Microbiological Diversity Demonstrates the Potential which Collaboratively Metabolize Nitrogen Oxides (NOx) under Smog Environmental Stress

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Abstract. Recently, smoggy weather has become a daily in large part of China because of rapidly economic growth and accelerative urbanization. Stressed on the smoggy situation and economic growth, the green and environment-friendly technology is necessary to reduce or eliminate the smog and promote the sustainable development of economy. Previous studies had confirmed that nitrogen oxides (NOx) is one of crucial factors which forms smog. Microorganisms have the advantages of quickly growth and reproduction and metabolic diversity which can collaboratively Metabolize various NOx. This study will design a kind of bacteria & algae cultivation system which can metabolize collaboratively nitrogen oxides in air and intervene in the local nitrogen cycle. Furthermore, the nitrogen oxides can be transformed into nitrogen gas or assembled in protein in microorganism cell by regulating the microorganism types and quantities and metabolic pathways in the system. Finally, the smog will be alleviated or eliminated because of reduction of nitrogen oxides emission. This study will produce the green developmental methodology.

1. The current situation
Haze Siege is inevitable in large cities during industrialization and urbanization. The dilemma appeared in several developed cities. For example, there is smoke event in Belgian Maas Valley in 1930 and in London in 1952, and photochemical smog pollution occurred in Los Angeles in 1943[1]. These accidents resulted in too many deaths in a brief time. Recently, smoggy weather has become a daily in large part of China because of rapidly economic growth and accelerative urbanization. Heavily polluted smog resulted in not only badly public traffic and too much health hazards in cities, but also hindered the sustainable development of economy. Therefore, smoggy air is one of hot spots of society which need to be addressed urgently.

Previous studies have confirmed that nitrogen oxides (NOx) from multiple sources is one of crucial factors which form smog. The smog will be reduced and eliminated if the emission of NOx is controlled effectively [1-9]. Currently, energy conservation & emission reduction technology is carried out to tackle its notorious smog problem. Although there is a certainly positive effect, the technology can’t solve the problem completely. For another, those treatments will have a negative effect on economic growth. Stressed on the smoggy situation and economic development, the green
and environment-friendly technology is necessary to reduce or eliminate the smog and promote the sustainable development of economy.

2. The recent progresses and problem
Since the smog has resulted in too many deaths around the world, scientists focused on the components, formation and treatments of the mixture particle, and the governments established a lot of funds to alleviate or eliminate the event. Jeffrey and his colleagues (2011) reviewed previous study and showed the history and formation about the smog in Los Angeles and London [1]. Chinese researchers reported the event in the century. Wang (2013) analysed nine water-soluble ions from PM 2.5 and PM 10 particle samples in heavy smog in Harbin city during the last 10 days in October, 2013. At the same time, the distribution effect of every ion was calculated [3]. Lu (2013) collected the meteorological data and the pollutants samples from 8 large cities (Beijing, Tianjin, Shijiazhuang, Ji’nan, Taiyuan, Zhengzhou, Xi’an and Wuhan). According to correlation analysis among principal component, atmospheric fine particulate matter (PM 2.5) concentration, particle size distribution, temporal and spatial variation, the relationship between haze and meteorological factors were achieved [4]. The current paper demonstrated that the main components of atmospheric particulate matter are certain water-soluble ions, including SO$_4^{2-}$ and NO$_3^-$ which are from sulphide (i.e. SO$_2$) and nitrogen oxides (i.e. NOx) produced by coal and fuel motor vehicle [1-11]. In addition, nitrogen oxides can catalyse photochemical reaction to increase pollution [1-11]. To alleviate the smog, it is an effective treatment to control the emission of sulphide and nitrogen oxides.

Compared to sulphide, nitrogen oxides have more negative effect on formation of smog. As we all know that energy conservation and emission reduction is not a perfect option. However, the chemical denitrification technology must be invested more cost on equipment and operation, and the secondary pollution is inevitable. For this, the scientists are dedicated to finding a reasonable way to control the emission of nitrogen oxides. Zhang (2014) selected some microorganisms to purify NO and NOx from smog, and the removal rate of NO and NOx can be up to 50% and 70% under optimization conditions, relatively [13]. However, Liu (2015) utilized the chemical absorption-biological reduction technology; they had not obtained satisfactory results [14]. Haze is still a normalization trend in northern cities when heating season come back.

3. The emission of N$_2$O during Sewage treatment
Nitrifying and denitrifying bacteria in activated sludge are widely used as denitrification treatment. According to the recent paper, the highest denitrification rate can be over 90% [15-21]. The two types of bacteria can metabolize NOx under different conditions. Cui (2015) analysed the denitrification process under heterotopic conditions [16]. Van Kesseld (2015) completed the biological event with a few microorganisms [17]. Nikolaev’s paper reported that denitrification was feasible under low temperature [18]. However, efficient sewage treatment led to increased emissions of N$_2$O because insufficiency of dinitrogen reductase activity can’t complete the transformation process from N$_2$O to N$_2$ gas. N$_2$O can be transformed into NO and constantly changed into NO$_2$ [2, 5, 6, 9]. To increase the enzymatic activity can be an alternative program.

4. The collaborative metabolism of NOx

4.1. The system of bacteria & algae cultivation
Microbiological diversity demonstrates the potential which collaboratively metabolize nitrogen oxides (NOx) under smog environmental stress because microorganisms have the advantages of quickly growth and reproduction and metabolic difference. We will attempt to design a kind of bacteria & algae cultivation system which is constituted by various microorganisms, including Nitrifying bacteria, Denitrifying bacteria, Pseudomonas, Bacillus subtilis, Chlamydomonas reinhardtii, and so on (table 1). There are various metabolism pathways on nitrogen element in these microorganisms, and the
biological system can metabolize collaboratively nitrogen oxides in air and intervene in the local nitrogen cycle.

### Table 1. Microorganisms and functions in the cultivation system

| Microorganism         | Function                        | Potential transformation |
|-----------------------|---------------------------------|--------------------------|
| Nitrosobacteria       | Ammonia oxidation, Assimilation, Deamination | NH$_3$ $\rightarrow$ NO$_2^-$, NH$_3$ $\Leftrightarrow$ P-NH$_2^*$ |
| Nitrifying bacteria   | Nitrification, Assimilation, Deamination | NO$_2^-$ $\rightarrow$ NO$_3^-$, NH$_3$ $\Leftrightarrow$ P-NH$_2$ |
| Denitrifying bacteria | Denitrification, Assimilation, Deamination | NO$_3^-$ $\rightarrow$ NO$_2^-$, NH$_3$ $\Leftrightarrow$ P-NH$_2$ |
| Pseudomonas           | Denitrification, Assimilation, Deamination | NO $\rightarrow$ N$_2$, N$_2$O $\rightarrow$ N$_2$, NH$_3$ $\Leftrightarrow$ P-NH$_2$ |
| Bacillus subtilis     | Denitrification, Assimilation, Deamination | N$_2$O $\rightarrow$ N$_2$, NO $\rightarrow$ N$_2$, NH$_3$ $\Leftrightarrow$ P-NH$_2$ |
| Chlamydomonas reinhardtii | Denitrification, Photosynthesis, Assimilation, Deamination | NO $\rightarrow$ N$_2$O, NH$_3$ $\Leftrightarrow$ P-NH$_2$ |

P-NH$_2^*$, the amino group on the protein molecules

#### 4.2. The cycle of collaborative metabolism of NOx

The nitrogen oxides can be transformed into nitrogen gas or assembled in the amino group on the protein molecules in microorganisms by regulating the types and quantities and metabolic pathways in the system (figure 1).

![Figure 1: The cycle of collaborative metabolism of NOx](image)

#### 5. Perspective
Summary, the imbalance of nitrogen cycle resulted in these problems. It is necessary to recovery the balance by regulating the metabolic pathways and level of nitrogen cycle. The growth advantages of microorganisms demonstrated the potential which intervene in the cycle and become a nitrogen pool in the circulation [22, 23]. The cultivation system which consist of various microorganisms will produce beneficial effect on the cycle. The recovery is possible if microbiological types, quantity and metabolic way can be regulated rationally. Especially, the activity of dinitrogen reductase should be improved effectively. The total activity can be increased for growth of the number of denitrifying bacteria, and the enzymatic activity in single bacteria can be increased by developed genetic engineering technology. Finally, the smog will be alleviated or eliminated for emission reduction of nitrogen oxides. This strategy will produce the green developmental methodology.

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