APPLICATION OF INTELLIGENT SYSTEMS USING KNOWLEDGE HUB AND RFID TECHNOLOGY IN HEALTHCARE WASTE MANAGEMENT IN THE UK AND CHINA

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Abstract: The paper describes an intelligence system using a knowledge hub integrated Radio Frequency Identification (RFID) technology and digital imagery in the management of healthcare waste. This paper outlines the definition of healthcare waste both in the United Kingdom and China together with recent changes in the classification of this waste in the last few years with regard to clinical, laboratory testing and biological waste etc. Statistical information regarding the quantity of healthcare waste is outlined indicating predicted interpretation of future of waste production and the issues involved in traditional incineration and land fill operations. The paper describes a knowledge hub to provide monitoring, tracking and verification systems to assist government agents in providing audited records for anticipated legislation and public scrutiny. The system using rule-based intelligence systems linked to developed simulation software to provide logistical support via what- if scenarios.

1 INTRODUCTION

Healthcare waste or medical waste is mainly produced from clinical treatment, laboratory testing, biological culture and animal experiments (SEPA(China), 2003). It usually contains infectious materials, drugs and sharp objects such as syringes, which are undoubtedly harmful waste that contains a large number of viruses, bacteria and harmful chemical reagents. Healthcare wastes are some of the most dangerous wastes due to the high pollution risk that will damage both our health and the environment (DEFRA, 2006, Zhan and Jiang, 2008).

The disposal and treatment of healthcare waste is a concern of many countries' government initiatives and environmental pressure groups. Simply burning and then landfilling them as normal waste was historically the case, however this may spread harmful components for example from exhaust gas emissions and toxic metal substances that could cause serious pollutions (EA, 2008b, SEPA(China), 2003). In addition, uncontrolled and low-technology treatment of healthcare waste usually results in public unrest or panic and could cause a risk of epidemical disasters. Therefore, healthcare waste or medical waste is usually treated as hazardous waste in most countries. For example, it is listed on the "National Hazardous Waste List" of China since 1998 and also listed in the hazardous categories in UK (DEFRA, 2007, EC, 2000, SEPA(China), 2008).

The UK Department for Environment, Food and Rural Affairs (DEFRA) estimates that approximately 200,000 tonnes of healthcare waste is produced annually in the UK with 26,450 tonnes of this requiring high-temperature processing, and 173,600 tonnes suitable for alternative technology treatment (DEFRA, 2007). Controlling all the healthcare waste and sending them to the correct treatment facility is not an easy procedure for most countries, particularly in developing countries, such as China.

Healthcare waste is a significant environmental issue. However, due to the complex situation concerning the treatment requirements of different types of healthcare waste and also the large volume,

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there is a lack of a suitable system to track and audit the healthcare waste. The paper proposes the design of a system that can provide tracking, verification and auditing for the disposal of healthcare waste and can also provide logistic support.

This paper firstly explains the current situation of healthcare waste in UK and China, and discusses two cases that concern the knowledge management system or RFID applications. Finally, the proposed system is discussed, and its process and application are outlined.

2 HEALTHCARE WASTE IN UK AND CHINA

The UK and China have different definitions about the waste from healthcare services. However, they have similar concerns about the waste in that it needs to be treated and controlled circumspectly.

2.1 Current Situation in UK

Currently, 'Healthcare waste' is the official name in UK which replaced the term 'medical waste', 'clinical waste' and 'hospital waste' since the 'Hazardous Waste Regulations' came into force in July 2005 (DEFRA, 2007).

In the UK, not all healthcare waste is hazardous waste, in fact, about 33% of healthcare waste is normal waste, which is from hospital offices – most of them are paper or office supplies etc. The 'Hazardous Waste Regulation' describes healthcare waste as the waste generated in the healthcare environment, and the 'European Waste Catalogue' (EWC) gives a clear definition in C18 ('EWC 18') (EC, 2000). These wastes are divided into two categories which respectively concern human and animals, and contain 16 sub-categories. However, only 7 of them are hazardous, and their hazards are categorised by 'Hazardous Waste Regulation' in H9 (infectious), H6 (toxic), H7 (carcinogenic) and H11 (mutagenic) respectively (DEFRA, 2007).

The UK produces about 200,000 tonnes of healthcare waste annually. Currently, there is no detailed statistic to show healthcare waste in the entire UK (excludes Scotland and Northern Ireland) and only the hazardous healthcare waste statistics of England and Wales are available from the Environment Agency (EA). This indicates that the amount of waste in 2006 is 142,305 tonnes, and this accounts for almost 8 times more than in the year 2000 (only 16,456 tonnes) as shown in Figure 1. The data for 2005 is influenced by the new regulations on waste management system and new data gathering introduced in mid-2005 to coincide with the new Hazardous Waste Regulations (EA, 2008a), and this effects comparability of the information. However, Figure 1 does indicate that the waste tonnage has increased since 2003, and certainly, will continue to increase in future years with predicated population growth (Zhang et al., 2008).

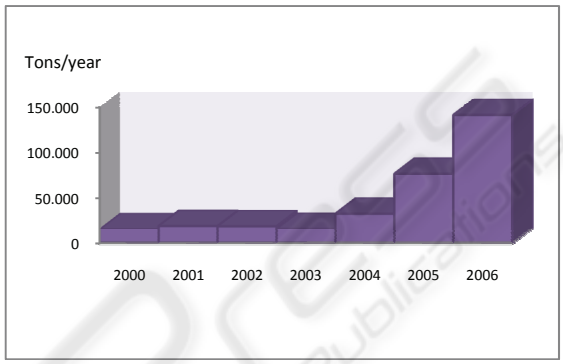

Figure 1: Trends of Healthcare Waste in England and Wales from 2000 to 2006, source: EA.

2.2 Current Situation in China

In China, this type of waste is normally referred to as 'medical waste', as there is no official translation. According to the Healthcare Waste Management Act published in June 2003, medical waste which is produced in healthcare organizations in medical-related activities were all treated as hazardous waste. In addition, the latest version of 'National Hazardous Waste List' of China published in June 2008, has categorized them into HW01 (Medical Waste), HW03(Waste Drug or Pharmaceuticals) and HW16(Sensitization Material Waste) (SEPA(China), 2003, SEPA(China), 2008).

Currently, there is no detailed data about medical waste in China. The only information published is by the 'National Development and Reform Commission of China' in 2006 which is based on information relating to the number of clinical beds. It indicates that China produces about 0.65 Mt medical waste annually and this will increase by 30,000 tonnes to 0.68 Mt in 2010 (NDRC, 2006). Although there is no accurate statistics, it is assumed that the increasing trends of waste will be similar to the UK.

2.3 Treatment Methods

Normally, the treatment methods for healthcare waste have two broad categories, high-temperature

and non-burn/low temperature alternative methods (DH, 2006). Some typical treatment methods are as follows:

- Incineration – Normally operated at 800-1000°C. It is widely used throughout the world, as is low cost, easy operation with low technology requirement. It can completely destroy the bacteria, viruses and most of chemical components, in addition, the volume and weight of treated waste will be reduced to approximately 20%. However, during the incineration, harmful gases may be produced and may give rise to emission into the atmosphere, particularly for low-technology incinerators (DH, 2006).
- Autoclave – This technology uses saturated steam in a vessel above atmospheric pressure to treat the material for disinfecting. It is a traditional method used in hospitals and is appropriate for healthcare wastes (Zhao et al., 2005).
- Microwave – The system uses electromagnetic waves to destroy the microbes by thermal energy (DH, 2006). Currently, most of the waste is required to be wet. This method is more complex than incineration technology (Zhao et al., 2005).

3 CASE REVIEW

The paper outlines two case studies relating to RFID application in medical waste and/or knowledge management technology.

Firstly, a trial of RFID applied to medical waste management in Japan in 2004. It was launched by 'Kuregha Environmental Engineering Ltd', which is a leading Japanese waste management company, and IBM who provided the technical support for the trial. They attached RFID tags to containers which are made from different materials such as cardboard and plastic to test them in IBM's RFID Solution Centre (IBM, 2004). IBM claimed, that this is the "first medical waste traceability testing" (IBM, 2004). This trial was launched in July 2004, and there is no further evidence as to whether this trial was successful. Taiwan has also launched a trail by its environment Protection Administration January 2006, and the latest reports have shown that the RFID read/write function is in the process of testing.

The second case the 'iKnow' system which was developed by a paediatric research group at British Columbia's Children's Hospital is a system 'used by clinicians at the hospital to develop knowledge rules for improving patient care in surgical operations'. A decision support system based on the rules in the operating room to assist anaesthesiologists in dealing with adverse events (Dunsmuir, 2007). Figure 2 shows the system, and also its functions. This is an expert system which uses rule-based reasoning mechanism. These rules allow reasoning from physiological and demographic data sources to provide clinical explanations and advice (Dunsmuir, 2007), and the knowledge base of the system can contain some other types of data such as pictures. This system is more complex than the previous cases outlined, as it includes reasoning and maintenance and decision making support functions.

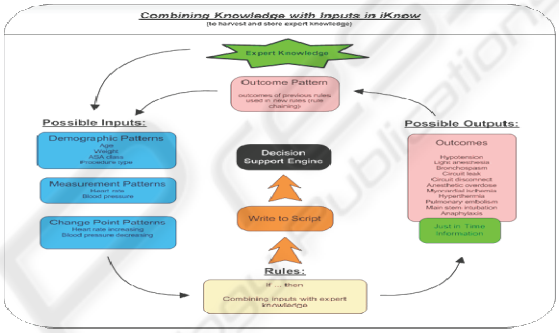

Figure 2: The iKnow System Work Process (Dunsmuir, 2007).

4 PROPOSED TRACKING AND AUDITING SOLUTION

Healthcare waste management and auditing to prevent illegal disposal is becoming an urgent environmental issue, particularly in developing countries. A proposed solution using a knowledge technology system (knowledge hub) to audit and track healthcare waste from its source to treatment facility and/ or disposal location is discussed.

The design will use RFID technology and digital imagery to integrate records including location, volume and weight, container movement, delivery tracking inventories and scheduling etc (Atkins et al., 2008). It works with the support of a knowledge management system which helps management to make decisions of scheduled logistics of waste to treatment plants and also provides the instruction to deal with the hazardous healthcare waste for the operating staff.

The design of the proposed system can be viewed from two aspects: firstly, providing the evidence of healthcare waste being sent to the

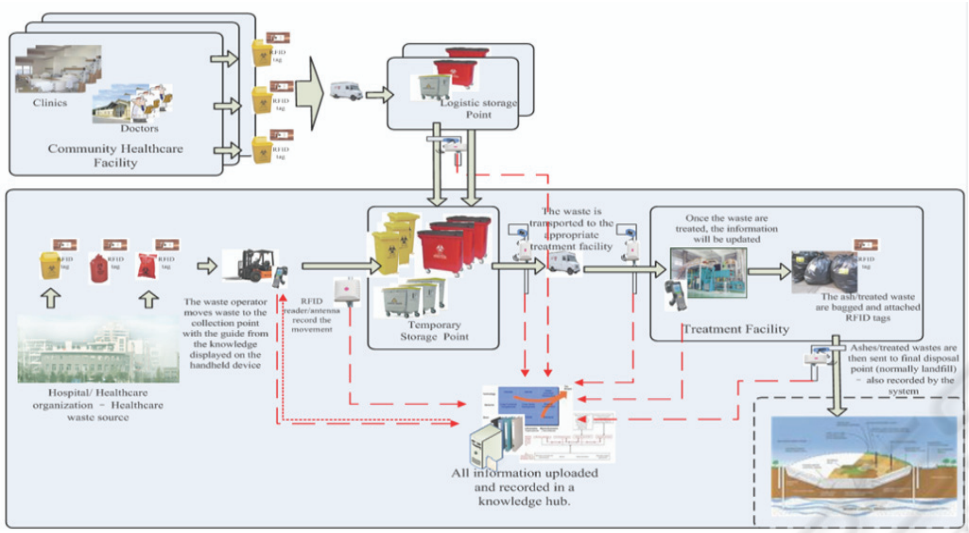

Figure 3: Proposed Medical Tracking and Verification System using RFID Technology.

correct treatment facility and preventing fly-tipping during transportation. This relies on comparison of the information from destination and the source site, including RFID records, image or video records, operators checking and the possible use of built-in weight systems. The second aspect is the logistic / instruction support that helps management to choose the appropriate treatment facility to dispose the waste and real-time instructions to the operating staff.

Figure 3 illustrates the system of a 'Community Healthcare Facility' and 'Hospital/Healthcare Organization' which are the two typical healthcare facilities and healthcare source sites. The healthcare waste must be classified and bagged in the source sites and a RFID tag is then attached to the container (bag, sealed box, or bins etc.) with a unique ID. The ID relates to information about the waste such as weight, type, and current location etc. The information is located in the central server, and can be checked by a hand-held RFID device. The operators can update the information as appropriate. The storage points for temporary holding the healthcare waste are all equipped with RFID sensors and digital imagery cameras, which can generate records of waste movement. Once the waste arrives at or leaves from these points, the records will be updated to the central server. The destination sites are also equipped with similar equipment to monitor the waste arrivals.

The records include the time and date, container ID, waste type, weight, which are related to the RFID tags ID, and the image / video records are associated with the RFID data to eliminate fraud in the system and preventing fly-tipping. The status of the waste in the system is updated in real-time based on records that are generated each time the container passes the RFID sensors. In addition, hand-held devices can also be used to update information manually by the operators to prevent the system reading errors and to correct any mistakes.

Figure 3 indicates, that before the waste goes to be treated (e.g. incineration); an RFID sensor will record and then upload the information. Then the RFID tag on the container will be removed and a new ID will be given for future utilization. Alternatively, the tags can be discarded if they are the low-price passive tags. The next step is to re-bag the treated waste with a new RFID tag to enable tracing it to the correct destination for disposal such as landfill sites.

Hand-held devices are used by the operating staff involved in the system, including vehicle drivers, cleaners, and management etc. The device is a small sensor that links to the central server, and can display information from the system. The instruction and logistical support information will be automatically downloaded from the knowledge management system when it is required. The information notifies the operators which container should be transported or moved to the correct location in a specific time, and also notifies the procedure of transporting this type of waste and any particular cautionary instructions.

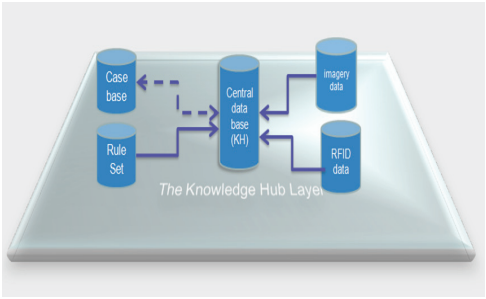

Figure 4: Structure of the Knowledge Base.

The proposed system is designed using a knowledge system as the back end support, and includes a knowledge base system and reasoning to provide the logistical support for the waste management. The reasoning system is designed using Rule-based Reasoning and may associate with Case-based reasoning (CBR) system. The structure of the knowledge base is illustrated in Figure 4. There are three proposed databases operating in the system which are as follows:

- RFID database that stores the information from the RFID equipment;
- Image database for auditing and tracking evidence;
- A possible Case database that provides the data for Case Based Reasoning.

These three databases are integrated and their information is sent to a central database, referred to as a 'knowledge hub', which offers the integrated information for the reasoning process.

Figure 5 illustrates the structure of the knowledge system, and it is designed in four layers. The lowest layer (layer 4) is the hardware layer, which is the route for inputting the data and information from the RFID and imagery equipment to the knowledge system. Layer 3 is the knowledge base layer, and there are three databases that store different data which integrates into the knowledge hub. The data will be used in the reasoning layer, but the imagery data will only be used in the top layer for providing evidence of transportation and logistics. The second layer is the reasoning layer. Rule-based reasoning is the main reasoning mechanism for generating the best solution for logistical and tracking support and Case-based reasoning may be adopted as a backup in future work. The result of the reasoning layer provides a multiple solution by identifying the optimal solution after checking from the rule-based reasoning and the field data is then passed to the highest layer visualisation to provide the resolutions for decision support. This visualisation layer is designed using web application for easy access, and represents the logistical solution and records of the waste transportation using appropriate simulation software developed for the project to provide what-if scenarios (Zheng et al., 2008). This layer can also be designed to support the individual software or application for more detailed security and verification checking.

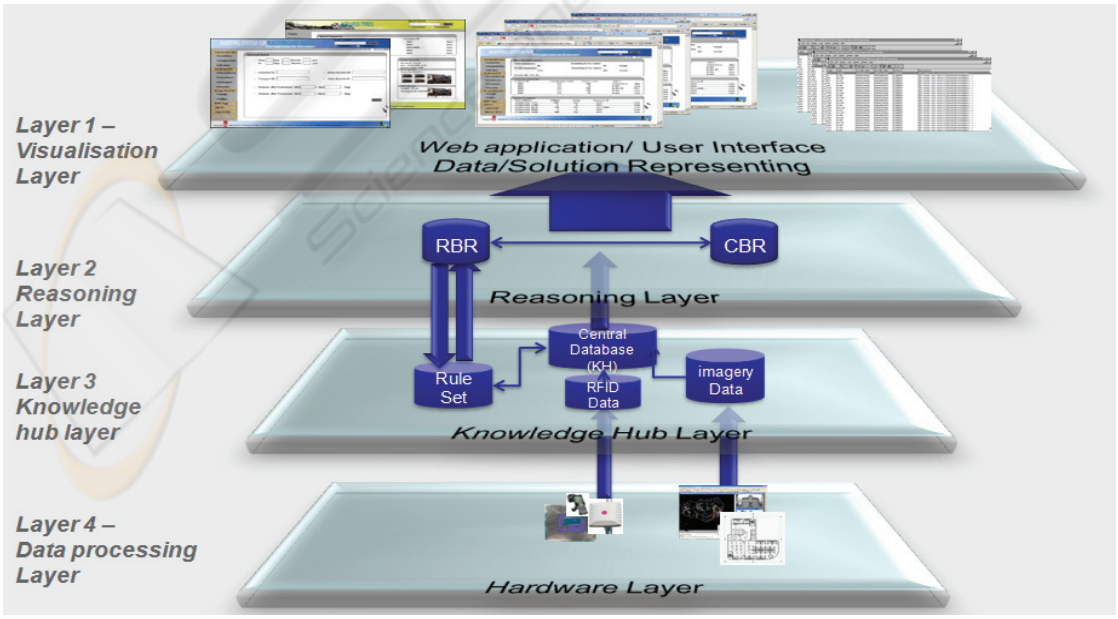

Figure 5: Structure of the Knowledge System.

5 CONCLUSIONS

The paper reviews the current urgent situation of healthcare waste production, treatment and disposal, and the trend of increasing tonnage in the UK and China. Currently there is no successful automated auditing and tracking system available for healthcare waste management. Healthcare or medical waste is one of most dangerous hazardous wastes in that it can contain viruses, bacteria and harmful chemical reagents. Uncontrolled or just low-technology treatment of healthcare waste usually results in public unrest or panic and could produce epidemic disasters for example SARS. A proposed system which is based on RFID and knowledge technology to provide auditing, tracking, verification and logistical support is outlined in this paper. This system can ensure that the waste is directed to the correct destination and provide verifiable evidence for auditing purposes and for independent scrutiny. The proposed system can also be used with other types of waste either for recycling purposes or safe disposal of for example, plasterboard, tyres, wood and glass to make the waste disposal more environmentally friendly and contribute to viable recycling solutions.

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