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RFID-Enabled Web-Based Interface for a Chemical Storage Management System

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ABSTRACT

The management of a chemical inventory is necessary for safety purposes as well as for fulfilling regulatory compliance. In most academic laboratories, the management of chemicals is still being done manually, which is time-consuming. As a result, data are not updated and expired chemicals are unintentionally used. This research proposes that UHF Class 1 Gen 2 Radio Frequency Identification (RFID) technology be used in the development of a chemical inventory information system to ease chemical tracking as well as to shorten the inventory process time. An information system integrating RFID data and a web-based rule identification interface was developed. WAMP 2.2.17, PHP 5.3.5 and MySQL 5.5.8 were downloaded and a programming language was written to check the expiration date of the chemicals as well as to produce alert notification status. Wireless technology through GSM modem helped in producing alert messages using the Short Message System (SMS) of the nearly expired chemicals to the handphone of the person in charge in real time.

Keywords: Chemical inventory, chemical management system, Radio Frequency Identification (RFID) Technology, information system, web-based interface

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INTRODUCTION

The chemical inventory process is essential in the chemical storage management system. The storage must be managed systematically for safety purposes as well as for regulatory compliance and standardisation. A good inventory system contains complete information about storing, tracking and

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reporting and must be easy to manage so that the person in charge can take the necessary action for remedial tasks as and when needed. It is important for an academic institution to have or develop its own chemical inventory management system so that its chemicals inventory annual report can be easily produced. By developing and building an accurate chemical inventory system, better decisions can be made to maximise worker safety, safeguard the community, reduce waste and cost and also ensure more timely and effective environmental compliance (Kraus, 2005).

Chemicals are one type of hazardous material which are regularly used and stored in the laboratories of academic institutions. 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 when chemicals are used.

On the other hand, Good Laboratory Practice (GLP) requires the chemical inventory to be updated at least once annually. In addition, it is essential for a proper chemical inventory process to be deployed in laboratories that complies with the International Organisation of Standardization (ISO) regulations and Occupational Safety and Health Act (OSHA) Hazardous Communication Standard (Vijayan, 2005). The proper management of the system will prevent accidents while handling chemicals as well as ensure accurate research results. Foster (2005) suggests that storage of these chemicals must be managed systematically and the quantity and expiration date should be monitored carefully to ensure chemicals are stored in safe amounts, to prevent expired chemicals from being used, to prevent a stockpile of unneeded chemicals and also to provide more efficient use of laboratory storage space.

However, performing the inventory process manually is very time-consuming as the printed data on the labels of containers have to be read and inspected one by one. As mentioned by Gibbs (2005), the task is becoming more challenging for diverse and decentralised laboratories in an organisation. Indeed, the inventory process in some laboratories in academic institutions is not being done regularly due to the tedious work involved and lack of time, resulting on non-conformity reports being issued during compliance and surveillance audits. In some instances, chemicals with expired shelf life have been found or were accidentally used.

In the era of globalisation, new technologies have been invented and developed to ease task performance. It is a good practice to develop an inventory system that can enhance the performance of research labs and shorten the time needed for inventory taking. A knowledge-based information system, the Internet and wireless connection, a web server, Global System for Mobile Communication (GSM) modems, Short Message Service (SMS), Radio Frequency Identification (RFID) and barcodes are some of the considerable choices available that allow global interoperability and ubiquitous interaction between devices (Steinberg, 2009) that can aid in efficient inventory-taking. A web server consists of a computer connected to the Internet (typically with an allocated static IP address) and the necessary software (Grout *et al.,* 2012). In recent years, SMS has become the first choice method for reaching audiences (Ismail, 2013).

RFID is wireless sensor technology that is based on the detection of electromagnetic signals (Domdouzis *et al.,* 2007), thus RFID reading can be done remotely. It does not require a direct line of sight to transfer information because it is sent via radio waves. No contact between chemicals and human skin is necessary, thus tracking of chemicals is easier. Therefore RFID technology is believed to be an added advantage in performing the chemical inventory process.

Existing Chemical Inventory Systems

Nowadays, several individual institutions have started using or have deployed their own chemical inventory system. Some acquire a commercial system and implement it while others develope their own system based on their requirements. With such initiatives, the chemical inventory process is becoming top prority in most organisations to ensure safety and compliance.

Williams (2013) mentions that an accurate chemical inventory is the foundation for overall chemical management initiatives. He suggests eight tips to be considered before starting an inventory. Inventory accuracy can be used as the leading indicator, which will help one identify root causes and develop corrective actions for maintaining a safe, reliable and accurate system (Quigley *et al.,* 2012).

Rooney (2001) summarised a few examples and features of chemical inventory software available in the market such as Chemoventory, CISPro by ChemSW, Chemtracker by Stanford University, Hazmin by Logical Technology Inc., EMAX by EMAX Solution, SMART by MDL Information Systems, ChIM by Ventere and some others as shown in Table 1. Some of these products are open-source-web-based but with limited capabilities while others come as full versions with licence but cost some amount of money. Gibbs (2005) reports that in 2005 Stanford University had developed a web-based application for chemical inventory information management for non-profit organisations through consortium members.

TABLE 1: Summary of Existing Chemical Inventory Software

Inventory Name	Company	Features
Chemoventory	ChemoventoryInc, CA, USA	Two versions: Standard and Lite. Requires open source PHP web server and MySQL database
CISPro	ChemSWInc, CA, USA	Can be implemented with wireless palm top scanner. Can scan chemicals anywhere in a facility and uplink the info to the database using wireless network
Chemtracker	Chemtracker Consortium/ Stanford University	Web-based application, accessible to other non-profit organisations through consortium membership
Chem Alert	Local Gov. Corporate Services Australia	Annual Licence
Hazmin	Logical Technology Inc., IL, USA	Browser-based access, one database for multisite reports
ESSIHS	HIS Inc, Colorado, AZ, USA	Tracks locations and amounts of hazardous materials on site
EMAX	EMAX Solution/SciQuest	Specialised in chemical e-business, relates to the pharmaceutical marketplace
OARDC	Ohio State University	Web-based, managed by location of room

Integrating Chemical Inventory Software with RFID

Eventhough an institution might have already built or purchased chemical inventory software, it is essential for the institution to conduct regular inspections on the chemicals. Besides the tedious work, the inventory process must be performed regularly to ensure that the chemicals are in a proper state and condition.

Currently, RFID technology is being used for chemical identification and location monitoring (Wang *et al.,* 2008). RFID is a wireless sensor technology that is based on the detection of electromagnetic signals to automatically identify people, animal or objects. A typical RFID system consists of three components: a transceiver/reader, an antenna and a transponder (RF tag), which is electronically programmed with unique information (Stanczak, 2007). If an RFID passive tag is found in the electromagnetic zone that is produced by the antenna, the tag detects the activation signal of the reader. There are two main categories of RFID systems: passive and active tags. Chien and Chen (2007) mention that RFID devices with power supply that actively transmit to a reader are known as active tags and un-powered tags that are triggered by a reader are called passive tags. RFID works in different frequencies depending on its use. RFID technology is being used worldwide in diversified applications such as supply chains, asset tracking, transportation, libraries, animal tagging, e-passport and others (Angeles, 2005). Asset tracking enables the user to track asset locations and monitor asset usage status in real time by using a mobile wireless sensor attached to each asset (Dickman *et al.,* 2007).

There are two RF technologies currently available in the market for item level tagging. The high-frequency (HF) system, which operates on 13.56 MHz frequency, has long been believed to be the best system (Potyrailo *et al*, 2007). Previously, Ultra High Frequency (UHF), which operates on 858-960 MHz, did not work that well for item level tagging. However, with current technologies, the manufacturer of UHF has been able to create 'Near Field UHF', which has similar performance capabilities as HF tags (Fletcher, 2010). Roberti (2006) mentions that the maximum reading range for HF is approximately 3 feet whilst for UHF it is approximately 30 feet or 10 metres. Kelly (2005) reports that in comparison to barcode or magnetic strip technology, RFID device does not need to be positioned precisely relative to the scanner to read the data. Furthermore, RFID tags are able to hold more information. With a response time of less than 100 ms, RFID readers can read many tags virtually instantaneously (Roberts, 2006). Since RFID readers can retrieve all data stored in pre-programmed tags in a split second, using them helps to reduce the time and effort required by the storekeeper to conduct the regular inspection process and update the inventory data.

Many suppliers use RFID together with Geographic Information System (GIS) and Global Positioning System (GPS) to track the movement of chemical barrels or drums between the warehouse and the manufacturing facilities. Only in recent years some efforts are being done to integrate RFID and the chemical inventory management system on a smaller scale such as in one particular institution or academic laboratory.

Gillespie (2006) reports that ChemSW. Inc. in California has launched CISProMobile, the integration of high frequency (HF) RFID solution with its chemical inventory system, CisPro Inventory Management System. A handheld software client allows CISProMobile users to

enter inventory data into a Windows-compatible handheld device. However, it is known that the HF system has limited read range capabilities.

The technical group of Kali Laboratories (2010) report that they use the ICEGEIN RFID solution to enhance and control their work process and provide instant access to chemical information. They use fixed readers mounted on a wall near the laboratory doors. The reader picks up the signal if a chemical container is moved through the door. With this kind of system quite a number of readers are required to be installed. A lot of investment has to be made, and this method is only suitable for big organisations.

To deploy a system, one institution has to decide which technology best suits its need. All decisions depend on the institution's need, arrangement of its chemical lab facilities and its financial potential.

MATERIALS AND METHOD

This research proposes the use of a type of RFID Ultra High Frequency system (UHF) to perform the task of chemical tracking in one of the laboratories in Universiti Putra Malaysia. Figure 1 illustrates the proposed Chemical Storage Management System that uses RFID application and wireless technology.

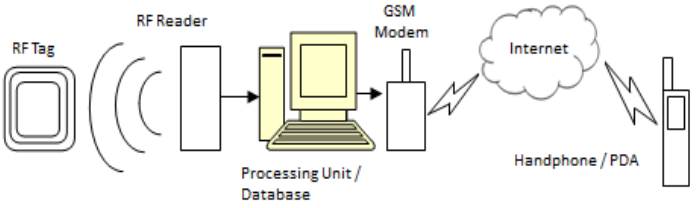

Fig.1: The Proposed Chemical Management System

In the first phase of this project, an information system for chemical tracking is developed using Radio Frequency Identification (RFID) technology. First, unique identification data is programmed into the chip in each RF tag. The pre-programmed tags are then tagged to each bottle of chemicals. The reader then decodes the data, which are encoded in the integrated circuit of the tag.

The next phase is to develop the chemical information system from the data imported from the RFID readings. All related data from the RFID reader can be transferred to any computer system for processing. The additional data is entered in the database such as Chemical Name, Manufacture, Amount, Location, Room Number, Expiry Date, Person in Charge and Contact Number. The information system is also used for monitoring and analysing the utilisation of chemicals in an identified laboratory.

In the final phase, a knowledge-based rule identification interface supporting the RFID and wireless sensor network is developed for the notification of nearly-expired chemicals through Short Message System (SMS) to the storekeeper in charge. The identification interface is developed using PHP and MySQL in a Server. The Server is connected to a GSM Modem so that data of the triggering system can be sent to personal mobile devices such as a handphone or PDA monitored by the store keeper in real time.

Hardware

The proposed RFID system structure consists of UHF RFID transponder (UHF passive tags), interrogator with antenna (UHF reader) and a middleware (embedded in a computer). The wireless system integration is between a computer and a GSM Modem. The specifications for each device used in this project are as follows:

RFID Tags

In this project, UPM RaflatacDogBone passive tags were used because of the efficiency, reliability and low cost. They operated on Global 860-960 MHz frequency and EPC Class 1 Gen 2 Protocol. They consisted of up to 240-bit EPC memory including 32-bit unique serial number. They were of adhesive type with an antenna size of 93 x 23 mm (3.7 x 0.9 inch).

RFID Mobile Reader/Scanner

The UHF Gen2 Mobile Reader (MUHF H300) used in this project was a UHF scanner device with Bluetooth connectivity to a Personal Digital Assistance (PDA). It operated on the frequency range of 902 -928 MHz band. It used EPC Class 1 Gen 2 Tag Air Interfaces.

GSM Modem

This project used SMS Gateway Development kit (Q24 Modem) for the modem as the interfacing device. Connecting a GSM modem to a computer allows the computer to communicate over the mobile network by sending and receiving Short Message System (SMS) and Multimedia Message System (MMS) messages. The SMS Engine is a Windows application that sends and receives SMS messages. This SMS Engine uses the MS Access Database, namely "SMSEngine5.mdb", to store incoming SMS messages and to check if there are any pending SMS messages to be sent out. The operator only needs to insert the record into the database to send out SMS messages and then retrieve the record from the database to read received SMS messages.

The Software

The operation software, namely "RFID Asset Tagging", is installed in the Personal Digital Assistance (PDA) database. In this project, the information captured was kept in a local database and could be exported to other computers through a .csv file through USB connection. The software was built on .Net Compact Framework 3.5 in Windows CE operating system.

Asset Registering

In the proposed system, firstly, all the passive tags have to be registered. Each chemical tag must be registered according to the pre-programmed unique serial number (tag id number) as the fixed identifier. Chemical information such as the chemical name and location or any other information is then added in the specified fields accordingly and saved in the integrated chip inside the tag. Then, the tags are affixed to chemical containers or bottles in a specified

location or laboratory accordingly. In this project, this process was repeated until all the chemical containers were tagged.

Assets Scanning

One of the essential steps in the inventory process is asset tracking, which in this case, is chemical tracking. It is important to update current lists of chemicals that are in stock. Results from the process will provide information of chemicals that are out of place or missing. Fig. 2 shows the scanning process of RFID tags in this project with the data then being transferred to a computer for further processing.

Fig.2: Process of Scanning/Transferring RFID Data into Processing Unit

To start the scanning process, the reader is placed near the containers with affixed pre-programmed tags. In this project, during the scanning process, the reader scanned and decoded the data which was encoded in the integrated circuit chip of the nearby tags randomly. The programme was written such that the tag numbers would be sorted in ascending order after the "stop" button was pressed. The unique serial number of the tags and pre-programmed information were displayed on the PDA screen in ascending order for easy checking. Missing tag numbers in the list indicated that those particular chemicals were out of place as shown in Figure 3. This information could be exported to a computer or any processing unit for further processing.

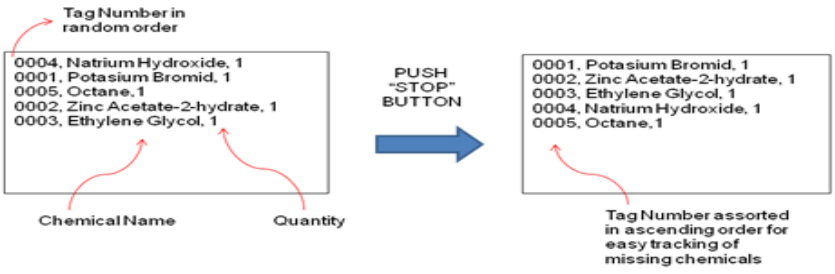

Fig.3: Mechanism of Chemical Tracking

Development of Information System for Chemical Expiration Alert Status

In this project, the results of the scanning were transferred to a computer in a spreadsheet file (.csv) and then saved as an Excel file (.xls or .xlsx). From this data, an information system or complete database was created for further data manipulation. More information regarding particular chemicals such as Manufacturer, Quantity, Location, Expiry Date, Person in Charge, Contact Number, MSDS and so on could be added and tabulated according to person in charge preferences. Figure 4 illustrates the development of a wireless system.

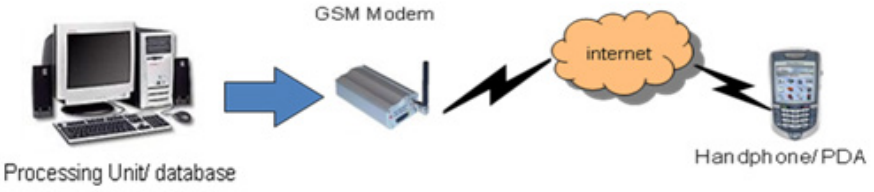

Fig.4: Wireless System Development

In this project, this information system or database was then uploaded to a server and could be accessed by everyone through Internet connection with a specified address. However, only identified moderators with a specified password acted as administrator. Thus, any changes made in the database could be seen by the other users from their locations as the devices supported the wireless Internet application. In general, it is advisable to convert the spreadsheet from Excel (.xls or .xlsx) to Access (.mdb). The database is more flexible and easily upgraded in .mdb rather than .xls form. As long as the tag number is retained as identifier, all the data can be added and transferred easily and linked to the host through Open Data Base Connectivity (ODBC).

In general, once the database has been developed, the status of each chemical has to be determined by checking the expiration date. In this research, the alert status was printed out if a chemical was going to expire within a specific number of days (for example, 10 days) to notify the user to take necessary action. In order to send the alert message about nearly-expired chemicals to the user, a calculation of the difference between today's date and expiration date of the chemicals has to be made.

In this research, the chemical inventory system was produced using web-based scripting languages such as JavaScript or PHP Hypertext Preprocessor (PHP) and MySQL database. It is easier to refresh the page automatically using PHP since it works in a web-based environment. The time in the programme is compared to the time and date on the server. The programme for a display running clock in this project was written in PHP.

The following is the process in general. Firstly, a web server such as WAMP (for Windows-based) has to be downloaded. The PC is then upgraded to become a local-host server. In this project, WAMP 2.2.17 was downloaded since it is Windows-based. After that, a programme is written to read or extract data from the access database and to display the information in a table using PHP scripting language; the file name is then saved to index.php and kept in a

folder in the "www.directory". The "local host" is then clicked and the programme is prompted to go to the Wampserver homepage and open the folder with the saved file name. The result is then displayed.

The third phase of the project is to send the alert message to the storekeeper's handphone if any chemical is going to expire at a certain time. The system will read the "status" from the database, compare the date and send an alert through the Internet or a wireless connection. Therefore, a GSM Modem has to be linked to the server using ODBC again. A GSM modem provides an interface that allows applications such as send/receive messages over the modem interface. It is a connection that is created to define a connection between a computer and a database stored on another system.

RESULTS AND DISCUSSION

In this research data of chemicals were taken from one of the laboratories in the Institute of Advanced Technology, namely Advanced Materials and Nanotechnology Laboratory (AMNL1). The chemicals were kept in seven separate shelves or compartments namely A1, A2, B1, B2, C1, C2 and D2 respectively. The chemical containers were made of various types such as plastic, glass and metal and were of different sizes and shapes. The list of all the chemicals involved in this research is shown in Table 2.

TABLE 2: List of Chemicals Tracked in this Research

Tag Id	Name of Chemicals	Location	Tag Id	Name of Chemicals	Location
21	Zinc Oxide 99.7%	A1 AMNL1	53	Nickel Powder 99.8%	B1 AMNL1
22	Zinc Oxide 99.7%(2)	A1 AMNL1	55	Strontium Nitrate	B1 AMNL1
23	Zinc Acetate Dihydrate	A1 AMNL1	56	Silica Gel (Lab Reagent)	B1 AMNL1
27	Zinc Oxide 99.9%	A1 AMNL1	57	Silica Gel (Bendisen)	B1 AMNL1
30	Sodium Hydroxide-Merck	A2 AMNL1	59	Nickel Powder 99.8% (2)	B1 AMNL1
31	Sodium Hydroxide	A2 AMNL1	60	Nickel (ll) Oxide 99+%	B1 AMNL1
32	Sodium Hydroxide(2)	A2 AMNL1	61	Zinn(IV)-oxidreinst	C1 AMNL1
34	Nickel Powder 99.5%	B1 AMNL1	62	Nickel(ll) Oxide 99.8%	C1 AMNL1
35	Titanium (IV) Oxide	B2 AMNL1	63	Cobalt (II) Chloride	C1 AMNL1
36	Aluminium Nitrate Nanohydrate	B2 AMNL1	64	Polyvinyl Alcohol 98-99%	C1 AMNL1
37	Bismuth (lll) Nitrate	B2 AMNL1	65	Poly(vinylidene fluoride)	C1 AMNL1
38	Bismuth (lll) Nitrate (2)	B2 AMNL1	66	Citric Acid	C1 AMNL1
39	Potassium Permanganate	B2 AMNL1	67	Glycine	C1 AMNL1
40	Iron (lll) Nitrate Nanohydrate 98+	B2 AMNL1	68	Copper (ll) Sulfate-5-hydrate	C1 AMNL1

TABLE 2: (Continue)

41	Nickel (ll) Nitrate	B2 AMNL1	69	Iron (ll,lll) Oxide 99.9%	C1 AMNL1
42	Nickel (ll) Nitrate (2)	B2 AMNL1	70	Barium Chloride Dihydrate	C1 AMNL1
43	Barium Peroxide 95%	B2 AMNL1	201	Graphite	C2 AMNL1
44	Iron (III) Chloride 6-hydrate	B2 AMNL1	202	Graphite(2)	C2 AMNL1
46	Maleic Acid	B2 AMNL1	203	Graphite(3)	C2 AMNL1
47	Yttrium (lll) Oxide	B2 AMNL1	204	Carbon(powder)	C2 AMNL1
48	Zinc Nitrate 6-hydrate (Hmbg)	B2 AMNL1	83	Iron (lll) Oxide 99.5% (metal)	D2 AMNL1
49	Zinc Nitrate 6-hydrate (BODI)	B2 AMNL1	84	Strontium Carbonate, 99%	D2 AMNL1
50	Cyclopentanone	B1 AMNL1	85	Bismuth(III) Oxide, 99.90%	D2 AMNL1
51	Copper (ll) Nitrate Trihydrate	B1 AMNL1	86	Strontium Acetate	D2 AMNL1
52	Cobalt Powder	B1 AMNL1	87	Calcium Acetate Monohydrate, 98%	D2 AMNL1

Chemical Registering and Tracking

As mentioned before, this system used UHF RFID passive tags. A total number of 50 samples (passive tags) were used and pre-programmed with each chemical's name and location according to the tag number. Each tag was then affixed to the back of each bottle. The bottles were placed on the shelves. Using MUHF H300 UHF Gen2 Mobile Reader, the tags were scanned to check the location of the bottles. The output displayed the missing chemicals, if any.

Information System Development

In this project two methods of developing the information system were considered. The first method was Microsoft Excel Spreadsheet. However, Excel cannot refresh a page on its own; this has to be done by an operator. Therefore, the date and time cannot be compared automatically in real time. To overcome this problem, a scripting language had to be used. JavaScript was chosen at first. In JavaScript, refreshing the page required the use of "meta equiv", and this was not compatible with the display running clock. So a second alternative, HTML, was tested. In this programme, a meta refresh tag or meta redirect tool is used for reloading and redirecting web pages. The meta tag in this programme is found within the <head> of the HTML document. When a page is refreshed, the syntax looks like this:

<meta http-equiv="refresh" content="600">

where, 'http-equiv="refresh"' is the attribute that informs the browser that this meta tag is sending a HTTP command rather than a standard meta tag. Refresh is an actual HTTP

header used by the web server. It tells the server that the page is going to be reloaded or sent somewhere else whilst 'content="600"' is the amount of time in seconds for the browser to reload the current page.

However, Meta refresh tags have some drawbacks. Meta refresh redirects have been used by spammers to fool search engines. So, search engines remove those sites from their database. If a lot of Meta refresh tags are being used to redirect pages, the search engines may decide the site is spam and delete it from their index.

PHP scripting language was chosen for consideration next. In PHP, to refresh a page, the function "header" is chosen. This worked fine with the display running clock.

An example of the programme is shown below:

```
<?php
// this refreshes current page after 5 seconds.
header( "refresh:5;" );
 ?>
<?php
```

Another problem arose when calculating and comparing two dates. If a direct date feature was used, the output sometimes gave the wrong answer. To overcome this problem, the "strtotime" function had to be used. It is a function that changes "date format" to "string format" for easy subtraction between the two dates. The function "strtotime" will parse about any English textual date time description into a Unix timestamp (the number of seconds since January 1, 1970 00:00:00 GMT). All dates are calculated in milliseconds since that date, with a day containing 86,400,000 milliseconds. An example of the programme using "strtotime" is shown below:

```
$today = strtotime($todays_date);
$expiration_date = strtotime($exp_date);
if ($expiration_date> $today) {
            $valid = "yes";
           } else {
$valid = "no";
}
```

During this phase, a complete information system or database should be fully developed. The output will result in easy inventory checking as well as producing an inventory report.

Development of Alert Notification Message via SMS

The final phase of the project was to send the alert notification notice via SMS to the person in charge for necessary action to be taken. A programme was written in Javascript, PHP and MySQL to print the header, current date and time at the top of the output display. This enabled

it to read the data from the Access file and to print out the output in a new table form. Date comparison between the current date and the expiration date was done to print out the "status" of each chemical. If the status was "alert", it would read the phone number of the person in charge and send the SMS accordingly. The flowchart of the programme and the system interface are shown in Fig.5 and Fig.6 respectively.

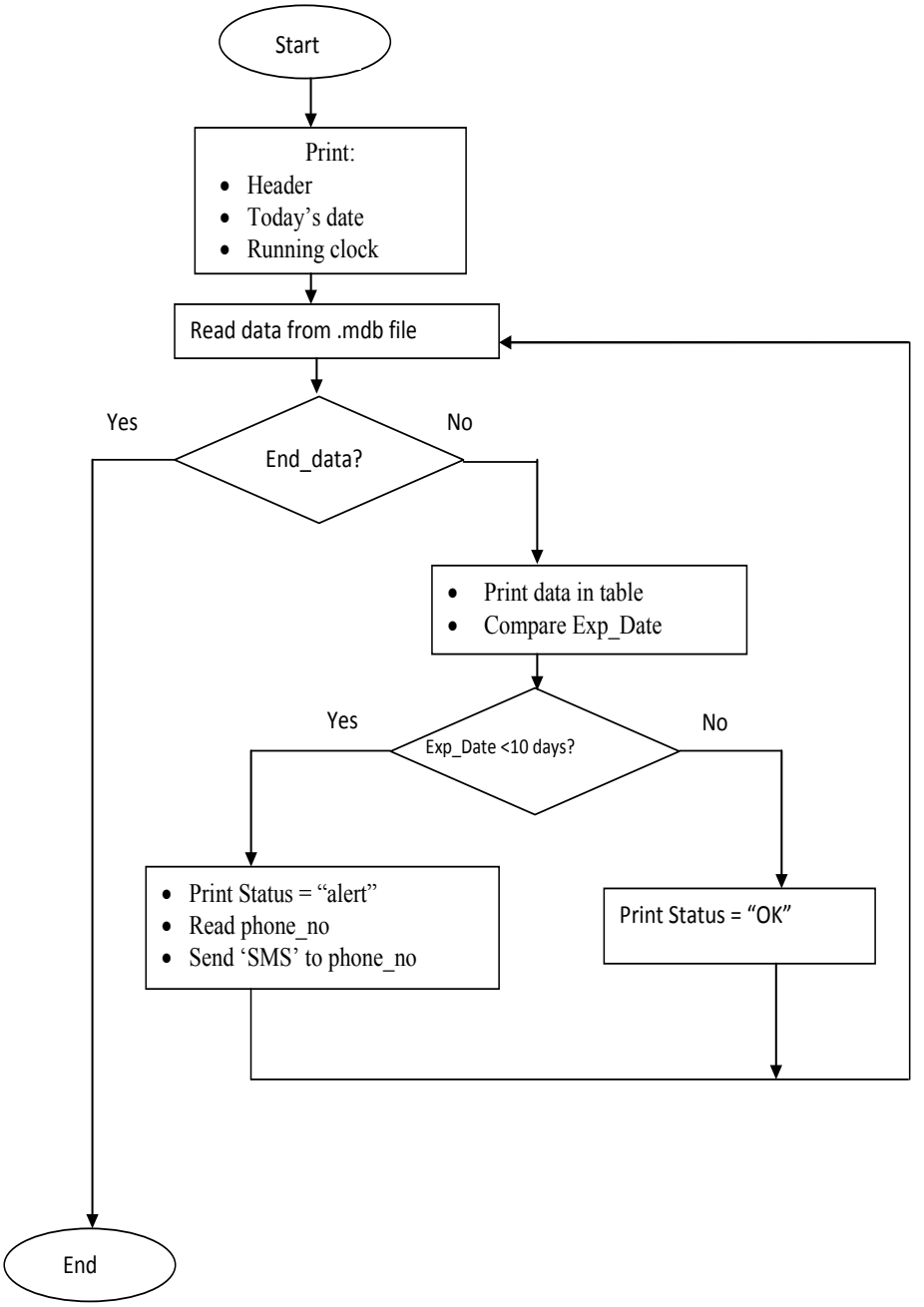

Fig.5: Flowchart of the Programme

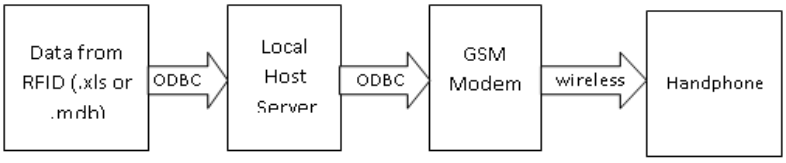

Fig.6: System Interface

The basic programme for sending SMS messages as shown below was suggested by MOBITEK System Sdn. Bhd. (2007):

```
<?php

//establish connection to Access database via ODBC
    $conn = odbc_connect('SMSEngine3','','');
    if (!$conn)
            {exit("Connection Failed: " . $conn);}

//queue outgoing SMS into Outbox table
$sql="INSERT INTO Outbox (Message, Mobile,
DateTimeQueue, SentStatus) VALUES
('$_POST[Message]','$_POST[Mobile]',date(),'P')";
$rs=odbc_exec($conn, $sql);

echo "Your message - '" ." ". $_REQUEST["Message"] ." ".
"' to this phone number - " ." ". $_REQUEST["Mobile"] ." ".
"is being queued. It will be send out in a moment.";
 //close connection to database
odbc_close($conn);
?>
```

With the many drawbacks taken care of, the example output of the information system is shown in Fig. 7, whilst Fig. 8 shows an example of outgoing SMS messages sent to the respective person in charge.

CONCLUSION

In this project, an information system for chemical tracking was developed using UHF Radio Frequency Identification (RFID) technology application. UHF was chosen because it provides a longer read range (up to one hundred metre) compared to HF technology, which is normally used by several companies. The information system that was developed interfaced with the exported RFID data for chemical tracking as well as for providing expiration date alert notifications. In the last phase, the remote-based alert system was developed through a wireless connection to send alert notifications to the respective persons-in-charge.

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Chemical Storage Management System
17:38:01
Wed Jan 11 2012 17:37:35 GMT+0800 (Malay Peninsula Standard Time)
Today's date is 2012-01-11

ChemId	Chemical Name	Chemical Expiry Date	Telephone Number	Chemical Location	Chemical Status
71	Manganous Sulfate Monohydrate powder (4)	2012-02-01 00:00:00	0192335363	B1 AMNL1	OKI
72	Manganous Sulfate Monohydrate powder (3)	2012-01-20 00:00:00	0192335363	B1 AMNL1	Alertl
73	Manganous Sulfate Monohydrate powder (2)	2012-10-16 00:00:00	0192335363	B1 AMNL1	OKI
74	Calcium Sulfate Hemihydrate(4)	2012-01-15 00:00:00	0192335363	B1 AMNL1	Alertl
75	Calcium Sulfate Hemihydrate(3)	2012-06-25 00:00:00	0192335363	B1 AMNL1	OKI
76	Calcium Sulfate Hemihydrate (2)	2012-04-15 00:00:00	0192335363	B1 AMNL1	OKI
77	Manganous Sulfate Monohydrate powder	2012-02-15 00:00:00	0192335363	B1 AMNL1	OKI
78	Calsium Sulfate Hemihydrate	2012-05-30 00:00:00	0192335363	B1 AMNL1	OKI
79	Molecular Sieve UOP type13x	2012-02-15 00:00:00	0192335363	B1 AMNL1	OKI
80	Magnesium Hydroxide xtra pure	2012-10-31 00:00:00	0192335363	B1 AMNL1	OKI
93	Sodium Sulfate Anhydrous	2012-12-01 00:00:00	0192335363	B2 AMNL1	OKI
94	Sodium Nitrate	2012-01-31 00:00:00	0192335363	B2 AMNL1	OKI
95	Sodium Nitrate	2012-02-15 00:00:00	0192335363	B2 AMNL1	OKI
96	Aluminium Nitrate Nanohydrate	2011-12-31 00:00:00	0192335363	B2 AMNL1	Alertl
97	Aluminium Nitrate 9-Hydrate	2012-02-20 00:00:00	0192335363	B2 AMNL1	OKI
98	Magnesium Nitrate 6-Hydrate	2012-03-31 00:00:00	0192335363	B2 AMNL1	OKI

Fig.7: Database Developed Using PHP Scripting Language

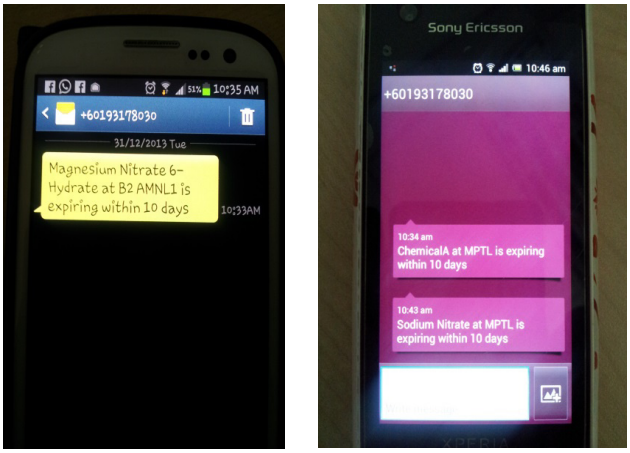

Fig.8: Alert Message Sent to the Person in Charge via SMS

As discussed previously, when using RFID technology, the tracking of chemicals in a lab becomes easy and the time taken to perform the inventory process is shortened as an RFID reader can retrieve all data stored in a programme simultaneously at the same time. No PPE and direct contact are required between the operator and the chemicals. The results of this project may help lab storekeepers to manage their chemical inventory in a proper and simplified way.

The system that was developed in this study is user-friendly. It can be used for tracking and monitoring chemicals as well. For instance, the data for expiration date from the database will be used for automated checking of nearly-expired chemicals. A wireless system was developed to trigger alert notifications to the storekeeper that certain chemicals were approaching their expiration dates. Thus, necessary remedial actions could be taken by the storekeeper to avoid unforeseen accidents. As has been explained above, using a web-server scripting language gives better results than using a spreadsheet method for date comparison as the expiration date can be easily calculated and compared to the server time, which is always running. The designed remote-based triggering system alerts and notifies the storekeeper if a chemical is approaching its expiration date. The message can be sent at any time (even after office hours or on public holidays) through Short Message System (SMS) to the handphone or any mobile device of the storekeeper.

For future work, the proposed system in this research can be applied in any other asset tracking besides chemicals.

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