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# Influence of Reconstructed Residential Building on Indoor Climate

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**Abstract**

The paper is oriented on the influence of reconstructed residential building on indoor climate. After the reconstruction of residential building, which was comprised of replacement of windows, thermal insulation of external wall and regulation of heating, the dwellers were complaining about different problems. Therefore, the questionnaire survey was carried out, which showed significant increase of the number of allergies and respiratory diseases and also the occurrence of molds. The high number of unspecified allergies was among the newly arisen allergies. Furthermore, the high increase of CHOCHP - chronic obstructive pulmonary disease and respiratory problems were detected mainly by elderly people. The experimental measurements of indoor climate were carried out in order to find the causes of increased sickness rate. The most critical was the air relative humidity from the parameters of indoor climate. Long-term high values of air relative humidity were discovered and there was a search for the link with the number of efficient natural ventilation per day. There was a stereotype of one ventilation per day, what was proved as insufficient. Subsequently, the dwellers were informed about the correct way of ventilation and the desired number of ventilations per day. After five months, the questionnaire survey was carried out again, which showed the decrease of mainly allergic and respiratory problems. Furthermore, it was proved that no one was able to meet the recommended number of ventilations from the long-term perspective. Dwellers found it as unfeasible and annoying. During the whole period, the measurements of air relative humidity were carrying out and the biggest problem appeared to be 7-hour interval when there is no ventilation and thus the air relative humidity is reaching unacceptable values. Therefore, the allergic and respiratory problems were the most significant in the morning. In the paper is the scientific analysis and outputs from experimental measurements in flats. In the conclusion of this paper are suggestions on ventilation systems, which could deal with the researched problem.



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*Keywords:* reconstructed residential building; air relative humidity; ventilation in flats;

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## 1. Introduction

Old residential buildings in Slovakia are under reconstruction in large scale. It is related to the support from government in the form of loan and small interest rate. First phase of reconstruction is the exchange of old permeable windows for modern quality impermeable windows. The next important phase of reconstruction is thermal insulation of external walls and regulation of heating system. These phases will significantly contribute to energy saving of residential building.

Provision of optimal indoor climate in residential interiors is very important also after the reconstruction. Hygrothermal microclimate is characteristic for heated residential interiors. The fundamental quantities for evaluation of hygrothermal microclimate are internal air temperature, operative temperature, globe temperature, air relative humidity and air velocity [1]. Then, total clothing insulation, total activity, surface temperature and PMV and PPD indexes are set [2].

Optimal value of air relative humidity is about 40%, suggested value is 50% [3]. Health problems arise, if the relative humidity decreases to 20% or exceeds 60%. The long-term value of relative humidity 60% can cause the condense humidity on structures and the increase of moulds. By this relative humidity in comparison with value 35%, surviving microorganisms are twice propagated and it results into inception of allergies and respiratory diseases. Causes of high relative humidity in residential buildings are various: thermo-technical defects of external wall, improper operation of building, insufficiently dried-up construction, impact of human activities and stay – in four-person household, approximately 12.5 kg of water vapour gets into the air daily. By nowadays sealed windows of residential buildings, the only way of adjustment of high relative humidity is ventilation so far [4]. Forced ventilation system is unfeasible by us so far.

## 2. Research of allergic and respiratory diseases in residential interiors

The unhappiness of dwellers and increased sickness rate of users of residential interiors was noticed in many residential buildings after the reconstruction. Attention was focused on these problems. Therefore, the questionnaire survey was carried out focusing on health problems of dwellers in the flats.

### *2.1. Characteristic of research*

For research purposes was chosen the residential building in Bratislava. Majority of dwellers had the old not sealed wood windows exchanged for modern plastic tight windows from June 2012, therefore this period was included into the time of reconstruction. The reconstruction of residential building took place in the summer 2013.

Residential building has ten floors; flats are located on the last seven floors. External cladding is from porous concrete panels with thickness of 300 mm. The flat roof is insulated with boards Polsid with thickness of 70 mm. Heat transfer coefficient of the existing structures that change: external wall 0,60 $W/m^2K$, roof 0,51 $W/m^2K$. The reconstruction of residential building comprised mainly the insulation of external walls and roof. In reconstruction was included external wall insulation with EPS insulation with thickness of 100 mm and roof with thickness of 120 mm. Heat transfer coefficient of insulated constructions: external wall 0,24 $W/m^2K$ and roof 0,19 $W/m^2K$.

### *2.2. Methodology of research*

Questionnaire survey was carried out after reconstruction of residential building between 9.-17.12. 2013 (external air temperature was from -3 to +8 °C). In this period the impact of outside allergens was small. Into the research was involved majority of dwellers, 137 persons. Among them were children, students, working people with various education level and pensioners. Parts of questions were aimed at evaluation of health – allergic and respiratory diseases before replacement of windows and insulation of building and in time where questionnaire survey was carried out.

### 2.3. Analysis and results of research

Fig. 1 represents the results of number of all allergic diseases [5] – one person can have more allergies – before and after reconstruction of residential building. Fig. 2 shows the percentage increase of allergic diseases according to age distribution of dwellers. From the given pictures is obvious the increase of allergic diseases, mainly in age category 20-34 years and in age 50-64 years.

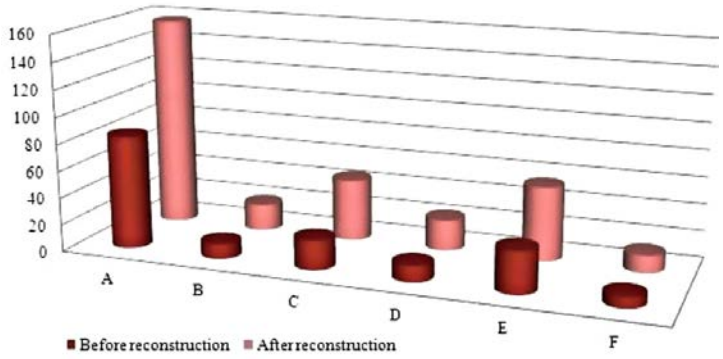


Fig. 1. Number of all allergic diseases before and after reconstruction of residential building,
Legend: A-Total count, B- Count in age 0-19 years, C- Count in age 20-34 years, D- Count in age 35-49 years, E- Count in age 50-64 years, F- Count in age over 65 years.

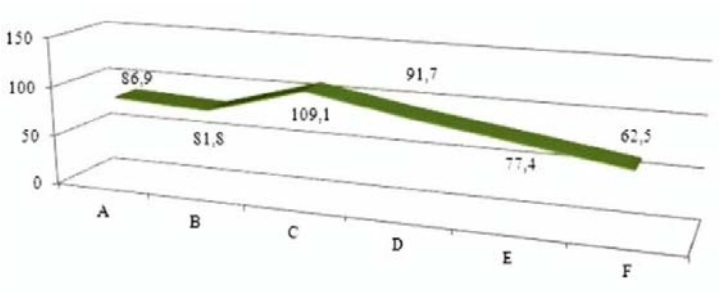


Fig. 2. Percentage increase of all allergic diseases.

Fig. 3 represents results of number of moulds allergic diseases before and after reconstruction of residential building. Fig. 4 shows the percentage increase of mould allergic diseases according to age distribution of dwellers. From the given pictures is obvious the increase of mould allergic diseases in all age categories.

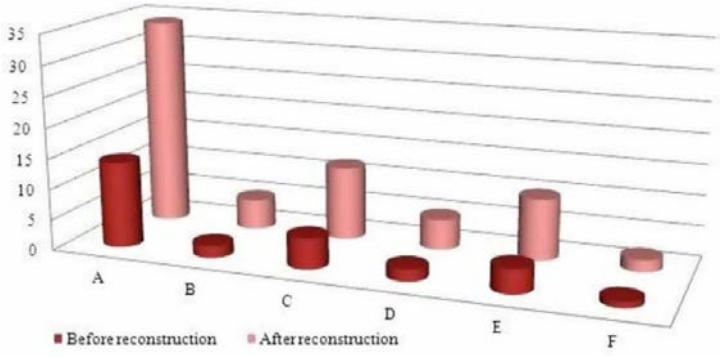


Fig. 3. Number of moulds allergic diseases before and after reconstruction of residential building.

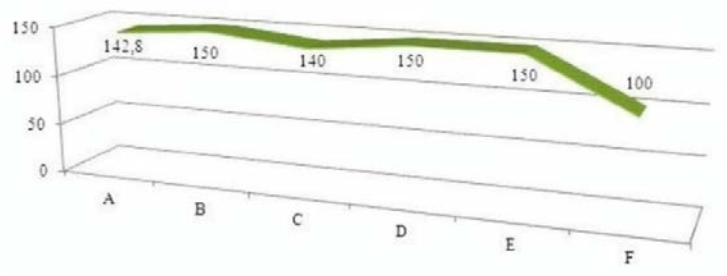


Fig. 4. Percentage increase of moulds allergic diseases.

Fig. 5 represents results of number of unspecified allergic diseases before and after reconstruction of residential building. Fig. 6 shows the percentage increase of unspecified allergic diseases according to age distribution of dwellers. It is obvious from the given pictures that there was increase of unspecified allergic diseases, mainly in age categories 35-49 years, 50-64 years.

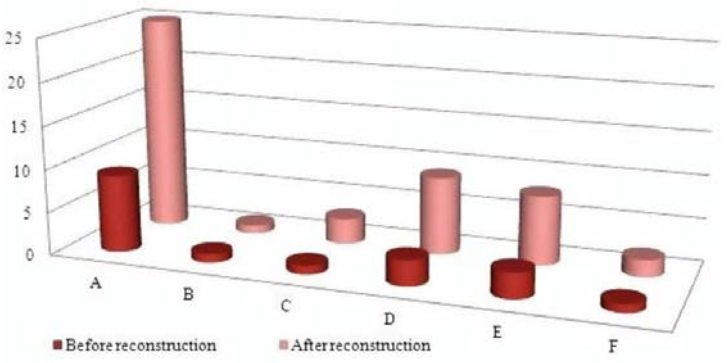


Fig. 5. Number of unspecified allergic diseases before and after reconstruction of residential building.

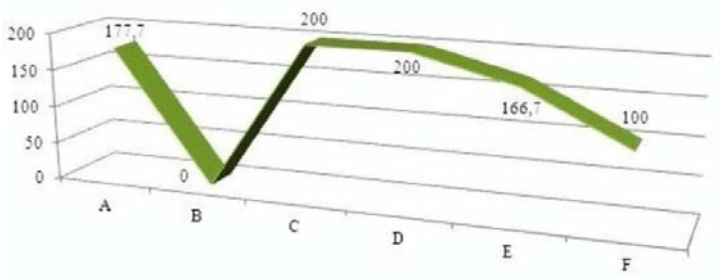


Fig. 6. Percentage increase of unspecified allergic diseases.

Fig. 7 represents results of number of respiratory diseases and chronic obstructive pulmonary disease [6] before and after reconstruction of residential building. Fig. 8 shows the percentage increase of respiratory diseases and chronic obstructive pulmonary disease according to age distribution of dwellers. From the given pictures is obvious the increase of allergic diseases and chronic obstructive pulmonary disease, mainly in age category 50-64 years and in age over 65 years.

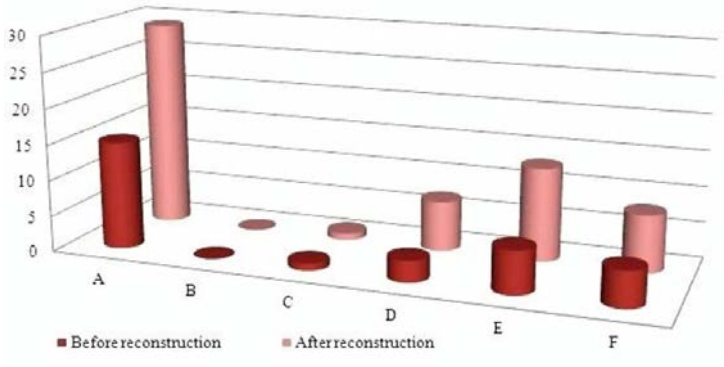


Fig. 7. Number of respiratory diseases and chronic obstructive pulmonary disease before and after reconstruction of residential building.

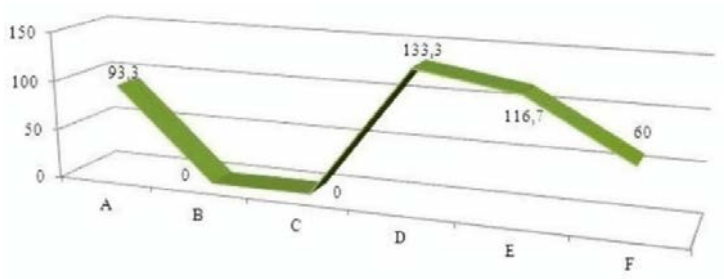


Fig. 8. Percentage increase of respiratory diseases and chronic obstructive pulmonary disease.

### *2.4. Discussion*

From Fig. 1 to Fig. 8 is obvious, that health of dwellers deteriorated after reconstruction. There was an increase of allergic diseases, mainly unspecified. It can be assumed, that high relative humidity causes allergy, which cannot be diagnosed nowadays and noticeably contributes to emergence mainly of interior allergies such as mold allergy or mites. Furthermore, it can be assumed that high humidity has proportion in emergence of respiratory diseases and chronic obstructive pulmonary. No one instructed dwellers how they should behave reconstructed residential building. They kept their previous habits mainly the ones concerning ventilation of residential interiors. Therefore, the research continued and investigates the causes of deteriorated health of dwellers after the reconstruction of residential building.

## 3. Research of indoor climate in residential interiors

The research continued with investigating the parameters of indoor climate in residential interiors in residential building, in which the previous research was carried out. In this research were carried out the experimental measurements of indoor climate in residential interiors. The goal of experimental measurements was to seek for causes of deteriorated health of dwellers after reconstruction, which could be related to the change of indoor climate parameters.

### *3.1. Methodology of research*

Measurements took place between 19. - 29.12. 2013 in bedrooms of selected flats, which were inhabited by two working people. Measuring logger recorded: external and internal air temperature, globe temperature and air relative humidity [7], [8].

External air temperature was in range from -3 to +9 °C and operative temperature from 20,1 to 22,9°C. There were found out high values of air relative humidity. Then ventilation habits of dwellers were examined in examined flats. For dwellers of residential buildings, the training took place on 30.12. 2013 about appropriate ventilation. After two and four weeks, there were carried out measurement of air relative humidity in examined bedrooms and survey about natural ventilation habits [9]. Research continued by testing of micro-ventilating position of window in examined bedrooms. Last part of research between 1. - 15.2. 2014 took place in pensioners' bedrooms.

### *3.2. Analysis and results of research*

In bedrooms of selected flats were found high values of air relative humidity, average values in examined bedrooms in two-hours intervals are shown at Fig. 9.

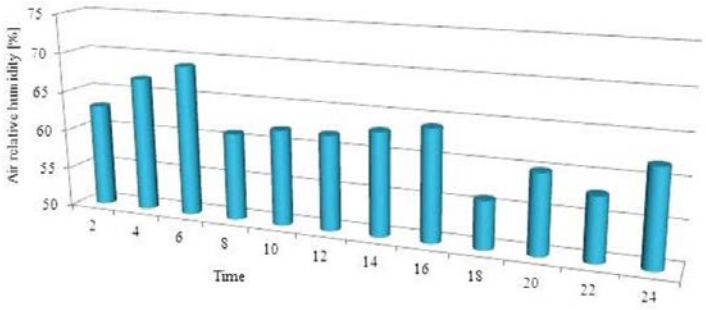


Fig. 9. Values of air relative humidity in two-hours intervals.

Then ventilation habits of dwellers were examined in examined flats. Table 1 represents percentage proportion of dwellers depending on number of ventilation per day.

Table 1 Percentage proportion of dwellers depending on number of ventilation per day.

| Description | No ventilation | Ventilation once | Ventilation twice | Ventilation 3-times |
|---|---|---|---|---|
| Percentage proportion of dwellers [%] | 25 | 52 | 20 | 3 |

High values of relative humidity were caused by improper ventilation of bedrooms. There was not ensured sufficient air exchange. Some of the dwellers exchanged not sealed windows for new sealed and they did not know that they have to change ventilation habits in flat. After the regulation of heat system, the operative temperature decreased to 21,8 °C in average in time period from 17 to 21 h in bedrooms. It represents the decrease in average in that time about 2,1 °C with what the dwellers were not satisfied. Original five-position thermostatic valves began to work only as two positioned. In the fourth position, the heater switched off and in the fifth position it began to heat.

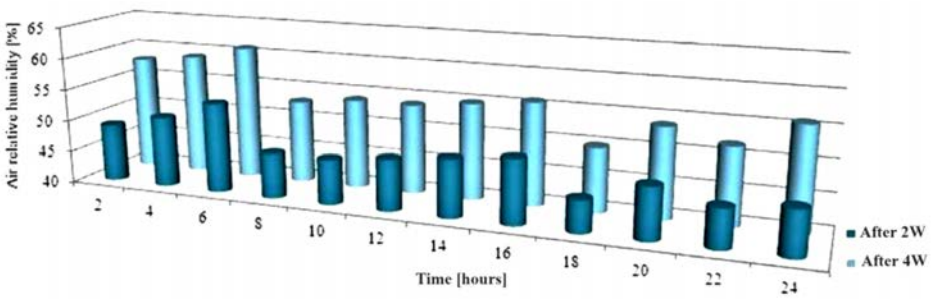


Fig. 10. Values of air relative humidity in two-hours intervals after two and four weeks.

For dwellers of residential buildings, the training took place on 30.12. 2013 about appropriate ventilation. After two and four weeks, there were carried out measurement of air relative humidity in examined bedrooms and survey about ventilation habits. External air temperature was in range from -3 to +8 °C. The outcomes are shown in Fig. 10 and in Table 2.

Table 2 Percentage proportion of dwellers depending on number of ventilation per day.

| Percentage proportion of dwellers [%] | No ventilation | Ventilation once | Ventilation twice | Ventilation 3-times | Ventilation 4- times | Ventilation 5- times |
|---|---|---|---|---|---|---|
| After two weeks | 3 | 6 | 56 | 29 | 4 | 2 |
| After four weeks | 9 | 30 | 47 | 13 | 1 | 0 |

From the outcomes, it is obvious that first two weeks after training ventilation discipline improved, what brought decrease of relative humidity, but not sufficiently. After four weeks' time the ventilation discipline got deteriorated, what led to increased values of air humidity. Although ventilation discipline did not get back to values before training, but was insufficient to achieve satisfactory values of air humidity. From research, it is obvious that nobody was able to sustain recommended number of ventilation in long term period. Furthermore, research found that the most serious problem, the time period during the bedtime (7 - 8 hour) - when bedrooms are not ventilated, still remains. Research continued by testing of micro-ventilating position of window in examined bedrooms whether it is able to ensure sufficient ventilation of bedrooms in order to have optimal values of air humidity. Measurements of air relative humidity proved that this type of ventilation is not sufficient during winter period and decreases operative temperature, what leads to increased costs for heating.

Last part of research between 1.-15.2.2014 took place in pensioners' bedrooms, because they stayed at home and could meet three-hour ventilation interval – 7, 10, 13, 16, 19, 22 h. External air temperature was in range from -4 to +10 °C. The outcomes are shown at Fig. 11.

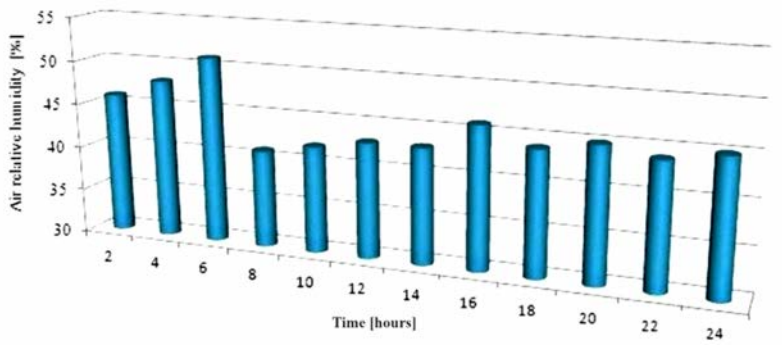


Fig. 11. Values of air relative humidity in two-hours intervals

### *3.3. Discussion*

From this research, it is obvious that if the number of ventilation is between 5 and 6 per day in time interval between 4 to 6 minutes then it is possible to achieve optimal values of air relative humidity during day. There still remains problem of high values of relative humidity during night. Researched proved that if there is correct ventilation during day, values measured at dawn are not as high as by improper ventilation during day. Pensioners also expressed that number of ventilation five times per day, they are not able to fulfil in long term period and find it bothering and unfeasible. It means that reconstruction of residential building on one hand it brought significant energy saving and aesthetical improvement of facade, but on the other hand the health problems related to insufficient ventilation of residential interiors arose. The research showed that provision of sufficient ventilation of residential interiors and thus decrease of air relative humidity is not achievable only by natural ventilation using windows.

## 4. Conclusions

The reconstruction of residential building is enormously positive thing, mainly in terms of energy saving and in terms of aesthetical valuation of facade. Negative aspect of the reconstruction is, as the research showed, the high values of air relative humidity that contribute to emergence of allergy on moulds and mites but mainly to supposed allergy on air relative humidity. Furthermore, it can be supposed that high air relative humidity has proportion in emergence of respiratory diseases and chronic obstructive pulmonary disease – even in non-smokers. It is possible that it helps in emergence of other diseases what is worth to research further.

The next part of the research focused on experimental measurements showed, that high values of relative air humidity were also caused by improper ventilation of bedrooms. This research showed that by the sufficient ventilation it is possible to achieve optimal values of relative humidity during day. It is obvious from the research that neither working people nor pensioners are able to fulfil recommended number of ventilation and they find it bothering and unfeasible. Furthermore, research found that the most serious problem, the time period during the bedtime (7 - 8 hour) - when bedrooms are not ventilated, still remains. Micro-ventilation did not bring desired effect. We can conclude that it is not feasible to provide sufficient ventilation of residential interiors just by natural ventilation using windows and by this decrease the air relative humidity. Standard forced ventilation system with pipeline in existing residential buildings is not feasible so far, not only because of aesthetic and economic aspect but also because of operational aspect. Therefore, it is important to seek for such forced ventilation system, which would remove the negative aspect and would be ready for application in real world scenarios. Possible solution will be windows with recuperative heat exchanger and forced ventilation.

## Acknowledgment

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## References

[1] M. Jokl, Evaluation of the Hygrothermal Microclimate Based on Human Psychology, USA, 2010, p.6
[2] L. Bánhidi, L. Kajtár, Komfortelmélet, Theory of Thermal Comfort, Muegyetemi kiadó, Budapest, 2000, p.436
[3] Standard STN EN ISO 7726 Ergonomics of the thermal environment. Instruments for measuring physical quantities.
[4] J. E. Christian, H. Trechsel, Moisture Control in Buildings, Philadelphia PA: ASTM, 1994, p. 220
[5] H. Müller-Burzler, Allergy, Pragma, Prague, 2007, p. 154
[6] H. W. Macnee, I. Stephen, M.D. Rennard, Fast Facts: Chronic Obstructive Pulmonary Disease, Health Press Limited, United Kingdom, 2009, p. 139
[7] Standard STN EN 15251 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.
[8] Z. Magyar, T. Révai, What is the Best Clothing to Prevent Heat and Cold Stress? – Experience with Thermal Manikin, West Indian Medical Journal 62, 2013, pp. 140-144.
[9] D. Etheridge, Natural Ventilation of Buildings, John Wiley & Sons, United Kingdom, 2011, p.454