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PASSIVE RFID-BASED CHEMICALS' STORAGE MANAGEMENT SYSTEM

ROSIAH OSMAN

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PASSIVE RFID-BASED CHEMICALS' STORAGE MANAGEMENT SYSTEM

By

ROSIAH OSMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the Requirements for the Degree of Master of Science

July 2014

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

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by

ROSIAH OSMAN

July 2014

Chair : Associate Professor Abd. Rahman Ramli, PhD

Faculty: Institute of Advanced Technology

The management of chemical inventory in laboratories is necessary for safety purpose as well as fulfilling regulatory compliance. As for academia laboratories, frequent inspections and data updating of chemicals storage are very crucial to prevent unforseen accidents to students and researchers. In most academia laboratories, management of chemicals are normally still being done manually which is very time consuming. As a result, the report data is not being updated and expired chemicals may accidentally being used. This research proposes UHF Gen2 Passive Tags Radio Frequency Identification (RFID) technology to be used in the chemical inventory management system to shorten the inventory process time. Laboratory experiments were done for chemical storage tracking on several RFID reading conditions such as various distances between the tags-reader and also orientation angle of the tags-reader. For distance less than 30 cm, the detection rate was 90% and above. The captured data was then exported to personal computer for further data processing and manipulating such as chemical tracking, quantity checking and producing alert notifications. Microsoft Excel Spreadsheet is used in recognizing the nearly expired chemicals through color code alert notice. Meanwhile, Global System for Mobile Communication (GSM) modem which provides mobile device connectivity between the database to remote application server system was connected through Open Data Base Connectivity (ODBC). JavaScript, PHP and MySQL programming languages were written to check on the expiration date of the chemicals as well as producing the alert notification status via Short Message System (SMS) in real time to the person-in-charge's handphone. The system was tested and the recipients received the notifications accordingly through their mobile phones which means that the result was successful. The proposed system has been implemented in chemical environment of academia laboratories only however it is applicable for other asset tracking environment for future use.

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Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

SISTEM PENGURUSAN PENYIMPANAN BAHAN KIMIA BERASASKAN RFID PASIF

Oleh

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Julai 2014

Pengerusi : Prof. Madya Abd. Rahman Ramli, PhD

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Pengurusan inventori kimia di semua makmal adalah penting bagi tujuan keselamatan serta memenuhi pematuhan perundangan. Bagi makmal akademik, pemeriksaan yang kerap dan pengemaskinian data bahan kimia adalah sangat penting untuk mengelakkan kemalangan yang tidak dijangka berlaku terhadap pelajar dan penyelidik. Dalam kebanyakan makmal akademik, pengurusan dan pemeriksaan bahan kimia masih dilakukan secara manual yang memakan masa yang panjang. Hasilnya, laporan data tidak dikemaskini mengakibatkan bahan kimia yang telah luput tarikh telah digunakan secara tidak sengaja. Kajian ini mencadangkan penggunaan teknologi *UHF Gen2 Passive Tags Radio Frequency Identification (RFID)* dalam pembangunan sistem pengurusan inventori kimia di laboratori yang telah dikenalpasti untuk memendekkan masa proses. Ujikaji makmal telah dijalankan ke atas pengesanan bacaan RFID dengan beberapa keadaan seperti pelbagai jarak antara tag-pengimbas dan juga sudut orientasi tag-pengimbas. Untuk jarak yang kurang daripada 30 cm, kadar pengesanan adalah 90% dan ke atas. Data terhasil kemudiannya dieksport ke komputer peribadi untuk pemprosesan dan manipulasi data selanjutnya seperti pengesanan kimia, pemeriksaan kuantiti dan pengeluaran amaran pemberitahuan. *Microsoft Excel Spreadsheet* digunakan dalam mengenalpasti bahan kimia hampir luput melalui notis amaran dengan kod berwarna. Sementara itu, modem Sistem Global untuk Komunikasi Mudah Alih (GSM) yang menyediakan sambungan peranti mudah alih di antara pangkalan data untuk sistem pelayan aplikasi jauh disambung melalui sambungan *Open Data Base Connectivity* (ODBC). Bahasa pengaturcaraan *JavaScript, PHP* dan *MySQL* ditulis untuk menyemak tarikh tamat tempoh bahan kimia serta mengeluarkan status pemberitahuan amaran melalui Sistem Pesanan Ringkas (SMS) dalam masa nyata kepada telefon bimbit pengguna berkenaan. Sistem ini telah diuji dan penerima menerima pemberitahuan sewajarnya melalui telefon bimbit mereka dan menunjukkan sistem ini berjaya dilaksanakan. Sistem yang dicadangkan ini telah dilaksanakan dalam persekitaran kimia makmal akademik sahaja bagaimanapun ia boleh digunakan untuk lain-lain persekitaran pengesanan aset untuk kegunaan masa depan.

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LIST OF ABBREVIATIONS

RFID	Radio Frequency Identification
RF	Radio Frequency
PPE	Personal Protective Equipment
GLP	Good Laboratory Practice
ISO	International Organisation of Standardization
OSHA	Occupational Safety and Health Act
NCR	Non-Conforming Reports
SMS	Short Message System
AMNL	Advanced Materials and Nanotechnology Laboratory
GIS	Geographic Information System
GPS	Global Positioning System
HF	High Frequency
ROI	Return on Investment
UHF	Ultra High Frequency
PC	Personal Computer
GSM	Global System for Mobile Communication
PDA	Personal Digital Assistant
EPC	Electronic Product Code
MMS	Multimedia Message System
ODBC	Open Data Base Connectivity
GUI	Graphical User Interface

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CHAPTER ONE

INTRODUCTION

1.1 Chemical Storage Management System

Chemicals are type of hazardous materials which are regularly used and stored in academia laboratories for performing teaching and research experiments. Chemicals exposure can be hazardous to humans due to chemical reaction to human skin and their vaporization into the air. Some chemicals are corrosive and must be properly handled. Normally, Personal Protective Equipment (PPE) such as hand gloves, lab coats and goggles have to be put on for safety and self protection during chemical operation in any chemical laboratories.

However the chemical storage must be managed systematically. Good Laboratory Practice (GLP) requires chemical inventory to be updated at least annually to comply with International Organisation of Standardization (ISO) regulatory and Occupational Safety and Health Act (OSHA) Hazardous Communication Standard. As suggested by Foster (2005) chemical storage must be managed systematically to ensure the chemicals are in adequate amount, to eliminate the unneeded chemicals and to provide more efficient use of laboratory's storage space. The quantity and expiration date should be monitored carefully to prevent outdated chemicals from being used.

Chemical storage management system is a tool that contains complete and accurate information about chemical metadata, storing, retrieving, tracking as well as producing reports. It is important for any academic institution to have or develop its own chemical inventory management system so that chemicals will be maintained systematically and inventory report will be easily produced.

The chemical inventory process is an important element in chemical storage management system. Quigley et al. (2012) mentioned that inventory accuracy can be used as a leading indicator to help identify chemical management problems and must be able to predict future events before they occur. The inventory process and the system itself must be easy to manage so that the person in charge can take proper action for any remedial task. Williams (2013) mentioned that an accurate chemical inventory is the foundation for overall chemical management initiatives. He suggested eight tips to be considered before starting an inventory. One of them is to centralize data across the facility and company and develop a routine inventory schedule perhaps annually. By developing and building an accurate chemical inventory, better decisions could be made to maximize worker safety, safeguard the community, reduce waste and cost, also ensure more timely and effective environmental compliance (Kraus, 2005).

Recent technologies and inventions play important role in todays living. A lot of modern softwares and devices are being created and invented to speed up any task as technologies emerged. Internet and wireless connection, Radio Frequency Identification (RFID), barcodes, knowledge-based information system, web-based

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server, Global System for Mobile Communication (GSM) modems are some examples of considerable choices which allow global interoperability and ubiquitous interaction between devices (Steinberg, 2009; Perumal, 2006) to serve the purpose.

One of the technologies that can be used to accelerate performing inventory process time is by using RFID. According to Stanzack (2007), RFID is a technology that use radio waves to automatically identify people, animal or objects. It is a wireless sensor technology which is based on the detection of electromagnetic signals (Domdouzis et. al., 2007), thus RFID reading can be done remotely. It does not require direct line of sight to transfer information because it is sent via radio waves. Thus no contact between chemicals and human skin is necessary and tracking of chemicals will be easier. Therefore integrating RFID technology and web based application is believed to be an added advantage in performing chemicals inventory process, developing chemical inventory, checking for missing chemicals as well as sending alert notification for expiring chemicals.

1.2 Problem Statement

The chemical inventory must be managed systematically for safety purpose as well as the regulatory compliance and standardization. However, the chemical inventory process in most academia laboratories are still being done manually. Other than putting on the personal protection equipment, the user has to hold the bottles one by one in order to read the printed data on the labels during inventory inspection. Thus, performing the inventory process manually is very time consuming. As mentioned by Gibbs (2005) the task is very challenging especially for diverse and decentralized laboratories in an organization. Thus inventory data in some laboratories on campus is not being updated regularly as required due to the tedious work and lack of ample time of the storekeeper. As a result, there are some chemicals with expired dates are still kept in the storage and accidentally being used. This shortcoming may cause accidents to happen. Besides it will result in non-conformity report to be issued during audit. It is found that this issue usually contributed most of non-conformance reports (NCRs) during ISO compliance and surveillance audits. For example in Compliance Audit Report done by Standards and Industrial Research Institute of Malaysia (SIRIM) towards Universiti Putra Malaysia (2009), both NCR reports were issued on this matter alone.

Only in recent years, several individual institutions have started using or deployed their own chemical inventory system. Some institutions acquire a commercial system and implement it on the campus. One example of these commercial products is Chemoventory by Chemoventory Inc, (Rooney, 2001). It is offered in two versions; standard and lite. 'Standard' version needs to be purchased whilst 'Lite' version is an open source web base but only with limited capabilities. Some other products come with full version with licence such as Chem Alert but very costly especially on the annually licence renewal.

With the help from recent technologies such as RFID and web base system, inventory checking process time will be reduced. An example of company using RFID technology in chemicals environment is CISPro (Gillespie, 2006). However the company used high frequency (HF) tags which have limited reading range that is

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less than one meter. Furthermore they only produced inventory system which integrates RFID for chemical tracking and quantity checking only.

Kali Laboratories, the fifth largest generic drug manufacturer in USA uses ICEGEIN RFID solution (ICEGEN Report, 2010) to enhance and control their work process and provide instant access to chemical information. They use fixed readers mounted on the wall nearby the laboratory doors. The reader will pick up the signal if a chemical container is passed through the door. With this kind of system quite a number of readers are required to be installed. A lot of monetary investment has to be made and this method is only suitable for big organizations.

Salim et al. (2012) have developed a framework of chemical inventory. It is found that this system produced visual alarm notification only and also focused on stock control.

Jabar et al. (2013) have integrated mobile and web application in ubiquitous environment Cloud to Device Messaging (C2DM) to provide notification alert in healthcare. However the system is limited to the availability of smartphone only. James (2013) has implemented Optical Character Recognition (OCR), iphone and barcode to check expiration date of food items, however the detection of expiry date by OCR scanning failed in most attempts.

Until now no research work has been reported about checking on the chemical expiration date and sending alert notification via short message system (SMS).

1.3 Research Objectives

In order to fill in these research gaps this project suggested that a chemical storage management system to be developed in an organization to enhance the inventory process performance and shorten the process time. The information system can be developed by their own using the existing system such as Microsoft Excel Spreadsheet or Microsoft Access Database with low monetary investment. This system must be easy to operate by all users or persons in charge. The system can then be integrated with web based system through internet connection. The persons do not have to perform the inventory checking on the expiration date manually since they will receive alert notification message about expiring chemicals via their mobile devices at any time of the day.

The main objective of this project is to implement RFID technology to perform the management of chemical storage system. This project uses Gen2 Ultra High Frequency (UHF) RFID technology to create chemical inventory database and perform the chemical tracking. It will focus on sending the alert message through short message system (SMS) when the system found that one particular chemical is going to expire. In this project UHF technology is used because it has longer reading range (more than one meter) compare to High Frequency (HF). This is to assure that all RFID tags applied on the chemical bottles kept on top the the shelves(overhead) can be read. The passive tags are chosen because of the lower cost compare to active tags.

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The objectives of this research are:

1. To develop database for chemicals inventory using Radio Frequency Identification (RFID) technology application.
2. To perform chemicals tracking and expiration date monitoring process and to verify the technical specifications of Gen2 Ultra High Frequency (UHF) RFID technology.
3. To design a remote based alert notification system for expiring chemicals through short message system (SMS).

Figure 1.1 illustrates the proposed Chemical Storage Management System which uses RFID application and wireless technology.

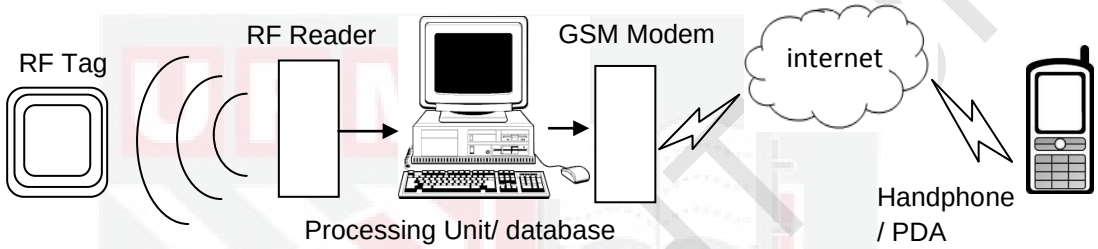

Figure 1.1. The Proposed Chemical Management System

1.4 Scope of the Project

This project focuses on maintenance of chemicals storage management system in a chemical laboratory environment even though the system can be applied to other inventory system as well. The experiment for this project was done in the former Advanced Materials and Nanotechnology Laboratory (AMNL1) and Functional Devices laboratory (FDL), Institute of Advanced Technology, Universiti Putra Malaysia. All chemicals used in this project were stored on the shelves in a cabinet in the lab.

UHF RFID scanner was used to read the passive tags which were fixed on the chemical bottles/containers. The parameters to be considered while taking the readings were the distance from the scanner and the tags, the placing of the tags on the bottles and also the orientation/arrangement of the bottles in the shelves. All data from the experiment were then transfered to a personal computer which operates in Windows based platform. WAMP was downloaded for algorithm development and programming languange was written in PHP and MySQL.

The first phase of the project focuses on the development of chemicals inventory with the integration of RFID application. The second phase focuses on chemicals storage monitoring including tracking chemicals for stock counting and producing alert notification display for expiring chemicals during maintenance work of the system. However the spreadsheet file will produce visual notification only where it cannot refresh the display page automatically. Therefore web based server method has to be developed as an alternative. The final phase focuses on development of algorithm for sending alert notification of expiring chemicals via SMS to the store keeper. All those three phases will cater the three objectives of the project.

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Some assumptions were taken into consideration such as all chemicals used in this project must have expiration dates stated on the bottles/containers. All the chemicals were properly arranged such that the tag on the chemical containers will be easily seen and must not be hidden for better RFID reading capabilities and finally all selected places/locations must have wireless network coverage.

1.5 Contribution

From the discussion of previous works, it is found that there are some drawbacks while implementing RFID in their system.

As been mentioned before, some providers used high frequency (HF) RFID in their system which has limited read range (up to one meter only) whereas in this project, Ultra High frequency (UHF) RFID which has better read range (up to 4.5 meter) is being used so the area coverage will be broader.

This project also proposed a cost saving system by using only one unit RFID reader with low cost passive tags affixed to the specific items. Thus it is suitable for most small and medium size organizations with budget constraints compared to company that uses quite a large number of fixed readers mounted on the walls nearby the doors.

Most projects in previous work focused on chemicals stock control. Salim et al. (2012) produced visual alarm notification only for out of stock chemicals. Some works have been done on the integration of mobile and web application in ubiquitous environment to provide notification alert. However it limited to the availability of smartphone thus produced compatibility issue. In my project, besides the display of catchy visual alarm notification by using color code, it also uses new algorithm for sending reliable short message system notification in real time to the user. GSM and ODBC integration provide wireless connection, SMS can be sent to any mobile phone with no compatibility issue.

Some works done on checking the expiration date of other items such as food items by implementing Optical Character Recognition (OCR), iphone and barcode, however the detection of expiry date by OCR scanning failed in most attempts. In terms of durability, barcodes are fragile and cannot work with dirt covering, easily torn and so on. In addition, only one barcode can be read at one time, thus more time is required to perform the process. In my project, RFID is used because it is more efficient, also time and energy saving.
The outcome of this project may help the storekeeper to manage the chemical inventory in a proper and simplified way using current technologies by integrating UHF RFID technology and wireless sensor network. The proposed system will help the store keeper to reduce effort and maintenance time to keep good record of the chemicals inventory. The result will give ideas how to fix the tags on the bottle as well as the arrangement of the bottles with affixed tags on the shelves to get the best RFID detection rate.

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By using RFID technology it will help the storekeeper to reduce time and effort required to perform inventory process since RFID reader can retrieve all data stored in a program simultaneously at one time. The developed information system can be controlled from data processing unit for easy and fast transaction. All data will be updated easily, the time and date will be updated automatically using web-based server's time.

The designed of remote based notification system will alert and notify the store keeper the expiring chemicals from inventory data at any time even after office hours or during public holidays by sending SMS to the handphone or any mobile device of the storekeeper. The algorithm for alerting the store keeper via SMS is the novelty of this project. It may help in the research gap of implementing the alert notification of nearly expired chemicals in real-time via SMS.

1.6 Thesis Organization

Chapter One begins with introduction to chemicals as hazardous materials, chemical storage management system and the advantage of developing or deploying own chemical inventory in one's institution. It also discusses on the use of emerging technologies that can be applied to help in reducing inventory process time as well as sending alert notification. The research objectives are stated, the problem statement in current situation and the contribution of the project are also given.

Chapter Two explains briefly on RFID history, types of tags, RFID system, RFID standard and protocols as well as the wireless system such as internet and web base. This chapter also discusses about chemical inventory software available in current market and some highlights on companies that use integration of RFID with their inventory system and their limitations and constraint. It also discusses on challenges in implementing RFID in chemical environment.

Chapter Three presents the detail of methodology and design concept of the proposed project that uses RFID, GSM modem and internet connection facilities to enhance the simplicity of managing the inventory system. It also explains on hardware and software used in the project. The development of information system for data manipulation such as chemical quantity checking and chemical expiration date is being explained in detail in this chapter as well as the development of wireless system integration for alert system.

Chapter Four reports the experimental results of design and implementation of RFID in chemical lab environment, also the percentage of RFID detection on tag samples. This chapter also discusses on the pros and cons of the two methods of information system development; Microsoft Excel Spreadsheet and Web-based Scripting Language. The problems faced during establishment of wireless system between the terminal and mobile device using GSM modem, the programming for sending the alert notification, system testing and performance are also being discussed in this chapter.

Chapter Five concludes the thesis by summarizing the result and conclusion, stating the contributions and identifying future research direction.

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