PROFILE
Particulates Pollution Management and Economic Analysis of Small Rural Enterprises in Mountain Areas: A Case Study of Wenquan Town in China

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ABSTRACT/At present, many rural enterprises in China’s mountainous areas are developing rapidly, and due to poor planning and improper management, in an uncontrolled manner. These small enterprises are making atmospheric pollution far more serious and more difficult to control than before. Thus, as is the case with most developing countries, China is facing the challenge of managing the increased environmental pollution that is accompanying its economic development. This paper examines the case of cement dust pollution in the town of Wenquan in Sichuan province in order to determine how to adjust the relationship between development of rural enterprises and atmospheric environmental pollution in mountainous areas. Using the single objective linear programming method, and based on the principle of overall optimization, an optimal control plan for different pollution sources was worked out and an economic assessment on reclamation of cement dust was completed. According to our analysis, after implementation of this plan for four years, two months, the concentrations of suspended particles in Wenquan will achieve the requirement of the national third-order ambient air quality standard; the current serious dust pollution will be completely controlled; and the reclamation of cement dust will totally compensate for the cost of dust control and will result in 92,000 yuan of pure profit per year. At that time, the economy and environment will be in harmony.

During the past decades, five types of small rural enterprises—small coal mines; small brick, cement, and chemical fertilizer factories; and iron and steel factories—arose in China. These small enterprises play a very important role in activating the rural economy, by employing idle and surplus laborers and in increasing state revenue. However, because of obsolete techniques and equipment, and improper management based on a principle of deriving quick profits, these enterprises worsen the local environmental quality and disturb the ecological balance, agricultural economics, and residential health (Qu 1984). In some areas, where too many factories are crowded together, and in some blocked valleys, where it is difficult for atmospheric pollution to be dispersed or diluted, the atmospheric pollution is serious (Ning 1999).

In China, as in other developing countries, atmospheric pollution is more serious than other types of pollution. It is estimated that reduction of grain yield due to atmospheric pollution results in a loss of 1500-1700 million yuan each year (Zhang 1986). Therefore, the immediate benefits of lower investment by rural small-scale enterprises are obtained at the cost of ruining environmental conditions. At present, thousands of rural enterprises are operating in conditions of poor planning, improper production structure, backward techniques and equipment, poor management, high consumption of resources and energy, and lack of provisions for environmental protection (Qu 1984). In order to solve these critical problems, some multifaceted control measures should be taken immediately. In areas to be developed, every enterprise must be set up under a unified plan and the impact of the enterprise on the natural environment

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should be assessed, so that the location, scale, and products of the enterprises can be properly selected according to local environmental conditions. Thereby rural industry may be developed steadily while, at the same time, atmospheric pollution can be limited to an acceptable standard level.

General Situation of Atmospheric Particulates Pollution in the Wenquan Area

There are mountains around Wenquan, located in the upper reaches of the Yangtze River and in the east part of Sichuan Province, which form a Y-shaped valley (Figures 1 and 2). Because limestone resources are very rich there, the building material industry is developing rapidly. The main products are cement, dolomite powder, lime, and prefabricated cement components.

In addition to more than ten small cement factories, there are also some other small enterprises such as a small paper manufacturing factory, a handicraft mill, etc. They are located within an area of about 1 km². All the factories except the state-owned cement factory are without facilities for dust collection. Large quantities of harmful particles less than 5 μm in diameter are emitted into the atmosphere; these particles do not disperse quickly and accumulate in the valley, so atmospheric pollution in this area is very serious. In order to develop the local economy and to serve the Three Gorges project, the building materials industry in Kaixian, the county in which Wenquan is located, will be further developed. In accordance with the economic development plan drawn up by the local government, cement production in the county at the end of this century will increase by 2.56 times that of the 1985 level. Accordingly, the annual volume of industrial waste gas will reach 734 million standard cubic meters including 235 million standard cubic meters of dust and fumes. If gravity and inertial dust separators or other primary dust collecting equipment are used at that time, the dust collecting rate will reach 50% and the annual dust emission will accordingly be decreased to 1173.79 tons. However, the daily average concentration of dust and fumes will still increase from 1.70 mg/m³ currently to 3.02 mg/m³ by the year 2000, which is five times more than that prescribed by the national third-order ambient air quality standard (Table 1).

The cement production, annual amount of emitted dust, and dust emission rate per unit production of seven cement factories in Wenquan by the end of 1990 are given in Table 2. From the data, the status of the dust emission and concentration levels by the end of the year 2000 can be estimated.

Based on the box model, if atmospheric stability is neutral, without the formation of temperature inversion, and \( u = 0.8 \) m/sec, it is estimated that the concentration of suspended particles in Wenquan is 1.70 mg/m³, which is equal to 3.4 times of that prescribed by the national third-order ambient air quality standard (Ning 1989). On a windless morning with temperature inversion, the concentration of dust and fumes would reach 34.20 mg/m³, which is 21.8 times higher than that prescribed by the national third-order ambient air quality standard (Ning 1989). Presently, the average concentration of SO₂ in Wenquan is 0.047 mg/m³ and is lower than that required by the national standard. As to NOₓ, CO, and other pollutants, their concentrations are much lower than that prescribed by the national standard.

Therefore, the major atmospheric pollutant in Wenquan is dust and the major pollution sources are the seven cement factories. In order to control atmospheric pollution, it is critical to take proper measures to reduce dust emission.

Optimal Control of Cement Dust Pollution in Wenquan

Basic Principle of Optimal Control

The single-objective linear programming method is used to select the optimal plan to reach the fixed goal with the greatest benefit. Linear programming is the most effective method to establish an optimal model. It has two advantages: high efficiency at solving problems and convergence at the total optimal solution rather than at the partial optimal solution. Its objective function is determined by the real situation. The policy decision variables are the various ranges of different control measures taken by each pollution...