Is the air that we breathe during sleep affecting our sleep quality?

N. Canha[1,2,*], J. Lage[1], J. Belo[3,4], M. Picado[3], P. Macedo[3], T. Faria[1,5], M. Meira e Cruz[6,7], S. Cabo Verde[1], C. Viegas[5,7], C. Alves[2], S.M. Almeida[1]

[1] Centro de Ciências e Tecnologias Nucleares, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
[2] Centro de Estudos do Ambiente e do Mar (CESAM), Departamento de Ambiente, Universidade de Aveiro, Aveiro, Portugal
[3] ESTeSL - Escola Superior de Tecnologia da Saúde de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal
[4] CIST, ESTeSL - Centro de Investigação em Saúde e Tecnologia da ESTeSL (Health and Technology Research Center - H&TRC), ESTeSL, Lisboa Portugal
[5] GIAS, ESTeSL - Escola Superior de Tecnologia da Saúde de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal
[6] Associação Portuguesa de Cronobiologia e Medicina do Sono, Lisboa, Portugal
[7] Unidade do Sono – Laboratório de Função Autonómica, Centro Cardiovascular da Universidade de Lisboa, Lisboa, Portugal
[8] Centro de Investigação em Saúde Pública, Escola Nacional de Saúde Pública, Universidade NOVA de Lisboa

*Corresponding email: nunocanha@ctn.tecnico.ulisboa.pt

SUMMARY
This study aimed to understand the impact of indoor air quality during sleep on the sleep quality of the occupants through the evaluation of the exposure to indoor air pollutants during sleep of 9 couples and the assessment of their sleep quality through polysomnography. Associations between data of indoor air quality and sleep's parameters were assessed, where CO, CO_2, RH and T revealed to have an impact on the sleep of the occupants of the bedroom.

KEYWORDS
Indoor air quality; sleep; exposure; particulate matter; bedroom

1 INTRODUCTION
Humans spend around one third of their life sleeping and it is well known that sleep plays a crucial role in human welfare and performance. In last decades, awareness of the impact of indoor air quality (IAQ) on the health of buildings' occupants has greatly increased but, however, research has been focusing mainly on micro-environments where people carry out their activities during daytime (offices, dwelling, schools (Canha et al., 2016) and others).
Assessment of the impact of IAQ on sleep's quality has been scarcely studied (Canha et al., 2017), making it difficult to identify if environmental factors may affect the quality of sleep and, if so, which ones.
The present study aimed to assess IAQ during sleep along with sleep's quality in order to evaluate the existence of associations between IAQ and sleep's quality. For that, a multidisciplinary team was gathered involving experts from sleep medicine and indoor air quality.

2 METHODS
Nine volunteer couples participated in IAQ and sleep monitoring during the 2017 cold season in the urban area of Lisbon, Portugal. The inclusion criteria of volunteer couples was based on several restrictions to minimize confounders: ages between 25-40 years, healthy, non-

smoking, without children below 5 years and without sleeping problems. For each couple, the monitoring scheme was as follows :
- during the first week, IAQ monitoring was conducted during 3 nights (weeknights)
- during the second week, a polysomnography study was done during 2 nights (weeknights)
IAQ monitoring was based on a comprehensive multi-pollutant assessment where physical (temperature and relative humidity), chemical (carbon dioxide, carbon monoxide, formalde-hyde, volatile organic compounds, particulate matter – PM_{10} and $PM_{2.5}$) and microbiological (fungi and bacteria) parameters were identified and quantified.
Sleep's quality indicators were quantified by a level II polysomnography (PSG) during two weeknights in a row, which allowed to evaluate sleep efficiency, latency and stages, respiratory and movements' events, and heart rate variability. The second night PSG's results were used in order to minimize the first night effect. Spearman correlations between IAQ data and sleep parameters of male individuals were assessed.

3 RESULTS
The results related to the heart rate frequency (HRF) showed that the standard deviation from the mean value increased in those participants that were exposed to higher levels of PM_{10} (rs=.583; p=.099) and $PM_{2.5}$ (rs=.600; p=.088). During REM sleep, the HRF acceleration and deceleration index increased towards higher CO concentrations (r=.643; p=.085 and r=.627; p=.096). During the NREM sleep a decrease in the pulse transit time was associated to higher concentrations of CO_2 (rs =-.650; p=.058). The respiratory rate was lower in those subjects that were exposed to higher levels of relative humidity, in both NREM (rs =-.678; p<.05) and REM (rs =-.816; p<.05) sleep. In opposition, during the REM sleep the respiratory rate increased when the temperature was higher (rs =.680; p=.093).

4 DISCUSSION
Despite the size of the studied population, the presented results showed that there are some evidences that the increase in some parameters of indoor air quality and thermal comfort can be associated to alterations in cardiovascular and respiratory function. The study of cardiovascular and respiratory activity during the sleep has been used to assess the autonomous activation functioning, thus our results indicated possible effects that control it.

5 CONCLUSIONS
This study allowed to understand which parameters of indoor air quality and thermal comfort may have an impact on the sleep quality of the occupants. Further research relying on a larger study population should be conducted to confirm these preliminary results.

6 REFERENCES
Canha N, Lage J, Candeias S, Alves C, Almeida SM. 2017. *Atmospheric Pollution Research*. 8: 1132–1142.
Canha N, Mandin C, Ramalho O, Wyart G, Ribéron J, Dassonville C, Hänninen O, Almeida SM, Derbez M. 2016. *Indoor Air*. 26(3): 350-365.