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Original

Introduction of a Simple Chamber for the Production and Simulation of Airborne Pollutants for Laboratory Use

Hossein Fallah[1]*, Abolfazl Barkhordari[2], Gholamhossein Halvani[3], Rajabali Hokmabadi[4]

[1] PhD Student of Ergonomics, Department of Occupational Health and Ergonomics, Faculty of Health, Tabriz University of Medical Sciences, Tabriz, Iran• [2] PhD, Department of Occupational Health, Faculty of Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran• [3] MSc, Department of Ergonomics, Faculty of Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran• [4] MSc, Department of Occupational Health Engineering, Health School, North Khorasan University of Medical Sciences, Bojnurd• Corresponding Author: Fallah Hossein, Email:Fallah_hossein@yahoo.com, Tel: +98-0913-2572540

Abstract

Background: Designing training aids for students to increase their practical capability and skills is done by using modern educational methods. The aim of this study was to design a simulator of airborne pollutants for measuring gases, vapors and particles in the lab for student training. **Methods:** The present study investigated different systems based on reviewing the literature of conducted research studies around the world. Then, designing the simulator system of the airborne pollutants was carried out after studying the capabilities of available systems, considering the viewpoints of experts and focusing on the aims of the study. **Results:** The designed chamber consisted of a main component which, in addition to some complexes such as the blowing system, the evacuation funnel, the warming chamber, and control box, made the production and simulation of the particle and gaseous pollutants feasible in different atmospheric conditions. **Conclusions:** The production and simulation of airborne pollutants in an experimental chamber under controlled conditions can facilitate the accomplishment of different assessments on pollutants. The designed device benefits both having a simple yet creative fabricated system and low manufacturing costs. Therefore, it can be used readily as a suitable device for extensive research on pollutants in the educational and research centers.

Key words: Simulation chamber; Airborne pollutants; Sampling; Laboratory

Introduction

Currently, the most significant method for the assessment of workers' exposure to air pollutants are the air sampling procedures and biological monitoring [1,2]However, the assessed exposures via these methods may not be applied to other different environments and conditions. Therefore, other methods of assessing exposure in work environments should be used instead of monitoring including modeling methods. [1,3,4] Despite the availability of numerous chemical exposure

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assessment methods, [5,6] none of them can be considered as the best standard by itself due to some measurement errors. [7,8] Regarding these limitations, the application of these production and simulation systems in the laboratory can facilitate the research on pollutants in the workplaces. Simulation, which is in fact an imitation of a real system or process, can be used in the analysis, comparison, and improvement of complicated systems. Production, collection, and measurement of aerosols in a controlled laboratory range can function as a significant device in determining the potential spread of particles from different sources. The particles produced on the laboratory scale can resemble the environmental pollutants regarding size, form, composition or, at least, other components, without being affected by other pollutants. [9,10]

Experimental dust production is done for many purposes as studying the control processes of factories, inhalational toxicology, environmental health, research epidemiology, and pharmacological issues. Today, a wide range of laboratory and commercial instruments are used to produce aerosols and there are several distinct classes of dust producers including floating devices, particle falling chambers, cylinder-shaped containers, and revolving tubes. Furthermore, various types of production chambers for re-suspension and sampling of particles[10] biological applications,[11] wind erosion and unstable particles[12] have been designed and used. Dust measurement tools are also used for other goals such as the simulation of the dust in workplaces,[13] controlling processes,[14] drug industry[15,16] exposure of laboratory animals to dust particles for research purposes,[17,18] sample preparation for chemical analysis,[19] study of echo physiological effects on the amount of accumulation of particles on leaves,[20] simulation of dust infiltration into buildings,[21,22] and predicting the accumulation and spread of particles on other planets or extra-atmospheric space.[23] Furthermore, simulation chambers have been used for research purposes in several studies as the following.

Chung et al.(2000) used a chamber to assess particles and formaldehyde vapors when machining MDF plates.[24] Another study (2006) in California used a cheap double-purpose chamber to investigate gases as well as particles.[25] This device was also used to evaluate the biological factors of dust measurement in houses.[26] Another application of the chambers was the assessment of particle explode ability. Mention can be made of the 20-L Siwek chamber used extensively for this goal.[27] Lee et al. (2005) investigated the effect of temperature differences on the scattering of airborne pollutants in a chamber fabricated for this purpose.[1] The study by Page (2000) investigated the correlation between electrostatic properties and moisture in coal dust using a chamber designed for this purpose.[28] Furthermore, another study conducted on coal dust for laboratory tests used a chamber called Marple.[29] The study by Randal (2010) used a chamber to assess agricultural dust.[30] Lingjuan et al. (2003) investigated the effectiveness of some samplers using a special chamber.[31] Another study (2002) on the simulation of Mars dust particles in low speeds used a chamber called Merrison.[32] Moreover, Urbain et al. (1996) investigated the effect of chronic exposure of swine to dust and endotoxins using a simulation chamber.[33] One application of experimental chambers is testing different fire detectors and gas leakage detectors, e.g., the study by Charles (2009) which assessed smoke detectors in mines using an experimental simulation chamber. [34] The study by Kenneth et al. (2007) investigated the post-explosion events of mines using an experimental chamber named Fike.[35] Another study by Afshari et al. (2005) focused on the investigation of the sources of work environment dust particles as cigarette smoking, deodorant sprays, burning candles, vacuum cleaners, meat toasting by electric stoves, ironing, and gas stoves using a chamber. [36]

Approximately, all of the simulation chambers used in above-mentioned studies had experimental usage, and due to their limitations, they are not used for educational purposes. Consequently, the purpose of the present study was to introduce a simple yet creative designed chamber for the simulation of airborne pollutants in laboratory conditions. The specific properties of this device make it suitable for the production of particle pollutants, gas, vapor, and varying atmospheric conditions within the chamber. It is hoped that these capabilities make the production and sampling of various pollutants possible in laboratory conditions.

Methods

Reviewing the related literature, it was found that a wide range of simulation chambers had been designed and fabricated for different purposes. However, the main point was that each chamber was designed and applied for just one specific research purpose and multi-purpose designs were both complex and expensive. Therefore, the researcher decided to design such a system with high complex capabilities and low costs. The aim of this study was to design and produce training aids for students to increase their practical capability and skills using modern educational methods. Therefore, In this study, the features and capabilities of the built-in device were described. As well as the similar studies published in these subjects, the statistical methodology of research (Sampling, Sample size, Analysis method) was not required.

Some investigation revealed that the newly devised system should be capable of both production of particle pollutants, gases, vapors, and various work environment conditions, and the possibility of simulation of various conditions as well as simultaneous simulation of pollutants. Based on the defined capabilities of the device, the determined structure and equipment for this purpose were suggested. Then, various designs were studied and their advantages and disadvantages were determined. After that, the best design of the system was offered by considering parameters such as simplicity, cost-effectiveness, portability, and sensitivity. Ultimately, the general design of the chamber was decided by considering ergonomic principles, and the location of parts was determined.

Afterward, the details provided on the map and the pre-model was made using other materials and after ensuring the proper operation of the prototype, the main model was built using original materials. In the end, all parts and components of prototype were tested and deficiencies and defects were identified and removed. Since the main goal of building this system was using it for train in gap plications; therefore, its performance was reviewed and approved by several occupational health masters. Since one of the potentiality of device was releasing of gases and vapors in the inner chamber; thus, a little amount of benzene placed in a heating chamber and released into the main chamber by passing air volume and temperature. Then, the uniformization was performed in education. Subsequently, benzene quantity was measured using detector tubes. This procedure was repeated several times with the same conditions and after each test, the chamber was thoroughly washed and the measured values were compared.

Results

The simulation chamber consisted of a main component integrated with other parts as the air blowing system, materials evacuation funnel, the warming chamber, and the control box. This makes the production and simulation of gaseous and particle pollutants in various air conditions Figure 1.

Figure 1. Photograph of airborne pollutant simulation chamber

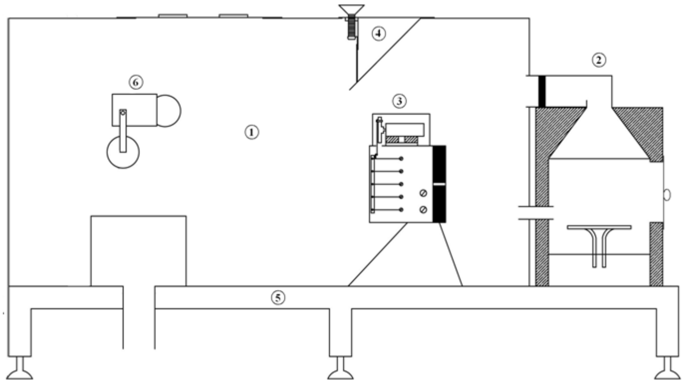

Figure 2: Schematic diagram of airborne pollutant simulation chamber
(1. Main chamber, 2. Warming chamber, 3. Blowing system, 4. Evacuation funnel, 5. Platform, 6. Filament lamp)

The main chamber was a rectangle cube with 40 × 40 × 80 cm2 dimensions and could be attached to the input/output ports of the warming chamber via the lateral wall.

The warming chamber is located adjacent to the main chamber. It has a structure similar to an oven. It has both the capability of regulating its internal temperature and controlling the volume of the passing air into the warming chamber. This multi-purpose chamber is capable of controlling temperature, moisture, vaporization of solvents, and their transmission into the main chamber Figure 2.

The blowing system is another component of this device located within the main chamber. It includes a fan with adjustable speed and air-directing blades with adjustable speed. The function of this part is the production of air current at different speeds and also the production of directed or disturbed current in the main chamber Figure 3. The evacuation funnel is another component of this chamber which enables us of producing particle pollutants via the falling mechanism. This is in fact a slopped chamber with an adjustable slot. It is located in the upper plane of the main chamber and above the blowing system and makes the production of particle pollutants possible Figure 4. The control box contains electric circuits and controls Figure 3; therefore, the equipment of the system and parameters as the main fan speed, the amount of the movement of air-directing blades, the amount of warmth produced in the chamber, the rate of the volume of the passing air in the warming chamber, and also the rate of radiating warmth can be controlled parallels and simultaneously with controls located on it. In this way, many conditions can be produced and simulated even for just one specific pollutant in the main chamber.

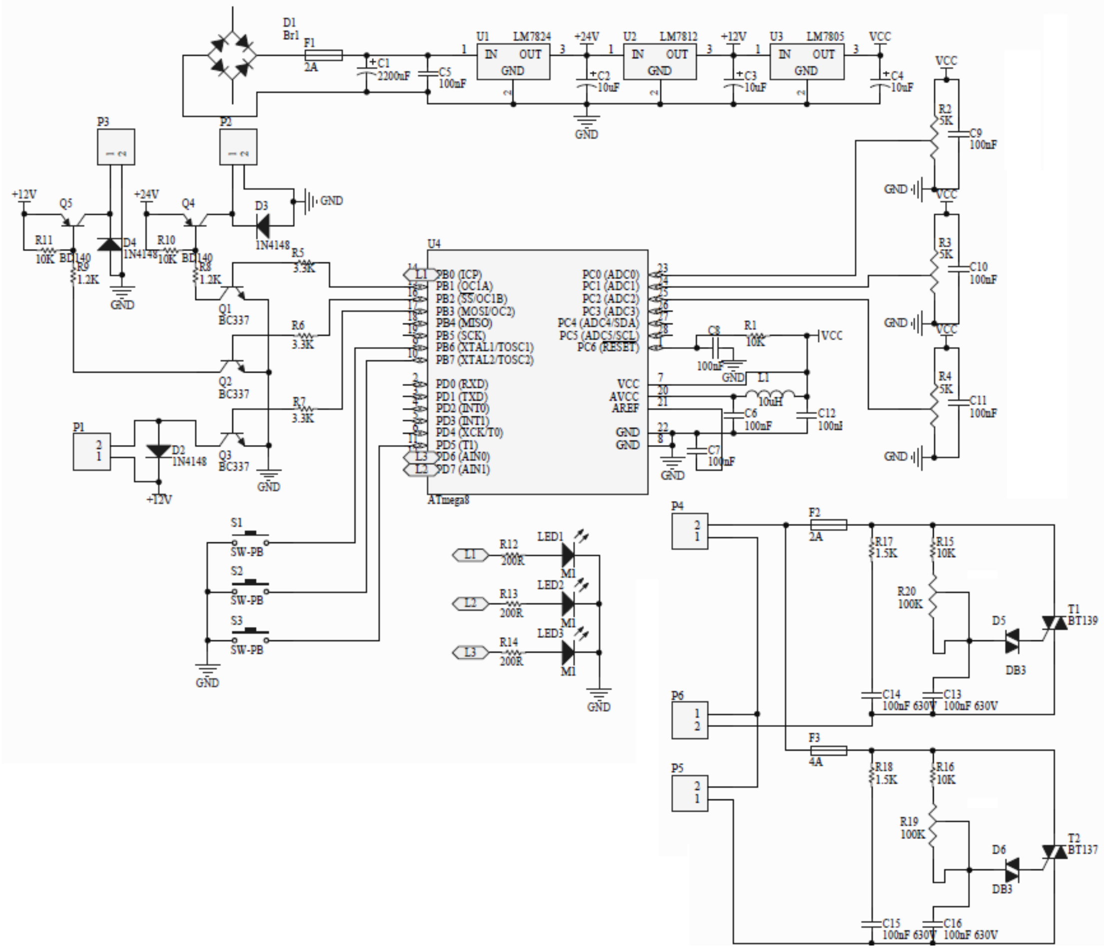

Figure 3. Schematic design of electric circuit of airborne pollutant simulation chamber

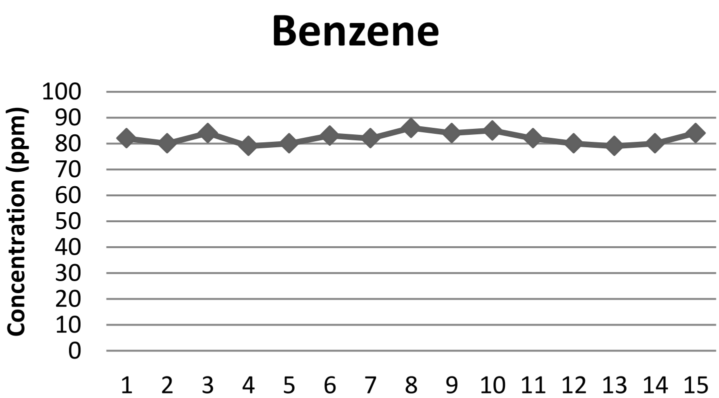

Figure 4. Benzene concentrations measured during 15 repeated tests in same conditions

The main chamber and all the peripheral components are located on a platform with adjustable legs Figure 5.

Using the above components, the production and simulation of gaseous and particle pollutants and various air conditions in the main frame become possible which will be explained as the following:

1-Production of particle pollutants: To do so, the powdered materials are poured into the evacuation funnel. While the fan of the air blowing system is circulating, the amount of falling of materials can be adjusted by turning the upper control of the funnel. In so doing, the falling powdered materials are exposed to air current and scattered in the main chamber space.

2-Production of pollutants in the gaseous and vapor forms: To release gases and vapors in the main chamber, a chemical or solvent should be placed in the warming chamber. The pollutants can be scattered in the main chamber space by changing the warming chamber temperature and controlling the amount of air passage in the chamber.

3-Production of various air conditions: Regarding the adjustability of temperature and passage of air in the warming chamber, the amount of temperature and moisture of the main chamber can be readily adjusted and an air current with different speeds can be produced in the main chamber with the air blowing system. Furthermore, directed and disturbed air current may be produced in the main chamber by adjusting the amount of movement of blades in front of the fan. Moreover, radiating heat with adjustable intensity may be produced by the filament lamp located in the wall of the main chamber Figure 2, 6. It should be mentioned that these capabilities can be used parallels; therefore, various conditions may be simulated.

The results of the benzene emissions assessment in the chamber showed that benzene amounts measure dafter each experiment were nearly similar, as well as, the mean benzene concentrations measured after 15 repeated tests in the same conditions (at all stages of measurement, volume of benzene was 1cc and the temperature and air flow velocity conditions were the same and equal to laboratory conditions)was 81.86 ppm Figure 4.

Discussion

Production and simulation of airborne pollutants in a laboratory chamber can create controlled conditions and make the various assessments of pollutants possible. Due to some complex risks at workplaces, the use of suitable instruments for assessing exposure to air pollutants is crucial.[37] Regarding the problems and limitations of the educational setting and research, the airborne pollutant simulator can be applied as a useful device.

This system has the capability of producing and simulating the gaseous, particle, and vapor pollutants, and various air conditions in the experimental setting of laboratory. It can be used for different methods of assessment of exposure to gases, vapors, and aerosols. The methods are currently used for the assessment of exposure to gases and vapors include: direct reading devices, detector tubes, complete air samplers, bubblers, and solid absorbent samplers. Moreover, the direct reading devices, impingers, filters, and size-selective samplers can be used for assessing exposure to aerosols.[38] This chamber can be easily used to evaluate the pollutants using each of the above-mentioned methods; therefore, it can have a wide range of educational and research applications. The fabrication of this device is an invention and there is no similar one. No reference is made to a device with similar capability, form, size, etc. in the literature.

Conclusion

Due to the fact that simplicity and low cost are among the important factors for the selection and application of educational technology, and since this system enjoys a simple structure and creative design for the production and simulation of the particle, gaseous, and vapor pollutants, and is cost-effective; therefore, it is advised as a suitable tool for using in educational settings. Regarding the point that the main purpose of the fabrication of this device is its use in the educational settings, complex components are not used in it as far as possible. However, it enjoys the merit that other components may be added to it to increase its capacity and capability.

Conflict of interest

The authors declare no conflict of interests.

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