study describes trends in victims from CO poisoning after exposure to briquette gas over the past 70 years. Fortunately, several epidemiological studies on the incidence of CO poisoning in South Korea have reported similar incidences to each other, and these results were considered very accurate. Also, the data from the Population and Housing Census of South Korea is highly reliable as it was held for the entire nation.

This study identified changes in heating systems and annual coal consumption in South Korea over the past 70 years. Based on these data, we estimated the number of people using briquettes as a
heating fuel in the past. In addition, the number of victims of CO poisoning has been calculated, reflecting the incidence of CO poisoning, and the severity of illness according to heating facilities. We confirmed that the peak number of CO poisoning victims occurred about six years earlier than peak annual briquette consumption. We estimated that over 17 million people experienced CO poisoning in the 1970s and 1980s and that approximately 100,000 people were severely affected each year. We also estimated that more than 2,000 people died at the peak year of poisonings. Severe CO poisoning is known to cause neuropsychiatric sequelae such as cerebral palsy by inducing brain hypoxia [5,24]. Since these effects are persistent in CO poisoning survivors, the health effects of the high rates of CO poisoning in the 1970s and 1980s are likely to be ongoing. Therefore, estimating the size of the Korean population suffering from neurological sequelae due to CO poisoning in the past is helpful in understanding the disease burden due to neurological sequelae caused by CO poisoning in the present living population. In addition, since coal briquettes are still widely used as a heating fuel in North Korea, the results of this study could be used as an important data source for estimating the extent of CO poisoning in the North Korean population in the future. Our findings could be used in future research on delayed-effect disorders caused by CO poisoning.

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DISCLOSURE

The authors have no conflicting interest to declare.

AUTHOR CONTRIBUTIONS

Research conception and design: KJH

Methodology: CHK and KJH
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**FIGURE LEGENDS**

Figure 1. Flow chart of the estimation of the carbon monoxide poisoning

Figure 2. Estimated number of victims from carbon monoxide poisoning and anthracite consumption in South Korea, 1951-2018

Supplementary Figure 1. Mortality from carbon monoxide poisoning based on data of the National Statistical Office and the National Police Agency

Supplementary Figure 2. Description of carbon monoxide poisoning causes, 1990-1999
Table 1. Estimated number of households using briquettes as heating fuel, based on Population and Housing Census data

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of houses</th>
<th>Direct briquette heated system (Coal briquette fuel hole system)</th>
<th>Heat piped briquette boiler system (Piped coal briquette boiler system)</th>
<th>Coal briquette stove</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1,000,905 (867,842-1,133,969)</td>
<td>238,096 (207,915-268,277)</td>
<td>52,483 (17,991-86,975)</td>
</tr>
<tr>
<td>1960</td>
<td>4,370,599</td>
<td>22.9% (18.9%-26.0%)</td>
<td>2.6% (2.2%-3.0%)</td>
<td>1.2% (0.4%-2.0%)</td>
</tr>
<tr>
<td>1970</td>
<td>5,792,767</td>
<td>2,628,709 (2,553,023-2,704,396)</td>
<td>45.4% (44.1%-46.7%)</td>
<td>150,906 (126,691-175,121)</td>
</tr>
<tr>
<td>1975</td>
<td>6,750,350</td>
<td>3,550,414 (3,248,396-3,852,432)</td>
<td>52.6% (48.1%-57.1%)</td>
<td>223,856 (115,551-332,161)</td>
</tr>
<tr>
<td>1980</td>
<td>7,969,201</td>
<td>3,968,304 (3,759,700-4,176,908)</td>
<td>50.3% (47.4%-53.2%)</td>
<td>278,897 (202,225-355,569)</td>
</tr>
<tr>
<td>1985</td>
<td>9,571,361</td>
<td>4,166,089 (4,154,900-4,179,278)</td>
<td>50.3% (47.4%-53.2%)</td>
<td>3.5% (2.5%-4.5%)</td>
</tr>
<tr>
<td>1990</td>
<td>11,354,540</td>
<td>1,555,560 (1,385,249-1,725,872)</td>
<td>5,485,427 (5,237,911-5,732,942)</td>
<td>48.3% (46.1%-50.5%)</td>
</tr>
<tr>
<td>2000</td>
<td>14,310,126</td>
<td>13.7% (12.2%-15.2%)</td>
<td>48.3% (46.1%-50.5%)</td>
<td>1.5% (1.1%-2.0%)</td>
</tr>
<tr>
<td>2005</td>
<td>15,887,128</td>
<td>45,192 (16,319-74,065)</td>
<td>217,434 (154,485-280,383)</td>
<td>1.5% (1.1%-2.0%)</td>
</tr>
<tr>
<td>2010</td>
<td>17,341,966</td>
<td>48,032 (18,254-77,811)</td>
<td>245,432 (178,539-312,325)</td>
<td>1.5% (1.1%-2.0%)</td>
</tr>
<tr>
<td>2015</td>
<td>19,111,731</td>
<td>27,091 (5,099-49,083)</td>
<td>323,202 (247,894-398,510)</td>
<td>1.9% (1.4%-2.3%)</td>
</tr>
</tbody>
</table>

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Note: CI = Confidence Interval.
Table 2. Incidence per 10,000 people at risk for briquette gas exposure, and distribution of victims according to the degree of carbon monoxide poisoning in previous studies

<table>
<thead>
<tr>
<th>Degree of carbon monoxide poisoning</th>
<th>Incidence per 10,000 population at risk of briquette gas exposure (the distribution of victims)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A study on carbon monoxide poisoning in 1974 (Study area: Seoul)\textsuperscript{17}</td>
</tr>
<tr>
<td>Mild</td>
<td>244 (79.8%)</td>
</tr>
<tr>
<td>Severe</td>
<td>45 (14.5 %)</td>
</tr>
<tr>
<td>Death</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>Unspecified</td>
<td>16 (5.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>306 (100.0%)</td>
</tr>
</tbody>
</table>
Figure 1. Step process for calculating the number of victims from briquette gas poisoning

- Number of house using coal briquette
- Percentage of using each heating facility at house
- Number of persons per household

*Population and Housing Census*

- Number of house using coal briquette

*Yearbook of energy statistics*
1990-2014

- Incidence of briquette gas poisoning in house units by the type of heating facilities

*Research paper*
Household using coal briquette fuel hole system: 11.1%
Household using piped coal briquette boiler system (or using coal briquette stove): 6.6%

- The ratio of members who experienced actual briquette gas poisoning among members of households at risk of briquette gas poisoning

*Research paper*
40.2%

- The distribution of victims according to severity levels of carbon monoxide poisoning

*Research paper*
Mild: 86.3%
Severe: 13.5%
Death: 0.3%

- The proportion of unintentional exposure cases among victims of briquette gas poisoning

*Cause of death statistics (1990-1999)*
91.1%

- Estimation of the number of victims due to unintentional briquette gas poisoning from 1951 to 2018 in South Korea

- Comparison of trends with annual consumption of anthracite in the residential and commercial domains

*Coal supply and demand by year in South Korea*
1951-2018

- Comparison of trends with other death statistics

*Police Statistical yearbook (1965-1976, 1992-2010)*
*Cause of death statistics (1985-2018)*
Figure 2. Mortality trends of briquette gas poisoning in South Korea, 1951-2018