Effect of Indoor Climate on Labor Productivity: A Case Study in a Shipping Storage

Rautio S[1], *Hannula M*[2], *Jungman H*[2], *Niemelä R*[1], *Reijula K*[1]
[1]Finnish Institute of Occupational Health, Helsinki, Finland
[2]Tampere University of Technology, Tampere, Finland

Introduction

Productivity is one of the most important factors affecting the overall performance of any organization. Productivity is defined as the ratio output divided by the input used to produce the output. The output refers to products and services produced by an organization (2). Increased attention has been paid to the relationship between the work environment and productivity in the 1990s. Laboratory and field studies show that the air quality and thermal conditions at work may have a notable impact on the performance of the occupants, and consequently on labor productivity (1,3,4). This relationship, however, has been insufficiently explored.

The aim of the study was to assess quantitatively the effect of indoor climate on labor productivity in a shipping storage where heavy zinc bars were handled. The further aim of the study was to investigate the methods suitable for assessing the effect of indoor climate on labor productivity.

Materials and Methods

The study was performed as an intervention aiming to improve the indoor climate in a storage building. Air quality and thermal conditions , the perceptions of the workers, and labor productivity were determined before and after the implementation of the improvements.

About 30 workers in two shifts handled heavy zinc bars in the shipping storage (area 3600 m^2, volume 16000 m3). The original ventilation system consisted of five roof-installed extractors with a total flow rate of 4.8 m^3/s. The following renovations were made at the storage building in November 1998: installation of air curtain units at the doors, and a temperature- controlled supply air system (flow rate 2.5 or 5.0 m^3/s, filters EU3 and EU7), painting of the walls, maintenance of the lighting system, as well as installation and commissioning of an automatic weighing and tacking line of the zinc bars.

Thermal conditions and critical air contaminants were measured in October 1998, in November 1999, and in February 2000. The work activities and activity levels in the storage building, and the measurement methods and strategies were similar at all measurements.

A validated indoor air questionnaire (MM040EA) was conducted before the renovation in October 1998, and after it in November 1999. The questionnaire included questions

on backqround factors, physical environmental factors, psychosocial factors, medical history on allergic diseases, and building- related symptoms reported by the occupants. Productivity was measured by using a simple partial productivity ratio, labor productivity. It is the ratio between the output and the labor inputs used to produce the output. The input and the output were measured in the physical units to eliminate the effect of price changes and inflation. The labor input was measured in work hours, and the output in tons of zinc putted on board. The measurement frequency was one month.

Results

The thermal environment improved as a result of the renovation. The average temperature increase was +3.6 °C...+ 6.2 °C at a height of 0.2 m, and +6.0 °C...+6.6 °C at the height of 1.5 m. (Table1). The average air velocity in the occupied zone of the storage building decreased (Table 1).

Table 1. The average thermal conditions in the storage building and outdoors

Date	Air temp. height 0.2m (°C)	Air temp. height 1.5m (°C)	Air velocity, height 0.2 m (m/s)	Air velocity, height 1.5 m (m/s)	Temp. outdoors (°C)	Wind outdoors (m/s)
Oct 98	10.9	11.7	0.4	0.2	-0.1...+5.2	2...7
Nov 99	17.1	17.7	0.3	0.2	+1.2...+5.5	3...4
Feb 00	14.5	18.3	0.2	0.1	-0.7...-8.5	2...4

The effect of the air curtain system on the air temperatures was significant. In a typical situation, when the door was opened without the air curtain, the temperature dropped by 12.5 °C...15.5°C. When the air curtain was on, the temperature remained the same or even rose slightly, about +0.5°C.

The concentrations of the dominant contaminants decreased by 30 %...90 % (Table 2). The use of 2-ethoxyethyl acetate was discontinued due to the automation of the weighing and tacking line of the zinc bars. The average concentrations of contaminants fell to a level of less than 10 % of the corresponding Occupational Exposure Limits due to the renovations.

Table 2. The average concentrations of contaminants in the storage building

Date	NO (cm^3/m^3)	NO_2 (cm^3/m^3)	CO (cm^3/m^3)	Airborne dust (mg/m^3)	Zn_2O_3 (mg/m^3)	TVOC ($\mu g/m^3$)	2-ethoxyethyl acetate (cm^3/m^3)
Oct 98	2.3	0.51	<2*	0.48	0.050	3281	31
Nov 99	1.6	0.27	<2*	0.11	0.014	316	**
Feb 00	1.1	0.02	<2*	0.08	0.003	110	**

* under detection limit **use of solvent eliminated

The average illuminance was 138 lux before the renovation, and 183 lux...223 lux after the renovation. The increase in average illuminance varied from 38 %...60 %. After the

renovation the illuminance level was sufficient for the tasks that were performed in the storage building.
The noise exposure of the workers was from 77 dB(A)...88 dB(A) before the renovation, and from 74 dB(A)...88 dB(A) after it.

The indoor air questionnaire showed that the percentage of dissatisfied with draught fell from 67% to 37 %, with dust and dirt from 70 % to 32 %, and with poor lighting from 40 % to 22 % (Figure 1). The percentage of dissatisfied with noise increased from 60 % to 75 %. The workers commented on the new ventilation system as a new source of noise.

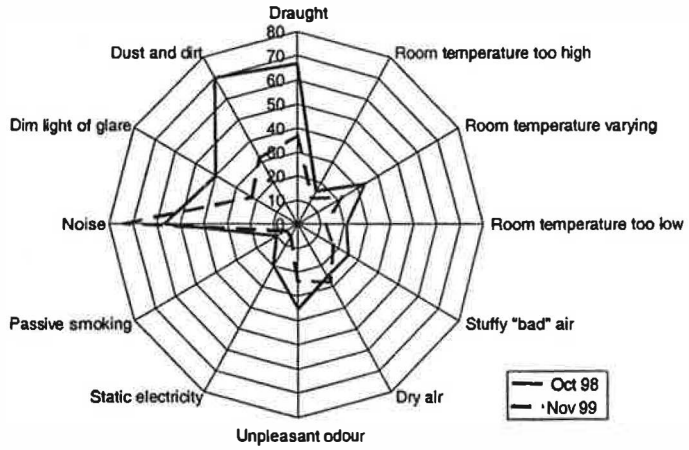

Figure 1. Indoor air questionnaires before (Oct 98) and after the renovation (Nov 99).

Monthly changes in labor productivity in the storage building during 1998 and 1999 are shown in Figure 2. The average productivity in 1999 was 9.3 % higher than that in 1998.

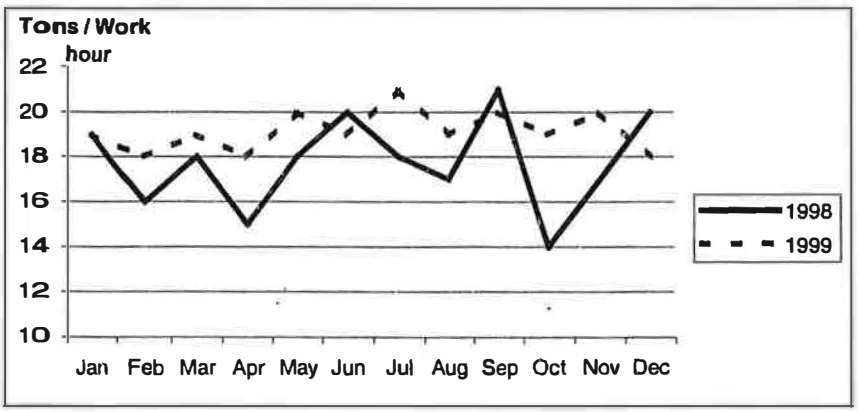

Figure 2. Labor productivity in the storage building

Discussion

As a result of the renovations in the shipping storage the thermal conditions improved notably: the average air temperature rose from the level of 11°C to 15°C...18°C, whereas the average air velocity fell from the level of 0.2 m/s...0,4 m/s to 0.1m/s...0.3 m/s. Also the air quality had clearly improved: the concentrations of dominant air contaminants decreased by 30 %...90 %. Of the non- climatic environmental factors the illuminance increased by 38 %...60 %, whereas the noise exposure of the workers remained at 74 dB(A)...88 dB(A). The renovation had a clear impact on the workers' subjective evaluations, as the proportion of dissatisfied significantly decreased, excepting the evaluation of noise. The proportion of dissatisfied can be taken as an indirect indication of productivity. The direct measure of the labour productivity, expressed as tons of zinc/man- hour increased by 9.3 %. In addition, the monthly production rate was more even in 1999. The positive change of labor productivity can be due to many reasons, one of them being better indoor air quality. Another factor that may affect productivity is e.g. production volume. So far, the contribution of potential confounding factors has not been analysed. The study clearly demonstrated the power of the multidisciplinary study design.

References

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