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RESEARCH LETTER

Combining Patient Care and Environmental Protection: A Pilot Program Recycling Polyvinyl Chloride From Automated Peritoneal Dialysis Waste

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INTRODUCTION

Dialysis produces large amounts of plastic waste, much of which is potentially recyclable, but recycling is seldom performed.[1-3] This stagnant situation is expected to change, because by the end of 2024, 175 United Nations members have agreed to develop a legally binding agreement on plastic pollution, and the organization "Health Care Without Harm" has called for no exemption for plastics derived from medical supplies, a choice that will hopefully change the management of medical-related plastic waste.[4,5]

More than 25% of the polymer products used in medicine (including flexible blood containers, intravenous solution bags, flexible tubes, and oxygen masks) are made of polyvinyl chloride (PVC), because of its biocompatibility, chemical stability, and resistance to sterilization. PVC is a thermoplastic polymer, which currently ranks third in terms of production volume worldwide.

PVC disposal, especially incineration, produces dioxins, the exposure to which has been linked to risk of cancer, developmental problems in children, and infertility in adults. Toxicity of PVC products is also linked to plasticizing additives, mainly phthalates, which are suspected to be carcinogens and can leach out when the PVC is disposed in landfills, thereby contaminating groundwater supply.[6]

One feature of PVC, to date underexploited in medicine, is that it can be recycled up to 8 times.[7] Although most automated peritoneal dialysis (APD) plastic waste has not been in contact with bodily fluids (only the drainage line in is brief contact with the effluent) and is fully recyclable, one of the main barriers to the recycling of health care waste is that it is considered "hazardous".[8,9] To the best of our knowledge, however, only few programs for recycling PVC derived from peritoneal dialysis exist, in Australia and New Zealand, Colombia, and Guatemala, all run by, or in collaboration with, the Baxter Company. Some companies, such as RECOMED in the UK or Vinyl Council in Australia, have been increasingly involved in this activity. Although there is some online information about recycling programs on the companies' websites, we were not able to find any published data.[S1–S4]

In this paper, we describe a recycling program for the PVC waste (drainage line included) from APD. This pilot experience helps identify barriers to systematic recycling and makes it possible to propose solutions to overcome them, making the program patient friendly and financially sustainable.

RESULTS

Feasibility Study

All patients enrolled (20 patients) in an APD program at the Médica Santa Carmen clinic in Mexico City were invited by verbal request to participate (October–November 2022) and were instructed to save all their APD waste material and return it to the clinic at their next appointment (Supplementary Figure S1). The collected material was sent to a processing facility and tested for quality (purity and physical characteristics of the PVC).

Cost Analysis

The cost analysis was based on the financial characteristics of Mexico City, and included equipment (industrial mill, industrial dryer, separator, container, and vehicle), and running costs (rent, water, electricity, supplies, gasoline, and employee wages) (Supplementary Figure S2). Earnings were inferred using PVC resin prices (19 Mexican pesos [$1.12] per kg, July 2023). (Details in Supplementary Methods.)

Feasibility Study

Of the 20 patients invited, 12 agreed to participate; mean age was 57 ± 17.5 years, 8 were males, 7 diabetics, and median APD vintage was 3.3 ± 0.6 years. None of the patients were insured; in the study setting, patients pay about $1000 per month for the APD program, which includes materials, delivery, and a monthly medical appointment in the clinic. Conversely, patient follow-up with social security programs usually have fewer resources and less frequent medical appointments, potentially experiencing more difficulties in following such a program.

The main reasons not to participate were perceived complexity to lack of time (6 patients), transportation problems (living far from the center: 2 patients).

All patients used the Baxter HOMECHOICE CLARIA machine with an average daily prescription of 9 liters of dialysate (two 6 L bags per night) with no daytime dwell.

During an observation time of 1 month per patient, we collected 195 kg of APD waste (about 16 kg per patient), from which we obtained 116 kg of PVC (59%).

The average time to manually separate waste was about 1 minute per kit (0.280 kg of PVC) (17 kg of PVC per hour) (Supplementary Movie S1). After separation, the plastic was machine shredded, and machine dried (the amount of PVC obtained after full processing was 8.5 kg/h). A sample of the processed material fulfilled the company's (EIQSA) quality requirements (purity and material characteristics) for sale to companies making cables and shoe soles (Supplementary Movie S2).

Financial and Environmental Sustainability Study

The main costs considered in the financial analysis are reported in Table 1.

To achieve a return on investment in 5 years, we calculated the need to retrieve at least 3.2 tons of PVC per month, derived from 5.5 tons of APD waste, corresponding to the waste from 345 patients, about 5% of the PVC waste resulting from APD in Mexico City, where we estimated that about 7000 patients are currently on APD (Supplementary Table S1).[S5–S7] However, once the initial cost is covered, the system will break even with about 263 patients per month. This would correspond to recycling about 3.7% of the PVC waste resulting from APD in Mexico City.

We estimated that for every kg of PVC resin produced we avoid the consumption of 13 liters of water, 20 KwH of energy, and 5 kg of CO_2 emissions, as compared to the production of virgin PVC resin (Supplementary Table S2) (Figure 1).[S8,S9]

Table 1. Cost analysis

Costs[a,b]	Mexican pesos	US dollars[c]
Fixed assets		
Mill[d] (Custom made Mill10 HP, 7.4 kWh engine)	145,000	8529
Dryer[d] (Custom made 35 kWh energy consumption)	180,000	10,588
Processing device[d] (not yet purchased 75 kWh 150 kg/h capacity)	150,000	8823
Van	315,900	18,582
Total	790,900	46,522
Monthly costs to recover initial investment in 5 yr	13,182	775
Monthly costs for recycling PVC from 345 patients on APD per month		
Wages per worker (considering 2 workers)[e]	8589 (17,178)	505 (1010)
Rent	15,000	882
Electricity (3500 KW/h)	10,000	588
Water (5000 l) (1.5 l/kg PVC obtained)	1000	59
Gasoline[f] (90 l)[c] (250 km/wk)	2000	118
Miscellaneous supplies (bags, spare parts)	2000	118
Monthly costs to recover expenses in 5 yr	13,182	775
Total	60,360	3550

APD, automated peritoneal dialysis; PVC, polyvinyl chloride.
[a]Amount of material to be sustainable PVC: 3.2 tons, using current PVC resin prices (19 Mexican pesos [$1.12] per kg).
[b]Number of employees required: 2, considering that each employee can process 8.5 kg/h, and works an 8-hour day and a 6-day week.
[c]17 Mexican pesos per $1 (average July 2023 rate).
[d]Estimate made by industrial suppliers in Mexico (www.eurotecsa.com,www.maquinariaparaplastico.com/services).
[e]Using current (2023) minimum wage legislation in Mexico including Social Security and legally required benefits.
[f]22 Mexican pesos ($1.3)/l.
For this pilot program, we did not purchase any commercial industrial hardware and our machines were custom made.

DISCUSSION

In this pilot study, we demonstrate the feasibility of implementing a recycling program involving patients on APD. We suggest, albeit on a small scale, that many patients would be interested and willing to be involved. We also show that the PVC obtained from APD plastic waste can be incorporated into the production chain of thermoplastic compounds without needing complex processes or expensive machinery; of note, all our machines were custom made (Supplementary Movies S1 and S2). To the best of our knowledge, PVC recycling programs are available in a few settings.[S2–S4] In the

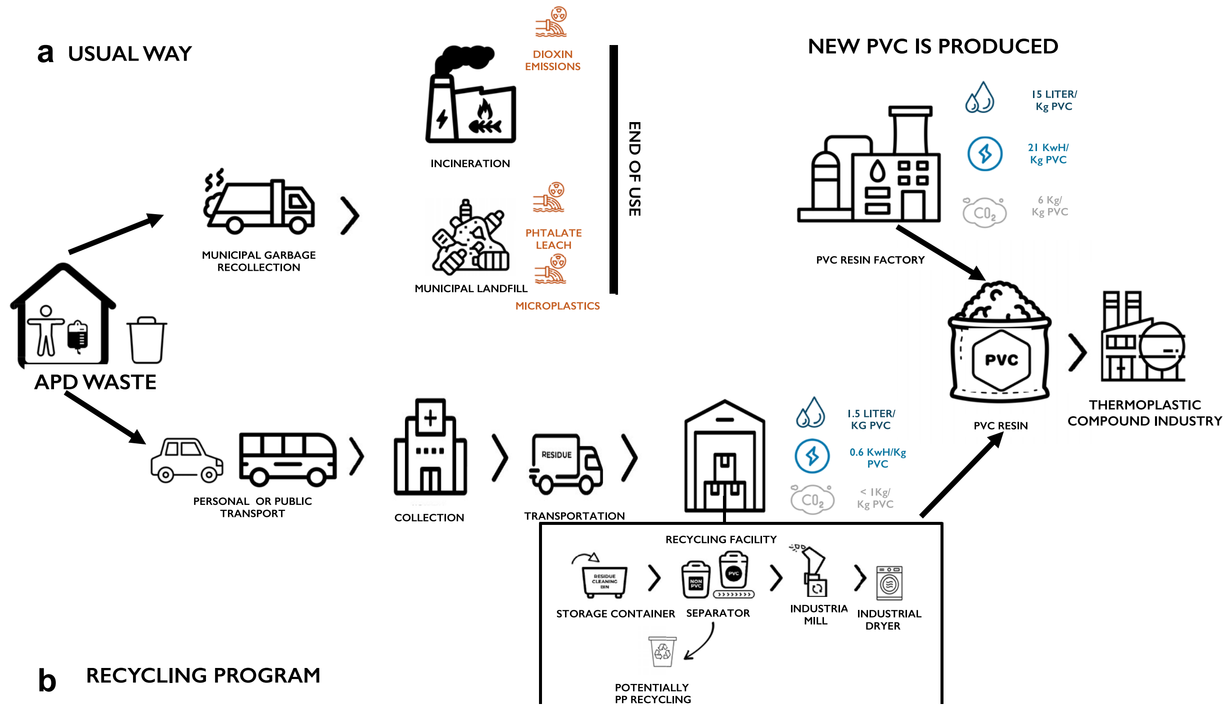

Figure 1. Comparison between a linear and a circular PVC management. Usual management: fuel consumption and CO_2 generation are induced by the transportation of the APD waste, depending on how it is disposed of, in a landfill or by incineration. If disposed by incineration, the PVC can produce dioxins and CO_2 emissions. If in a landfill, the PVC can leach phthalates into the groundwater. As this is a linear economy, this is the final step of the process. To obtain virgin PVC, new resin must be produced. The production of 1 kg of PVC consumes about 21 KwH, 3 to 15 l of water and emits 6 kg of CO_2.[S8,S9] Recycling program: fuel consumption and CO_2 generation are induced by the transportation of APD waste to the collection center and from the collection center to the processing facility. This environmental cost may be reduced by combining it with patients' visits to the hospital and/or delivery of PD materials. In the separation process, 240 g of PP are discarded for every kg of PVC produced. The PP can also be separately recycled. Recycling 1 kg of PVC consumes about 0.6 KwH, 1.5 l and emits less than 1 kg of CO_2. Overall, the "usual waste management" may consume less gasoline, but is associated with the emission of dioxins or leaching of phthalates and microplastics into the environment. Thirteen extra liters of water, 20 extra KwH of energy consumption and 5 extra kg of CO_2 emissions are needed for every kg of new PVC resin produced.[S5,S6] APD, automated peritoneal dialysis; PD, peritoneal dialysis; PP, polypropylene; PVC, polyvinyl chloride.

absence of published data, we are not aware of any ongoing programs in the settings where the authors of this contribution work (Italy, France, and, before our program, Mexico). Of note, contact with several dialysis companies did not lead to a shared program in Mexico, nor was such a program systematically proposed in European countries. This situation may underline why it is important to be proactive in setting examples and proving feasibility. Along this line, this independent pilot experience makes it possible to identify potential obstacles to success.

First, we could not convince all patients to collaborate. In keeping with other reports, the main reasons were linked to transporting and storing waste, not to lack of interest.[S10] Second, separating PVC from other plastic waste is labor intensive, especially if manually performed (17 kg of PVC per hour) (Supplementary Movie S1). Third, PVC is an inexpensive raw material and recycled PVC can be more expensive than the virgin product.

There are, however, possible solutions. First, the infrastructure and the logistics are already in place to deliver peritoneal dialysis supplies. We can exploit this network to collect waste. Second, although the process of separating PVC is time consuming, it takes about 1 minute to do this for each kit. Involving patients by instructing them on how to separate materials as part of the peritoneal dialysis procedure would save time and reduce costs. Third, recycled products are becoming consumer appealing and new laws proposing extra taxes on plastics composed of new materials make recycling more profitable.[S11]

The crucial issue in our program is scale. Collecting the plastic waste of less than 1% of the Mexican APD population and about 5% of the patients on APD in the capital would allow the project to be financially sound (345 patients/mo allow to recoup the investment in 5 years; about 263/mo are required to ensure the financial balance afterwards).

Furthermore, recyclable PVC is not restricted to APD waste and could include continuous ambulatory peritoneal dialysis bags and a wide array of medical material. Moreover, the process can be applied to a wide range of plastic compounds used in health care, including polyethylene (used to make intravenous bags and tubing) or polypropylene (commonly used for syringes, packaging, and most non-PVC APD plastic waste).

The financial sustainability of such a program is higher in low to medium income countries such as Mexico, due to the lower cost of labor. The interest in feasibility in these settings is enhanced by the presence of difficulties encountered in optimal medical waste management in low to medium income countries; thus, making recycling even more planet friendly.[S10,S12]

In summary, establishing a recycling program for PVC derived from APD waste is feasible. The material obtained can be used as a raw material in the production of PVC compounds, thus favoring migration from a linear economy to a circular model. Although the use of PVC has recently been criticized in favor of other plastic compounds, the interest in this independent program is not limited to a specific type of plastic, but may show the possibility of recycling in itself.

At the time of this report, the first 2 authors have founded a nonprofit organization (RE-PVC), rented a warehouse, bought an industrial mill, and hired one worker. APD plastic waste is collected from the clinic where the pilot study was set up and from 2 further facilities in Mexico City. Hemodialysis nonhazardous plastic waste (for example, solution bags used to prime the hemodialysis circuit and plastic bags used to discard the priming solution) is also being collected (over 100 kg of PVC retrieved in 3 months). The next step, that will allow us to confirm feasibility on a larger scale, is ongoing. It starts with an educational intervention about green nephrology, followed by a survey administered to patients and health care teams to better understand willingness, availability, and barriers to participate. An educational video (developed from Supplementary Movie S1) on how to separate the PVC components of the peritoneal dialysis kit is being validated by patients and nurses. We hope that this program may be another small step toward improving the sustainability of dialysis.

DISCLOSURE

All the authors declared no competing interests.

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DATA AVAILABILITY STATEMENT

The data collected for the study, including individual patient data and a data dictionary that defines each field in the data set, will be made available as deidentified participant data to researchers who propose to use the data for individual patient data meta-analysis. Data will be shared following approval of the proposal by the corresponding author and a signed data access agreement. All data available are reported in this research letter. However, authors are available for answering any query on the discussed issues.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Supplementary Methods.

Supplementary References.

Figure S1. Plastic waste from an APD session.

Figure S2. The main steps of PVC recycling.

Table S1. Number of KRT patients in Mexico and in Mexico City.

Table S2. Comparison between the usual waste management and the pilot program.

Movie S1. Patients may separate PVC, and this takes 1 minute per APD session.

Movie S2. Processing of PVC from APD.

STROBE Statement.

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