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Hospital Waste Management in Kidney Transplantation Procedure: Implications and Solutions

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Abstract - *The number of patients diagnosed with end-stage renal disease (ESRD) in Indonesia is increasing annually, showing a similar trend with the global prevalence. With its superior outcome, kidney transplantation remains to be the treatment of choice for ESRD. The treatment with transplant kidney procedure makes extensive use of presterilized disposable items which, after use, are contaminated by blood. The preferred route of disposal of such items is by incineration. Disposal costs have risen and this increase in costs has not been matched by waste management programs in kidney transplantation procedure. Many of the waste itemslikecontainerforbloodproductsandintravenousinfusionfluidcontainerwhichiswidelyused in kidney transplantation procedure generated also contain polyvinylchloride (PVC) whose incineration is environmentally sensitive. Furthermore blood tubing sets contain plasticizers such as di (2-ethylhexyl) phthalate (DEHP), which is known to pose health risks to specific groups of patients. The generation of hospital waste in a kidney transplantation procedure is analyzed, issues associated with disposal are discussed, and approaches toward a cost effective environmentally sustainable hospital waste management program are reviewed.*

Keywords *– Hospital Waste, End Stage Renal Disease, Kidney Transplantation.*
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1. Introduction

End-stage renal disease (ESRD) treatment worldwide by kidneytransplantationproceduresteadily growing every year. Such patients receive treatment either in a hospital, a stand-alone treatment center, or their own home. One of the reasons for the widespread use of kidneytransplantationprocedure has been the availability of prepackaged and sterile infusion set items for renal pefusionto perform treatment safely and effectively. Such items forkidneytransplantationprocedureand their packaging materials are used once and then discarded. In a vanishing, but simpler age, items used were consigned to the garbage and disposed of through a variety of routes. Today this approach to waste has been severely curtailed by legislation that controls the route of disposal and mandates that such disposal have a minimal environmental impact. Governments and environmentalists increasingly view garbage as a resource issue, resulting in the emergence of sustainable waste management policies or recycling, as well as the implementation of waste education and awareness programs[1].

This article focuses on the implications of waste generated in thekidneytransplantationprocedure and the environmental issues arising from such waste, and discusses methods and approaches to minimize waste production.

Waste Generated by the Kidney Transplantation Procedure Process

The kidney transplantation procedure generates a variety of waste, including solid waste such as plastics arising from the containerbloodproduct, the blood tubing sets, syringes, and concentrate containers. Small amounts of metal from vascular access devices and needles, as well as glass from pharmaceutical preparations used during treatment (e.g., drugs and anticoagulant) are also generated. Since each of the items used in the procedure is prepackaged, the treatment also generates packaging waste. Many of the items used, such as intravenousinfusion fluid container, blood tubing sets, and start and end packs, are purchased in bulk and are delivered to the

kidneytransplantationprocedure in cardboard containers of varying sizes.[2]

The waste generated may be further subdivided into clinical and nonclinical waste. The legal definition of "clinical waste" is given in the Controlled Waste Regulations of 1992 as "any waste which consists wholly or partly of human or animal tissue, blood or other bodily fluids, excretions, drugs or other pharmaceutical products, swabs or dressings, or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to any person coming into contact with it; and any other waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation, treatment, care, teaching or research, or in the collection of blood for transfusion, being waste which may cause infection to any person coming in contact with it."[2]

Clinical waste is a costly, troublesome, and hazardous commodity. Comprising approximately 30–40% of the total solid waste from acute hospitals, it may be responsible for more than 60% of disposal costs. Variously described as clinical, medical, health care, "red bag", "yellowbag", infectious or hospital waste, few precise descriptions exist and confusion arises from differences in terminology. Several formal descriptions of clinical waste exist. Clinical wastes are notoriously variable in com- position and waste volumes vary considerably. Without source segregation, the innocuous fraction inflates disposal costs and distorts waste production figures thatarethe basis for strategic and resource planning (Table 1). Most clinical wastes arise in hospitals or veterinary centers, though huge quantities are generated daily in a diverse range of other locations, often in individually small quantities. For these, logistics costs may be prohibitive but safety is paramount, and waste management standards must not decline because of cost concerns.[3]

Table 1. Wide variations in clinical waste composition

Wastecompositionstudies	Averageweight
Clinicalwastesack	2,65kg (range 0.5 – 9.4 kg)
Paper including confidental papers	30 – 38 % byweight
Plastics	20 – 28%
General domestictypewaste	6 – 10%
Sharps	1 – 2.5%
Prescriptionpharmaceuticals	0.4%

Composition varies widely with the site of waste arising, source segregation and the nature of healthcare, and may vary over time in response to changes in medical practice. Hypodermic need les and surgical blades are occasionally found in clinical waste containers intended only for soft wastes. Sharps includes also broken rigid plastic items, sharp or broken glass, and metal items capable of causing cut or penetrating injury.

Containers for Clinical Waste

The ubiquitous plastic clinical waste sack is a convenient and cost-effective primary container for soft wastes, compact in storage, and readily color-coded to delineate different waste streams. Sack closure can be problematic. Gathering to tie the neck, or using a cable tie or tape for closure, risks injury if sacks contain sharp items. An outer cardboard box provides effective support and is the preferred option in several countries, but elsewhere attracts criticism because of size, convenience, cost, and suit- ability. Virgin plastic should be eliminated in favor of a high proportion of recycled material for waste containers. Rigid or semi-rigid containers that are compact in storage, with standardization of shape and size, facilitate logistics and introduce the possibility for auto- mated handling. Cost is a key determinant, and a barrier to change. Interestingly, one current trial is investigating fewer and radically smaller containers for clinical wastes, intended to force segregation and ensure separate disposal of wastes for which a less expensive disposal stream would be more appropriate. Although innovative, this high risk and unreliable strategy increases the possibility for segregation errors that result in hazardous wastes entering a nonhazardous stream.

Waste containers should be color-coded to distinguish them from other waste streams, labeled to indicate their contents, and ideally marked with a biohazard warning symbol supplemented if necessary with an additional written warning. Labeling waste containers to indicate their origin facilitates waste generation statistics that are the basis for resource planning and billing, and ensures accountability for waste management performance.[4]

Cytotoxic and cytostatic drug wastes, and the medical disposables used for their preparation and administration, present particular hazards due to the high toxicity of these agents. These antineoplastic medicines are particularly harmful, even in small concentration, and should be managed only by high-temperature incineration. Incineration is recognized to provide the only safe method for their terminal destruction. For disposal, cytotoxic drug wastes must be placed into robust leak proof containers with tight-fitting leak proof lids, and appropriately labeled and color-coded to provide clear identification and separation from other waste streams. Repeated (occupational) exposure can be especially dangerous and handling of these wastes, even when packaged in sealed containers, must be minimized.

Bulk handling of primary waste containers is facilitated by the use of large lidded and wheeled waste carts. These must be reserved solely for this purpose, appropriately labeled and color-coded, and kept locked at all times to prevent unauthorized access.[4,5]

Good-quality leak proof and burst proof sacks are essential and these must be handled with care to avoid spillage. Sacks must not be compressed as this increases the

possibility for disruption or seepage of contaminated fluids. Disposal chutes damage waste sacks, causing spillage and aerosol contamination that can spread to all floors of a building and must never be used. Safety is paramount at every stage. Hospital ancillary and support staff should be provided with suitable personal protective equipment (PPE) comprising heavy-duty workwear with reinforced puncture-resistant gloves or gauntlets, though around the world standards vary widely and many have access only to thin-walled latex or nitrile gloves that offer no protection against penetrating injury, or no gloves at all. The ubiquitous clinical waste container is a convenient, though, inappropriate dumping ground for many 'difficult' or nonstandard wastes including broken thermometers, equipment items, aerosol cans, and batteries. These items must be excluded from the clinical waste stream and waste managers must provide more suitable disposal route, though in practice this may be difficult to manage and impossible to enforce.

Sharps containers must be constructed throughout from puncture-resistant material. Simplicity of design and robust fail safe fittings reduce the probability of spillage of contents. Several international design and performance standards exist. The aperture must be sufficiently wide to allow easy deposit of used items, with a simple but effective tamperproof snap-fit closure. Sharps bins for diabetics and other community-based patients requiring regular injection therapy might be returned for disposal to a family physician, pharmacist or local hospital, or collected by licensed contractors. In some countries, postal return of suitably packaged small sharps bins can be cost-effective and convenient but is prohibited in many countries by legislation prohibiting the transport of hazardous materials by post, however, securely these may be packaged.[5]

Table 2. Key step to effective disposal

Disposal to suitable container	Segregation at source Correct container Suitable identification of wastes Correct closure of container	Use personal protective equipment (PPE) and hygiene precautions	Training of staff : audit of performance	Environmental protection (local, global)
Transport and storage	Precautions againsts pillage Dedicated vehicles Dedicated storage area Wasted security			
Waste treatment	Select suitable treatment – elimination of infection risk Process validation and control Management of pharmaceutical & tissue waste-requires incineration Environmental protection – management of effluents from waste treatment			
Disposal of treatment residues	Resources recovery if possible Energy from waste option			

There is a paucity of information regarding the hazards associated with clinical wastes. BBV infection is the major risk, though respiratory, enteric, and soft tissue infections are occasionally recorded. Fortunately, the incidence of acquired infection appears low, but epidemiological relationships are difficult to define due to lack of coordinated reporting systems. Low infection rates may reflect deficiencies in reporting and be more apparent than real. Safe disposal can be technically undemanding (Table 2), complicated only by overarching obligations to safety and environmental protection. However, the potential for harm, for example, following sharps injury, maybe profound, and handling of clinical wastes requires great care at all times.

Almost no data exists to demonstrate any risk of infection in health care premises directly attributable to clinical wastes. However, it is universally accepted that this risk is nonetheless real and every attempt must be taken to ensure the highest standards of waste management and hospital hygiene at all times. Hygiene is compromised by contamination of reusable waste containers and though this equipment can be sanitized, single-use waste containers are preferred unless sanitization of containers is rigorous and properly validated. Bulk waste carts present particular problems. These may be contaminated with 'hospital' pathogens including enteric Gram-negative bacilli, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and enterococci originating from wastes. Routine cart washing eliminates soiling but does not sanitize carts and as disposal contracts rarely dedicate waste carts to a particular hospital the transfer of microorganisms between different hospitals becomes a real risk. To prevent this, wastes should be taken to bulk waste carts stored remotely, though in practice this more cautious approach takes second place to the convenience of carts wheeled into clinical areas.[4,5]

Soft wastes can be placed into plastic sacks. For wet or heavy wastes, and for large items that cannot be contained within a sack, rigid plastic waste bins provide a suitable alternative. Waste sacks should be supported in metal frames fitted with a foot-operated lid. Soft-close lids will be appreciated by patients, particularly at night. Waste sacks

and bins must be located close to the point of use. Waste containers must be removed and replaced regularly, when no more than two-thirds full. Sacks should be removed daily, though sharps bins can be replaced less often. The area around waste containers may be contaminated with blood and body fluid splashes, though this may not be visible. Close coordination between waste management and cleaning services is essential.

Pathology wastes present particular problems as these contain a high proportion of blood and other body fluids, tissue wastes, glass and other sharps, hazardous chemical wastes, and microbiological cultures. Micro- biology wastes should be autoclaved before removal of the disposal. Tissue wastes must be segregated for incineration, whereas other fractions may be treated by any suitable alternate treatment technology (ATT) (nonincineration) process. Close liaison is necessary between laboratory staff and the site waste manager.[5]

Information regarding the amount and types of waste generated by kidneytransplantationprocedure is lacking. To provide some estimate, we collected, weighed, and classified the individual items used. A single set kidney transplantation procedure session produced 2.5 kg of solid clinical waste, of which 38% (0.95 kg) was plastic. In thekidneytransplantationprocedurethereanimportant step, preservationofkidney. There are two main sources for kidney graft injury: ischaemia (warm and cold), and reperfusion injury. The aims of modern kidney storage solutions include: control of cell-swelling during hypothermic ischaemia; maintenance of intra- and extra-cellular electrolyte gradient during ischaemia; buffering of acidosis; provision of energy reserve; and minimization of oxidative reperfusion injury. There is no agreement on which of the mechanisms is most important for post-ischaemic renal graft function. No storage solution seems to combine all mechanisms Presently, University of Wisconsin (UW) solution and histidine-tryptophan-ketoglutarate (HTK) solution are equally effective and are standard for multi-organ or single kidney harvesting procedures. The characteristics of HTK are its low viscosity, low potassium concentration and low cost. University of Wisconsin solution has been the standard static cold preservation solution for the procurement of liver, kidney, pancreas, and intestine. University of Wisconsin, HTK, and Celsior solutions have provided similar allograft outcomes in most clinical trials, however, some differences have become apparent in recent studies and registry reports. Marshall's hypertonic citrate solution (MHCS) is also suitable for use in the preservation of human kidneys before transplantation. In experimental studies of kidney preservation, HTK and UW retained a greater capacity to preserve endothelial structure and pH buffering function during warm ischaemia in comparison to MHCS and Celsior, especially in DCD donors. In the absence of a cost-utility analysis, the results of the meta-analysis from the randomized controlled trials (RCTs) comparing UW with Celsior and MHSC in standard cadaver donors, indicate that these cold storage solutions are equivalent. For living donors, in whom immediate kidney transplantation is planned, perfusion with crystalloid solution is sufficient.The procedurestepsneeded in a kidneytransplantcertainlyproducelargeamountsofmedicalwaste. This waste was heterogeneous and contained a variety of materials, such as the membranes used in the polypropylene, polycarbonate, as well as polyvinyl chloride (PVC). This latter material was the most common, accounting for 0.65 kg of the waste. The outer packaging, mainly plastic, of individual items such as procedure packs amounted to another 0.075 kg. On the basis of these values, the amount of waste generated by a patient on thrice-weekly kidney transplantation procedure not reusing their dialyzer is estimated at 390 kg per year, of which 101 kg is PVC. Associated with such waste is the production of waste cardboard derived from the packaging. This has been excluded, since this material is collected centrally and recycled. Thus a typical renal unitandkidneytransplant treating would produce tons per year (approximately 39,000kg per year) of waste, of which 10,100 kg is PVC. For comparisonpatients treated by continuous ambulatory peritoneal kidney transplantation procedure (CAPD), and performing four exchanges a day, the total daily solid waste produced is 1.69 kg, of which 56% (0.94 kg) is PVC.[6]

Waste Storage

Secure storage areas must be available for clinical wastes. Scavenging is not unknown, and additional security precautions may be necessary for wastes containing prescription drug wastes. In some resource-poor regions, illicit scavenging from wastes, even after landfill deposit, is sadly very common. This necessitates additional security, with measures to address underlying poverty and public health issues and issues of corruption, as well as educational and high-level political intervention.

Site hygiene is essential with regular checks and precautionary measures to prevent pest infestation. Clinical waste storage must be separated from areas for other wastes. Robust fire precautions are essential. Smaller satellite waste storage areas may be required at locations throughout a hospital site. These too must be secure. Too often, satellite storage of waste carts obstructs corridors, stairwells, doorways and external walkways, and obstructs fire escape and emergency access routes.[7]

Wastes must never be left on the floor. Spillages must be cleared promptly, using defined spill procedures and equipment reserved specifically for this purpose. If wastes are treated on site, there must be clear separation of input and output streams. Collection staff must use carts and road vehicles dedicated to the carriage of clinical wastes. These should have smooth and impervious surfaces to facilitate decontamination and retain fluid spillages. There should be separate driving and goods compartments, with separate compartments for clean supplies. For road transport, many countries require hazardous wastes vehicle identification

plates, with drivers trained and equipped to deal effectively with spillages and other emergencies.[8]

Waste Treatment Technologies

Several core technologies are available for the treatment of clinical wastes (Table 3). Incineration is widely considered the definitive or 'gold standard' treatment process, though there is a trend toward its use for only the most difficult waste fractions. A number of incinerator variants are available, all of which can operate success- fully with clinical wastes. Capital and operating costs may be particularly high. Adverse public perception of incineration as a heavily polluting and hazardous process that blights communities inevitably complicates planning and regulatory approval that is invariably difficult and costly to secure. However, with effective gas cleaning, incinerator emissions can be maintained within tight regulatory limits. Although the bottom ash residues are generally safe, highly toxic pollution control residues require care in disposal and are increasingly prohibited from many landfill sites. Notwithstanding, incineration is appropriate without source segregation for all clinical wastes including cytotoxic and bulk pharmaceutical wastes, and human and animal tissues, and provides flexibility with minimum environmental impact.

Non burn or ATT processes for clinical waste treatment take various forms. These vary greatly in size and configuration, from small units suitable for a hospital ward or clinical laboratory to commercial systems processing in excess of 1 ton per cycle. Short cycle times with modest operating and maintenance costs make ATT systems particularly attractive, though bulk pharmaceutical and tissue wastes must be excluded. Some systems require pre shredding of wastes to ensure uniformity of feedstock and adequate penetration of heat or chemical sterilants. ATT processes do not achieve the massive volume reductions up to 97% seen with incineration, though reductions up to 50% by volume and 30% by weight can be achieved with many systems. The wet weight of ATT treatment floc is approximately 18–25% and freight costs and landfill charges for treatment residues may be high but can be mitigated by materials recover or waste-to-energy conversion. Although often competing with incineration, combining ATT systems with incineration of 'difficult' wastes provides a useful mixed-mode framework for waste treatment, reducing 'waste miles' associated with superregional incinerator facilities and reducing overall disposal cost.[9]

Alkaline hydrolysis processes for tissue waste disposal may offer further advantage. Treating tissue wastes with solutions of sodium hydroxide at temperatures of approximately 140 1C produces an amorphous liquid residue. Suitably downscaled, this provides a disposal option for occasional tissue wastes to be used alongside other ATT systems. With pharmaceutical wastes transferred to the chemical waste incineration sector, this could address almost all concerns about treatment of the more difficult clinical waste fractions while reducing the need for expensive and inevitably unpopular clinical waste incineration facilities.

ATT processes using 2450 MHz microwave energy showed considerable early promise but are still not widely used. Although effective, microwave systems can be noisy and many have been troubled by frequent breakdown. Large chemical treatment units are difficult to control and have not proved popular for clinical waste treatment. Smaller units for use in hospital wards or departments are promoted as a cost-effective option eliminating the need for transport of raw wastes.[9]

Although effective, these place additional demands on segregation to ensure exclusion of incompatible wastes. Reproducibility and control of the treatment cycle are foremost among concerns about these units, together with the risk of aerosol dissemination of microorganisms released to the clinical environment during charging and shredding of wastes, and concerns regarding the dis- charges to sewer that will contain disinfectant residues and perhaps disinfectant neutralizers, and other organic and particulate debris.

With every waste treatment process, operator training is essential to ensure full compliance with all safety and operational procedures. Disposal contractors must be diligent in monitoring efficacy of the treatment process, and must liaise closely with regulators who will oversee all aspects of performance. Fully automated control systems are preferred, with restricted key holder access preventing inappropriate or unauthorized modification of operating parameters.

Incoming wastes will generally be identified by their color-coded containers and accompanying documentation. This permits separation of individual waste streams destined for different treatment. Close liaison between contractors and producers ensures correct and accurate description of wastes to minimize the need for examination or analysis, though regular audit is required to monitor the accuracy of waste descriptions and the quality of sourcesegregation.[9]

Table 3. Waste treatment technologies

Incineration	Starved air incinerator	High capital, operating and maintenance costs
	Rotary kiln incinerator	Flexible – can accept all feedstocks
	Stepped hearth incinerator	Some systems less effective if wastes have high water content
	Pulsed hearth incinerator	Reduction in waste volumes
		Environmental protection requires costly effluent pollution abatement systems; some toxic effluents for disposal
	Waste-fired boiler	Complex maintenance requirement
		Flexible system but difficult to control effectively
	Pyrolysis	High efficiency though costly
	Plasma arc gasification	May require pre-shredding of wastes and containment of equipment
		Massive reduction in waste volume
		Small systems may be valuable for total waste management option for small and island communities, etc.
Alternate treatment technologies	Autoclave	Low cost and generally reliable
		Flexible and generally fail-safe operation
		Unsuitable for tissue wastes and bulk pharmaceuticals
		Not all systems provide complete containment
		Pre- or post-shredding of wastes required
	Chemical sterilization	Several sterilant options available (chlorine dioxide, sodium hypochlorite, glutaraldehyde, and peracetic acid)
		Requires pre-shredding of wastes
		Environmental concerns regarding effluents
	Dielectric heating (radio frequency irradiation)	Slow process times
	Microwave	Some systems are noisy
		Integral shredding of wastes necessitates containment
	Hot oil systems	Integral shredding of wastes necessitates containment
	Alkaline hydrolysis	Requires care with toxic and hazardous reactants
		Suitable for treatment of tissue wastes
		Suitable for small-scale and discontinuous operation
Low-technology options	Landfill	Highly undesirable
		Risk to groundwater
		Difficult to manage properly
		Security risks
	Open burning	Highly undesirable
		Difficult to manage properly; polluting
		Destroys waste items to prevent salvage
		Security risks
	Mechanical destruction	Risk of infection to operator
		Effectively prevents reuse of syringes and needles
	Disinfection	High risk of inadequate treatment
		Requires plentiful supply of suitable sterilant
	Encapsulation	Simple, low cost
		Dry Plaster of Paris easy to transport and store
		No sterilization but prevents reuse of needles

Routes of Clinical Waste Disposal and Issues Associated With Disposal

Clinical waste, unless rendered safe by treatment, may no longer be disposed of via landfill, but is incinerated. Although it is recognized that incineration reduces the volume of waste and minimizes the risk of accidental exposure, there are two major issues associated with this approach: emissions and cost. Until the 1990s, many hospitals had their own clinical waste incinerators. However, implementation of the Waste Incineration Regulations, the result of the transposition into U.K. legislation of the European Union (EU) Directive on the Incineration of Waste of 2000 has meant that emissions from many such incinerators were in excess of those permitted and were closed. Regulation of the Indonesia Ministry of Health Number 7 on 2019 about Hospital Environmental Health and Decision of the Ministry of Health Number 1204 on 2004 about Requirements of Hospital Environmental Health declare that Hospitals must process clinical waste properly so as not to harm the environment. The regulations were further updated in 2002, imposing more stringent limits for emissions and requiring that all incinerators comply with revised emission limits by the end of 2005.

Medical waste disposal is regulated at the state level. The Environmental Protection Agency (EPA) has regulations governing emissions from hospital/ medical/infectious waste incinerators, as well as requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for medical waste treatment technologies that use chemicals for treating the waste. A number of different agencies also have an interest, including the Department of Transportation Office of Hazardous Materials Safety, which regulates medical waste transport (49 CFR, Sections 172 and 173 m); the Food and Drug Administration (FDA), which regulates medical devices such as containers designed to safely contain used needles; the Nuclear Regulatory Commission (NRC), which regulates some types of radioactive medical waste; and the Occupational Safety and Health Administration (OSHA),

which regulates medical waste in the workplace. In view of the limited routes that apply to the disposal of clinical waste and the requirements associated with such waste, the disposal costs tend to be substantially higher than for domestic waste.[9]

A large part of the clinical waste generated is in the form of PVC. This material has attracted considerable environmental attention because its manufacture consumes some 30% of the world production of chlorine, a compound toxic to plant and animal life. Vinyl chloride monomer is a potent carcinogen. Environmental release and occupational exposure during manufacture have been two aspects of concern because in humans it is metabolized into chloroethylene oxide, which is mutagenic. International and national standards govern occupational exposure limits, and medical grade PVC contains less than 10 ppb of the monomer. Disposal of PVC via incineration is associated with the generation and dispersal into the environment of polychlorinated dibenzo[p]dioxins (PCDDs) and polycarbonateddibenzo[p]furans (PCDFs), both of which are present in flue gases and ash. However, the burning of waste is not the only source of these compounds. Over the past decade the environmental levels of PCDDs and PCDFs have fallen, but the impact of uncontrolled or open burning on the environmental load remains less wellcontrolled.[8,9]

The burning of PVC is associated with the production of complex chlorinated organic compounds with a wide range of molecular structures, a number of which are highly toxic. When emitted into the atmosphere, they enter the human food chain via fat-containing foods such as dairy products, fish, and meat. Exposure is associated with reproductive toxicity (reduced sperm counts in males), dermal toxicity (chloracne), endocrine effects, hepatotoxicity, and immune effects.

The Way Forward Waste Management and Reduction

Similar to energy management, it is important for renal services (kidney transplantation) to develop a waste management strategy. The effective segregation of waste produced at the source is a key factor in such a strategy. This approach prevents nonclinical waste from being streamed with clinical waste, which reduces disposal costs. An important element of such an approach is staff education. Nursing and technical staff are generally unaware of the differences in disposal costs for clinical and general waste. Ideally segregation should take place as close as possible to where the waste is generated, so as to prevent additional handling of the waste.

Such an approach may at first glance be considered impractical in the renal unit (kidney transplantation procedure) environment. However, a number of studies have highlighted the benefits from such an approach. For example, a study in a district general hospital setting in the United Kingdom showed that the introduction of waste sorting at the point of production led to a 30% reduction in the clinical waste generated. In a more recent Australian study set in a hospital with 70 beds, sorting at the source reduced the clinical waste produced by approximately 1300 kg (1.3 metric tons). Sorting at the source focuses primarily on the entry of nonclinical waste into the clinical waste stream.

Further cost savings may be made by the conversion of clinical waste to nonclinical waste, permitting their disposal at a lower cost. A number of different approaches have been suggested, the aim being twofold: first, to render the waste noninfectious, and second, to make the waste unrecognizable, permitting its disposal via landfill. However, such an approach may be subject to limitations; for example, in the case of PVC containing materials, despite making the object unrecognizable, they may still leech plasticizers into the ground. As an alternative, ground or shredded PVC can be recycled and incorporated into products such as floor mats and hoses.[10]

In addition to segregation at source, recycling of packaging material also reduces waste. Packaging can be divided into three broad categories: primary packaging, which protects the item itself; secondary packaging, which relates to larger boxes or cases in which groups of items are delivered to the user; and transit packaging such as wooden pallets and wrapping that are used for larger loads for transport. To reduce such waste, even though the boxes can be recycled, a number of medical device companies have started to replace the boxes with reusable tote pans and the wooden pallets with plastic pallets.

Recycling and reuse allow us to minimize the environmental impact of waste. The reuse of tools that can be recycled of kidney transplant procedure in the future has been widely practiced, however, the primary consideration has been financial rather than environmental. When kidney transplant device are reprocessed, the reduction in waste generated must be set against the environmental health issues associated with the use of chemicals for cleaning and reprocessing of the decice, as well as any potential mortality and hospitalization risks associated with reuse.[9]

Substitution of Hazardous Materials

Hazardous materials, which require special management and create specific risks to users and the community, should be replaced with less hazardous materials. Waste from kidney transplantation procedure units contains large amounts of PVC. Although therehasbeenareductionindioxinsandrelatedcompoundsvia incineration, disposal via landfill is associated with the release or leeching of phthalates in to the ground, while accidental combustion leads to atmospheric discharges of dioxins and dibenzofurans. Polyolefin, a class of materials that includes polypropylene, high- and low-density polyethylene, and poly-isobutylene, represent a potentially suitable alternative to PVC. They offer a similar flexibility to PVC, achieved by specific three dimensional molecular configurations rather than by the addition of plasticizers. A number of multinational companies are developing biodegradable plastics. One such material (Nodax, Procter

and Gamble) is based on poly (3-hydroxybutyrate-co-3-hydroxyhexanoate) (PHBH), which on disposal decomposes to water and carbondioxide by the action of microorganisms in the natural environment. This material is suitable for a variety of clinical applications, including wrapping, disposable wipes, and medical surgical garments.

To render PVC flexible it is blended with plasticizers, most commonly di(2-ethylhexyl) phthalate (DEHP). For a number of years there have been concerns about the possible health effects of this compound both in the general population as well as in specific patient groups.11

Because of these issues, a number of regulatory agencies have evaluated the safety of this compound. AnFDA safety assessment undertaken in 2001 reported that DEHP may not be safe for infants, children, and adults receiving certain medical treatments that involve PVC containing medical devices. In 2002 a Health Canada Expert Advisory Panel recommended that health care providers not use DEHP-containing devices in the treatment of pregnant women, breastfeeding mothers, infants, males before puberty, and patients undergoing cardiac bypass, kidney transplantation procedure, and heart transplant surgery. The report also named certain patient groups and medical procedures that require urgent action: "Alternate measures are immediately justifiable and should be introduced as quickly as possible to protect those subpopulations at greatest risk, namely the fetus, newborns, infants, and young children receiving transfusions, ECMO, cardiopulmonary bypass, exchange transfusion, kidney transplantation procedure, TPN (total parenteral nutrition) and lipophilic drug for mulations"[8,9,10]

Major medical device manufacturers as well as purchasing groups have signaled their intent to shift their product development and purchasing activities away from PVC in favor of alternative materials.

2. Conclusion

More comprehensive research evidence is required to inform and support clinical waste management and its regulation. Although inevitably unwelcome, further policy and practice changes are needed and these must be supported by a comprehensive research strategy. There is great need for improved packaging for wastes necessitating innovation and investment in design and development. Economists, environmental scientists, and politicians must work together to evaluate the merits of managing all health care wastes as a single waste stream with post process materials or energy recovery. This may require further basic and transitional research, and regulatory support, to deliver a commercial and environmental advantage that is not met by the current approach of source segregation. Elsewhere, the world community must address the role of waste management in the delivery of safe health care in developing countries and support the design, manufacture and introduction of effective low-technology approaches to waste treatment for use in those regions, while providing assistance in education and technical support in these emerging economies.

At the strategic level, planners must address the impact of warfare, famine, and other natural disasters, and major epidemics or pandemics, on waste disposal practice that must be responsive to these extreme circumstances. In planning for these eventualities, approaches to disposal must accommodate sometimes critical pressure on the resource infrastructure. Protecting public health is imperative. Speed of response and flexibility are essential. Flexibility may conflict with legal and other constraints governing environmental, health and safety, and waste management issues but where legislation imposes restriction on humanitarian aid and public health there must be scope for discretion, setting aside established legislation in circumstances where regulation would impede delivery of aid. Early review of the executive action that permits relaxation of waste management and other legislative constraints is essential, with restoration of normal legislative obligations as soon as circumstances permit.

Though characterized by a succession of relatively small steps, recent years have witnessed continual improvement in waste management standards. Further change must be evidence based and managed effectively to ensure universal uptake and full compliance. At every level, comprehensive training is essential and this should be intercalated in the training curriculum for health care staff, to raise awareness of the risks and of the financial, environmental, and legislative impact of errors of disposal. Although often overlooked, the ongoing training and supervision of ancillary workers and waste handlers is essential.

Kidney transplantation procedure owes much of its success to the availability and use of prepackaged sterile items, however, the use of such items generates a considerable amount of clinical and nonclinical waste. A kidney transplantation procedure unit treating lot of patients generates tons of waste annually, of which a substantial portion is clinical waste. The cost of disposal of such waste is between £180 and £320 per metric ton. Compliance with more stringent environmental requirements will undoubtedly result in further increases in disposal costs. To minimize costs, kidney transplantation procedure units need to review their clinical waste disposal practices and introduce waste management programs. Since much of the waste generated is PVC based, consideration should also be given to the use of alternative materials whose disposal is more "environmentallyfriendly."[11]

Opportunities for advances in environmental protection and pollution control must be balanced against the demands of health care delivery. A properly measured risk-based approach should take precedence over cumbersome approaches to disposal driven by ideology alone. Safe and effective clinical waste management is expensive, but neither 'fashionable' nor 'sexy.' Often

relegated in importance, it receives only cursory management attention and a reduced budget allocation. However, there is a universal responsibility for the safe disposal of clinical and other wastes to reduce the environmental footprint of health care activities and of the disposal process itself, and to ensure the safety of those involved at every stage of the disposal chain, from generation to final disposal.

References

[1] Office of the Deputy Prime Minister: Strategic planning for sustainable waste management. London: HMSO(2005)

[2] Clinicalwaste: a guidance to local authority client officers on the disposal of clinical waste. Northampton: National Association of Waste Disposal Officers (NAWDAO), Institute of Waste Management, (2005)

[3] Chaerul M, Tanaka M, and ShekdarAV. (2008) A system dynamics approach for hospital waste management. Waste Management 28: 442-449

[4] Lee B-K, Ellen becker MJ, and Moure-Ersaso R. Alternatives for treatment and disposal cost reduction of regulated medical wastes. (2004). Waste Management 24:143-151.

[5] Salkin IF. Conventional and alternative technologies for the treatmentofinfectiouswaste.(2003). Journal of Material Cyclesand Waste Management 5:9--12.

[6] A. Breda (Chair), K. Budde, A. Figueiredo, E. LledóGarcía,J. Olsburgh (Vice-chair), H. Regele EAU Guidelinesof Renal Transplan. (2019)

[7] Tudor TL, Marsh CL, Butler S, Van Horn JA, and Jenkin LE.(2008). Realising resource efficiency in the management of health care waste from the Corn wall National Health Service (NHS) in the UK. Waste Management 28:1209-1218.

[8] Safety assessment of di(2-ethylhexyl)phthalate (DEHP) released from PVC medical devices. Rockville, MD: Center for Devices and Radiological Health, U.S. Food and Drug Administration, (2001)

[9] Tickner JA, Schettler T, Guidotti T, McCally M, Rossi M: Health risks posed by use of di-2-ethylhexyl phthalate (DEHP) in PVC medical devices: a criti- cal review.(2001) Am J Ind Med 39:100–111.

[10] Hill SS, Shaw BR, Wu AH: The clinical effects of plasticizers, antioxidants, andothercontaminants in medical polyvinylchloride tubing during respiratory and non-respiratory exposure. (2001). Clin Chim Acta 304:1–8

[11] Safety assessment of di(2-ethylhexyl)phthalate (DEHP) released from PVC medical devices. Rockville, MD: Center for Devices and Radiological Health, U.S. Food and Drug Administration.(2001)