APPLICATION OF KNOWLEDGE HUB AND RFID TECHNOLOGY IN AUDITING AND TRACKING OF PLASTERBOARD FOR ENVIRONMENT RECYCLING AND WASTE DISPOSAL

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Abstract: The traditional disposal of waste in landfill sites is causing serious environmental concerns due to the amount of hectares consumed by this method and the waste of resources which results from not being proactive in effective recycling. The construction industry, for example, contributes approximately 108mt of the total 335mt of waste annually produced in the United Kingdom of which 50-80% could be reusable or recyclable. Construction waste is composed of at least 1mt of plasterboard waste which has resulted in serious problems because of the emission of hydrogen sulphide gas which is odorous and causes a health hazard to people living near disposal sites. Consequently, this material can only be disposed of in licensed and special designed sites. Plasterboard can be recycled and some countries, for example Japan, Canada, United States and, recently, the United Kingdom, are using this technology to obviate the issue of landfill. This paper outlines knowledge hub using Radio Frequency Identification (RFID) linked to Computer Aided Design (CAD) systems for providing auditing and monitoring systems for environmental recycling and/or licensed disposal of plasterboard waste.

1 INTRODUCTION

The disposal of waste has become a sensitive topic in recent years in terms of environment, health and economic cost. There are a number of government initiatives and environmental pressure groups seeking environmental, socially responsible, and economical means of future waste disposal.

In general, waste is a combination of many types of material, and most of them are harmful and polluting. Waste takes many years to break down, and can pollute water courses and the land even when it is carefully disposed of (McDougall and White,2001).

Waste production is now a serious issue, and the UK is currently producing around 335mt of waste annually, including 50mt of industrial waste, 25mt of commercial waste and 72mt of demolition waste(ARIC and DEFRA, 2007; DEFRA, 2006b).

Demolition waste and construction waste are becoming an increasing problem particularly due to the re-development of urban areas. This requires appropriate attention in terms of recycling rather than traditional landfill disposal, which results in long term environmental problems. Traditional regeneration of urban areas results in harmful material from demolition building being mixed in with general waste. During its decomposition in landfill sites, building waste such as plasterboard can break down with organic waste and generate Hydrogen Sulphide gas (H_2S) which is odorous and dangerous to health in high concentration (Granholm and Chester, 2007).

The disposal of hazardous waste such as plasterboard needs an auditing system to track and visually record the correct disposal of the material in licensed sites and/or its recycling in an environmentally appropriate way. The advent of computer and wireless technology can provide a solution by using a combination of RFID technology and wireless imagery to integrate data into a knowledge hub for auditing and procedural verification.

This paper explains and discusses the necessity of an auditing system for demolition and

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construction waste with particular reference to plasterboard waste. A case study concerning tracking systems that can be used for domestic waste will be discussed in relation to a proposed integrated auditing system concerning the environmental recycling and disposal of plasterboard waste.

2 UK WASTE INFORMATION

The total amount of waste produced in the UK in 2004 was around 335mt annually(DEFRA,2006a). Figure 1 shows that the largest amount of waste is from the construction and demolition sector which contributes 106.1mt, and accounts for 32% of the total UK waste(DEFRA,2006a). The information on construction and demolition waste also includes excavated soil, miscellaneous materials and hard materials, such as brick, concrete and road infrastructure (DEFRA,2006a).

The construction and demolition (C&D) waste sector represents a large percentage of the waste created (32%), and is undoubtedly a significant aspect of the waste disposal issues in the UK. In England, there are over 90 million tonnes of construction and demolition waste (total for UK is 107.5 mt) generated (DEFRA,2006a). The amount of landfill from the construction and demolition sector is consequently causing environmental issues particularly if it contains harmful materials. The challenge is to ensure that in the future a much higher percentage of construction and demolition waste is either recycled and/or disposed of in a safe manner.

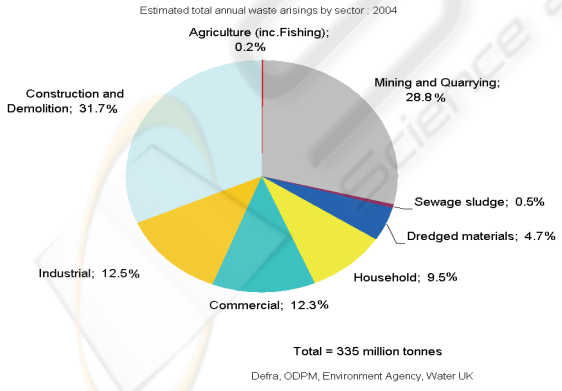

Figure 1: Estimated Total Annual Waste by Sector in the UK 2004 (DEFRA,2006a) (modified by authors).

3 THE PLASTERBOARD WASTE

3.1 Current Landfill in UK

Plasterboard is a popular material that is usually used in the interior finishing of buildings, because it is easy to use, relatively cheap, and provides a high quality finish. It is widely used in industrial construction, typically for house building in the construction of room partitions and ceilings etc.

In the UK, the current disposal method of plasterboard waste is usually in landfill sites. Information from DEFRA in 2007 indicates that more than 1mt of plasterboard from the construction and demolition sector is being sent to landfill with only 70,000 tonnes being recycled. It is anticipated that over next 15 years the volume of plasterboard waste will increase because of expansion in its use and the rise in construction projects (DEFRA,2007). Consequently, plasterboard waste is becoming a serious concern because of the hazards in disposing of this type of material in traditional landfill sites. Plasterboard should be recycled on a much larger scale than the present 7% to obviate the problem of landfill disposal.

Currently, landfill facilities that only accept non-biodegradable waste (gypsum materials should be disposed in landfill sites which do not accept biodegradable wastes to avoid the emission of hydrogen sulphide when mixed with organic waste) are limited in England and Wales compared to the total number of waste disposal facilities. In England, there are only 316 landfill sites (Wales has 16 sites) which accept non-biodegradable waste out of a total of 1055 landfill sites in England (DEFRA,2006c). Consequently, recycling and/or disposal of plasterboard in a licensed landfill site requires an auditing and tracking system to provide evidence for future verification.

3.2 Problem for Landfill Plasterboard

Plasterboards are made from fibre materials and gypsum. The gypsum ($CaSO_4 \cdot 2H_2O$) is usually in the middle layer of the plasterboard and sandwiched together by two pieces of fibre material such as paper or cloth. Plasterboard waste contains a high proportion of gypsum and once placed in a landfill site with biodegradable organic waste, will decompose to produce hydrogen sulphide gas (H_2S) (Marvin,2000). This gas is noxious and extremely malodorous at low concentration levels, and can be toxic at higher levels resulting in

pollution of the environment and causing a health and safety issue (Marvin,2000).

In July 2005, The Landfill Regulations of UK was amended and now requires that gypsum or other high sulphate-bearing materials should be disposed of in landfill sites which do not accept biodegradable waste, in order to avoid the emission of hydrogen sulphide (Bradshaw,2005). Plasterboard can now only be disposed of in specially designed landfill sites which do not accept normal waste, such as household, organic, and other types of waste which can be broken down by living organisms. The purpose of this regulation was to try and avoid the plasterboard emitting harmful gas when associated with organic waste, but waste buried in the ground can still be problematic. In 2006 WRAP, the UK DEFRA agency launched a project on the recycling of gypsum to find alternatives to landfill disposal. (Recycling Today, 2006).

3.3 Overview of Plasterboard Recycling Methods

The recycling of plasterboard waste will reduce the amount of plasterboard entering the waste system to avoid damaging the environment. There are several techniques for recycling plasterboard, but in general, the main method is crushing to release the gypsum and combining with the plasterboard production cycle to make a new product(Hamm et al.,2007).

4 CASE REVIEW – PLASTERBOARD RECYCLING AND WASTE TRACKING

4.1 Recycling Plasterboard Case Review

Plasterboard recycling has been used in a number of countries such as Japan and Canada to make new products. The difficulty is not the method of recycling, but how to track and logistically supply the processing plants to ensure there is sufficient waste supply delivered on time and dramatically reduce the amount of tonnage going to landfill which is currently more than 93% in the UK.

A Japanese company Yoshino Gypsum Ltd is using recycled plasterboard waste to make new plasterboard, which they refer to as "Tiger Board". Their plasterboard is made from a mixture of raw gypsum from mining, and a by-product from generating power plants and waste plasterboard operations which is collected from construction or demolition sites (Yoshino-gypsum.com,2007). The waste plasterboard is crushed twice to produce a gypsum powder and during the process any paper material is removed from the gypsum and the powder is mixed with raw materials. However, only 5% of the gypsum material is from plasterboard waste and thus the amount of plasterboard actually recycled is limited.

4.2 Waste Tracking Case Review

Tracking systems are not a new concept, but their application to construction and demolition waste is novel, especially for plasterboard waste. Some case studies of tracking confidential or domestic wastes are outlined as follows:

A Canadian company called NJE Consulting provides an RFID solution for the secure destruction of confidential paper records. They use a tracking and auditing system for auditing confidential waste, such as the paper waste from some government departments, and provide evidence to prove that the confidential material is promptly and completely destroyed. Figure 2 outlines the process. Firstly, the containers are all RFID-tagged, and the staffs record each transfer using a hand-held RFID data-collecting device. Once this confidential waste arrives at the destroying facility, it is promptly destroyed, and the data from the RFID data-collection device is securely downloaded to a central server over an encrypted network (NJE,2007). Customers then can check the status of their confidential waste.

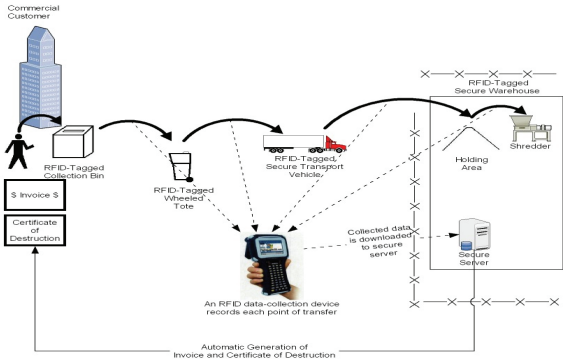

Figure 2: RFID-based Information to Automatically Generate Customer Invoices and Certificates of Destruction(NJE,2007).

5 PROPOSED SOLUTION USING KNOWLEDGE HUB AND RFID TECHNOLOGY FOR AUDITING AND TRACKING

An outline and description of a proposed solution using a knowledge technology system (knowledge hub) to audit and track the plasterboard waste from its source to recycling and/ or disposal location is discussed.

The aim of the proposal can be viewed from 3 aspects: firstly, the auditing of plasterboard waste removed from the construction site during refurbishment and/or demolition of the building (including off-cut plasterboard waste); secondly the monitoring of plasterboard supplies during construction and refurbishment; and finally the auditing and tracking facilities for predicting the amount of plasterboard waste and the logistics of inward and outward movement.

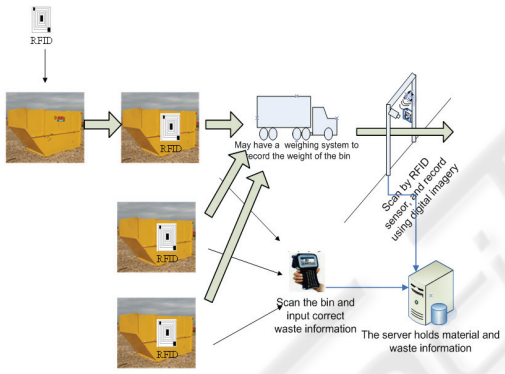

Figure 3: The Outward Material Handling System for Waste Plasterboard.

Figure 3 shows that each plasterboard waste container (skip or compactor skip) is marked with a unique ID and RFID tag in the demolition or construction site. The ID relates the information of the waste container, such as the total load, unloaded weight, location etc. This information is located in the central information server, and can be checked or updated by a hand-held RFID device. The operator can input real time information about the waste as appropriate; this system could also be used for other kinds of waste such as asbestos, timber and glass etc. When the waste containers are fully loaded, they are transported through a special gate to the recycling company or appropriate licensed landfill site. The gate is equipped with RFID sensors and digital imagery to create records which could be supplemented with mobile imagery and logging devices on site. The record is uploaded to the central information server and shows the logistics of the containers and the appropriate tonnages of plasterboard waste being transported or delivered to recycling and/or landfill sites (Atkins et al. 2003; Zheng et al. 2006; Zheng et al. 2007).

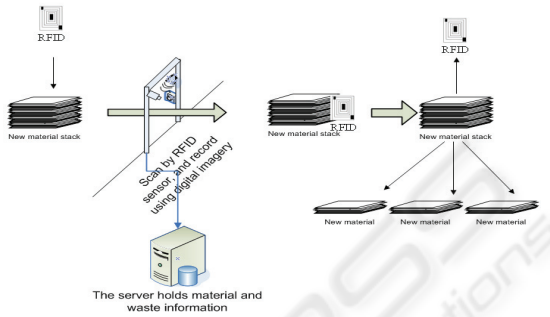

Figure 4: Inward Material Handling System.

Figure 4 shows the inward logistics of the proposal for new plasterboard material stacks which are marked with a unique ID and RFID tag at the construction site or before being transported. The construction site is equipped with imaging equipment (static picture and/or video) and an RFID sensor connected to a central server (Information Hub) which contains the material information. The sensor will trigger the imaging equipment to start recording this information, which is then sent to the central server with date, time, and ID number. These records can be checked to show how much plasterboard is delivered to the site. Figure 4 also shows that as plasterboard is used in a construction the RFID tags are then removed from the stack, to ensure that the plasterboard is not recorded again. Consequently, after building is completed, the information contained in the central server could show how much plasterboard was used in the buildings, determine the wastage, and assist in auditing disposal and identifying and rectifying inefficiency through the waste produced. This information can be used in the refurbishment and demolition of buildings in the future.

Using Computer Aided Design (CAD), tools such as AutoCAD Architecture 2008 can be used to estimate plasterboard waste by integrating the information into a repository with digital imagery (Autodesk.co.uk,2007). Figure 5 shows that after the existing building has been surveyed, the building plan can then be drawn in AutoCAD Architecture 2008. AutoCAD Architecture 2008 allows the user to draw the plan in a 2D environment but at the same time automatically generates 3D building components. The user can determine the

construction of the build as identified in the survey and apply the information to the relevant wall and ceiling type of the waste material that needs to be disposed. This allows 'Tags' to be attached to the walls that can automatically generate the area of specified materials, i.e. plasterboard.

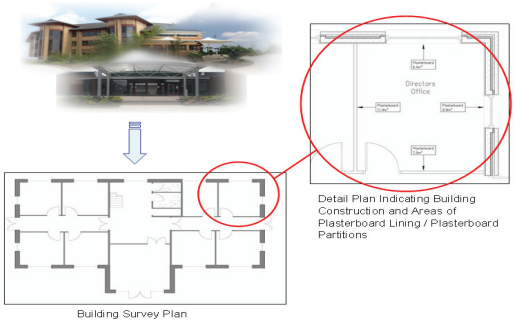

Figure 5: Surveying the Target Building and Indicating Plasterboard Materials.

The final stage is to calculate the volume of plasterboard used in the buildings. Figure 6 shows that AutoCAD can be used to estimate and identify the individual rooms together with the area of material used and generate a schedule of the waste plasterboard information. This schedule can then be exported into a repository and using spreadsheet applications can be programmed to generate the total volume of the material from different aspects of the building construction. This information can be used to determine the volume and tonnage of plasterboard waste (or of other materials as appropriate for recycling) that will be generated during the refurbishment and/ or demolition. This information can then be imputed to the central server and compared to the information from the RFID sensor to provide specifications of the material to be disposed of, and assist in the logistics of supplying recycling or disposal sites.

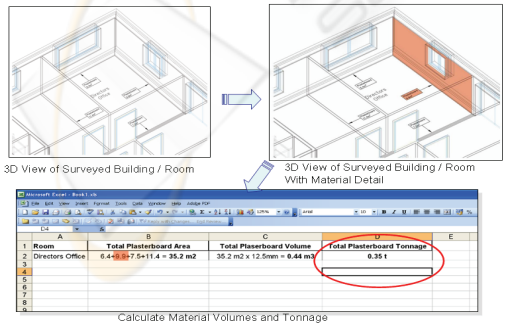

Figure 6: Predicting the Correct Volume and Tonnage of Plasterboard in Advance.

Ensuring that the plasterboard waste goes to the correct destination requires the co-operation of construction firms and recycling and waste disposal companies (recycling company or landfill site). At the destination sites, sensors and imagery (cameras) need to be used to record the transport information in real time. The function and mechanism of the sensor and the imagery would be similar to those used at the construction sites, but on a smaller scale and using fixed and mobile devices to give more mobility for easier operations.

This system can be used to support construction companies in determining the amount of plasterboard waste produced in refurbishment or demolition as well as appropriate construction quantities to obviate unnecessary waste (Atkins et al.,1986; Atkins et al.,1987). The system can be used to provide the verification and tracking of waste disposal required for auditing and complying with government and/or public scrutiny. This proposed system can also be used within recycling companies, to help them maintain adequate supplies and coordinate their inbound logistics of deliveries using simulation to improve their efficiency and process plant control for more efficient environmental solutions to hazardous waste as well as other construction material such as wood and glass etc (Atkins et al.,1996; Atkins et al.,1985).

6 CONCLUSIONS

This paper reviews current waste production and the increasing trend of certain waste categories in the UK, particularly construction and demolition waste which accounts for 335mt per annum, and noticeably increased between 1998 and 2005. In particular, plasterboard waste is causing a significant problem for landfill sites as it has a high gypsum content, which can result in the emission of hydrogen sulphide (H_2S) gas when it decomposes with organic waste. Currently, there are two ways to avoid this hazardous emission: either dispose of the plasterboard in special landfill sites which only accept non-biodegradable wastes, and/or recycle the plasterboard waste which would be the preferred environmental solution. However, the amount of plasterboard waste currently recycled is extremely low: only 70,000 tonnes which is about 7% of the total UK waste. Recent information from DEFRA (SweeneyII,2005), anticipates that plasterboard waste will continue to increase in the next 15 years. In the plasterboard application outlined in this paper, an auditing and tracking system is necessary to solve

and provide verification and logistic support to this environmental problem (AK and Atkins,2007). This system is being designed to use RFID technology and digital imagery to integrate records including construction material, location, volumes and weight, container movement and delivery tracking inventories and scheduling etc. It will be integrated into a knowledge hub that can be used to predict the scheduled logistics of plasterboard waste to recycling plants using simulation techniques to improve processing operations. This system can ensure that containers of plasterboard waste go to the correct destination and provide verifiable evidence of each stage of the operation for auditing purposes and independent scrutiny. This can also be used by waste disposal or recycling companies to provide improved logistical support to the recycling of other materials such as wood and glass to improve recycling capability.

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REFERENCES

ARIC and DEFRA. "Waste Arisings in the UK." Available from: www.ace.mmu.ac.uk/ Cited: 03-Oct-2007.

Atkins, A S, J C Atkin, R N Singh and A M H Zadeh. 1986. "An Alternative Method of Surface Disposal and Stabilization of Coal Mine Tailings." In Geotechnical and Geohydrological of Waste Management. Fort Collins: Rotterdam Boston.

Atkins, A S, N I Aziz and Rao B S. 1996. "Applications of Multimedia in Strategic Management in Engineering Design Associated with Occupational Hazards of Dust." In 96 International Symposium on Mining Science and Technology. Xuzhou, Jiangsu , China: Balkema , Guo & Golosinski.

Atkins, A S, R N Singh, A Barkhordarian and A H Zadeh. 1987. "Pumpability of Coal Mine Tailings for Underground Disposal and Regional Support." In 2nd International Symposium on the Reclamation, Treatment and Utilization of Coal Mine Wastes. University of Nottingham, Nottingham NG7 2RD.

Atkins, A. S., R. N. Singh and Hughes D. 1985. "Settable Composition and Methods of use thereof ", patent by Coal Industry (patents) Ltd. Hobart House, London.

Autodesk.co.uk. 2007. "Autodesk AutoCAD Architecture 2008." Autodesk Inc.Available from: www.autodesk.co.uk, cited: 14-Oct-2007.

Bradshaw, Ben. 2005. "The Landfill (England and Wales) (Amendment) Regulations 2005 " In Statutory Instrument 2005 No. 1640, ed. DEFRA.

DEFRA. 2006a. "Estimated Total Annual Waste Arising by Sector: 2004 ": Department for Environment, Food and Rural Affairs, Available from:http://www.defra.gov.uk/environment/statistics/waste/download/xls/wrfg02.xls, Cited: 02-Oct-2007.

DEFRA. 2006b. "Estimated Total Annual Waste Arisings by Sector in United Kingdom: 1997-2003 ": Department for Environment, Food and Rural Affairs, Available from: http://www.defra.gov.uk/environment/statistics/waste/download/xls/wrfg02.xls, Cited: 02-Oct-2007.

DEFRA. 2006c. "Operational Waste Facilities in England and ales at the end of June 2006." Environment Agency and Department for Environment, Food and Rural Affairs.

DEFRA. 2007. "Waste Strategy for England 2007." Department for Environment, Food and Rural Affairs.

Granholm, Jennifer M. and Steven E. Chester. 2007. "Drywall Recycling." Michigan, US: Michigan Department of Environment Quality.

Hamm, H., R. Huller and J. Demmich. 2007. "Recycling of plasterboard." Zkg International 60(5):68-74.

Marvin, Emma. 2000. "Gypsum Wallboard Recycling and Reuse Opportunities in the State of Vermont." Vermont Agency of Natural Resources.

McDougall, F. and P. White. 2001. Integrated solid waste management a life cycle inventory. Oxford: Blackwell Sciences.

AK, Awangku PG HJ Ali A. H. and A. S. Atkins. 2007. "A Strategic Business Tool for Mobile Infrastructure – Wireless Ubiquitous Computing." In Institute for Systems and Technologies of Information, Control and Communication Funchal, Portugal.

NJE. "NJE Consulting ": Available from:www.nje.ca, cited: 28-Sep-2007.

Recycling Today. 2006. "UK Agency Offering Money for Gypsum Recycling Projects." Available from: http://www.recyclingtoday.com/news/news.asp?ID=10242 Cited: 8-Oct-2007.

Sweeney II, Patrick J. 2005. "Chapter2 Auto-ID Technologies: Why RFID Is King of the Hill." In RFID for Dummies. Hoboken: Wiley Publishing.

Yoshino-gypsum.com. "YOSHINO GYPSUM CO., LTD." Available from:http://www.yoshino-gypsum.com/en/sekkou/what/what04.html, cited: 28-Sep-2007.