UNIVERSITI PUTRA MALAYSIA

EFFECTS OF TEMPERATURE AND VELOCITY ON CHLORINE DISPERSION IN AN INDOOR STORAGE SYSTEM USING COMPUTATIONAL FLUID DYNAMICS SIMULATION

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By

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Abstract of thesis to be presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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The manufacturing companies producing chemical products have to deal with a variety of inherent environmental risks in conducting their operations. Nowadays, the indoor release of hazardous chemical gases which are heavier than the air is one of the risks that require an in-depth scrutiny. The reason for this claim is that the dense clouds of gases have a tendency to initially flow on the ground level, which in turn, causes fatal injuries or other potential health threats to human beings. Although the existences of these gases are dangerous, factories are not able to reduce their emissions risk to an absolute zero amount. Consequently, it is important to investigate what factors affect the indoor movements and dispersions of the heavier-than-air dangerous gases. In this study, computational fluid dynamics (CFD) software using FLUENT 14.5 code was employed in order to model the accidental indoor dispersion of a common dense gas, chlorine, from a small undetected leak into an indoor industrial environment. Computational fluid dynamics (CFD) has outstanding capabilities in illustrating realistic simulations even for the cases of geometrically complex scenarios. Results of the simulations showed that the chlorine dispersion would behave like the liquid when it was being flown on any surface. Moreover, it was found that the chlorine density gradually increased on the ground level. Specifically, findings from this research revealed that mixing results for chlorine dispersion patterns are subject to different levels of temperature, wind amount, and wind direction. There is a direct relationship between temperature and chlorine gas dispersion. To support, among the temperatures studies in this research, namely 270K, 297K, and 315K chlorine gas dispersion was the highest at temperature 315K, ranging from 8×10^{-3} to 1×10^{-2} ppm. This study also showed the effect of wind velocity on chlorine gas dispersion at different temperatures. Specifically, at 270K, chlorine gas dispersion was 0.001 - 0.595 ppm, 0 - 0.0005 ppm, and 0 - 0.005 ppm at the wind velocities 1 m/s, 3 m/s, and 5 m/s, respectively. However, chlorine gas dispersion with the same wind velocity speeds remained constant, within the range of 0 - 0.005 ppm. All of these factors had significant relations with chlorine dispersion in indoor environment. In this research, the effects of ventilation on dispersion of chlorine were analyzed and their results were

compared with wind velocity simulations Overall, the effects of the environmental factors with the release and spread of chlorine in indoor space were meticulously investigated.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk Ijazah Master Sains

KESAN SUHU DAN KECEPATAN ANGIN KE ATAS PENYEBARAN KLORIN DALAM SISTEM PENYIMPANAN DALAMAN MENGGUNAKAN SIMULASI PENGKOMPUTERAN DINAMIK BENDALIR

Oleh

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Syarikat-syarikat perkilangan yang menghasilkan bahan kimia perlu mengambil kira pelbagai risiko alam sekitar yang wujud dalam menjalankan operasi mereka. Dewasa ini, pelepasan gas kimia secara tertutup berbahaya yang mana lebih berat daripada risiko udara yang memerlukan penelitian yang mendalam. Tuntutan tersebut dibuat adalah disebabkan oleh kerapatan uap gas yang mempunyai kecenderungan untuk mengalir pada permukaan tanah, seterusnya, menyebabkan kecederaan maut atau ancaman terhadap kesihatan manusia. Walaupun kewujudan gas tersebut adalah berbahaya, kilang-kilang tidak dapat mengurangkan risiko pelepasan pada satu jumlah mutlak sehingga sifar. Oleh yang demikian, ia amat penting untuk mengkaji tentang faktor yang memberi kesan terhadap pergerakan dalaman dan penyebaran gas berbahaya yang lebih berat daripada udara. Dalam kajian ini, Pengkomputeran Dinamik Bendalir (CFD) dengan menggunakan FLUENT kod 14.5 di gunakan untuk membentuk penyebaran dalaman secara tidak sengaja bagi kebiasaan gas yang tebal, klorin, dari kebocoran kecil yang tidak dapat dikesan ke dalam persekitaran perindustrian yang tertutup. Pengkomputeran Dinamik Bendalir (CFD) mempunyai keupayaan tersendiri dalam menunjukkan simulasi realistik termasuk kes situasi geometri yang kompleks. Keputusan simulasi menunjukkan bahawa penyebaran klorin kelihatan seperti cecair apabila ia telah mengalir pada mana-mana permukaan. Selain itu, didapati bahawa ketumpatan klorin secara beransur-ansur meningkat kepada paras tanah. Secara khususnya, hasil kajian ini menunjukkan pencampuran keputusan bagi corak penyebaran klorin bergantung pada perbezaan tahap suhu, jumlah angin, dan arah angin. Kajian ini menggambarkan terdapat hubungan antara suhu dan serakan gas klorin. Bagi menyokong kenyataan ini, pada suhu 270K, 297K, dan 315K, penyebaran gas klorin adalah yang tertinggi pada suhu 315K, daripada 8×10^{-3}ppm untuk 1×10^{-2} ppm. Kajian ini juga menunjukkan kesan halaju angin ke atas penyebaran gas klorin pada suhu yang berbeza. Secara khusus, pada suhu 270K, penyebaran gas klorin adalah 0.001 – 0.595 ppm, 0 – 0.0005 ppm, dan 0 – 0.005 ppm dengan halaju angin dicatat pada jumlah 1m/s, 3m/s, dan 5m/s. Walau bagaimanapun, penyebaran gas klorin dengan kelajuan yang sama halaju angin tetap kekal, dalam julat 0 – 0.005 ppm Semua faktor-faktor ini didapati

mempunyai hubungan yang signifikan dengan penyebaran klorin dalam persekitaran dalaman. Kesan pengudaraan terhadap penyebaran klorin telah dianalisis dan keputusan tersebut didapati berbeza dengan simulasi halaju angin. Secara keseluruhan, kesan faktor-faktor alam sekitar terhadap pembebasan dan penyebaran klorin dalam ruangan tertutup telah dikaji dengan teliti.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science . The members of the Supervisory Committee were as follows:

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CHAPTER 1

INTRODUCTION

1.1 Introduction

One of the most significant current challenges in both the developing and developed countries is to protect the workers and the individuals who are employed in factories or reside near the industrial cities against toxic and dangerous substances, such as chlorine, dichlorodiphenyltrichloroethane (DDT), asbestos and so forth that are produced or used in various industries. Chlorine is a great antiseptic bleaching agent and it is solvent as well. Having two forms namely the liquid and gas, chlorine is a toxic material which brings about numerous hazards. In details, it can cause death or serious injuries if suitable safety measures are not taken, among which an appropriate room with ventilations, alarms, gas detectors, and other necessary equipment for keeping cylinders or tanks (Chlorine Safe Work Practices, 2006). In order to protect the people who have a direct contact with the chlorine equipment or live next to it, governments should be required to expand and perform safety, health, and environment instructions (OHSAS18001) in the industrial places. For instance, years ago in the morning of 14 July 2010, a chlorine leak incident was reported at Haji Bunder hazardous cargo warehouse in the Mumbai Port Trust (MPT), Sewri, affecting over 120 people in the neighborhood, including students, laborers, port workers and firefighters, of whom 70 were reported critical. This was observed to be a blatant case of ignorance and negligence as well as contraventions to the safety and environmental safeguards requirements under existing statues as well as non-maintenance of failsafe conditions at the site requisite for the chlorine storage (Sharma et al, 2010). If the chlorine tanks had been stored in accordance with the health, safety, and environment standards and the individuals had been cognized on chlorine leak gas in the short time, people would have never been killed in Mumbai.

Due to the extensive usage of chlorine in various industries along with increasing the risks of release gas in the spaces for the humans and environments, it is essential to conduct studies with the purpose of scrutinizing the chlorine release. In this research to examine the effects of natural factors on chlorine spread in indoor environments such as small storages. It is clear that various factors can be affected on dispersion of heavy gas in indoor environment such as wind velocity, temperatures and direction of wind.

1.2 Problem statement

Chlorine is toxic gas therefore, the Chlorine storage tanks should be located in separate clearly-defined areas that can be isolated in emergencies and need to be accessible for the emergency personnel. The chlorine storage areas should be protected by barriers or separated from the other processes or materials which might impose damage on the storage tanks (Chlorine Safe Work Practices, 2006). Indeed, in the current chlorine storages the alarm detectors are being used in order to protect them from the hazard of release (usually gas detectors) so that in case of any release, the detector will identify the chlorine particles from the indoor air, sending the alarm signals to the control center (Sun et al, 2004). There are cases of recorded events to

prove that the sensitivity of gas detectors can be affected by various factors such as low amount of the chlorine concentration, location of the detectors, defected power supply, high level of humidity, and so on (Stelling et al, 1999). According to the preceding statements, detectors are not appropriate to make a safe place for workers in the toxic gas storage and need to get more information about behavior of gases in different situations and will be investigated on parameters can be affected on chlorine dispersion in indoor environments.

The release of chlorine in the open area (Turner, 1994) or a big storage having good ventilations have been so far approved by some surveys (Siddiqui et al, 2012). In the most of the chlorine leakage in the open area, it is observed that the OHSAS 18000 instructions have not been included and the best description is the Mumbai Port disaster. Also, some of the small industries that utilize chlorine in their processes do not have appropriate ventilations or detectors and alarm systems.

According to the pervious paragraphs, investigate on repercussions of heavy gas dispersion in different situations are important point to reduce the damage of release it in indoor environment. Environmental factors, such as temperature and wind speed have direct relationship to spread dense gas. In this study, the effects of environmental factors on behavior of chlorine gas dispersion in the storage are investigated. In the previous work, researchers investigated the performance of ventilations in indoor environments. In these surveys the effects of environmental factors such as difference temperatures and wind velocity on chlorine dispersion in the storage were neglected.

Computational Fluid Dynamics allows the simulation of complex physical processes describing heat and mass transport phenomena with fully developed mathematical models. Specific models incorporated in CFD codes predict the turbulent mixing between gas molecules and air particles, in addition to cavity regions in the flow field (building wakes), which may result in entrapment of escaping gas at low heights for relatively long time with increased health effects (Sklavounos & Rigas, 2004). In this study, CFD shows the details of the gas spread in the storage with various parameters and helps researchers to forecast the behavior of chlorine dispersion in the room.

1.3 Scopes and Limitations

The case under investigation was a confined storage room, being used to store a chlorine storage tank. Chlorine was kept inside the tank at its vapor pressure and under room conditions. The intent was to simulate a leakage of chlorine from the tank with the aim of comparing the dispersion of chlorine in different conditions. The first limitation in this study was surveyed the effects of various temperatures in winter (270K), spring (297K) and summer (315K). Next limitation was surveyed the consequences of different wind velocity such as 1m/s, 3m/s and 5m/s in various temperatures in mention seasons on spread of chlorine in the open area.

1.4 Objectives

1. To simulate the dynamic of chlorine discharge from storage tank based on computational fluid dynamic (CFD)

2. To investigate chlorine distribution pattern in an indoor storage room with a closed, opened window and ventilated system.

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