Assessment of Biomedical Waste Generation in Dialysis Units: A Prospective Observational Study—Is it Time for “Green Dialysis”? 

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ABSTRACT

Introduction: Chronic kidney disease and as a consequence end-stage kidney disease (EKSD) is increasing globally. More and more people across the world are requiring hemodialysis (HD). The HD procedure produces a large quantity of biomedical waste. In addition, HD consumes a large quantity of water. In this study, we estimated the waste generated from our government-funded HD unit.

Materials and methods: It is a prospective study that was carried out in the dialysis unit in the nephrology department over a period of 1 year. The daily dialysis waste generated by the unit was measured using a spring balance. The proportion of plastic and nonplastic waste was determined. The quantity of biomedical waste generated per person in 1 year was calculated. Water input to the dialysis unit was noted. Water consumption per dialysis was calculated. Liquid chemical waste consumed was determined. Electricity consumed by the unit was measured by the electricity meter. The cost of waste disposal was calculated. The cost of electricity consumption and water consumption was also calculated.

Results: The approximate weight of waste disposables generated in one dialysis was 0.75 kg. Approximately each person generates 1.29 kg of waste per dialysis. Each dialysis required 125 L of reverse osmosis (RO) water and to generate 125 L of RO water 250 L of raw water was used. This happens as 125 L of water are rejected during the generation of 125 L of RO water. Thus, the net water consumption for each dialysis was 250 L. Chemical waste generated per dialysis includes 90 mL citric acid per dialysis and 130 mL bleach.

Discussion: Each dialysis patient produced 1.29 kg of waste per dialysis which was like other studies. Unlike other studies, the waste was not being reprocessed or recycled.

Conclusion: Hemodialysis produces substantial biomedical waste. Proper waste disposal techniques and policies to promote reduction, reuse, and recycling will go a long way toward promoting green dialysis and reducing environmental as well as economic burdens.

INTRODUCTION

About 2.61 million patients in the world underwent dialysis in the year 2010. It is estimated that in the year 2025, about 4 million patients will be treated with dialysis worldwide. Most end-stage kidney disease (ESKD) patients are treated with hemodialysis (HD). Peritoneal dialysis is employed less often. Hemodialysis numbers in India are believed to be 175,000 (0.175 million) annually. It is likely that the number of dialysis will increase due to the dialysis initiative by the government of India.

Public-funded dialysis was initiated for the first time in the country in 2009 in the erstwhile Andhra Pradesh. Currently, the Telangana government has developed the hub-and-spoke model of dialysis. There are three major hub centers in Hyderabad and each of these centers caters to 20–30 spoke centers which are located in the districts under them. These units are providing dialysis at the doorstep for most of the patients.

There is an enormous generation of biomedical waste from hospitals. Hemodialysis is a major contributor toward biomedical waste. Improper waste disposal damages the natural fauna and flora and is a harbinger of many infectious diseases. The disposal of biomedical waste is very expensive. There are very few studies on the magnitude of biomedical waste generation from dialysis units in India and this prompted us to take up the study.

MATERIALS AND METHODS

This was a prospective study that was performed in the nephrology dialysis unit over 1 year period from April 2022 to March 2023. The measurement accuracy of the scale used for the measurement of dialysis disposables was 0.1 gm. The daily dialysis waste generated by the unit was measured using a spring balance. The proportion of plastic and nonplastic waste was determined. The quantity of biomedical waste generated per person in 1 year was calculated. Water input to the dialysis unit was noted. Water consumption per dialysis was calculated. Liquid chemical waste consumed was determined. Electricity consumed by the unit was measured by the electricity meter. The cost of waste disposal was calculated. The cost of electricity consumption and water consumption was also calculated.

Variables are expressed as mean ± standard deviation or percentages or frequencies. Student’s t-test or analysis of variance was used to analyze continuous variables. Normality was tested using Kolmogorov–Smirnov test. Nonparametric variables were compared using Mann–Whitney U or Kruskal–Wallis tests were used as appropriate to compare nonparametric variables while categorical variables were tested using Pearson’s χ² test or Fisher’s exact test. A p-value of <0.05 was considered to be statistically significant. Epi Info™ version 7.1 was used for statistical analysis (Division of Health Informatics and Surveillance, Center for Disease Control, Atlanta, United States of America). The Institutional Ethics Committee provided the approval for the study.

RESULTS

The approximate weight of waste disposables generated in one dialysis is...
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shown in Table 1. The waste generated per month and yearly from the dialysis unit is given in Table 2. Each person generates approximately 1.2 kg of waste per dialysis. Each dialysis required 120 L of reverse osmosis (RO) water and to generate 120 L of RO water 250 L of raw water was used. This happens as 125 L of water is rejected during the generation of 125 L of RO water. Thus, the net water consumption for each dialysis was 250 L. Chemical waste generated per dialysis includes 90 mL citric acid per dialysis and 130 mL bleach.

Each dialysis consumes 3 KV of electricity. The cost of electricity for each dialysis was 8.5 INR per unit, that is, 25.5 INR per dialysis and the cost of water was 100 INR/kL, that is, 25 INR for each dialysis. The cost of waste disposal for each dialysis bed was 6 INR.

**Table 1: Waste estimated from one dialysis**

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialyzer</td>
<td>200 gm</td>
<td>Plastic</td>
</tr>
<tr>
<td>Blood tubings</td>
<td>250 gm</td>
<td>Plastic</td>
</tr>
<tr>
<td>Packing of dialyzer +</td>
<td>25 gm</td>
<td>Plastic</td>
</tr>
<tr>
<td>Blood tubings + syringes</td>
<td>50 gm</td>
<td>Silicon + metal</td>
</tr>
<tr>
<td>and fistula needle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline bottles empty × 4</td>
<td>50 gm</td>
<td>Plastic</td>
</tr>
<tr>
<td>Gauze</td>
<td>2.5 gm</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.7 kg (wet)</td>
<td>0.5 kg dry</td>
</tr>
</tbody>
</table>

**Table 2: Measured waste generated per month in the dialysis unit**

<table>
<thead>
<tr>
<th>Total waste per month (kg)</th>
<th>Dialysis number/month</th>
<th>Kg/patient per dialysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>2340</td>
<td>1,800</td>
</tr>
<tr>
<td>May</td>
<td>2088</td>
<td>1,740</td>
</tr>
<tr>
<td>June</td>
<td>2222.84</td>
<td>1,822</td>
</tr>
<tr>
<td>July</td>
<td>2238.2</td>
<td>1,805</td>
</tr>
<tr>
<td>August</td>
<td>2441.8</td>
<td>1,864</td>
</tr>
<tr>
<td>September</td>
<td>2156.28</td>
<td>1,812</td>
</tr>
<tr>
<td>October</td>
<td>2239.8</td>
<td>1,821</td>
</tr>
<tr>
<td>November</td>
<td>2287.5</td>
<td>1,830</td>
</tr>
<tr>
<td>December</td>
<td>2188.8</td>
<td>1,824</td>
</tr>
<tr>
<td>January</td>
<td>2337.4</td>
<td>1,798</td>
</tr>
<tr>
<td>February</td>
<td>2246.8</td>
<td>1,812</td>
</tr>
<tr>
<td>March</td>
<td>2146.76</td>
<td>1,804</td>
</tr>
</tbody>
</table>

Each person generates 1.75 lakh patients on HD in India. The data on waste generation from dialysis units is sparse. Hence this study was conducted to determine the biomedical waste produced from a publicly funded dialysis unit. The average number of dialysis done in our center per month was around 2,000.

Solid Waste

In our study, we found that the weight of disposables used in dialysis was 0.85 kg. Each person generated 1.239 kg of biomedical waste per dialysis in our study. If we take 144 sessions of dialysis each year for each person (presuming three dialysis per week) then each dialysis patient will generate 178.4 kg waste per year. In another study by Abhilash and Yadla Manjusha, the approximate waste generated per person per year was 1.08 kg/dialysis.

The percentage of plastic waste was 70% in our study. In the study by Piccoli et al., each dialysis session produced plastic waste produced per dialysis session ranging from 1.5 to 8 kg waste of plastic. Only 25% of plastic waste is recyclable. Polyvinyl chloride (PVC) and polypropylene (PP) are recyclable. However PVC and PP are often mixed with plastic tags, inks, and glues which interfere with recycling. Another issue is that though PVC is recyclable, PVC incineration is environmentally sensitive. Furthermore, Hoenich et al. demonstrated that blood tubing sets contain plasticizers such as di(2-ethylhexyl) phthalate (DEHP), which pose health risks to patients. The use of different types of plastic in the same device should be avoided as this may help in recycling. In addition to plastic, each dialysis session produces other recyclable waste like paper and cardboard and this accounts for 223–736 gm per dialysis session in a study by Piccoli et al.7

The most important hazardous waste in dialysis includes dialyzers, bloodlines, and needles. Infectious waste amounted to 1 kg per dialysis in our study. In the study by Piccoli et al.,7 potentially hazardous wastes varied from 1.1 to 8 kg, which varies with the type of dialysis machine and dialyzers, differentiation, and emptying policies. Żebrowski et al. in their study classified the dialyzers depending on the surface—(1) 1.4 m², (2) 1.5–1.6 m², (3) 1.7–1.8 m², and (4) 2.0–2.2 m². The lightest dialyzers in each group were FX class dialyzers while the polyflux were the heaviest. The weight difference between the lightest and heaviest dialyzers was 95 gm. PP was the lightest housing material, whereas the housing of the heavy dialyzers was polycarbonate. The density of polycarbonate is approximately 20% greater than the density of PP. In our study, the dialyzers used were of a single variety, that is, Elisio. These are made of polymers not containing bisphenol A or DEHP.

In our study, Elisio dialyzers were used with a fill volume of 80 mL. The filling volume was lowest in FX dialyzers whereas it was highest in Elisio dialyzers. The difference was 20 mL. Thus, choosing the lightest dialyzer with minimum fill volume can reduce dialysis waste. In a year, Żebrowski et al.9 estimated that a lighter dialysis set can decrease biomedical waste generation by 17 million kg. In our study dialyzers were completely emptied manually before discard. Fresenius 6008 machine allows for an emptying process at the end of dialysis unlike Fresenius 4008 and 5008 machines and reduces waste by 150 gm. However our machines did not have this facility. Hence, we practiced manual emptying of the dialyzer before discard.

About 1 minute time is required at the end of the dialysis session for differentiation between hazardous and nonhazardous waste and for separation of plastic and paper from among the nonhazardous waste in our study which is comparable to other studies. Segregation at source helps in reducing, reusing, and recycling.
In the developed world SteriMed, Sterishred, Meteka, and Celitron are systems that steam sterilize and then plastic waste is shredded into fine, confetti-like products. Plastics can be classified into VII grades. These include—(1) polyethylene terephthalate, (2) high-density polyethylene, (3) PVC, (4) low-density polyethylene, (5) PP, (6) polystyrene, and (7) other plastics, such as acrylic, nylon, polycarbonate, and polyactic acid. The numbers indicate ease of recycling, with one being the easiest. In dialysis units, PVC, PP, and polycarbonate are used. Also, some dialysis materials may have mixed plastics. Mixed plastics cannot be recycled easily. However, they can be incorporated into building materials—concrete bricks or can be added to molten bitumen (asphalt) which is then used for making the road surfacing. Studies in India and the Netherlands have shown that the ideal ratio is one part shredded plastic added to 10 parts bitumen. Plasticization of road surfaces has several benefits—(1) it increases the flexibility and durability of the surface, (2) it makes the road resistant to both extremes of heat and cold, (3) pothole formation is prevented, and (4) cracking of roads is reduced. Thus, even mixed nonrecyclable plastic can be utilized in laying roads. This is presently not being practiced in our unit.

Water Waste

The RO water used during each dialysis was 125 L which contributes to dialysis effluent waste. To generate this RO water around 250 L of raw water was used in our study (50% of rejected water is produced during RO water generation). However, another study by Agar et al. demonstrated that 500 mL of water was used for each session. Here, they had included water for priming, washing etc.11

Thus, dialysis contributes to a huge waste of water resources. This reject water generated by most RO systems though unfit for dialysis, meets the potable water criteria as it is already cleaned by the sand filter, carbon filter, and softener. However, in most places, it is “unacceptable” to drink. Agar et al. have used rejected water for steam sterilization, toilets, car washes, and gardening. Dialysis effluent can be used for toilet flushing. It is interesting to note that each toilet flush utilizes 5 L of water. Presently this RO reject water or effluent is not being utilized in our unit.

Chemical waste generated per dialysis includes 90 mL citric acid per dialysis and 130 mL bleach which is produced during machine sterilization. Ours is a single-use dialysis setup hence chemicals are not required for dialyzers and tubing reuse. In hospitals where reuse is practiced, chemicals needed for reuse, that is, renalin (peracetic acid) will also add to the liquid chemical waste.

Electricity used for each dialysis in our unit was 3 kWh which was comparable to a study by Nickel et al.12 in which per treatment electricity used was 3.5 kWh. This includes a pretreatment period of 60 minutes during which the hemodialysis machines undergo automatic system checks and there is also a 45-minute heat disinfection cycle after dialysis. Instead, cold disinfection and organic acids may be used to disinfect the dialyzers and machines to reduce electricity.

Carbon footprint is defined as carbon dioxide emissions associated with all the activities of a dialysis patient. It consists of direct emissions from fossil-fuel combustion in heating and transportation, emissions required to generate electricity, and emissions of other greenhouse gases, such as chlorofluorocarbons, nitrous oxide, and methane. The annual per-patient carbon footprint of satellite conventional HD is 10.2 tonnes of carbon dioxide equivalents in Australia while NHS estimates it to be about 7 tonnes per patient annually. The average carbon footprint of a person not on dialysis is 4 tonnes.13 In our study, we did not calculate the carbon footprint.

Cost

The approximate cost of waste disposal per dialysis bed is 6 INR per bed while in the European countries, it costs about 3 Euro to utilize 1 kg of medical waste.7 The cost of electricity for each dialysis was calculated as 25.50 INR. In a study by Nickel et al., the per-treatment cost of electricity was 0.33$ for 3.5 kWh and 2$ for 0.6 m3 water per treatment.12 Some units have suggested the use of solar panels to meet the electricity needs of the dialysis unit. The cost of installment is high however the returns can be noticed in 1 year and the break-even occurs in 2 years. The solar panel if handled appropriately has a life span of 20 years and works out to be cost-effective in the long run. In the United Kindom, the green nephrology network has saved 10 million euros in 1 year by promoting water and electricity saving initiatives.14

A position statement has been issued on green dialysis by the Nephrology Society of Australia and New Zealand.16 European Renal Association–European Dialysis and Transplant Association has also planned many initiatives aimed at promoting green nephrology in Europe.17 Green innovation of nephrology is also the main thematic of European Kidney Health Alliance in 2022.18 Italian society has also issued a position statement on green dialysis.19

There is no cost involved in the implementation of some of these policies. Implementation of these policies in all the dialysis units would result in major cost savings for our country.

Conclusion

A huge quantity of waste is generated during each dialysis. Proper segregation of waste at source, separation of biohazardous waste and recyclable waste helps in reducing the quantity of biomedical waste and thus protects the environment and reduces costs. Similarly repurposing dialysis reject water and effluent water in toilets and reusing the dialyzer waste as concrete may further decrease waste generation. Installation of solar panels may reduce electricity consumption and reduce carbon footprint. Formulation of state and national policy on green dialysis may be an important step forward.

Limitation

It was a single-center study. The carbon footprint of the unit was not calculated.

Acknowledgment

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References

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