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VENTILATION REQUIREMENT TO BE CONSIDERED IN OFFICE ENVIRONMENT

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ABSTRACT

In order to reconsider the ventilation requirement in office environment and air environmental indices to determine it, field measurements were carried out. The amounts of outdoor air taken into air conditioning system were controlled in three levels and the concentrations of various indoor air pollutants were measured.

It was found conclusively that 30 cubic meters per hour per person of intentionally introduced outdoor air was appropriate for ventilation requirement for offices and carbon dioxide was also appropriate as an index. As for the air distributions in building the phenomena concerning infiltration and exfiltration are hard to describe except for such a case like one closed air conditioning system, we have to give more careful considerations.

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In Japan we have "Law for Maintenance of Sanitation in Buildings" established in 1970. The law provides the indoor air environmental standards as shown in Table 1. which should be followed in "specially designated buildings" having a total area of not less than 3000 square meters and intended for use for offices, entertainment facilities, department stores, etc.

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equation (1).

$$Q = \frac{M}{C - Co} \qquad (1)$$

where Q is ventilation requirement (fresh outdoor air volume per unit time per person), M is amount of carbon dioxide generated by person per unit time and C and Co are the concentrations of carbon dioxide indoor and outdoor respectively. On the supposition that M is 0.02 $m^3/h/p$, C and Co are 1000 ppm and 330 ppm respectively, the ventilation requirement Q shall be 30 m^3/h per person provided that there are no other sources of air pollution.

In Japan, however, there are two main arguments concerning the reduction of ventilation requirement in office buildings from the standpoint of energy conservation; the first, it is possible to reduce it as much as 10 $m^3/h/p$ without violating the law because of infiltration and/or low occupancy in rooms; the second, it is no matter even if the standard for CO_2 concentration is exceeded in well-controlled indoor environment as CO_2 is not a poison in itself.

To check these arguments and to consider how ventilation requirement be decided field measurements were carried out in one of office buildings, which have air conditioning system in each floor.

This work is featured in controlling the outdoor air intake to air conditioning system in three steps. The aim of this study is to consider the ventilation requirement in office buildings and to select one or two environmental indices to determine it as well.

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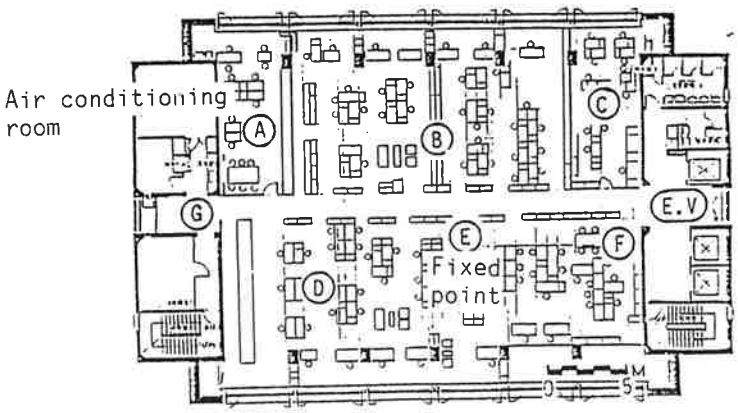
Diurnal time variations of concentration of air pollution, actual smoking amount and occupancy are shown in Fig. 2. (a) to (h).



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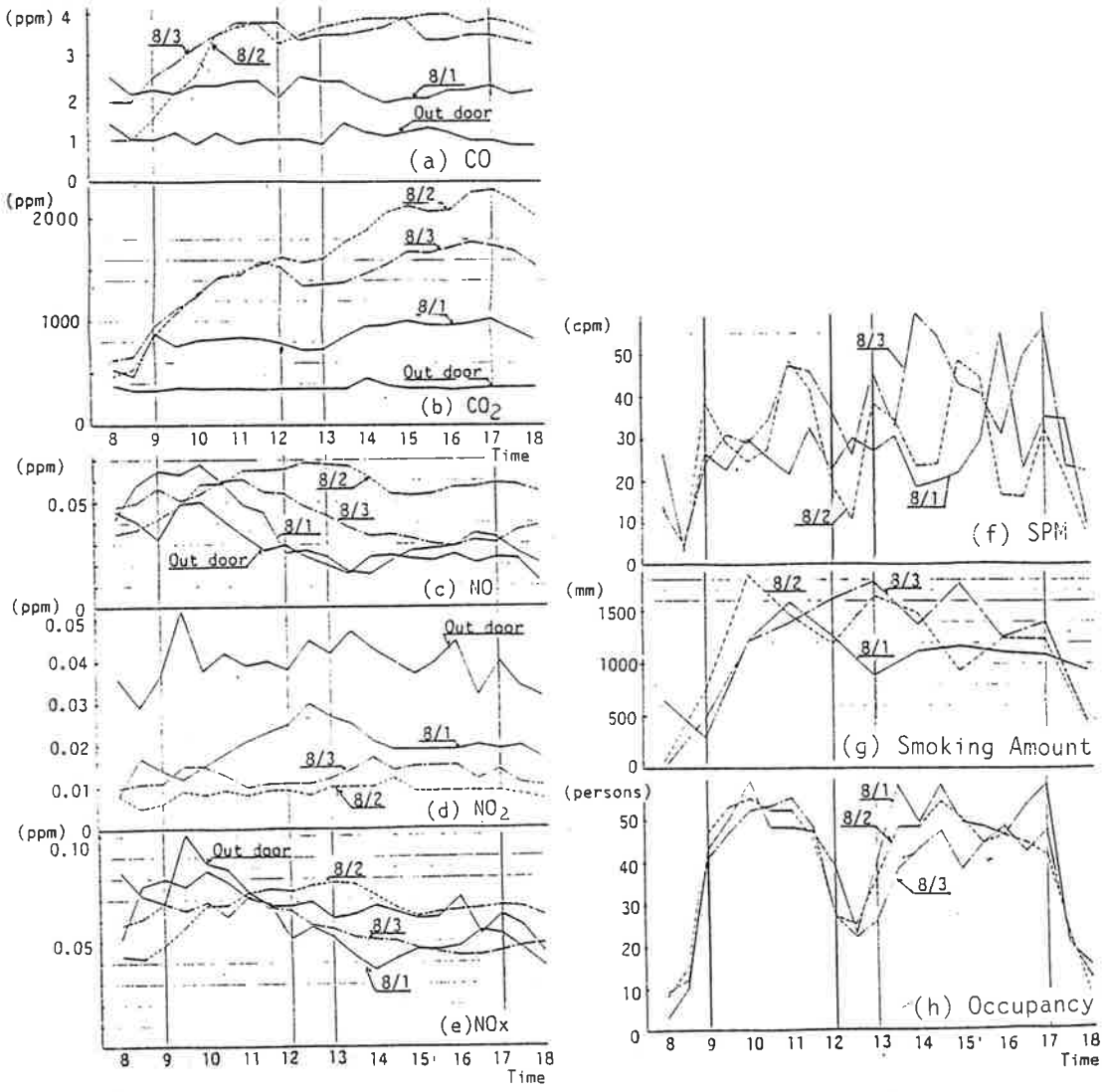

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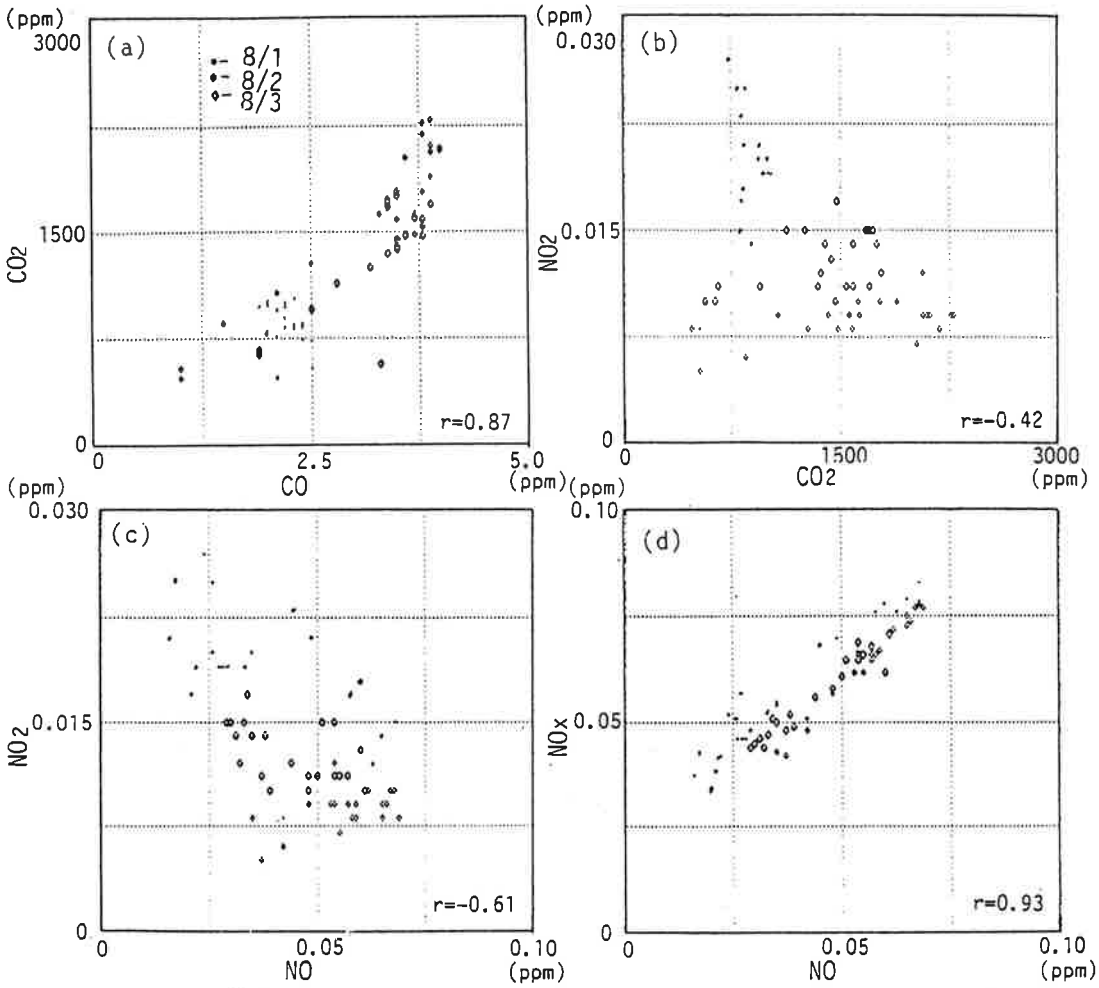
Some of the relations among various values are shown in Fig.3. and 4. As seen in Fig.3(a), the relation between the values of CO and CO_2 has high correlation coefficient (r=0.87). The values of NO_2 was low compared with those of NO, so the correlation coefficient between NOx and NO had high value (r=0.83). The concentration of SPM and that of CO_2 are usually said to be proportional in many offices, but in these measurements there was little connection between them. Especially on 8/2 (when CO_2 showed high values) Fig. 4(b) shows a



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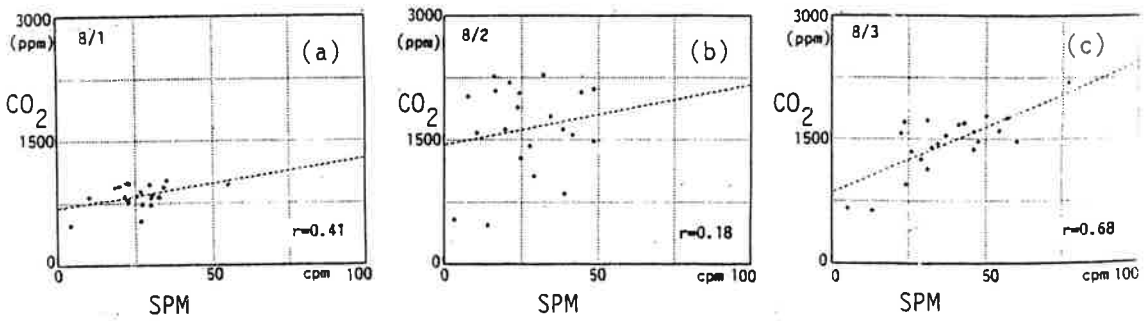

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Fig.5(a) to (d) show the outline of the relations between the amount of outdoor air intake per hour per person and the average concentrations of various air pollutants. As comparatively steady values were obtained both in occupancy and in air pollution throughout every afternoon, the average values of the data from 13:30 through 17:00 were adopted as their representatives.

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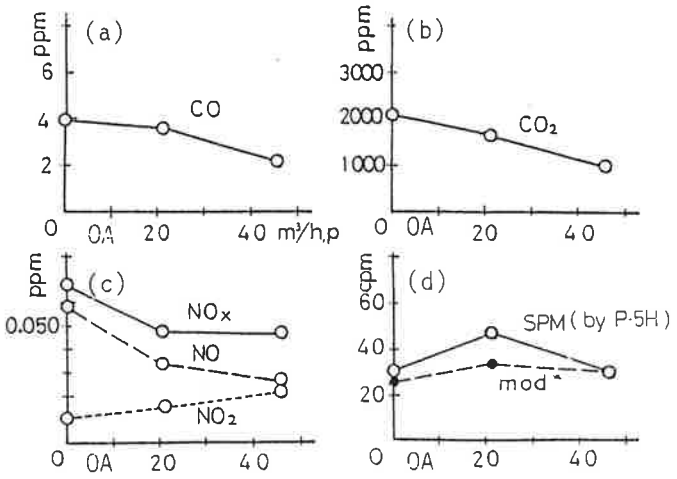

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TABLE 5.

Amount of outdoor air per hour per person

Date	Calculated	Measured	Difference
8 / 1	37.5 m^3	45.8 m^3	8.3 m^3 Exfiltration
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CONCLUSION

Field measurements in one of office buildings were carried out controlling the outdoor air intake.

All correlations of possible combinations of two variables among various values of air pollution and the outdoor air intake were examined.

CO_2 and SPM have been told to be proper indices so far, in this field work only CO_2 is found to correspond to the amount of outdoor air intake and to be most proper as an index of office environment.

Though there are many problems to be further studied on air balance in air conditioned office buildings, 30 m^3/h/p of intentional fresh air seems to meet the minimum ventilation requirement in office environment.

ACKNOWLEDGEMENT

The authors express their appreciation to the co-workers of IPH, the students and the members of Ando Construction Co. Inc. who helped them with the measurements. This project is supported by national funds from the Ministry of Education in Japanese Government.

REFERENCES

C.P. Yaglou et al.,Ventilation Requirements,ASHVETrans.,42(1936)pp.133-162.
S. Yoshizawa, Indoor Environmental Standards and Ventilation Requirements, (in Japanese) Journal of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan,54(4),(1980) pp.301-307.
Y. Nakazawa and M. Narasaki, Ventilation Rates (in Jap.), JSHACSE,54(1),(1980) pp.27-32.
S. Yoshizawa, How to Consider Ventilation Requirement (in Jap.), Journal of Architecture and Building Science, 96(1185), (1981) pp.19-22.
S. Fujii, S. Yoshizawa, T. Irie et al.,Study on Standardization of Occupancy Rate and its Diurnal Variation in Buildings for Determination of Ventilation Requirement in Designing Ventilation Equipment(in Jap.), Trans.of Ann. Meet. of SHACSE, (1981) pp.437-448.
ASHRAE 62-81 Standards for Natural and Mechanical Ventilation, (1981).
S. Yoshizawa, Indoor Air Pollution in Office Buildings with Oxides of Nitrogen, Proc. of 6th International Symposium on Contamination Control, Tokyo,(1982) pp.255-260.
T. Irie, S. Yoshizawa and H. Komine, On Indoor Air Pollutions Induced by Smoking (in Jap.), Proc. of 2nd Clean Air Tech. Conference, (1983) pp.79-80.

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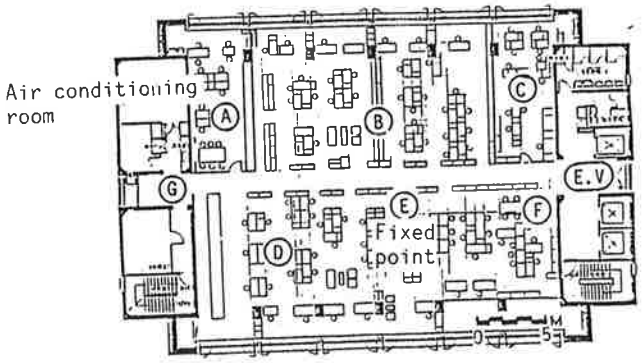

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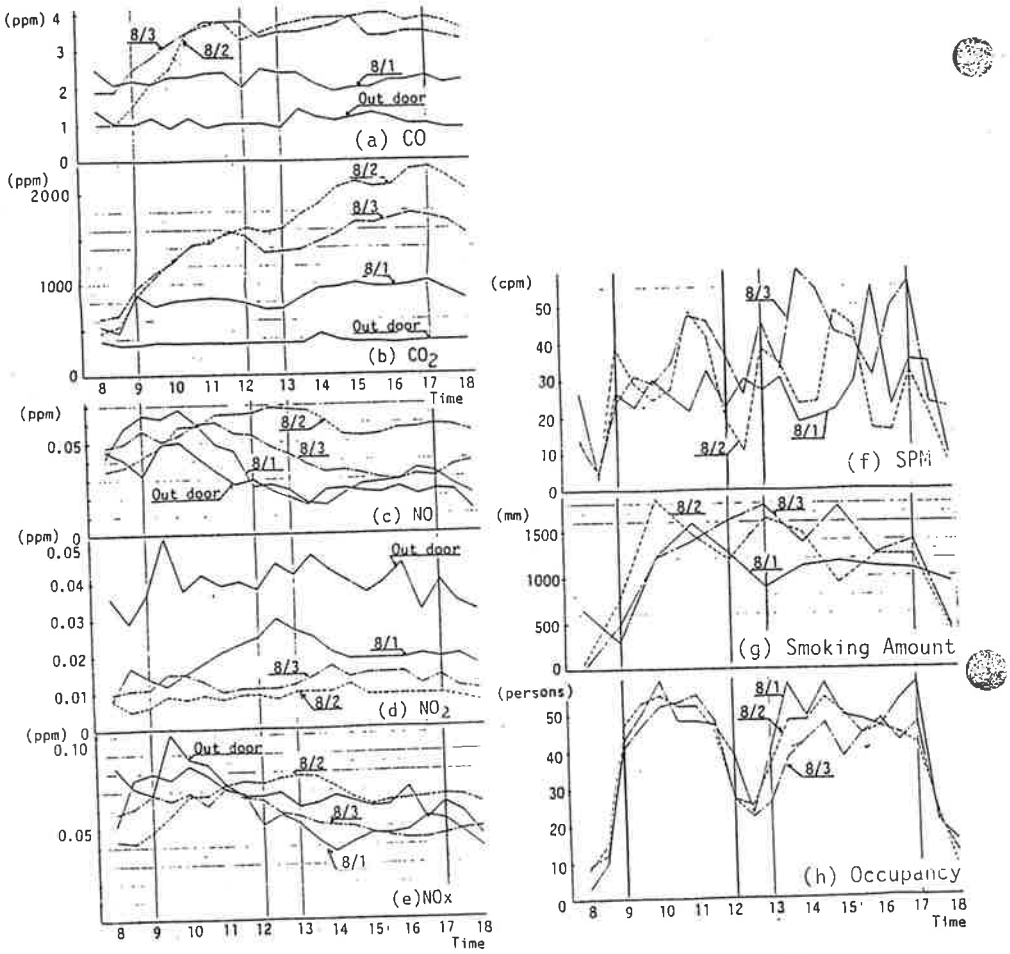

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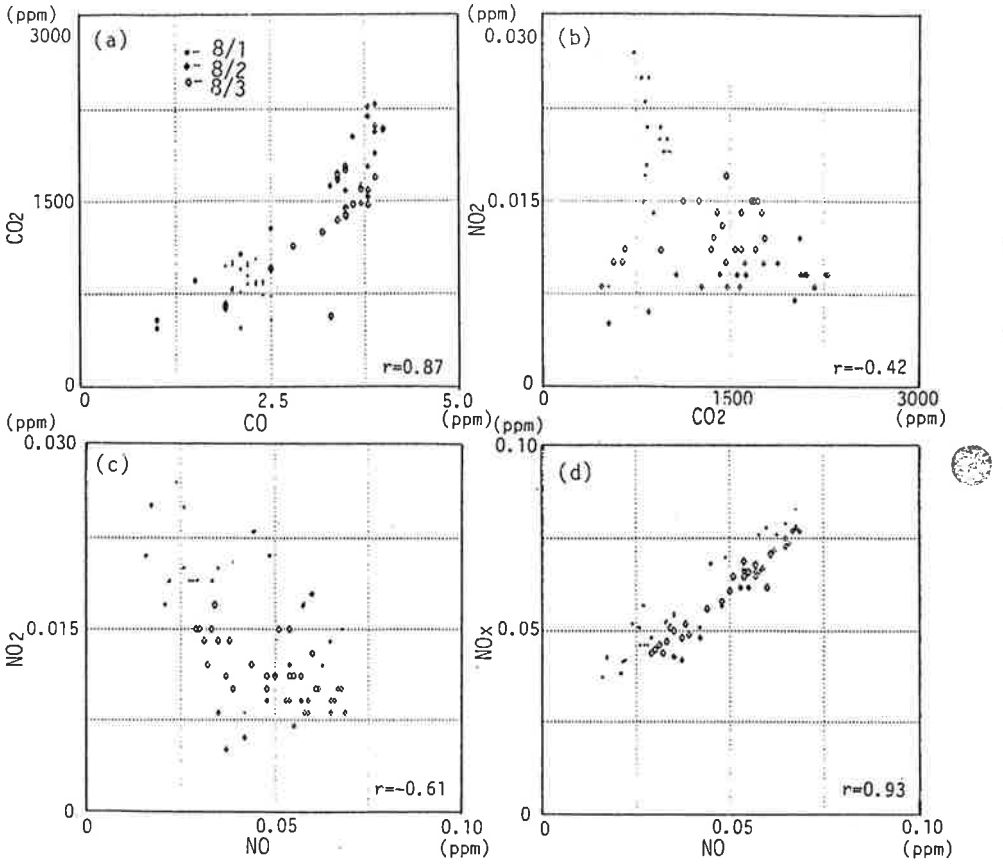

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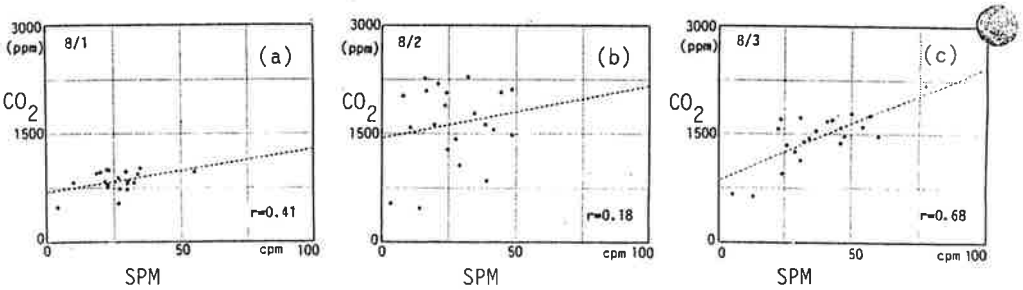

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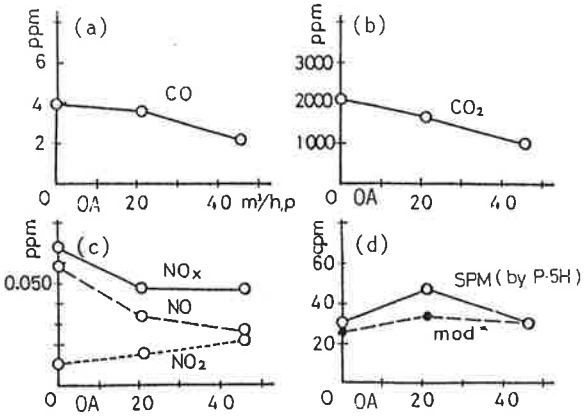

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Field measurements in one of office buildings were carried out controlling the outdoor air intake.

All correlations of possible combinations of two variables among various values of air pollution and the outdoor air intake were examined.

CO_2 and SPM have been told to be proper indices so far, in this field work only CO_2 is found to correspond to the amount of outdoor air intake and to be most proper as an index of office environment.

Though there are many problems to be further studied on air balance in air conditioned office buildings, 30 m^3/h/p of intentional fresh air seems to meet the minimum ventilation requirement in office environment.

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REFERENCES

C.P. Yaglou et al.,Ventilation Requirements,ASHVETrans.,42(1936)pp.133-162.
S. Yoshizawa, Indoor Environmental Standards and Ventilation Requirements, (in Japanese) Journal of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan,54(4),(1980) pp.301-307.
Y. Nakazawa and M. Narasaki, Ventilation Rates (in Jap.), JSHACSE,54(1),(1980) pp.27-32.
S. Yoshizawa, How to Consider Ventilation Requirement (in Jap.), Journal of Architecture and Building Science, 96(1185), (1981) pp.19-22.
S. Fujii, S. Yoshizawa, T. Irie et al.,Study on Standardization of Occupancy Rate and its Diurnal Variation in Buildings for Determination of Ventilation Requirement in Designing Ventilation Equipment(in Jap.), Trans.of Ann. Meet. of SHACSE, (1981) pp.437-448.
ASHRAE 62-81 Standards for Natural and Mechanical Ventilation, (1981).
S. Yoshizawa, Indoor Air Pollution in Office Buildings with Oxides of Nitrogen, Proc. of 6th International Symposium on Contamination Control, Tokyo,(1982) pp.255-260.
T. Irie, S. Yoshizawa and H. Komine, On Indoor Air Pollutions Induced by Smoking (in Jap.), Proc. of 2nd Clean Air Tech. Conference, (1983) pp.79-80.