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# Research on the Synergistic Emission Reduction of Air Pollutants and Greenhouse Gas in the Chemical Industry under the Background of Double Carbon

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## Abstract

**Against the backdrop of the "double carbon" target constraint and environmental protection, how to deal with climate change and improve air quality has become a prominent task for China. The chemical industry is a major source of air pollutants and greenhouse gas (GHG) and faces a significant challenge in effectively coordinating emission reductions. In this paper, the main air pollutants (VOCs, $NO_x$, $SO_2$) and GHG (mainly $CO_2$) were determined according to the characteristics of the chemical industry. It was proposed that the emission of air pollutants and GHG could be calculated by measurement, material balance, emission factor and other accounting methods. Based on the emission calculation, the synergistic emission reduction effect of air pollutants and GHG was investigated by the cross-elasticity coefficient of synergistic emission reduction and the coordinate system of synergistic control effect method, and the emission reduction potential was explored. Finally, based on the above research, the control implementation plan for air pollutants and GHG was proposed in three aspects: source reduction, process control, and end treatment, providing reference for synergistic emission reduction of different types of pollutants.**

## Keywords

**Chemical industry; Air pollutants; GHG; Emissions accounting; Synergistic emission reduction.**

## 1. INTRODUCTION

The chemical industry has been facing the double pressure of synergistic emission reduction of air pollutants and greenhouse gas (GHG), which needs to actively explore coping strategies for sustainable development [1]. In terms of synergistic control of air pollutants and GHG, the United Nations Intergovernmental Panel on Climate Change (IPCC) has repeatedly mentioned the synergistic effect of GHG and air pollutant emission reduction [2]. Reducing carbon emissions and controlling pollution have become the essential choice for green and sustainable development of the chemical industry [3].

The combustion of fossil fuels in the chemical industry releases GHG (mainly $CO_2$) [4] and emit air pollutants such as $SO_2$, $NO_x$ and VOCs [5] at the same time, which determines the existence of strong emission homology and synergistic emission reduction measures for air pollutants and GHG [6]. Scholars have already researched the synergistic emission reduction of air pollutants and GHG in China. H.Q. Qian et al. [7]analyzed the potential synergistic benefits of major industrial sectors in reducing $NO_x$, $SO_2$, $CO_2$ and other pollutants, while implementing specific interventions for businesses to achieve substantial synergistic emission reduction. The emissions and varying synergistic reduction effectiveness of air pollutants and GHG were quantified by H.X. Zhang et al. [8], indicating different degrees of synergy based on pollutant

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types. B.L. Zhang et al. [9] established a homologous emission inventory of urban air pollutants and GHG, revealing fixed combustion and mobile sources as the primary contributors to $SO_2$, $NO_x$, and $CO_2$ emissions, while process sources dominated VOCs emissions. However, there is currently a notable lack of research on the synergistic reduction of pollution and carbon emissions within the chemical industry, and a comprehensive study on accounting and evaluation methods for air pollutants and GHG has yet to be conducted.

This paper focuses on the synergistic effects of GHG and air pollutants emission in the chemical industry. It emphasizes the identification of air pollutants and GHG types emitted during the economic production processes in the chemical industry. The research introduces methods for accounting emissions and evaluation emission reduction. Based on these methods, the synergistic correlation between the reduction of air pollutants and GHG is analyzed. In addition, emission reduction measures are proposed in terms of source reduction, process control and end treatment. This comprehensive approach aims to provide theoretical and scientific support for advancing synergistic pollution control and carbon emission reduction in the chemical industry.

## 2. METHODS

### 2.1. Accounting methods

(1) Air pollutant accounting methods. This study focuses on VOCs, $NO_x$, and $SO_2$ air pollutants as research subjects. Measurement, material balance and emission factor methods can be simultaneously used to calculate the emissions of the three pollutants in organized emission processes within the chemical industry. The measurement method entails calculating pollutant emissions using data acquired through on-site measurements. The material balance method utilizes the balance relationship of material quantities between the input and output sides, following the law of mass conservation, to calculate pollutant emissions. The emission factor method directly calculates pollutant emissions by utilizing selected factors outlined in industry guidelines, accounting for the composition and characteristics of raw materials in various processes. The emissions of VOCs can also be calculated using formulaic or equation-based methods, while $NO_x$ and $SO_2$ can be estimated using analogy and experimental methods. Additionally, the actual production and operation of the chemical industry also generates a significant amount of unorganized emissions that cannot be ignored. The dispersed and irregular nature of unorganized emissions makes them difficult to estimate by measurement methods. In general, pollutant emissions from unorganized sources are determined using the material balance method.

(2) GHG accounting methods. The accounting of GHG emissions is crucial for comprehending the GHG emission intensity and carbon emissions in the chemical industry [10]. It is an important prerequisite for the implementation of GHG emission reduction activities, and also a significant basis for promoting the coordinated emission reduction of conventional air pollutants and GHG. In the chemical industry, GHG accounting focuses primarily on the accounting of carbon emissions using methods such as emission factors, mass balance and measurement. The emission factors method is the most commonly used method. However, due to the differences in regional climatic conditions, quality of energy consumption, efficiency of fossil fuel combustion and statistical methods, the measurement of different types of energy consumption and the associated carbon emission factors are prone to large variations. The carbon mass balance calculation can reflect the actual emissions that occur at the source of carbon emissions based on specific chemical industrial processes. This method distinguishes not only between different types of equipment, but also between individual units and subunits. The measured method has a high economic cost and is suitable for emission sources with easy determination of concentration and flow rate [11].

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### 2.2. Evaluation method of synergistic emission reduction

Based on the accounting results of air pollutants and GHG emissions in the chemical industry, selecting an appropriate synergistic emission reduction evaluation method is necessary, with the aim of deeply understanding the relationship between different emission reduction strategies and providing a scientific basis for the development of sustainable synergistic emission reduction programs. The commonly used evaluation methods for air pollutants and GHG emission reduction generally include the cross-elasticity coefficient of synergistic emission reduction and the coordinate system of synergistic control effect.

The cross-elasticity coefficient of synergistic emission reduction can characterize the synergistic emission reduction effect between air pollutants and GHG. This method comprehensively considers the cross-effects of multiple emission reduction factors in the chemical industry, which more truly reflects the actual emission reduction situation and helps to set more targeted strategies. The detailed steps are divided into determining the emission reduction factors, establishing the models, calculating the elastic coefficients and simulating the emission reduction effects. The elastic coefficients are calculated mainly based on the analysis of historical or simulated data, reflecting the corresponding change range of other factors when one factor changes.

The coordinate system of synergistic control effect refers to the emission changes of air pollutants and GHG in the chemical industry expressed by coordinate points and marked in a two-dimensional rectangular coordinate system. The positive coordinate values indicate an increase in emissions, while negative values express a decrease in emissions. When the coordinate point is in the first quadrant, it represents the simultaneous increase of GHG and air pollutants; when in the third quadrant, the two have a synergistic effect on emission reduction; when in the second and fourth quadrants, the emissions of the two increase and decrease respectively, there is no synergistic emission reduction effect.

## 3. MEASURES OF SYNERGISTIC EMISSION REDUCTION

### 3.1. Source reduction

(1) Adjust the layout of plants. Under the premise of balancing economy and environmental protection, the layout of plants is adjusted to reduce the emission concentration of air pollutants and GHG, and reduce the influence range of plants. For example, the process equipment near residential areas can be deactivated to reduce the impact on the surrounding sensitive points. Then, the air diffusion model, such as AERMOD, is used to simulate and predict the peripheral environmental impact of air pollutants and GHG emissions in the plants area, verify the effectiveness of the plant layout adjustment.

(2) Select high-quality materials and optimize the material compositions. On the basis of leak detection and repair (LDAR) work, the leakage points of production equipment in the chemical industry are continuously found and repaired. During the check and maintenance of the sealing points, the operating parameters (medium type, temperature, pressure, etc.), the properties of sealing materials (temperature resistance, pressure resistance, thickness, width, etc.) are recorded to eliminate the leaky seals and screen high-efficiency sealing materials. In addition, high-activity and high-selectivity catalysts are screened, and then added to existing equipment in the chemical industry in a certain proportion to indirectly optimize operating conditions, improve process efficiency and reduce air pollutants and GHG emissions.

### 3.2. Process control

(1) Optimization of equipment parameters and operating conditions. Install on-line monitoring devices at the main discharge outlets to record the main parameters of the

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production processes of chemical enterprises and improve the equipment parameters in a targeted manner. Moreover, the operation time can be optimized to avoid the high temperature period for loading operations, thereby reducing the overall emissions of air pollutants and GHG during the loading processes.

(2) Upgrading of equipment and process. Combined with the actual operation conditions such as production maintenance and load adjustment of chemical enterprises, the equipment is upgraded and the on-line reconciliation facilities of products are increased. For example, optimizing the external color, internal structure of the equipment to achieve the effect of synergistic emission reduction of air pollutants and GHG.

### 3.3. End treatment

According to the actual operation of the chemical industry, air pollutants and GHG are concentrated in various types of flue gas emitted by plants, which provides the possibility to achieve synergistic emission reduction through end treatment. Studies have shown that there is a synergistic effect between air pollutants and GHG control, reducing the emission of one party also has a positive effect on the emission reduction effect of the other party. VOCs can be treated by adsorption, condensation or membrane separation to prevent VOCs from being emitted into the atmosphere and to avoid the problem of converting VOCs to $CO_2$ by combustion, thereby reducing VOCs and GHG emissions meanwhile. The SCR denitration technology is upgraded by using new catalysts prepared by loading manganese, vanadium, titanium and other metals, so as to achieve the purpose of synergistic removal of VOCs and $NO_x$ without affecting the denitration efficiency. In addition, the $CO_2$ produced by tail gas treatment can be sequestered through storage, forest carbon sequestration, or processing into inorganic salts, green algae and other products.

## 4. CONCLUSION

The development of the chemical industry has generated a large consumption of fossil fuels, as well as a large amount of air pollutants and GHG. According to the objective situation requirements of China 's air pollution prevention and carbon emission reduction as well as the homologous synchronization of air pollutants and GHG emissions, the coordinated emission reduction of the above two should be paid attention to, so as to explore measures more in line with the long-term development of chemical industry. Accurate accounting of air pollutants and greenhouse gas emissions is essential for coordinated emission reduction efforts. The accounting methods mainly included emission factors, material balance, measurement methods and so on. According to the accounting results and research objectives, appropriate emission reduction evaluation methods should be selected, such as the cross-elasticity coefficient of synergistic emission reduction and the coordinate system of synergistic control effect method, whose purpose is to explore the relationship between different emission reduction strategies. The targeted emission reduction measures are proposed in source reduction, process control and end treatment to promote the sustainable development of the chemical industry.

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