SAPIENZA
UNIVERSITÀ DI ROMA

Safety of Industrial Plants

Lecture 11
Ergonomics
Quality of the workplaces
Aerodispersed chemical pollution

Contents and Goals

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Ergonomics and Ergotechnics

- Ergonomics (from greek "ergon" (work) and "nomos" (law)), according to the International Ergonomics Association is the discipline that deals with the interaction between the elements of a system (human and otherwise) and the function for which they are designed [Murrel, 1949].
- The ergonomics deals with the theory, the principles and the methods that are applied in the design, in order to improve user satisfaction, and the overall performance of a given system.
- It is the discipline that deals with the study of the interaction between people and technology.

Ergonomics and Ergotechnics

- The quality of the relationship between the user and the used medium is determined by the level of ergonomics.
- The most important requirement to determine the level of ergonomics of a system is safety, followed by:
  - Adaptability
  - usability
  - comfort
  - pleasantness
  - comprehensibility
  - …

A TOOL EASILY USABLE AND SAFE IS VERY ERGONOMIC

AN UNCOMFORTABLE USE OF A TOOL WHICH IMPLIES GREAT COGNITIVE EFFORT, IS NOT ERGONOMIC

Quality of the workplace

- The concept of air quality is related to:
  - suitability of air
  - pleasantness
- The pollution sources can be:
  - Of artificial nature (human)
  - Natural (for example of volcanic origin)

Quality of the workplace

- The concept of clean air does not coincide with that of natural air.
- Pure air is defined as not polluted air by any type of source, either artificial or natural.
- Dry air is defined according to the following composition:

  $4/5\ N_2 + 1/5\ O_2 + \text{Argon} + CO_2 + \text{other substances}$

  where we have, in volume,
  - Nitrogen 78 %
  - Oxygen 21 %
  - argon 1 %
  - carbon dioxide 0,033 %
- Indoor air quality is refered to the standard ASHRAE n°62 (1999) "*Ventilation for Acceptable Indoor Air Quality*".

Quality of the workplace

- There are two control methodologies for air quality:
  - Indirect
  - Direct

- In indirect control the contaminant concentrations are not detected and it is assumed that, ensuring adequate flow of fresh air, the following concentrations that are in the workplace are appropriate.

- The methodology of direct control foresees a direct measurement or even a monitoring of the workplaces.

Quality of the workplace

- To apply indirect control, the frame of reference is that of the mass balance for a pollutant in a workplace.

- The workplace is schematized as a system affected by pollutant emissions in its indoor, q (kg/h):
  - Q, flow of fresh air introduced into the workplace and expressed in m^3/h;
  - Ce, concentration of pollutants in the incoming air, in kg/m^3;
  - Cu, concentration of pollutants in the outcoming air, in kg/m^3;
  - Ci, concentration of pollutants in the workplace subject to the monitoring, in kg/m^3.

Quality of the workplace

- If the workplace is well-mixed, i.e., the concentration of the considered pollutant is the same at all points

  Ci concentration is the same of the air outcoming from the workplace

  Cu = Ci

- Moreover, if the workplace is stationary

  Q*Ce + q = Q*Cu = Q*Ci

- The flow rate of fresh air that have to be ensured to maintain the determined concentration of the pollutant is obtained by the mass balance:

$$Q = \frac{q}{C_u - C_e} = \frac{q}{C_i - C_e}$$

Quality of the workplace

- The above can be applied to different types of pollutants.
- The limit concentration of carbon dioxide (CO_2) which is tolerable in a civilized place is:
  - Ci = 0,25 % in volume of the considered place
  - Equal to Ci = 10^{-3} Kg/m^3
- The real values are significantly higher, as it is assumed that the environment is in stationary conditions and in complete mixing:
  - in civil places the real flows are equal to 3 or 4 times the minimum value;
  - In industrial places the safety coefficient is higher and the flows are 10 times the minimum value
- Carbon dioxide is particular important in technical practice, because it is taken as the index size of the level of pollution caused by people in the environment.

Quality of the workplace

- The path of fresh air has to be considered, too.
  - the expelled air has to actually remove the pollutant:
    - a washing effect of the place by the fresh air fed has to be obtained
    - the danger of a short circuit has to be avoided
    - areas of stagnation have to be avoided
    - the stratified areas in the top have to be taken into account. In general, they do not interest as they are not occupied by the operators
    - intakes of fresh air should not be placed under the grilling of the sidewalks or even on the walls of a courtyard where vehicles with engine running may stationed permanently
    - the intake grilles should not be installed close to those of air expulsion of the ventilation system of near building.

- The increasing of the speed of the air leaving makes more turbulent and ample the air movement in the place:
  - danger of currents
  - Noisiness

THE GENERAL PRINCIPLE TO FOLLOW IS TO AVOID, AS MUCH AS YOU CAN, THE STALLED WITHOUT THE GENERATING THE DISADVANTAGES MENTIONED

Quality of the workplace

- We can check:
  - **carbon dioxide**
  - **odors**
  - **environmental water vapor**
- A less accurate control is performed on:
  - tobacco smoke (it is not related to the metabolic expenditure and therefore to the placing of carbon dioxide, but it strongly depends on the customs and on the number of smokers in the considered place)
  - powders (they not only depend on people and activities, but also by other factors not easily predictable)
- The characteristics of the external air are defined in relation to the significant pollutants of a typical industrial site:
  - sulfur dioxide (H_2S)
  - nitric oxide (NO),
  - ozone (O_3)
  - carbon monoxide (CO)
- The concentrations are expressed:
  - in terms of average hourly if they have an almost immediate effect
  - in terms of average hourly calculated over periods of eight hours or on annual basis for those who do not have an aggressive effect immediately and it is necessary to evaluate the absorption in medium-long periods of time

Quality of the workplace

- The rules concerning the issues of air quality is made under the **D.Lgs.** 155 of 13 August 2010 (transposition of Directive 2008/50 / EC, at first **DPCM** of 28 March 1983):
  - the renewal air has to be free of odors, of significant amounts of lead and other pollutants
- **ASHRAE n. 62/1999** standard requires that:
  - the renewal air has not to contain dangerous amounts of toxic substances and has to be appropriate even in terms of pleasantness
- In Italy, the situation with respect to these indications is critical especially in the big cities. The ASHRAE, in case of renewal fresh air, suggests the minimum flows to be ensured, in accordance with the type of the considered place.

Quality of the workplace

Place	Persons/100 m^2	m^3/h person
laundry	10 ± 30	29 ± 65
garage	-	27
bedroom	-	54
meat processing	10	29
classroom	50	29
offices	7	36

ASHRAE specifications for the flow of fresh air

Aerodispersed chemical pollution

- Industrial workplaces often have aerodispersed toxic pollutants

- Particular attention should be paid to:
  - determine the types of pollutants taking into account the methods of implementation of the production
  - compare the reference concentrations with the allowed exposure limit values
  - perform technical controls of concentrations, which have to be exclusively made to the source

Aerodispersed chemical pollution

- The pollutants constitute gaseous or aerosol mixtures, ie suspensions of solid or liquid particles in the air. Their mass and dimensions allow them to remain in suspension for an observable time

- The following types of substances can be distinguished:
  - gases, ie substances that in the reference conditions (temperature of 25 ° C at atmospheric pressure) are in the gaseous state
  - vapors, ie substances in the gaseous phase which, under the conditions of reference, are liquid
  - powders or particulates, ie solid particles whose diameter is approximately between 1 and 25 μm
  - fumes and mists, solid or liquid particles that originate aerosol by condensation of substances previously present in the air in the form of gases; the particles are often of the order of tenths of **μm**

Aerodispersed chemical pollution

- The toxic pollutants can enter the body in general, through
  - the respiratory system,
  - the body surface,
  - orally
- The effects of taking toxics can be traced to:
  - forms of depression
  - destruction of tissues
- Moreover, these effects may be:
  - Immediate
  - protracted
  - Postponed
- The limit values are defined in relation to
  - properties of substances in the environment
  - results of toxicological tests
  - epidemiological data

Aerodispersed chemical pollution

- An important reference is that of the tables published and periodically updated by the **American Conference of Governmental Industrial Hygienists** (**ACGIH**).

- There are three rules concerning indication of the concentration limit, or TLV (threshold limit value):
  - **TLV - TWA** (*time-weighted average*), weighted average value over time, relative to an exposure equal to 8 hours a day for 5 days a week;
  - **TLV - C** (*ceiling,*), used for substances with substantially immediate effect; it expresses a maximum value of concentration that should not be exceeded;
  - **TLV - STEL** (*short-term exposure limit,*), is the maximum value allowed for brief exposure - no more than 15 minutes - and occasional - no more than four exposures in 24 hours, spaced at least an hour away from each other.

Aerodispersed chemical pollution

- Concerning the TLV the following indications can be adopted:
  - if the limit TVL - STEL is identified, this value should never be exceeded by hikes of concentration
  - If TVL-STEL does not exist, the following have not to be exceeded:
    - TVL-TWA limit in 8 hours time
    - 3 times the TLV-TWA value for more than thirty minutes / day
    - in any case the value of the parameter TLV-C

Aerodispersed chemical pollution

- The TVL limits given in ACGIH Tables refer to the absorption of toxics exclusively through the respiratory tract:
  - Where there is the indication "*skin* " near the name of a substance, the possibility of absorption of the pollutant by skin has to be considered

- In the case of substances with independent effect (ie they produce a different effect, or act on different parts of the body) we have to check - for each of them:

$$\frac{C_i}{TLV_i} < 1$$

- In the case of substances with additive effect, the following condition has to be checked:

$$\sum_i \frac{C_i}{TLV_i} < 1$$

- In the case of substances with a single effect, appropriate specific inquiries have to be made.

Aerodispersed chemical pollution

- the true limiting factor is constituted by the concentration of oxygen in the air, which should be in any case more than 18% in normal volume to atmospheric pressure

- In the end, there are some special categories of substances, which are worth considering individually:
  - annoying but not fibrogenic particulates (non-crystalline amorphous silica); if the percentage of quartz is less than 1% it does not generate serious damage
  - fibrogenic particulates (quartz), which cause the degeneration of the tissues of the pulmonary alveoli, which progressively becomes waterproof
  - silicates (asbestos), which is a key component of asbestos;
  - simple asphyxiatings (eg methane - CH_4 - and carbon dioxide - CO_2)
  - substances with variable composition, such as petrol vapors and welding fumes, which require specific analysis
  - carcinogenic substances

Aerodispersed chemical pollution

- The experimental measurements for the determination of the concentration of a pollutant in an environment require the availability of appropriate instrumentation.

- The used methods of analysis rely on many different principles:
  - for example, it is possible to make to react the air volumes which are object of the analysis with some substances that change - in a predictable way – the coloring (the **Draeger vials** - a specific vial of substance for each type of pollutant is needed)

Aerodispersed chemical pollution

- If it was not possible to intervene upstream of the process for eliminating aerodispersed pollutant, action can be taken in two different ways:
  - sampling and expulsion of the polluted air, and release into the workplace of clean air suitably treated from the hygrothermal point of view
  - recycling of air, by means of a sequence of sampling, purification and subsequent remission. This second method has serious limitations of use, as it assumes a constant control of the correct operation of the treatment plant
- Recycling of air, for instance, is not possible in presence of toxic pollutants, but it can be used in the case of cigarette smoke, body odors etc.
- The first kind of approach can be implemented in two different ways:
  - general ventilation, consisting of the dilution of the pollutants, creating an exchange of air with the outside
  - localized suction consisting of the capture by appropriate mantels placed near pollutant sources before they are dispersed in the air. The characteristic parameters of the mantels are:
    - the control volume, ie, the space in which the mantel exerts a useful action
    - the control speed, ie the speed of the air carried by the suction system; This speed has to be greater than the escape velocity of the pollutant

Aerodispersed chemical pollution

- In the use of mantels some precautions have to be taken into consideration:
  - place the mantel as close as possible to the source of the pollutant, so as to reduce the flow at the same speed of capture
  - directing the mantel so as to facilitate the capture of the pollutant
  - protect the operator
  - use directional flanges

- With regard to the problem of determining the speed with which the air has to move in the channels, it must be considered that the losses of load, i.e., the frictions that air itself meets while moving along the channels are proportional to $\mathbf{v^2/2g}$. This means that when the speed increases, the losses of load and the noisiness increase too.
  - normally, there is a tendency of speed of **15÷25m/s**