

# Estimation on Humidification and Ventilation for Infection Control in Residence for the Elderly



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## Abstract

**Purpose / Context** - The aim of this study is to clarify an estimation method of humidification for infection control in residences. In Japan indoor humidity is very low in winter especially in recent insulated houses without unvented stoves. Dwellers know that it is necessary to keep humidity adequate for infection control, but most of them don't know the moderate humidity or the effect of ventilation for infection control. In this study, the state of influenza infection control was evaluated using the measurement results on indoor air in the rooms of six Japanese facilities for the elderly. The temperature is kept better in these residences than that in common Japanese houses. But the humidity is quite very low in winter. The energy saving is thought to be one of the causes of this state.

**Methodology / Approach** - Under the assumption that influenza virus generate at a constant rate, the concentrations of survived influenza viruses in indoor air were calculated using an equation, which is given on the basis of the survival tests on influenza virus by G.J.Harper. The equation gives the concentration of influenza viruses using the ventilation rates and absolute humidity. Then an index on virus reduction which integrates ventilation effect and humidity effect was proposed.

**Results** - The energy consumption of ventilation and humidification for infection control is calculated using this index. The results show that it is effective to control ventilation rate for both of infection control and saving energy in many rooms in these facilities.

**Key Findings / Implications** - Effective strategies for infection control in residences are discussed using the index of influenza infection control.

**Originality** - The index of influenza infection control is proposed in this study. This index is useful to estimate indoor air quality. The index is expected to be used for the design of building performances and air conditioning systems.

**Keywords** - influenza, infection, humidity, ventilation, energy saving



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## 1. Introduction

In Japan, indoor humidity is very low in winter especially in most of the recent insulated houses without unvented stoves. The influenza infection is one of the high risk factors for dwellers' health. This prevention is very important especially for the elderly. Dwellers know that it is necessary to keep humidity moderate for infection control and they use portable humidifiers. Though they have to supply water frequently and keep them clean, these maintenance is not easy especially for the elderly. Most of them don't know the moderate humidity, the effect of ventilation or the energy consumption for ventilation and humidification.

In former studies, it was made clear that though the portable humidifiers are used in most facilities for infection control, indoor humidity is very low. The average humidity was lower than 40RH% (the standard value in AMAB1970 / the act on the maintenance of sanitation in buildings established in 1970) in most of the rooms in the facilities. Indoor humidity is thought to be very low in most new residences in winter in Japan. The control of humidity will be more necessary in Japan, because the population of the elderly is rapidly increasing.

## 2. Methods of estimating influenza infection control

### 2.1 Index for influenza infection control

Influenza infection through the air depends on ventilation rate and indoor humidity as shown figure1. J.Harper showed the influence of temperature and relative humidity upon the survival rate of virus in chambers. Jeffry Sharman et al. showed that the survival rate of influenza in the air depends on absolute humidity. Kurabuchi et al. showed simulation results on the movements of influenza viruses considering the influence of absolute humidity.

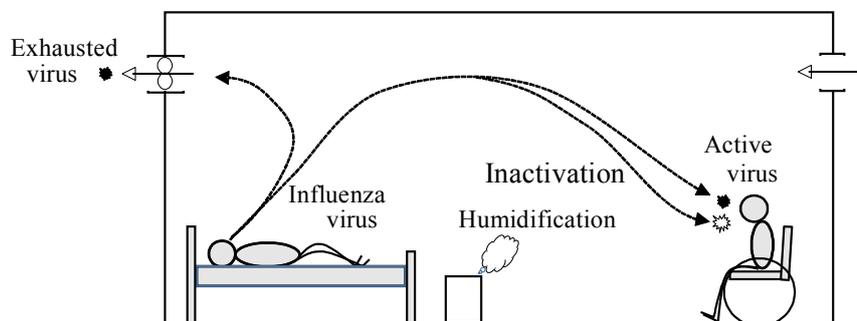


Figure 1 The mechanisms of influenza infection through the air

Figure 2 shows the data by G.J.Harper on the decrease of the survival rate of influenza viruses. The survival rates decrease first in the case of high absolute humidity. Approximation lines using the survival rates when the value is above 10% are shown in this figure. These correlation coefficients are high ( $R^2 = 0.49 - 0.94$ ).

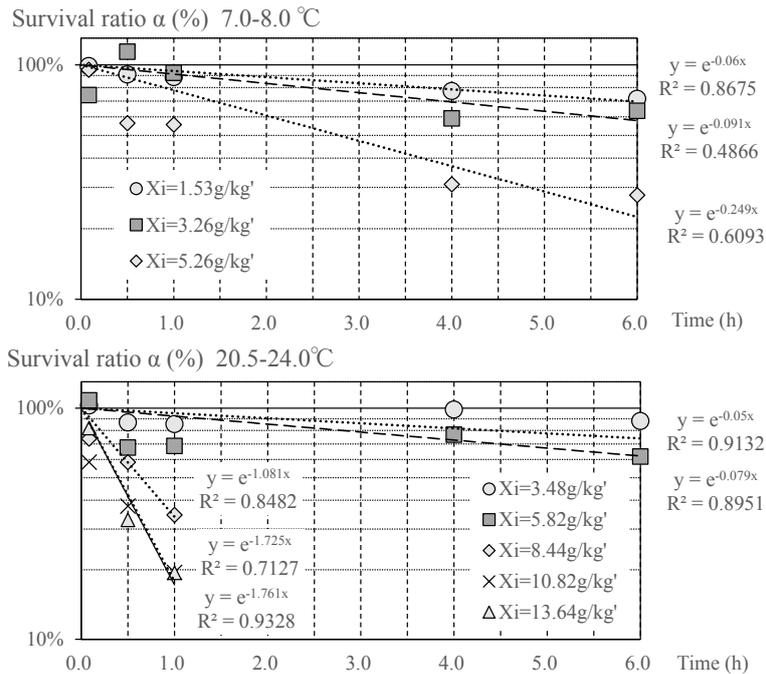


Figure 2 Exponential approximations of Influenza virus survival ratios in the tests by G.J.Harper

Figure 3 shows the relationship between the humidity and the exponents of these approximate equations  $\beta$ . This left figure shows that the exponent  $\beta$  depends on relative humidity. However the exponent is different by temperature. The right figure shows that the exponent  $\beta$  depends on absolute humidity. However the approximate equation of  $\beta$  when temperatures are 7.0-8.0 deg-C is not similar to that of 20.5-24 deg-C.

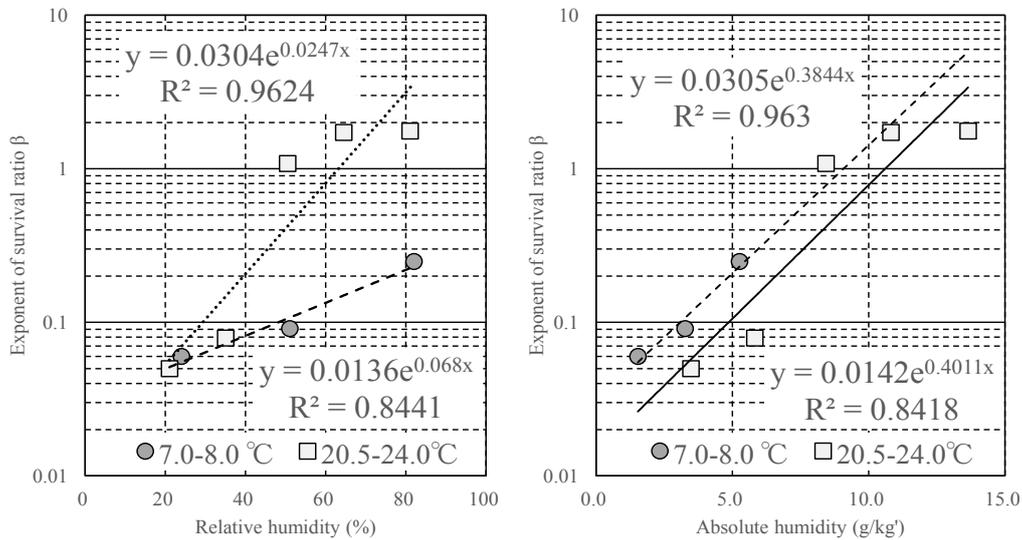


Figure 3 Relationship between the exponent of survival ratio  $\beta$  and humidity.

Therefore, the flowing equation of  $\beta$  (20.5-24 deg-C) is thought to be suitable for the estimation of the heating spaces.

$$\beta = 0.0142 e^{0.4011 x_i} \tag{1}$$

where,  $x_i$ : indoor absolute humidity (g/kg')

When the generation rate of influenza viruses is 0, the indoor concentration of influenza viruses  $C_{inf}$  ( $n/m^3$ ) is shown as the next equation (2).  $C_{inf}$  ( $n/m^3$ ) is the number of influenza viruses in the air at  $1m^3$ .

$$C_{inf}(t) = C_{inf}(0) e^{-\beta t} \quad (2)$$

This equation shows that the exponent  $\beta$  is correspond to ventilation time. Therefore, the concentration of influenza virus is calculated using the next equation (3) considering the effect of ventilation and absolute humidity.

$$C_{inf} = M_{inf} / (N+\beta) \quad (3)$$

Where,  $M_{inf}$ : generation rate of influenza viruses  
in the air of  $1 m^3$  ( $n/(m^3h)$ )  
N: ventilation time (1/h)

When the generation rate of influenza viruses from a person  $M_{inf p}$  is used, the next equation is given.

$$C_{inf} = M_{inf p} / (Q_p + \beta V_p) \quad (4)$$

Where,  $Q_p$ : ventilation rate a person ( $m^3/hp$ )  
 $V_p$ : space volume a person ( $m^3/p$ )

The ratio of the concentration of influenza viruses to the generation rate of influenza viruses from a person  $\Gamma$  is shown as the next equation. The ratio is thought to be an index of influenza infection control.

$$\Gamma = C_{inf} / M_{inf p} = 1 / (Q_p + \beta V_p) \quad (5)$$

The index of influenza infection control  $\Gamma$  is 0.027 when the indoor temperature is 24 deg-C and the indoor relative humidity is 40 RH%. The index of influenza infection control  $\Gamma$  is 0.031 when the indoor temperature is 17 deg-C (AMAB1970) and the indoor relative humidity is 40 RH% (AMAB1970).

The ventilation rate a person  $Q_p$  is calculated using the next equation.

$$Q_p = M_{CO_2 p} / D_{CO_2} \quad (6)$$

Where,  $D_{CO_2}$ : the difference of the indoor concentration  
and the outdoor concentrations of  $CO_2$   
 $M_{CO_2 p}$ : the generation rate of  $CO_2$  from a person

The energy loads for ventilation and humidification  $L_{vh}$  are calculated using the next equation.

$$L_{vh} = k_t \times D_{-t} + k_x \times D_{-x} \quad (7)$$

Where,  $k_t$ : coefficient of ventiration (=0.34)  
 $k_x$ : coefficient of humidification (=0.834)  
 $D_{-t}$ : the difference of the indoor temperature and the  
outdoor temperature  
 $D_{-x}$ : the difference of the indoor absolute humidity and the  
outdoor absolute humidity

## 2.2 Characteristics of the index of influenza infection control $\Gamma$ and the energy load $L_{vh}$

Figure 4 shows the characteristics of the index of influenza control  $\Gamma$ . The left figure shows a contour graph of  $\Gamma$  with indoor absolute humidity  $X_i$  and ventilation rate a person  $Q_p$ . The ventilation rate a person  $Q_p$  decreases with indoor absolute humidity  $X_i$ . This shows that when humidity is higher, the required ventilation rate tends to be lower.

The right figure shows the contour with indoor absolute humidity  $X_i$  and the energy load of ventilation and humidification  $L_{vh}$ . The contour was calculated under the following conditions. The outdoor absolute humidity was 3.0 g/kg<sup>3</sup>. The outdoor air temperature was 0 deg-C. The energy load  $L_{vh}$  increases with absolute humidity  $X_i$  and decreases when the absolute humidity  $X_i$  reaches a critical point. The tendency shows that if absolute humidity is higher than a critical point, the energy consumption will be saved.

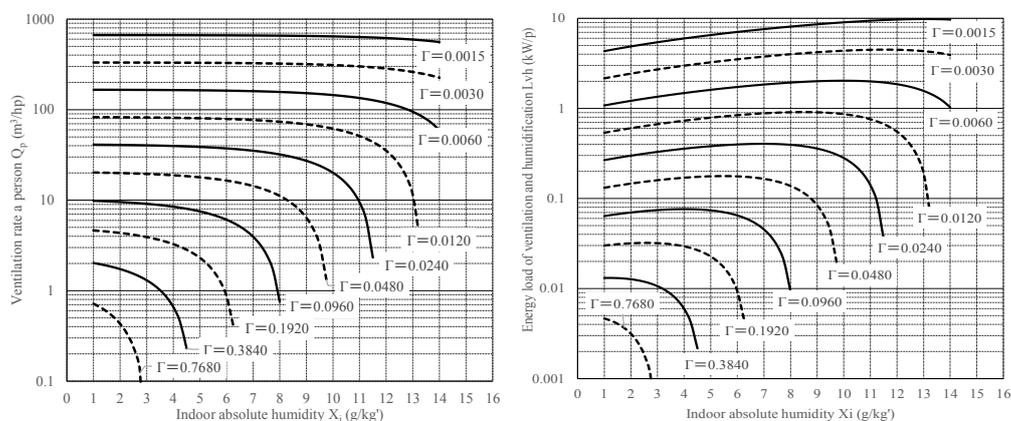


Figure 4 Relationships between absolute humidity and Ventilation rates a person  $Q_p$  / energy loads of ventilation and humidification  $L_{vh}$

## 3. Estimation of influenza infection control in facilities for the elderly

The state of influenza infection control was investigated using the measured temperatures, humidity and concentrations of carbon dioxide in the facilities for the elderly as shown in table 1. The facilities were built in 1970s to 2010s in northern areas of Japan (Hokkaido and Miyagi). Indoor spaces are heated with floor heating systems with the exception of a facility (MB) in Miyagi Prefecture. Their rooms and common spaces are humidified using portable humidifiers. Humidification units which are included in air conditioning systems are also used in HB and MB.

Table1 Summary of investigated facilities

Facility		HA	HB	HC	HD	MA	MB
building	construction	1980s	1970s	1980s	1970s	1990s	2010s
	num. of stories	3	3	4	3	4	4
room type		M.B.	M.B.	M.B.	M.B.	S.B./M.B.	S.B.
rooms	heating	F.H.	F.H.	F.H.	F.H.	A.C.+K.S.	A.C.
	cooling	-	-	-	-	A.C.	A.C.
	ventilation	E	E	E	E&S	E	E
humidification		P.H.	P.H.	P.H.	P.H.	P.H.	P.H.
Common Spaces	heating	F.H.	F.H.	F.H.	F.H.	A.C.	A.C.
	cooling	A.C.	A.C.	A.C.	A.C.	A.C.	A.C.
	ventilation	E&S	E&S	E&S	E&S	E&S	E&S
	humidification	P.H.	P.H.+H.U.	P.H.	P.H.	P.H.	P.H.+H.U.

M.B.: multi-beds, S.B.:single bed, A.C.: air conditioning, K.S.:kerosene stove, F.H.: floor heating,  
E: exhaust ventilation, E&S: exhaust and supply ventilation, P.H.:portable humidifier, H.U.: humidification unit

Figure 5 shows the change of daily average of indoor temperatures and absolute humidity in HA and MA. The temperatures are controlled to 22-26 deg-C in HA and to 20-24 deg-C in MA. The indoor temperatures are well controlled in most facilities. The indoor absolute humidity changes from 4.5 to 6.5 g/kg' in HA and form 3.5 to 8.0 g/kg' in MA. The indoor absolute humidity is low in all the facilities.

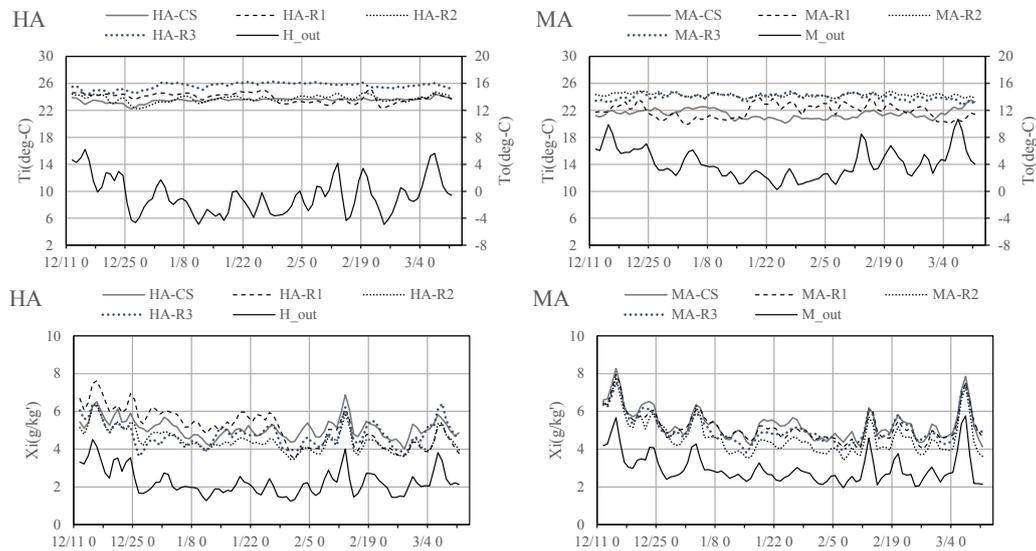


Figure 5 Change of indoor temperature and absolute humidity in HA and MA

Figure 6 shows the daily average ventilation rate a person  $Q_p$ . The ventilation rate gradually increased in this term. This increase of the difference between outdoor and indoor temperature is thought to be a factor of this tendency. The ventilation rate  $Q_p$  is influenced by the mechanical ventilation and opening windows by nursing care staffs and/or dwellers. The staffs often open windows to exhaust the smell while and after disposing of excretion in the facilities for the elderly. Therefore the ventilation rate is thought to change significantly.

Figure 7 shows the index of influenza infection control  $\Gamma$ . The index of influenza infection control  $\Gamma$  also changes significantly. The index decreased gradually in this term. One of the factors of the decrease is thought to be the increase of ventilation rate a person  $Q_p$ .

Figure 8 shows the energy load  $L_{vh}$ . The energy load changes significantly. The energy load  $L_{vh}$  increased gradually in this term. One of the factors of this increase is thought to be the increase of ventilation rate a person  $Q_p$ .

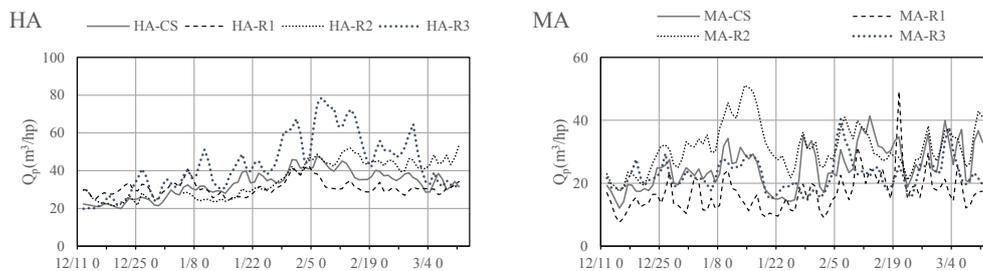


Figure 6 Change of ventilation rate a person  $Q_p$  in HA and MA

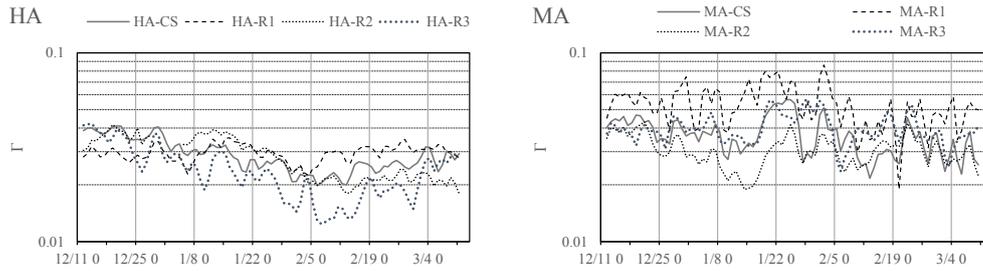


Figure 7 Change of Influenza-infection-control-index  $\Gamma$  in HA and MA

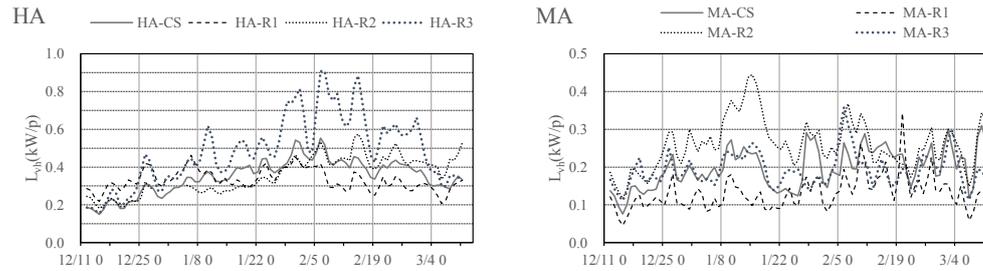


Figure 8 Change of energy load of ventilation and humidification  $L_{vh}$  in HA and MA

Figure 9 shows the relationships between indoor absolute humidity  $X_i$  and the ventilation rate a person  $Q_p$  and the relationship between indoor absolute humidity  $X_i$  and index of influenza infection control  $\Gamma$ . The index  $\Gamma$  is lower than 0.031 ((AMAB1970)) in the most facilities. The index  $\Gamma$  is higher than 0.031 in MA-R1,MA-R3 and MA-CS where the ventilation rates a person  $Q_p$  are low. There are not any significant relationships in these figures.

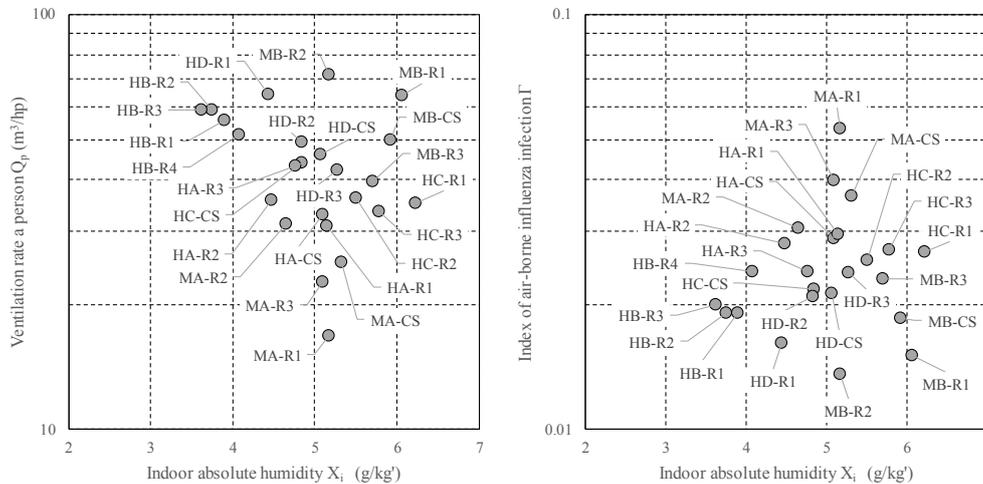


Figure 9 Relationship between absolute humidity and ventilation rate a person  $Q_p$  / index of influenza infection control  $\Gamma$

Figure 10 shows the relationship between the ventilation rate a person  $Q_p$  and the index  $\Gamma$  and the relationship between the index  $\Gamma$  and the energy load  $L_{vh}$ . The left figure shows that the index  $\Gamma$  depends on the ventilation rate a prson  $Q_p$ . The right figure shows that the energy load  $L_{vh}$  depends on the index  $\Gamma$ .

The main factor of the index  $\Gamma$  and the energy load  $L_{vh}$  are thought to be the ventilation rate a person  $Q_p$ , because absolute humidity is very low in all the facilities.

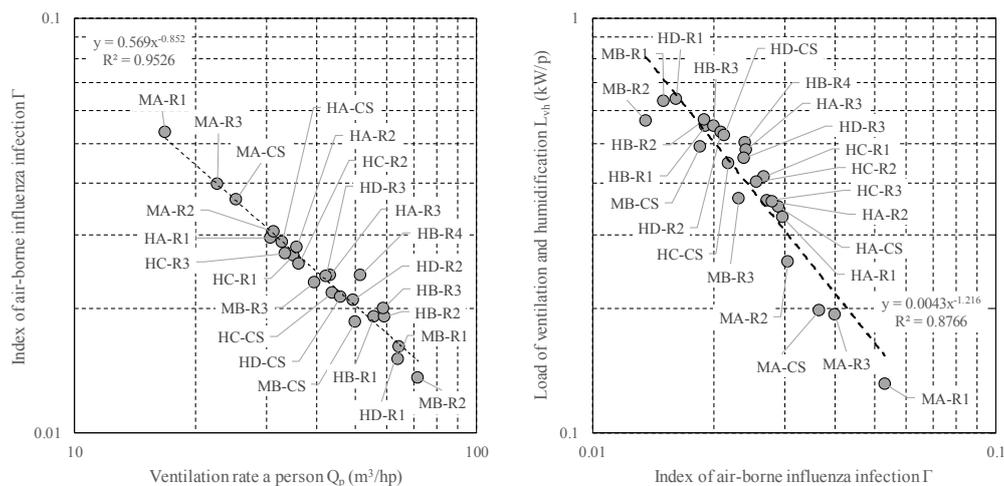


Figure 10 Relationship between ventilation rate a person  $Q_p$  and Index of influenza infection control  $\Gamma$  / relationship between index of influenza infection control  $\Gamma$  and absolute humidity and energy load of ventilation and humidification  $L_{vh}$

The index  $\Gamma$  made it possible to estimate the state of infection control in indoor spaces using the measured temperatures, humidity and concentrations of carbon dioxide. The index  $\Gamma$  and the energy consumption for ventilation and humidification  $L_{vh}$  varied from space to space. These results showed that it is necessary to control both of ventilation rates and humidification rates on the basis of the estimation using  $\Gamma$  and  $L_{vh}$ .

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