Study on Methods for Cost-Benefit Analysis of Atmospheric Non-point Source Emission Standards

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Abstract. Non-point source (NPS) emission standard is an important approach for NPS emission control. Study on cost-benefit analysis during the formulation of environmental standards is still in an initial stage in China, with insufficient studies made for cost-benefit analysis of NPS emission standards. In this paper, methods and ideas for cost-benefit analysis of NPS emission standards in China are studied on the basis of cost-benefit analysis theories and studies in America and China, thus putting forward methods to classify and calculate the costs and benefits of NPS emission standards. In the meantime, Emission Standard of Air Pollutant for Gasoline Filling Stations is used as an example to comprehensively discuss the methods for cost-benefit analysis of established NPS emission standards, thus maximizing the benefits of NPS pollutant prevention and providing reference to the formulation of other NPS pollutant emission standards, as well as cost-benefit analysis.

1. Introduction

Methods for formulation (revision) of NPS pollutant emission standards are now a hotspot for study, as there are increasing environmental problems caused by rapid industrial development in China. NPS emission standard is an important approach to control the NPS emission, a guarantee for smooth environmental law enforcement, and an important element in building China’s environmental protection system. In China, study on cost-benefit analysis during the formulation of environmental standards is still in an initial stage. In most studies, a combination of qualitative and quantitative analysis is adopted, with the focus placed on the estimation of terminal treatment cost and pollution reduction. As a result, little focus is placed on the estimation of benefits in environmental quality improvement and health, as well as economic impacts in such aspects as macro-economy, industrial structure adjustment and price variation [1]. Moreover, most of studies focus on the cost-benefit study of relevant policies in the thermal power industry, with insufficient studies made for cost-benefit analysis of standards for NPS pollution control.

In this paper, typical methods for cost-benefit analysis of NPS pollutant emission standards in China are modelled, and the Emission Standard of Air Pollutant for Gasoline Filling Stations is used as an example to comprehensively discuss the methods for cost-benefit analysis of established NPS emission standards, thus maximizing the benefits of NPS pollutant prevention and providing reference to the formulation of other NPS pollutant emission standards, as well as cost-benefit analysis.

2. Study methods

Cost-benefit analysis is also known as economic analysis, national economic analysis, national economic evaluation, etc. Among them, the cost-benefit analysis of pollutant emission standards...
mainly focuses on environmental impacts. Basic principles mainly include: Pareto Efficiency and Marginal Utility; Net Social Benefit and Economic Optimum Level of Pollution [2].

In China’s pollutant emission standards, there are no specific economic analysis documents or cost-benefit analysis documents mentioned, and only simple economic analysis (environmental cost analysis) and environmental benefit analysis are made in specifications for formulation of emission standards. According to the view on cost-benefit analysis in the sector of Environment Economics in China, the following five steps are generally necessary for cost-benefit analysis (economic analysis): first, description and analysis of standards; second, determination of baseline; third, implementation cost analysis; forth, implementation benefit analysis; fifth, cost-benefit analysis, and conclusion [3].

In this paper, the cost-benefit analysis of NPS pollutant emission standards mainly refers to exploring methods and ideas for cost-benefit analysis of NPS emission standards in China on the basis of cost-benefit analysis theories and studies in Europe and China, thus putting forward methods to classify and calculate the costs and benefits of NPS emission standards [4].

The cost-benefit analysis of NPS pollutant emission standards based on stakeholder analysis is to consider the cost-benefit analysis in the full life cycle of standard formulation, implementation, evaluation, revision and termination, and in particular, to identify key links of costs and benefits of NPS pollutant emission standards through analysis of its implementation, thus finding the way to improve the implementation performance. On this basis, the stakeholder analysis is integrated into the whole process of cost-benefit analysis of NPS pollutant emission standards [1,5].

![Figure 1. Frame Diagram for Cost-Benefit Analysis of NPS Pollutant Emission](image)

3. Main steps for cost-benefit analysis of NPS pollutant emission

The route for implementation of cost-benefit analysis of NPS pollutant emission in China is determined in combination with relevant studies on cost-benefit analysis and pollutant emission standards in and out of China.
3.1. Standard analysis
Standard analysis refers to determining the scope of cost-benefit analysis. The analysis of contents of NPS pollutant emission standards is the primary link and foundation of the cost-benefit analysis, as the specific contents and relevant indexes of the standard must be analyzed before analyzing its cost-benefit. As for description of the standard, it is necessary to clearly define the social background for the formulation of the standard, particularly the objectives of standard formulation and implementation, its goals and scope, definitions of terms, general requirements, key indexes, relevant appendices and other important contents. In the meantime, it is also necessary to clarify the pollution coefficients, pollution control methods, as well as pollution control equipment or facilities involved in the standard.

3.2. Determination of baseline
The baseline is the starting point for cost-benefit analysis of NPS emission standards, which reflects the results without the standards. In this study, the set baseline is the initial status of the society, economy, environment, etc., which are mostly the current emission standards.

3.3. Implementation cost analysis
The implementation cost of NPS pollutant emission standards refers to the cost incurred in the industry to meet the control requirements of emission standards, which can be divided into direct cost and indirect cost.

3.3.1. Direct cost. Direct cost refers to the cost that the polluter directly pays for emission standards for the purpose of satisfying the pollutant emission standards. The direct cost is the core to evaluate the implementation cost of pollutant emission standards. The direct cost can be divided into government cost, polluter cost and public cost according to different objects.

3.3.2. Indirect cost. Indirect cost refers to the cost indirectly incurred to the polluter by the emission standards. No indirect cost is considered in cost-benefit analysis of NPS pollutant emission standards, as the indirect cost cannot be accurately defined and measured.

3.4. Implementation benefit analysis
The implementation benefit analysis includes analysis of environmental, social and economic benefits. Among them, environmental benefit analysis mainly involves the analysis of change in pollutant emission after the standards are implemented. In this study, the focus shall be placed on the change in pollutant emission in typical areas. Social benefit analysis refers to the social benefit evaluation made in such aspects as whether the pollution events, complaints, etc. are decreased in the standards-involved industries emitting malodorous gas or disturbing the residents. As for economic benefit analysis, the focus should be placed on the income and deductible cost brought by recycling and reclamation of wastes, as well as reduced pollution fees (taxes) due to reduction in emission after the polluter implements the standards.

3.5. Cost-benefit analysis
The cost and benefit of NPS emission standards are obtained by analyzing and comparing various costs, benefits (effects) and other aspects of NPS emission standards (from such perspectives as cost-benefit, social and economic impacts). It is particularly important to accurately identify the main sticking points and links that result in high cost and low benefit of the current standards, and propose suggestions for the improvement of existing standards or formulation of new NPS pollutant emission standards, thus maximizing the benefits.

4. Modelling of function for cost of air pollutants in Gasoline Filling Stations

4.1. Description and analysis of standards
The Emission Standard of Air Pollutant for Gasoline Filling Stations comprises such parts as Scope, Normative References, Terms and Definitions, Oil and Gas Emission Control and Limit, Technical Measures, and Standard Implementation.

In the chapter of “Scope”, it clearly specifies the limited value of oil and gas emission, technologies and requirements of control, and methods for detection adopted in gasoline filling stations. The standard is applicable to the management of vapor emission in existing gasoline filling stations, as well as the environmental impact evaluation, design, completion acceptance and post-completion vapor emission management of new, renovated and expanded gasoline filling station projects.

Considering the features of air pollution control in gasoline filling stations, in this study, the government cost and polluter cost are considered, while social cost is ignored in cost-benefit analysis. In benefit analysis, quantitative economic and environmental benefits are considered.

4.2. Determination of baseline

Emission Standard of Air Pollutant for Gasoline Filling Stations (GB 20952-2007) is used as the baseline for cost-benefit analysis.

4.3. Cost analysis

4.3.1. Government cost. The calculation equation is as follows considering the direct cost arising from the formulation, implementation, supervision, inspection and management of standards, i.e. cost incurred by the government in formulating, implementing, monitoring and researching standards and ensuring their implementation:

\[ G = G_1 + G_2 + G_3 \]

Where, \( G_1 \) is the cost for formulation of the standard, including the cost incurred by investigations during formulation of the Emission Standard of Air Pollutant for Gasoline Filling Stations; \( G_2 \) is the cost for the initiation, opinion solicitation, review meeting, etc. of the standard, which shall be calculated based on the actual expenses incurred during formulation of the standard; \( G_3 \) is the cost for implementation, supervision, inspection and management of the standard, which are ignored in this study.

4.3.2. Polluter cost. In the standard, it is clearly specified that the following pollution control equipment and facilities comprise vapor recovery system, i.e. vapor recovery system for unloading gasoline, gasoline closed storage system, vapor recovery system for gasoline refilling, online monitoring system and vapor emission treatment equipment.

① Vapor recovery system for unloading gasoline refers to a system that recovers vapor generated when discharging gasoline from the oil tank truck into the oil tank in a closed manner.
② Vapor recovery system for gasoline refilling refers to a system that collects and sends the vapor generated when refilling the fuel tank of the vehicle to buried oil tanks.
③ Spilling control facility controls the possible spilling during gasoline unloading via shutoff valve, float or by other anti-spilling measures.
④ Buried oil tanks refer to oil tanks completely buried underground.
⑤ On-line monitoring system refers to a system that monitors whether the vapor liquid ratio, tightness of vapor recovery system and liquid resistance of the pipeline are normal during vapor recovery for gasoline filling. The system can remind the operator of taking corresponding measures, record, store, process and transmit the monitoring data in case of any abnormality.
⑥ Vapor emission treatment equipment refers to a device that recovers the vapor discharged from the vapor recovery system for gasoline filling by adopting such methods as adsorption, absorption, condensation and membrane separation.

In general, the polluter cost is modelled as follows:

\[ C = C_1 + C_2 \]

(Equation 4.1)
Where, $C_1$ is the investment cost and $C_2$ is the maintenance cost, without considering cost to treat other pollution.

$$C_1 = C_{11} + C_{12} + C_{13}$$

(Equation 4.2)

Where, $C_{11}$ refers to the investment cost of vapor recovery device, including the sum of the investment cost in gasoline unloading, storing and filling; $C_{12}$ refers to the investment cost of vapor treatment device; and $C_{13}$ refers to the investment cost of online monitoring system. In this study, $C_2$ - pollution control O&M cost and $C_3$ - cost for treatment of other pollution caused are not considered.

It can be obtained that:

$$C_1 = k_1 Q_1 + k_2 Q_2 + k_3 Q_3$$

(Equation 4.3)

Where, $Q_1$, $Q_2$ and $Q_3$ refer to treatment scale; $S$ refers to amount of pollutant removed; $k_1$-$k_7$ refer to coefficients calculated by using the status of pollution control technologies and survey data.

The standard specifies that the vapor emission mass concentration of the treatment plant shall be no more than 25g/m$^3$, and that the emission outlet shall be at least 4m above the ground plane.

It can be obtained that:

$$C_2 = k_8 S^{k_9} [(q_0 - q_2)/q_0]^{k_{10}}$$

Where, $q_0$ refers to pollutant emission standard, i.e. 25g/m$^3$; $q_2$ refers to concentration of pollutant at outlet; $k_8$, $k_9$ and $k_{10}$ refer to coefficients calculated by using the status of pollution control technologies and survey data.

To sum up, the polluter cost is:

$$C = k_1 Q_1 + k_2 Q_2 + k_3 Q_3 + k_4 S + k_5$$

(Equation 4.4)

$$\ln C_1 = \ln k_1 + k_2 \ln Q_1 + k_3 \ln Q_2 + k_4 \ln S$$

(Equation 4.5)

Equation 4.4 can be worked out by converting Equation 4.5 into multiple simple equations and calculating the value of correlation coefficients through regression analysis. Thus, value of coefficients $k_1$-$k_{10}$ can be calculated by using relevant data and taking the logarithm on both ends.

4.4. Benefit analysis

The benefit analysis of Emission Standard of Air Pollutant for Gasoline Filling Stations is to fully represent the advantages of the standard and the necessity for the formulation and revision of the standard. The implementation benefits include environment benefit, economic benefit and social benefit. Considering the features of NPS pollutant emission in gasoline filling stations, focus is placed on the environmental, economic and social benefits.

The environmental, economic and social benefits brought by the implementation of emission standards are inseparable and closely related. The economic and social benefits are indirect benefits which may not be rapidly and easily identified and may appear after a long period of time. Different from abstract economic and social benefits, the environmental benefit is direct benefit, which can be embodied in such forms as intuitive formula or chart. Therefore, in actual benefit analysis of the emission standard, focus is placed on environmental benefit analysis, with other benefit analysis as supplementary. The implementation benefit of emission standards are mainly calculated and analyzed in terms of environmental benefit, including the calculation of reduction of pollutants, reduction rate and current compliance rate.

Before and after the implementation of the new Emission Standard of Air Pollutant for Gasoline Filling Stations, compared with the Emission Standard of Air Pollutant for Gasoline Filling Stations (GB 20952-2007) (the vapor mass concentration shall be no more than 25g/m$^3$) and in combination with relevant forecast, in 2007, gasoline consumption was 9114*10$^6$ tons [6], diesel consumption was 5412*10$^6$ tons and VOC emission was 314*10$^3$ tons, which will be increased to 14419*10$^6$, 9616*10$^6$ and 724*10$^3$ respectively by 2020 if we take no other measures and keep implementing the current standard.

After the new standard is implemented, in 2020, the VOC emission will be reduced to 724*10$^3$ tons * emission limit in the new standard/25 (g/m$^3$) if the gasoline and diesel consumptions are still what we expect, which is the relative environmental benefits of the new standard.
4.5. Cost-benefit analysis of the standard.
Considering the cost (economic cost) and benefit (environmental benefits) calculated before, Emission Standard of Air Pollutant for Gasoline Filling Stations is economically feasible.

5. Conclusion
In this study, typical methods for cost-benefit analysis of NPS pollutant emission standards in China are modelled, and methods to classify and calculate the cost and benefit of NPS emission standards are proposed on the basis of cost-benefit analysis theories and studies in America and China. The stakeholders are involved in the whole process in cost-benefit analysis of NPS pollutant emission standards. In the meantime, Emission Standard of Air Pollutant for Gasoline Filling Stations is used as an example to analyze the cost and benefit of the standard after implementation, thus creating a cost-benefit analysis model to evaluate the feasibility of the standard. The determination of methods for formulation of NPS pollutant emission standards and cost-benefit analysis maximizes the benefits of NPS pollutant prevention and provides reference to the formulation of other NPS pollutant emission standards, as well as cost-benefit analysis.

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