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Research on the Cost Control of Pollution Control in the Exploitation Process of Shale Gas

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Reducing the cost of pollution control during exploitation of shale gas is of great significance for achieving sustainable development of energy and environmental. This paper takes the cost control of pollution control in the exploitation process of shale gas as the research objective, constructs the accounting system of pollution control cost in the exploitation process of shale gas and establishes the systematic measurement model of environmental cost. The M shale gas company is taken as an example and conducts the case analysis of the cost control of pollution control in the exploitation process of shale gas. The research results show that the pollution control cost in the exploitation process of shale gas includes environmental prevention and control cost and environmental damage cost. Through the analysis of the cost control result of M company Analysis, it realizes the internalization of external cost. This study provides references for shale gas companies to achieve scientific management and control decision-making of environmental costs and is of certain practical significance.

1. Introduction

With the accelerating industrialization and urbanization process, people's demand for energy consumption is gradually increasing, and energy and environmental issues are becoming more and more prominent, which are two major problems affecting and restricting the development of countries. Seeking and developing new energy sources to replace traditional energy sources such as coal and oil is one of the top priorities for countries all over the world (Adgate et al., 2014). As an unconventional energy source, shale gas is characterized by cleanness, high efficiency and high quality. Some studies have shown that (Vandecasteele et al., 2015) the reserves of shale gas in China rank first in the world and it has broad development prospects.
At present, the development of shale gas in the United States has made great progress. However, with the continuous maturity of development technology, people also discover that there are environmental problems such as groundwater pollution, air pollution and large water consumption during the exploitation process of shale gas. (Sununta et al., 2018). Therefore, how to economically, environmentally and efficiently exploit the shale gas is the focus of world's attention. American scholars JennerS and Lamadrid A J believe that it is conducive to reducing greenhouse gas emissions and public health using shale gas to replace conventional energy, but it may lead to methane leakage and water pollution (Chapman et al., 2016). Ballentine, Gignac believes that environmental cost control is conducive to the balanced development of economic and environmental benefits (Zhang et al., 2017). Since the development and utilization of shale gas in China has just begun, people are focusing on the economic evaluation of the development of shale gas (Schmidt, 2011) and the research on environmental impact evaluation and cost control of environmental control has just attracted the attention of people in recent years. Liang Peng et al. believe that sub-ecological environmental risks and polluted groundwater are the main environmental problems caused by the development of shale gas (Correa et al., 2018). In addition, many scholars have conducted research on the definition and classification of the environmental costs in the exploitation of natural gas and oilfield and the measurement and accounting of environmental costs, obtaining remarkable research results (Kanada et al., 2013). However, there are few studies on the cost control of pollution control in the exploitation process of shale gas, the majority of which stay on the theoretical level.

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Based on the above analysis, this paper studies the cost control of pollution control in the exploitation process of shale gas. The paper first analyzes the environmental impact that may occur in the exploitation engineering of shale gas and divides the environmental costs in the exploitation process of shale gas into environmental prevention and control costs and environmental damage costs on this basis. After that, the measurement of environmental costs in the exploitation process of shale gas is introduced in detail. Finally, the M shale gas company is taken as an example to control the its pollution control cost in the exploitation process of shale gas is calculated and evaluated, which realizes the internalization of external costs in M shale gas company and is conducive to promoting the sustainable development of companies.

2. Constructing the Accounting System of Pollution Control Cost in the Exploitation Process of Shale Gas

2.1 Classification of Environmental Costs in the Exploitation Process of Shale Gas

2.1.1 Environmental impact during the exploitation process of shale gas

The exploitation process of shale gas can be divided into four stages of drilling, well cementing, fracturing and extraction (Wu et al., 2015). Wastewater, solid waste and flue gas that may be generated in different stages will cause environmental pollution. However, in the final analysis, it can be divided into two categories of environmental pollution and ecological damage (Gao et al., 2016), as shown in Figure 1.

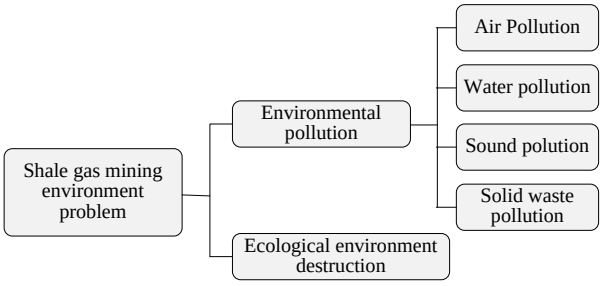

Figure 1: Major environmental problems arising from shale gas mining

2.1.2 Classification of environmental costs in the exploitation process of shale gas

In the exploitation process of shale gas, the environmental costs of the company can be divided into two parts: one is the environmental prevention and control cost, also known as the internal environmental costs of companies; and the other is the environmental damage cost, also known as the external environmental costs of companies (Yang et al., 2013). Table 1 shows the specific composition of environmental costs in the exploitation engineering of shale gas.

Table 1: Composition of environmental costs in shale gas mining projects

Type	Constitute content	
Environmental prevention and governance costs	Environmental protection equipment investment cost	Environmental protection equipment purchase fee
		Environmental protection equipment operation and maintenance costs
	Environmental management cost	Environmental monitoring fee
		Staff education fee
		Environmental certification fee
	Pollution treatment cost	Environmental protection fee
		Pollution control costs
Environmental damage cost	Ecological environment damage cost	Land ecosystem damage cost
		Water ecosystem damage cost

2.2 Measurement of Environmental Costs in the Exploitation Process of Shale Gas

The availability of the data and the operability of the method should be considered when selecting the measurement method and differentiated recording methods should be used for different environmental costs (Wang, 2017).

2.2.1. Measurement of environmental prevention and control costs

(1) Investment cost of environmental equipment
In order to minimize the environmental pollution caused by the exploitation process of shale gas, companies will purchase corresponding environmental protection equipment and the cost incurred is the investment cost of environmental equipment. The calculation formula is as follows (Rich et al., 2014):

$$C = C_1 + C_2 \tag{1}$$

$$C_1 = C_0 + C_{ci} \tag{2}$$

$$C_2 = C_1(a_1 I^n + a_2 I^{n-1} + \mathrm{K} + a_{n-1} I + a_n) \tag{3}$$

In this formula: C is the total investment cost of environmental equipment; C_0, C_1, C_2 and C_{ci} are the equipment procurement, initial investment, loan interest during the period and installation costs respectively; a_n is the investment proportion of the company on environmental protection equipment in n year; n is the equipment investment cycle; I is the loan interest of equipment during the period.
(2) Operation and maintenance costs of environmental protection equipment
The environmental protection equipment includes wastewater treatment equipment and dust removal equipment. The maintenance costs, labor costs and energy costs are the main environmental protection equipment costs during the exploitation process of shale gas (Marin and Rivero, 2018). Since it is difficult to measure the maintenance cost of environmental protection equipment, the approximate measurement method of 2% to 7% of the total equipment price is selected in accordance with practice.
(3) Environmental management costs
The environmental system certification, environmental monitoring and the environmental education and training for employees during the exploitation of shale gas are all environmental management costs and will be listed in the environmental report of companies.
(4) Environmental protection tax
The environmental protection tax is divided into the tax amount payable of atmospheric pollutants and water pollutants obtained by multiplying the pollutional equivalent converted by the quantity of pollutant discharged equivalent amount the specific adaptation tax amount, the tax amount payable of solid waste obtained by multiplying the quantity of solid waste discharged and the specific use tax amount and the corresponding tax amount payable of noise exceeding the decibel of national standard (Maringanti et al., 2011).

2.2.2 Measurement of environmental damage costs

(1) Land ecosystem damage costs
Table 2 shows the cost calculation method for land surface subsidence, vegetation damage and land occupation.

Table 2: Land ecosystem damage cost measurement method

Composition	Economic loss of surface subsidence and vegetation destruction	Economic loss of land occupation
Method	Replacement cost method	Opportunity cost method
Formula	$LC_R = M_R C_R$	$LC_0 = S_0 \sum_{i=1}^{n} \frac{b_1}{(1+r)n}$
Symbol meaning	LC_R is the surface subsidence, vegetation damage economic loss, C_R is the cost of reclamation and subsidence of cultivated land per hectare, M_A is vegetation damage and land subsidence area	LC_0 is the opportunity cost of land occupation, S_0 is the total area occupied by land, b_1 is the income per acre of farmland, n is the age, r is the discount rate

(2) Damage costs of water ecosystem
The damage costs of water ecosystem is shown in formula (4):

$$WL_W = W_D W_C \tag{4}$$

In the formula, WL_W represents the economic loss caused by the damage of water resources; W_D and W_c represent the amount and price of water damage.

3. Case Analysis of the Cost Control of Pollution Control in the Exploitation Process of Shale Gas Reservoir

3.1 Profile of M Shale Gas Company

M Shale Gas Company is affiliated with China National Petroleum Corporation (CNPC). PetroChina is the largest producer and supplier of crude oil and natural gas in China and holds a leading position in the industry. At present, PetroChina is increasing the exploitation of shale gas and it is estimated that the production of shale gas will exceed 10 billion cubic meters in 2020. While increasing the exploitation, PetroChina also pays great attention to environmental protection. Table 3 shows the list of environmental protection equipment purchased by M company.

3.2 Accounting of Environmental Costs of M Shale Gas Company

3.2.1 Environmental prevention and control costs

This paper selects the environmental costs incurred by M shale gas company in the Fuling development project in the whole year of 2016 for confirmation and measurement. Table 3 shows the specific situation of the environmental protection equipment investment by M shale gas company.

Table 3: M enterprise environmental equipment investment cost

Device		Total investment (Ten thousand yuan)	Operation hours (year)	Annual depreciation (Ten thousand yuan)
Dust removal equipment	Electrostatic precipitators	4380	20	174.9
	Auxiliary dust collector	310	25	12.7
	Chimney	1530	30	51.2
	Total	6220	——	238.8
Wastewater treatment equipment		840	25	33.3
Waste treatment equipment		6920	25	276.5
Noise processing equipment		160	30	5.4
Merge		14140	——	554

3.2.2 Operation and maintenance costs of environmental protection equipment

It is difficult to measure the maintenance cost of the above-mentioend environmental protection equipment, the approximate measurement method of 2% to 7% of the total equipment price is selected in accordance with practice. This paper selects the intermediate value of 4.5%. The operation and maintenance costs of noise, waste water residue and dust removal equipment are shown in Table 4.

Table 4: Operation and maintenance costs of noise, wastewater waste and dust removal equipment

Device		Maintenance cost (Ten thousand yuan)
Dust removal equipment	Electrostatic precipitators	480
	Auxiliary dust collector	177
	Chimney	88
	Total	745
Wastewater treatment equipment		630
Waste treatment equipment		311.4
Noise processing equipment		7.4
Merge		1693.8

3.2.3 Environmental management costs

Using the historical cost method, the environmental management cost is summarized as 1.5 million yuan through the summary of the relevant financial data of M shale gas company in 2016.

3.2.4 Environmental protection tax

(1) Tax amount payable of atmospheric pollutants
Table 5 shows the tax amount payable of atmospheric pollutants such asCO, NOX, SO2 and soot generated during the development of shale gas calculated according to relevant standards.

Table 5: Air pollutants should be taxed

Contaminant	Pollution equivalent(kg)	Applicable tax (yuan)	Tax payable (Ten thousand yuan)
CO	17 Ten thousand	1.6	27.2
NO_X	420 Ten thousand	1.6	672
SO_2	369 Ten thousand	1.6	590.4
Dust	54 Ten thousand	1.2	64.8
Total	——	——	1354.4

(2) Tax amount payable of water pollution, solid waste and noise pollution

The water pollution equivalent is 3.525 million kilograms and the tax amount payable for the water pollution is 18.43 million yuan referring to the local applicable tax amount. The tax amount payable of solid waste is 160,000 tons × 25 yuan = 4 million yuan. There is no noise pollution with the noise treatment equipment, so the tax amount payable is zero.

3.2.5 Environmental damage costs

(1) Land ecosystem damage costs

Table 6 shows the land ecosystem damage costs of M shale gas company from 2014 to 2016 calculated according to the measurement algorithm of land ecosystem damage costs.

Table 6: Land ecosystem damage cost

Composition	2014	2015	2016
Loss of cost of ecological service function	4370	1643	2168
Ecological environment quality degradation cost	745	591	227
Land reclamation, vegetation restoration costs	394	499	187
Soil erosion control cost	778	887	632
Total	6287	3620	3214

(2) Water ecosystem damage costs

Referring to the relevant drainage data of M company, the amount of water resources damaged by the exploitation of shale gas is 317×104 cubic meters/day. The average shadow price of water resources is 4.37 yuan and thus the water ecosystem damage cost is 1.44 million yuan.

3.2.6 Analysis of pollution control costs in the exploitation process of M shale gas company

Table 7: Summary of pollution control costs in the mining process of M company

Environmental cost type	content	Cost	Proportion of total cost
Environmental prevention and governance costs	Environmental equipment investment cost	14140	61.5%
	Environmental equipment operation and maintenance cost	1693.8	7.3%
	Environmental management cost	150	0.6%
	Environmental tax	3597.4	15.6%
Total		19581.2	85 %
Environmental damage cost	Land ecosystem damage cost	3214	14%
	Water ecosystem damage cost	144	0.6%
Total		3358	20%
Total cost		22939.2	15%

Table 7 shows the summary of pollution control costs during the exploitation process of M company.

It can be seen from the Table that the proportion of the investment cost of environmental equipment is the largest, which is 61.5%. However, due to the environmental equipment with good prevention and reduction of pollution, the quantity of pollutant discharged is reduced, thus reducing the environmental tax. In the exploitation process of shale gas, the total environmental prevention and control costs account for 85% of the total cost. Therefore, companies should improve the exploitation technology and strengthen the control management of environmental costs so as to reduce the environmental prevention and control costs. In addition, it can be seen that the environmental damage costs account for 15% of the total cost. Although this cost belongs to the external cost of companies borne by the society, this cost will gradually the internal cost of companies as the country is gradually tightening the environmental protection system. Therefore, if companies

want to achieve sustainable development, it is necessary to pay attention to environmental protection and enhance the control and management of environmental protection costs.

4. Conclusion

In order to realize the unity of economic and environmental benefits, this paper studies the cost control of pollution control in the exploitation process of shale gas. The specific conclusions are as follows:
(1) Based on the analysis of the environmental impact during the exploitation process of shale gas, the environmental costs of the exploitation of shale gas are classified.
(2) The accounting system of pollution control costs in the exploitation process of shale gas is constructed, and the systematic measurement model for environmental costs is established.
(3) Taking M shale gas company as an example, the calculation results of the pollution control costs in the exploitation process of shale gas are evaluated and the importance of the internalization of external costs and the control of environmental costs for sustainable development of companies is highlighted.

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