VERIFICATION OF THE JCAP ROADSIDE AIR QUALITY SIMULATION MODEL

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Abstract: By the reinforcement of the vehicle emission reduction requirement, NO_X concentration in a roadside atmosphere reduced clearly recently. However, the ambient NO_2 concentration does not show a variation. For the purpose of provision of data contributing to environmental policy making through development of high accuracy Air Quality Model and impact prediction of improved air quality, the Japan Clean Air Program had started.
A commercial CFD model of Star-CD was used as the roadside air quality model. The chemical reactions of NO oxidation with ozone, photodissociation of NO_2, and ozone formation are going to introduce in this model. Involving a spatial distribution of ozone concentration measurement, temporal and spatial variation of NO and NO_2 was measured by the devices of chemiluminescence method which were prepared by each chemical species. Concentration-change was measured at the same time in four sites every one second to pay attention to a percentage of NO_2/NO_X which varied from route neighborhood to lee side way. The air flow of each sites were monitored by the ultrasonic 3D anemometer. The effect of NO_2 concentration change due to the air stagnation or background ozone concentration was evaluated.

Key words: *nitric oxide, nitrogen dioxide, ozone, roadside air quality, vehicle emission*

1. INTRODUCTION

The nitric oxide (NO_X) emission from vehicles amounts about 50% in Tokyo, and it is considered as primary source. Not only vehicle emission regulation every several years but also riding into regulation to Tokyo was reinforced for reduction of the NO_X discharge. Decrease tendency of ambient NO_X concentration is confirmed, however nitrogen dioxide (NO_2) concentration is not seen to be changed. The aftertreatment of tailpipe emission (eg. oxidation catalysts) of the diesel vehicle is thought to be one reason. For the purpose of provision of data contributing to environmental policy making through development of high accuracy Air Quality Model and impact prediction of improved air quality, the Japan Clean Air Program had started in 1997 by the fund of Ministry of Economy, Trade and Industry and the cooperation of the auto industry and the petroleum industry. A tertiary stage of the quinquennium program began, and the name is changed in JATOP (Japan AuTo-Oil Program) now. A wide area air quality simulation, based on CMAQ, and the roadside air quality simulation are developed in this program.

A commercial CFD model of Star-CD was used as the roadside air quality model. The vehicle emission is calculated with traffic-flow model (Paramix) and the transient emission model, which is developed originally. The chemical reactions of nitric mono-oxide (NO) oxidation with ozone, photodissociation of NO_2, and ozone (O_3) formation are going to introduce in this model.

Observation was carried out to clarify verification of results of the roadside air quality simulation and to clarify the behavior of the NO_2 around the roadside. Involving a spatial distribution of O3 concentration, wind, atmospheric temperature, humidity, and solar radiation, temporal and spatial variation of NO and NO_2 was measured by the devices of chemiluminescence method, which were prepared by each chemical species. Behavior of NO_2 provided from observation is presented mainly.

2. OBSERVATION

As shown in Figure 1, a sampling line was changed by the solenoid valves to measure concentrations of NO, NO_X and O_3 by 3 altimetry (1, 3, and 10m from the ground) in one spot. Four spots (a north curbside, a south curbside (0m south remote point), 20m south remote point, 100 m south remote point) were set up in the direction that was perpendicular to the road (Ring No.8; average traffic volume is 2,400 vehicles hr^{-1}, and the type ratio of heavy duty vehicle is 11%), and simultaneous observation was carried out from March 4 to March 7 in 2008. Eight sets of the NOx monitor (Thermoelectron company, Model 42) were used and the NO_2 concentration was obtained from difference of NO_X and the NO. A variation of the NO_2 concentration was able to be measured in temporal response of around one second by this way. The air flow of each points were monitored by the ultrasonic 3D anemometer. The effect of NO_2 concentration change due to the air stagnation or background ozone concentration was evaluated. The data of the north wind was chosen, and analysis was carried out. Value of the north curbside point was going to be assumed as a background value, however, because the values of the north curbside point was affected by the building nearby, and several times of high concentration was seen, the value of the 100 remoteness point was used as a background value.

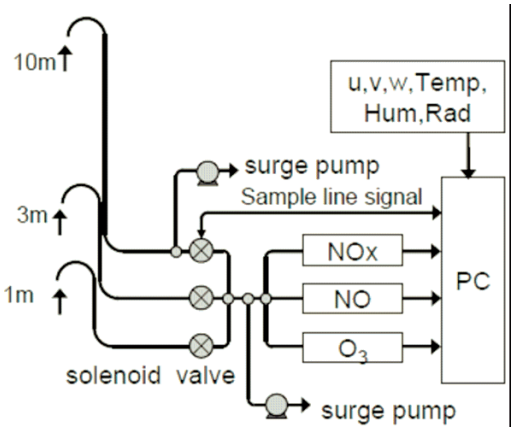

Figure 1. Sampling line and measurement system.

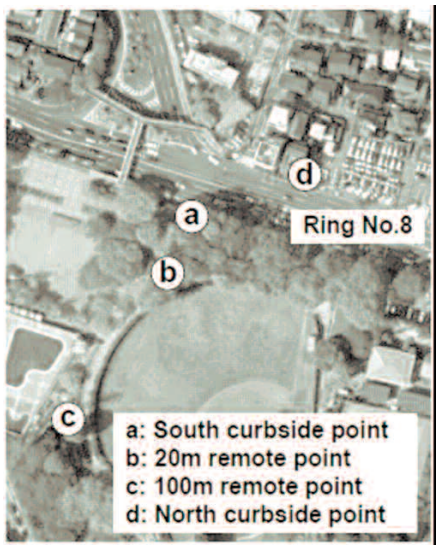

Figure 2. Location of the observation points.

3. RESULTS AND ANALYSES

From the observed data every one second, the data of lee wind condition of the road were analyzed. The lee wind condition was defined as the wind direction of 19 degrees and the deflection angle of the wind direction within 45 degrees, which perpendicular to the road. A time variation of the NO_X concentration was seen depending on traffic volume. Because the traffic volume was controlled by the signal of the intersection nearby, the NO_X concentration variation was seen corresponding with the signal cycle of 140 seconds. Figure 2 shows the mean values of 1m height provided in the lee condition for the observation period as a function of an elapsed time of the signal.

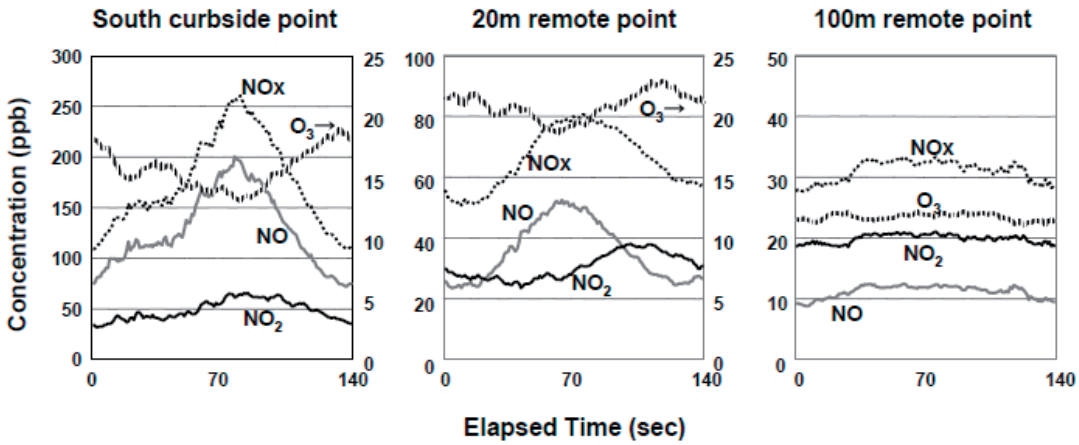

Figure 3. Time variation of gas concentrations observed at 1 m height during one signal cycle.

NO_2 concentration in a roadside atmosphere depends on two factors. The first is the direct emission from vehicles and the second is the oxidation from NO from vehicle and O_3 from ambient. From the time variation of the potential ozone concentration ($NO_2 + O_3$), the direct emission part was estimated as 8.4% of all discharge (NO_X) from vehicles. The mean value of NO_2/NO_X is shown in Table 1, and it shows space dependency. The reason why NO_2/NOx values increase as the distance from the road is NO_2 oxidation generation. The NO_2/NO_X value was found to be increased according to the ambient O_3 concentration also.

To estimate oxidation formation of the NO_2 between the south curbside point and the 20 m remote point, the value at the 100m remote point was assumed as the background concentration and the diffusion coefficient between the two points was estimated from a variation of the NO_X concentration.

$$theDiffusionCoefficient = \overline{\left(\frac{NOx(20m) - NOx(100m)}{NOx(0m) - NOx(100m)} \right)} \quad (1)$$

With this diffusion coefficient, gas concentration in the 20 m remote point was estimated by using the concentration measured at the curbside point only with diffusion change without chemical change. The difference with the estimated concentration and the observation concentration provides a portion of the chemical reaction. Table 2 shows the percentage of chemical reaction portion from the curbside point to the 20 m remote point. The formation of NO_2 and the loss of the NO should become the constant value theoretically. However, NO_2 formation was estimated to be higher as shown in Table 2. Table 2 shows the tendency that oxidation reaction increases according to height. This is suggested a lot of supply of O_3 from higher sky generates NO_2 much more.

Table 1. The mean value of NO_2/NO_X

NO_2/NOx	0m	20m	100m
10mH	48%	66%	65%
3mH	29%	47%	65%
1mH	28%	46%	64%

Table 2. The percentage of chemical reaction portion from the curbside point to the 20 m remoter point.

dC/NOx	NO loss	NO_2 generation
10mH	39%	44%
3mH	15%	20%
1mH	12%	13%

4. CHALLENGE

The roadside air quality simulation including the chemical reaction calculation is being carried out now. If results are in time, they are going to be shown.

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