Scenario Study on PM emission Reduction in Cement Industry

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Abstract. Cement industry is one of the high pollution industries in China. Evaluation of the primary particulate matter (PM) emission status and the reduction potential is not only important for our understanding of the effectiveness of current pollution control measures but also vital for future policy design. In this study, PM emitted from cement producing process in 2014 was calculated using an emission factor method. Three PM emission control scenarios were set up considering source control, process management and end-of-pipe treatment, and the PM emission reduction by 2020 under the three scenarios was predicted, respectively. In 2014, the primary PM emission from cement industry was 1.95 million tons. By 2020, the productions of cement and clinker were expected to increase by 12% and 7%, respectively, and the PM emission would increase by about 10%. By implementation of GB4915-2013 and comprehensive control of fugitive PM emission, the PM emission would probably be reduced by 34%. Another 7% decrease would be expected from source control. The second scenario can be considered as an assessment of the effectiveness of the revised emission standard, and this research can be used as a technical support to the environmental management authorities to make relevant policies.

1. Introduction

Cement is one of the most important and widely used building materials in the world, and its production and consumption is closely related to the economic growth, industrialization and infrastructure development in a country or area [1,2]. Cement production and consumption in China showed a rapid growth trend and the cement production increased by 133% from 2005 to 2014[3]. China has been world No.1 cement producer and consumer in the last two decade.

Cement industry has been identified as a main source of air pollution. A large amount of air pollutants emitted from cement production, including SO2, NOx, CO, especially primary particulate matter (PM) [4]. PM is discharged in every stages of cement production. About 70% organised PM

emission occurred in the kilns and other processes, such as raw materials handling, coal milling, belt transportation, coal preparation, are main sources of fugitive PM emission.

In literature, most researchers studied the application and effectiveness of the dust removal facilities and some papers estimated air pollutants emission status in cement industry years ago[5,6].The National Emission Standard of Air Pollutions for Cement Industry was revised and enacted in 2014, and it was supposed to have a significant impact on pollution control in cement industry. Systematic evaluation of the current PM emission status and estimation of PM emission reduction potential is essential for current air pollution prevention policy assessment and future policy making. In this research, we developed a method to estimate both organised and fugitive PM emission, and predicted PM emission reduction potential under three different scenarios.

2. Methodology

In this study, the current PM emission status in cement industry was evaluated using an emission factor method. The PM emission reduction potential in 2020 was estimated under three different scenarios (Table 1). Only direct primary PM emitted from cement production was considered.

Table 1. Three PM emission control scenarios in 2020

Scenario	Clinker and Cement Production	PM Control Measures
Scenario 1 (BAU)	Predicted according to the economic growth expectation during the 13th Five-year-Plan period and relevant cement industrial policies	Same as 2014
Scenario 2	Same as Scenario 1	Strict implementation of GB4915-2013, and take comprehensive measures to control fugitive PM emission
Scenario 3	Elimination of backward productivity and setting cap of clinker and cement production	Same as Scenario 2

The primary PM emission from cement industry can be calculated as (1).

$$\mathrm{PM} = \sum EF_{1i} \cdot P_{1i} + \sum e_{1i} \cdot P_{1i} + \sum EF_{2i} \cdot P_{2i} + \sum e_{2i} \cdot P_{2i} \quad (1)$$

Where, EF_1 and EF2 denote the emission factor of organised PM from clinker production and cement grinding, respectively;

e1 and e2 denote the emission factor of fugitive PM from clinker production and cement grinding, respectively;

P1 and P2 denote the clinker and cement production, respectively;

i denotes the ith production line.

The emission factors in the base year were obtained by studying the PM generated from cement production process, the efficiencies of different dust removal facilities[5-10] and online monitoring data from clinker kilns of different scales. The emission factors in scenario 2 and 3 can be predicted mainly according to the quantities of flue gas[11] and emission standards (GB4915-2013) for each cement production process. Fugitive emission factors were estimated from PM2.5 emission accounting

technical specification for cement industry[12] and the percentage of PM2.5 in TSP emitted from each cement production process[6,13]. The data were shown in Table 2.

Table 2. Emission factors of fugitive PM from clinker production and cement grinding in Scenario 1

Product	Process	Scale	E(kg/t product)
Clinker	New dry process rotary kilns	≥4000t clinker/day	0.1
		<4000t clinker/day	0.2
		<2000t clinker/day	0.4
	Shaft kilns	-	0.7
	Others	-	0.6
Cement	Cement mills	≥0.6 million tonns cement/year	0.2
		<0.6 million tonns cement/year	0.3

3. Results and Discussion

3.1. PM Emissions from Cement Industry in 2014

In 2014, the productions of cement and clinker in China were 2.5 billion tons and 1.4 billion tons, respectively. The total amount of PM emitted from cement industry was 1.95 million tons. The fugitive PM emission was comparable to the organised PM emission. The organised PM emitted from clinker production was the major contributor, accounted for 37% of the total emission, followed by the fugitive emission from cement grinding, the proportion was 32% (shown in Figure 1).

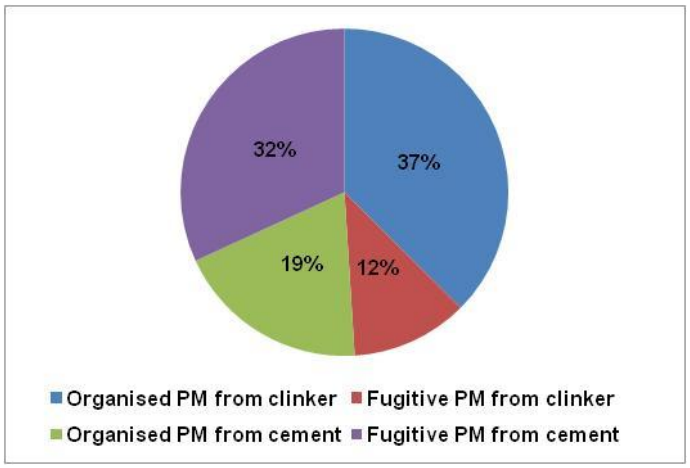

Figure 1. PM emission from each cement production process.

The quantities of PM emissions from cement industry in different regions vary in a relatively wide range (Figure 2). PM emissions in Guizhou province and Sichuang province exceeded 120,000 tons, which was over 20 times of that in Beijing and Tianjin.

The total amount of PM emissions is not only positively associated with the clinker and cement production, but also depends on the level of pollution control management. The effectiveness of PM emission control during clinker/cement production can be described as PM emission intensity, which was defined as the amount of PM emission per unit clinker/cement production. The average PM emission intensity during clinker production in mainland China was 0.68kg/t. The highest emission

intensities were observed in Guizhou province, Heilongjiang province and Xinjiang autonomous region, which were above 1kg/t (shown in Figure 3). It was probably due to the relatively insufficient emission control management.

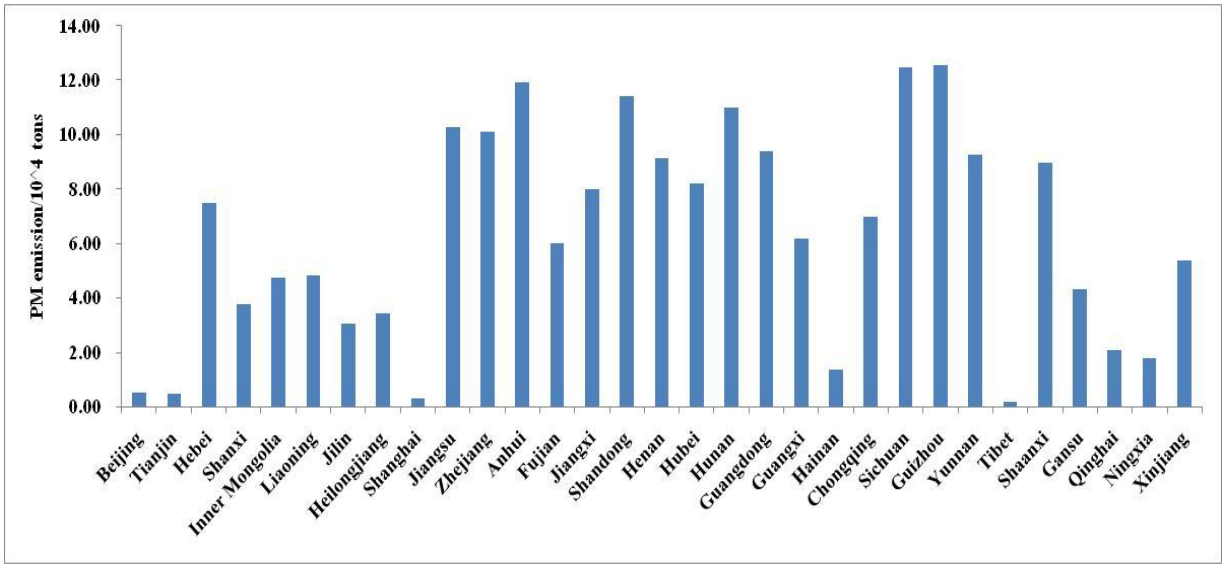

Figure 2. PM emission from cement industry in different provincial administrative regions in 2014.

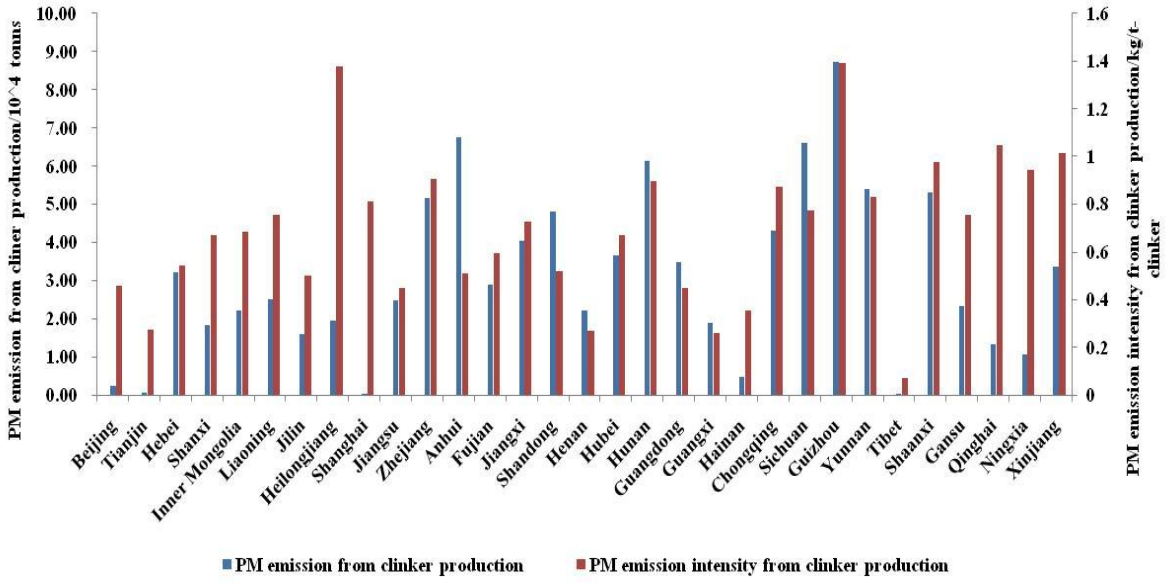

Figure 3. The quantities and intensities of PM emission from clinker production in different provincial administrative regions in China in 2014.

3.2. Scenario Study of PM Emissions from Cement Industry in 2020

The production of clinker and cement in 2020 is closely associated with the economic development, industrialization and urbanization. It also depends on the relevant industrial policies. The annual average growth rate of GDP in China is expected to be 6.5% during the 13th Five-year Plan period [14]. The scale and quality of urbanization will be promoted, and the infrastructure construction will be further strengthened. There is likely to be strong demand for cement. At the other side, the issue of

production overcapacity is perplexing the cement industry and enterprises within the industry. The average operation rate of the rotary kilns in 2015 was about 67%, and in certain areas, the operation rate was even lower than 50%. It is vital to resolve the serious problem of excess production capacity. Considering comprehensively all of the above-mentioned factors, the annual average growth rate of cement and clinker production in China during the 13th Five-year Plan was predicted to be 3% in this study, and the productions of clinker and cement in each of the provinces, autonomous regions and municipalities were estimated considering their current production status and the relevant policies in the 13th Five-year Plan period.

In 2020, the productions of cement and clinker would be 2.78 billion tons and 1.51 billion tons, an increase of 12% and 7%, respectively, compared with 2014. Jiangsu province and Henan province would still be the two largest cement production provinces, and their annual production would exceed 200 million tons. Under the pressure of elimination of excess capacity and air quality improvement in the Beijing-Tianjin-Hebei region, a decrease of the cement production in the two municipalities and a slight increase in Hebei province would be expected. The details are shown in Figure 4. In the BAU scenario, the PM emission control measures were supposed to be the same as 2014, and the total amount of PM emitted from cement industry in 2020 would be 2.15 million tons, an increase of 10% compared with 2014.

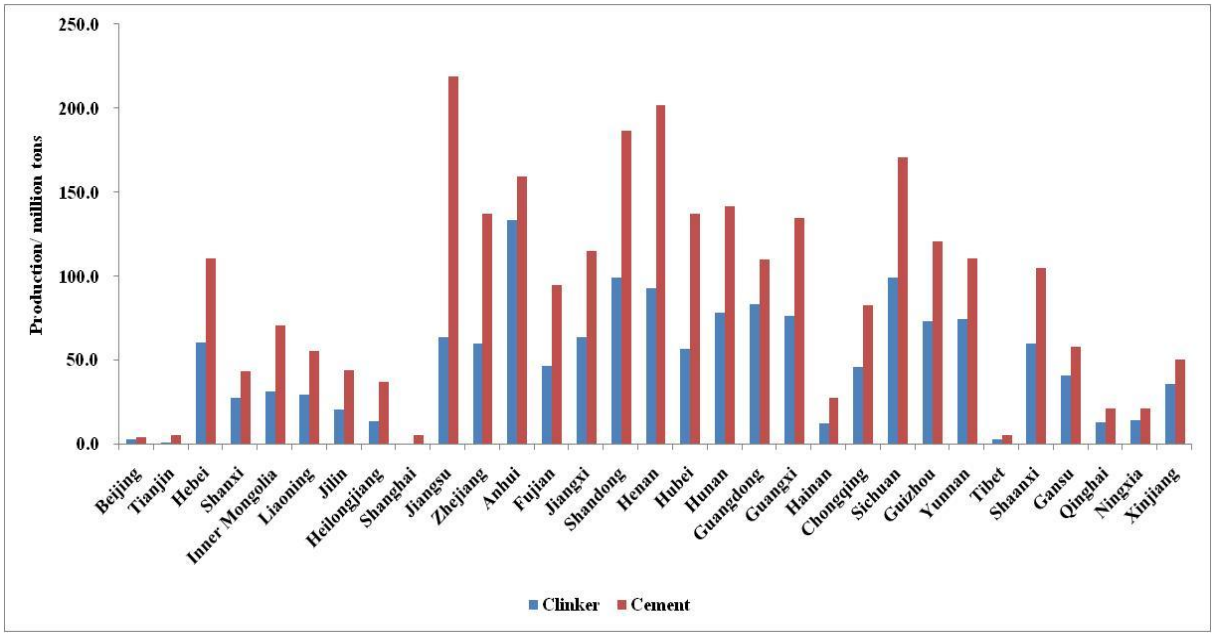

Figure 4. The production of clinker and cement in 2020.

PM pollution control can be considered from 3 perspectives: source control, process management and end-of-pipe treatment. Scenario 2 focused on end-of pipe treat (implementation of new emission standards) and process management (fugitive PM emission abatement), while Scenario 3 also considered source control. Under scenario 2, the PM emission would be reduced by 34% compared with BAU scenario, reaching 1.41 million tons. A further 0.14 million tons were expected under scenario 3. Implementation of higher emission standards could reduce organised PM emission effectively. The organised PM emission would decrease by about 40% since the new standard (GB4915-2013) took effect.

Fugitive PM emission is one of the important sources of particulate pollution in cement industry. Under the BAU scenario, fugitive PM emission contributed to over 40% of total PM emission. Actions must be taken to cut down fugitive PM emission. Firstly, advanced production technology should be widely adopted to prevent fugitive PM emission from the source. Secondly, fugitive PM can be collected and treated using dust removal facilities. Raw materials should be transported with closed belt conveyor and stored in closed warehouses. Thirdly, road dust resulted from raw materials and products transportation should be reduced. The fugitive PM emission would probably decrease by 25-30% by taking the above preventive measures.

4. Conclusions and Recommendations

In 2014, the PM emissions from cement industry in mainland China were 1.95 million tons. Organised emission was mainly from the clinker production process and fugitive emission was mainly from the cement grinding process. PM emissions from cement industry in the provincial administrative regions varied in a wide range due to the differences in the production scale and the particulate pollution prevention level.

According to the expectation of the economic growth during the 13th Five-year Plan period and the relevant industrial policies, the productions of cement and clinker were predicted to grow by 12% and 7%, respectively, compared with 2014. If the PM control remained at the same level as that in 2014, the quantities of PM emitted from cement industry in 2020 would increase by about 10%. Implementation of the new emission standards and comprehensive control of fugitive emission would probably reduce the PM emission by about 34%. Accelerating the elimination of outdated production capacities and strictly controlling the cement and clinker productions were highly likely to reduce the PM emission by a further 7%.

PM emission almost exists in every process of cement production. PM pollution prevention should be considered from three perspectives: source control, process management and end-of-pipe treatment. Meticulous management should be enhanced in cement industry.

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