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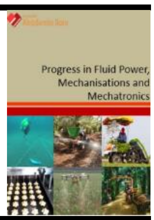

Indoor Air Quality Investigation Due to the usage of Mini Excavator in Enclosed Space

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ABSTRACT

This paper investigates the indoor air quality due to the usage of mini excavator in enclosed space . The impacts of indoor air quality in this enclose space room are ultimately determined by levels of contaminants and comfort parameters. Carbon dioxide and carbon monoxide have been used as an indicator of indoor air quality due to both to its use as tracer gas for air change rate estimation. A comparison test is conducted between mini excavator powered by electric motor and gasoline engine to establish whether the emmision is exceeding a recommended exposure limit. The acquired data is useful in defining indoor air quality and the proposal for a tele-operated electric powered mini excavator.

1. Introduction

The use of construction machinery in an enclosed space, especially during demolition and reconstruction activities, reduce the quality of air significantly. World Health Organization [1] reported that the importance of Indoor Air Quality (IAQ) in buildings arose from the fact that people tend to spend 90% of their time indoors. Air pollutants can accumulate up to concentration levels greater than those found outdoors. According to AHSRAE [2], while activities in workplaces are most commonly regulated by laws to protect employees, this does not imply to other indoor environments such as schools, gyms, cinemas and public offices. Measurements of indoor CO_2 concentration can be used to assess indoor air quality and ventilation [3]. While CO_2 concentration does not provide a comprehensive indication of indoor air quality, CO_2 monitoring can be used to assess the acceptability of a space in terms of human body odour and comfort. CO_2 is a colorless, non-irritating, odorless, and

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tasteless gaseous pollutant that may be emitted into the environment from anthropogenic or natural sources [4]. Temperature and humidity are important because thermal comfort underlies many complaints about "poor air quality." More than 90% of CO_2 emissions of construction machinery are generated by fuel consumption during machine operation throughout the life cycle from machine manufacturing to scrapping. Reduced fuel consumption directly leads to reduced emissions of global warming gases and thus the low fuel consumption technology in hybrid systems is more environmentally friendly than conventional systems as well as costing the customer less in fuel. The pollution and global warming has become a serious problem nowadays.

Figure 1 shows the example of excavators working in a building with enclosed space area. As a result of this, enclosed space working area of these excavator will be filled with CO_2 emission, temperature surrounding this area and poisonous carbon monoxide that is a by-product of incomplete combustion will increase. In addition, it is important to mention that if natural ventilation is not adequate to keep CO_2 levels below accepted limits, also other dangerous pollutants, either from outside or released by indoor sources can easily remain in the room.

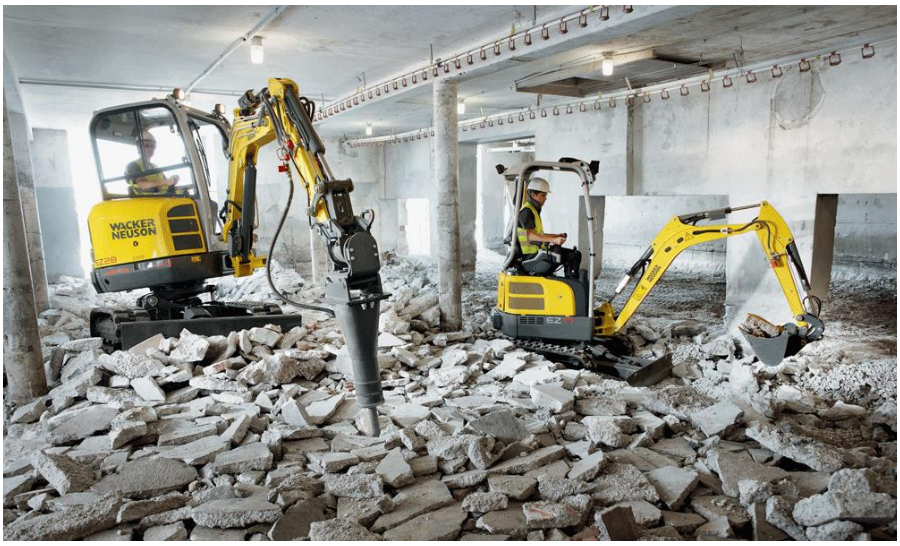


Fig. 1. Mini excavator with hydraulic hammer in an enclosed space

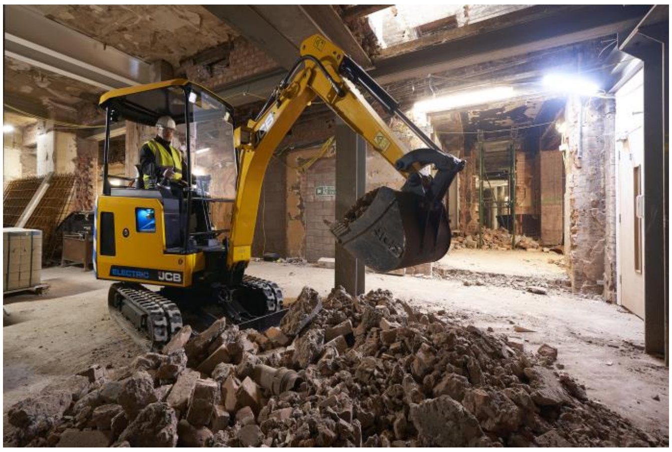


Fig. 2. A mini excavator used in an enclosed space

2. Methodology

Experimental design of this study is based on two types of excavators. First experiment is conducted using mini excavator powered by gasoline engine. Second, an experiment is conducted using mini excavator powered by electric motor. After completed equipment preparation, a venue for conducting experiment is prepared. Fig. 3 and Fig. 4 illustrate the layout of experiment. The experiment involves the use of Hydraulic Fluid Power Lab as an enclosed space application room. The dimensions of the enclosed space room are 24 feet by 72 feet, and the room has a height of 11 feet. This means that the total volume of air in this room is 19008 ft^2. This area does not include the existing furniture in this room. One side of this room is covered by windows. The experiment has been carried out in an enclosed space conditions during experimental runs, with all the windows are closed so that a closed space. This is to create an enclosed space with limited ventilation. The gasoline and electric mini excavator are placed at the centre of the enclosed space room about 36 feet from the wall and the engine of gasoline mini excavator is started. The excavator will be left alone for 15 minutes before measurement was taken. Fig. 3 shows the side view experiment layout for location of IAQ meter and Fig. 4 shows the top view experiment layout for gasoline and electric mini excavator. These points describe the location of the Indoor Air Quality (IAQ) Meter in an enclosed space room. After that, the measurement result from the IAQ meter will be collected for analysis. The second experiment will use an electric mini excavator which will repeat the use of the same method. The investigation will be focusing on the investigation of indoor air quality for natural ventilation in the enclosed space room. The results of these observations will be compared with the guidelines set by the ASHRAE air quality standards.

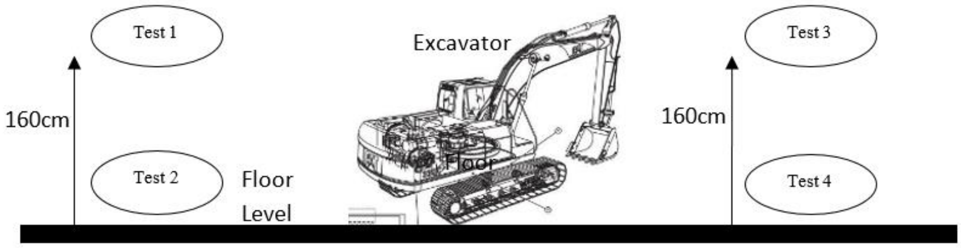


Fig. 3 Side view experiment layout for location of IAQ meter

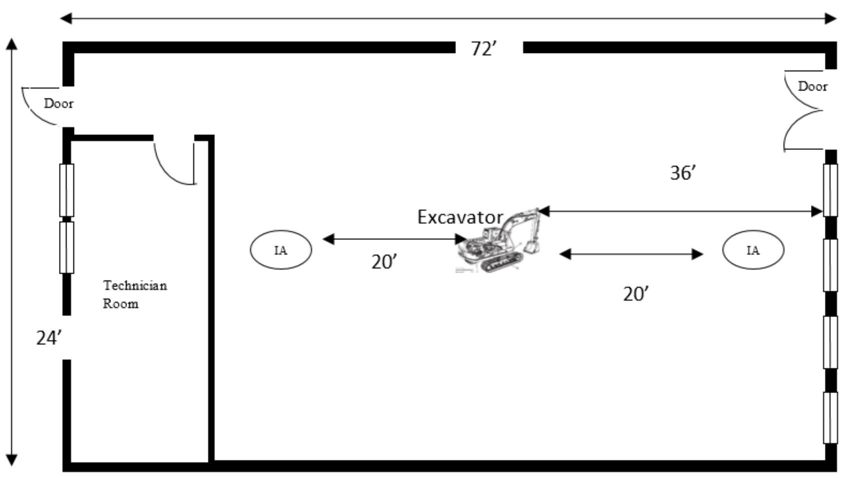


Fig. 4. Top view experiment layout for gasoline and electric mini excavator

2.1 Mini Excavator

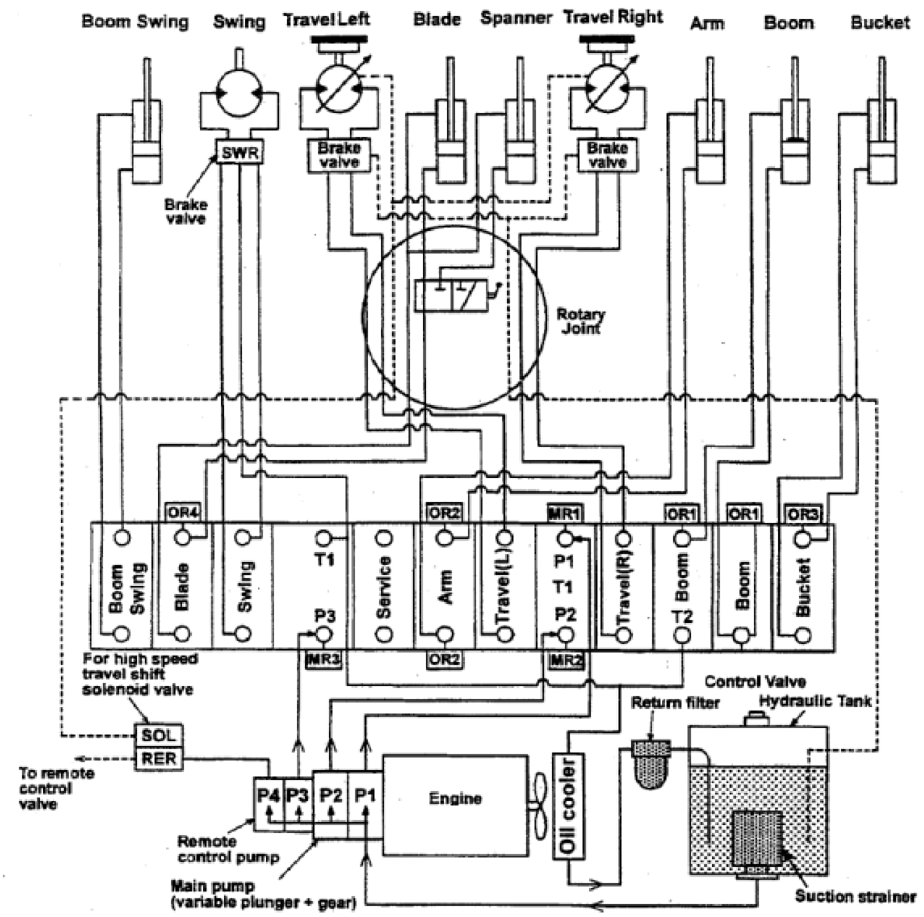
There are two types of mini excavator used to run this experiment. Figure 5 shows a mini excavator powered by gasoline engine that uses fuel as the source of power, while Fig. 6 shows a mini excavator powered by an electric motor. The SS60 super shovel is the smallest earthmoving in the world has an overall width of 19 inches (0.48 metre) and weight only 272 kg. The operator rides behind the excavator and balances the action of the bucket. The operator can sit or stand on a platform while operating the machine. The seat can be folded up when the platform is in use. The platform can be lowered 51 mm below ground level to act as an anchor and stabilize the machine. The excavator does not have a blade: all work is done with the bucket. The machine is not equipped with restraint system. In case of a roll over, the operator steps off from the machine.

Fig. 5. Excavator Kobelco SS60

Table 1
General Kobelco SS60 Mini Excavator Specification

General: Overall Length: 7'1'' Overall Width: 1'7'' Height: 3'7'' Bucket capacity: 0.25 cu ft Bucket width: 9 inches Fuel Tank: 2.2 US gal	
Performance	Travel Speed: 0.87 high, 0.50 low 2.6 mph
Boom swing speed	3.7 sec (90°)
Grade ability	47% (25°)
Stick digging force	1830 lb.
Bucket digging force	750 lb.
Operating weight	600 lb.
Motor	4cycle,
Type	gasoline engine (aircooled)
Rated output	(HP @ rpm) 3.5 @ 1600
Displacement	53.6 cu. in
Hydraulic System	Pumps: 2 gear pumps, Max. discharge pressure: 2,130 psi Hydraulic tank capacity: 1.85 US gal.

Fig. 6. Electric Excavator Kobelco SS60



Relief valve set pressure

Code	Item	Pressure MPa	Pressure kgf/cm²
MR1	Main relief valve P1 Pump	20.6	210
MR2	Main relief valve P2 Pump	20.6	210
MR3	Main relief valve P3 Pump	18.1	185
OR1	Overload relief valve (Boom)	24.5	250
OR2	Overload relief valve (Arm)	24.5	250
OR3	Overload relief valve (Bucket)	24.5	250
OR4	Overload relief valve (Blade)	20.6	210
SWR	Swing relief valve	15.2	155
RER	Remote control relief valve	2.9	30

Tank level capacity
19 liters
Total system volume
23 liters

Pump flow rate (Max.):
P1 ; 17.2 liter/min
P2 ; 17.2 liter/min
P3 ; 12.0 liter/min

The service ports used the flow shared by the P2 and P3 pump.

Fig. 7. Typical hydraulic circuit for engine driven mini excavator

The electric version of the excavator is the same model with Excavator Kobelco SS60, with the exception that the gasoline engine has been converted into using an electric-powered hydraulic power unit. Figure 7 shows the typical hydraulic circuit for engine driven mini excavator. Using electric powered excavator, there is no need to use the fuel to start the engine. So, the electric motor will be used to control the hydraulic motor. Electric motor as shown in Fig. 8 is used to control the hydraulic system in order to regulate the excavator boom movement. The voltage of the electric motor is 415V with 1460 revolution per minute. This power of electric motor is 11 kW and its frequency is 50 Hz.

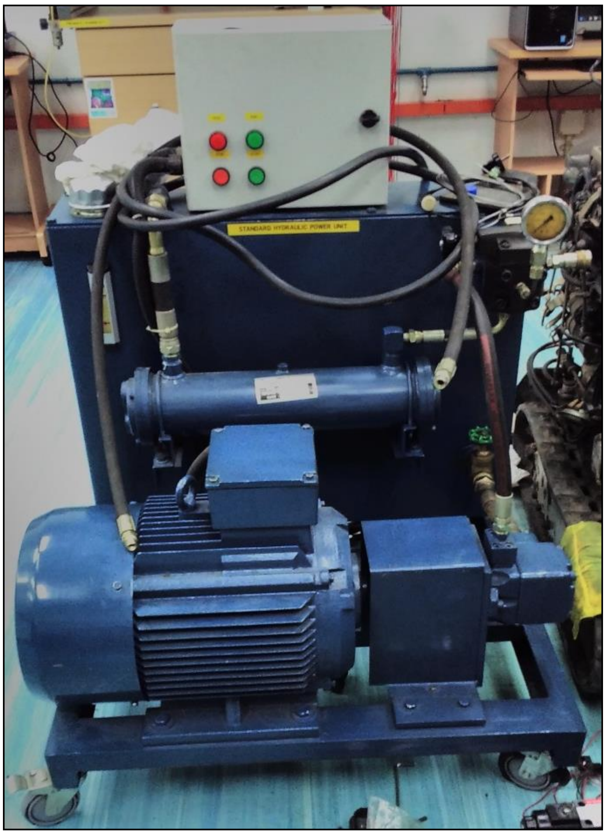


Fig. 8. Hydraulic power unit

2.2 Indoor Air Quality Meter

Figure 9 shows an Indoor Air Quality Meter used in the indoor air quality measurements. The measurements were conducted in the Hydraulic Power Lab at floor level and 160 m above the finished floor level. Parameters measured include carbon dioxide, carbon monoxide and temperature which were monitored in this lab with TSI IAQ meter data logger with carbon dioxide resolution 1ppm, accuracy ±3% or 50ppm, carbon monoxide resolution 0.1 ppm, accuracy ±3% or 3 ppm, and temperature resolution 0.1°C, accuracy ±0.6 °C. Fig. 3.7 shows the example of IAQ meter and table below describe a details of IAQ meter specification. TSI's IAQ-Calc™ Indoor Air Quality Meter 7545 is an outstanding instrument for investigating and monitoring indoor air quality (IAQ). The 7545 model simultaneously measures and data logs multiple parameters. Measurements are CO, CO2, temperature, humidity; and calculations are dew point, wet bulb temperature, and % outside air. The proprietary TSI LogDat2™ Downloading Software permits easy transfer of data to a computer. Data can be reviewed on-screen, or downloaded to a computer for easy report generation. Statistics function displays average, maximum and minimum values, and the number of recorded samples.

Fig. 9. Indoor Air Quality Meter

Table 2
Specification of IAQ Meter Model 7545

	Carbon Dioxide (CO2)	Carbon Moxide (CO)	Temperature
Range	0 to 5000 ppm	0 to 500 ppm	32° to 140° F (0° to 60° Celcius)
Accuracy	± 3% of reading or ±50ppm	± 3% of reading or ±3ppm	±1.0°F or ±0.6 °C
Resolution	1 ppm	0.1 ppm	0.1° F (0.1°C)
Sensor Type	Non – Dispersive Infrafed (NDIR)	Electro -Chemical	Thermistor

3. Results and Discussions

Figure 10 shows the obtained data, where a comparison between gasoline and an electric mini excavator was made. At the activity levels found in typical office buildings, steady-state CO2 concentrations of about 700 ppm above outdoor air levels indicate an outdoor air ventilation rate about 7.5 L/s/person. Laboratory and field studies have shown that this rate of ventilation will dilute odours from human bioeffluents to levels that will satisfy a substantial majority (about 80%) of unadapted persons (visitors) in a space. CO2 concentrations in outdoor air typically range from 300 to 500 ppm. Thus indoor CO2 concentrations of 1000 to 1200 ppm in spaces housing sedentary people is an indicator that a substantial majority of visitors entering the space will be satisfied with respect to human bio-effluents or body odour. However, that CO2 concentration is not a good indicator of the concentration and occupant acceptance of other indoor contaminants, such as volatile organic compounds off-gassing from furnishings and building materials. Thus, CO2 concentration is not a reliable indicator of overall building air quality [1]. The maximum levels of CO2 were largely above 1000 ppm, commonly used as a warning threshold limit for acceptable air quality in terms of comfort, which is related with temperature and humidity, body odour and short breathing [5]. Fig. 10 also shows that carbon dioxide concentrations already exceeded a recommended by ASHRAE [1]. Based on the graph carbon dioxide concentration level present shows a poor ventilation management in an enclosed space area. Elevated levels of carbon dioxide may indicate that additional ventilation is required. However, building a ventilation system in this space requires renovation, which may be costly.

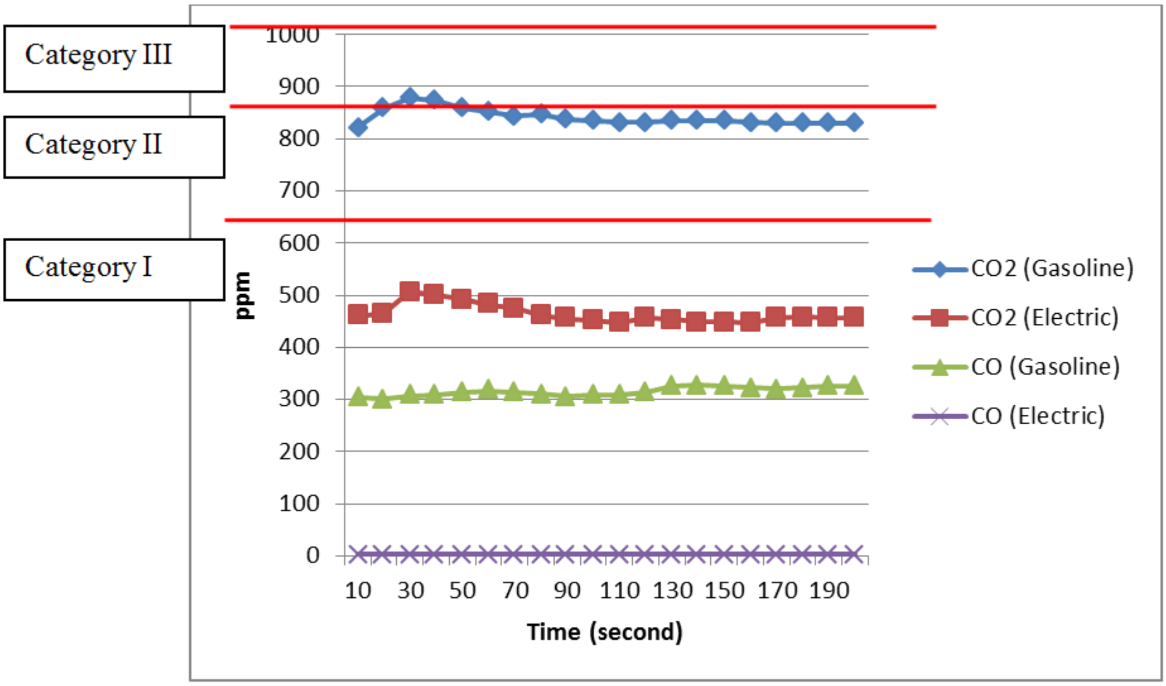


Fig. 10. CO2 and CO comparison of gasoline and electric excavator

While comfort is important to maintain productivity and concentration, many undesired airborne contaminants can actually pose a threat to human health. Based on National Institute for Occupational Safety and Health [6], all the result tested in the above figure already exceeded the recommended exposure limit (REL) for carbon monoxide of 35 ppm (40 mg/m3) as an 8-hour TWA and 200 ppm (229 mg/m3) as a ceiling (NIOSH, 1992). The NIOSH limit is based on the risk of cardiovascular effects. Furthermore, according to Occupational Safety and Health Administration [7], permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air (55 milligrams per cubic meter (mg/m3)) as an 8-hour time-weighted average (TWA) concentration also exceed the exposure limit. One of the most important indicators of the indoor air quality is the CO2 concentration [3]. It is well known, that high level of CO2 indoors means low ventilation or aeration rate, which corresponds to high level of indoor air pollution exposure to the occupant. It is known, that high level of CO2 concentration causes decreases productivity and comfort of the occupant, but most important is that long exposure might have harmful effect over human health. The European Committee for Standardization, or CEN, through EN 15251 standard [2], prescribes basically 3 different categories for indoor environment, depending on the CO2 concentration level. Category I represent high level of expectation and it is recommended for spaces occupied by very sensitive persons and persons with special requirements. The predicted percentage dissatisfied by the perceived air quality for this category is 15%. Categories II and III represent the normal level of expectation and the acceptable, moderate level of expectation from the environment. The predicted percentage dissatisfied by the perceived air quality for Category II is 20% and for Category III is 30%. There also exists Category IV, in which the values of the indoor air quality parameters are just outside the above mentioned categories.

4. Conclusions

Measuring indoor air quality levels of CO2 together with temperature and CO not only allows monitoring the comfort degree and productivity inside the room, but it also gives the possibility to estimate specifically the overall indoor air quality. However, with CO2 concentration levels only does not describe how good is the indoor air, because CO2 in not a toxic substance even if its metabolic accumulation indoor can have adverse, reversible effect, as described in the literature (limited brain capacity, short breathing, fatigue, drowsiness, etc.). The study found that indoor air quality levels of CO concentration are much higher than the recommended exposure limits at many sampling locations. Within the variables studied; type of mini excavator, utilization of natural ventilator, respectively, were recognized as the most influential factors controlling CO concentration in this enclosed space application. Its means that work site manager has to make plans and build additional ventilation, which made the uses of a gasoline powered excavator indoors considerably more expensive than outdoors. It is a complex task and required more interdisciplinary analyses. The physical measurements in the experimental study clearly showed low indoor air quality in the room. Nevertheless the enclosed space room occupy only one worker. If prolong exposure to these condition, occupants might be a risk for their comfort, productivity and the health.

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