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ORIGINAL ARTICLE

Haemodialysis therapy and sustainable growth: a corporate experience in France

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ABSTRACT

Introduction. Sustainable growth and environmental issues are currently a topic for all human activities, and dialysis represents a real challenge in this field because of high water and power consumption and the production of large amounts of care-related waste. In this article we describe data collection implemented in the NephroCare centres in France and the changes observed during a 13-year period regarding environmental parameters.

Methods. Monthly data collection (eco-reporting) was implemented in NephroCare centres in France in 2005. It covers three topics designed as key performance indicators (KPIs): electricity and water consumption and care-related waste production expressed, respectively, as kilowatt-hour (kWh), litres (L) and kilograms per session. We report on the three action plans (2005–10, 2011–14 and 2015–18) and changes observed during this 13-year period.

Results. During the period, power and water consumption declined by 29.6% (from 23.1 to 16.26 kWh/session) and 52% (from 801 to 382 L/session), respectively. At the same time, the yearly number of dialysis sessions has increased from 169 335 to 399 336. The sources of savings came both from improvements in the dialysis technology (dialysis machines and water treatment systems) and from updating and remodelling of the dialysis unit equipment and buildings. The care-related waste decreased from 1.8 to 1.1 kg because of regular staff training and the retrofiltration system, allowing the voiding of the remaining saline solution after dialysis. These savings have been estimated as equivalent to 102 440 tons of carbon dioxide.

Discussion. Implementation of KPIs and their regular monitoring by trained staff to evaluate water and power consumption and the reduction of care-related water production are essential to implement actions to reduce the impact of dialysis on the environment. These data show the importance of water treatment and dialysis technology to decrease water and power consumption and the production of care-related waste as well as upgrading or remodelling of buildings housing dialysis units. Other measures are discussed, including the reuse of rejected water by reverse osmosis, as well as behavioural changes that are needed to reach sustainable development of dialysis.

Conclusion. The first step to reach 'green' dialysis is to collect precise information from defined KPIs. This is the only way to design action plans to reduce the impact of dialysis therapy on the environment. Beyond this, the nephrology community must be sensitized to this challenge to be proactive and to anticipate future regulations.

Keywords: carbon footprint, care-related waste, eco-reporting, haemodialysis, power and water consumptions

INTRODUCTION

Sustainable growth and environmental issues are currently a topic for all human activities. The carbon footprint of the medical world is high. In 2007, the US healthcare sector represented 7% of the total US carbon dioxide (CO_2) emissions [1]. Dialysis therapy, and especially haemodialysis (HD), is a great challenge regarding the environment, especially because of the high water consumption [2] and waste production [3]. Among the four main Fresenius Medical Care Quality policies, commitments to the community include actions to reduce electricity consumption, water consumption and healthcare-derived care-related waste. In this article we describe the data collection method implemented in NephroCare centres in France and the changes observed during a 13-year period regarding environmental parameters.

MATERIALS AND METHODS

NephroCare is the European network of dialysis units belonging to Fresenius Medical Care (FMC). Since the beginning of the year 2000, quality and security are operated through an integrated management system (IMS) for continuous improvement.

The IMS integrates three different systems: quality, environment and security. The security system refers to health and safety issues at work [4]. Both internal and external International Organization for Standardization (ISO) audits are regularly performed at all levels of the healthcare organization from the headquarters to the smallest self-care dialysis unit. Besides the organizational issues (ISO 9001), every component of the company must fulfil the environmental standards (ISO 14001).

The first step of the environmental commitment relies on eco-reporting (also named eco-controlling), which began in 2005. Eco-reporting is a monthly monitoring covering three topics designed as key performance indicators (KPIs): electricity and water consumption, expressed in kilowatt-hours per dialysis session (kWh/session) and litres per dialysis session (L/session), respectively, and care-related waste production, expressed as kilograms/session (kg/session). Eco-reporting is under the supervision of the Country Quality Manager. Two important features have been necessary to implement eco-reporting. The first was to individualize the metres to measure water and power consumption directly related to the dialysis activity. Before implementation of the environmental plans, water and power metres could be common to other care activities, especially if the dialysis unit was part of a hospital or if belonging to a common building with other activities. Specific metres were implemented to individualize the specific dialysis consumptions. Dedicating metres to the water treatment system made possible the distinction of water consumption related to dialysis therapy (dialysate production) and water consumption from other activities (cleaning, hand-washing, hygiene, etc.). The second feature of eco-reporting implementation was staff training about the data collection, with the appointment at the unit level of a person in charge of this new task. These two points were mandatory for accurate data collection and for the design of subsequent environmental plans.

The second step of the FMC environmental commitment is the collection of data and their feedback at the country, region and unit levels. Data from all clinics in the Europe, Middle East and Africa (EMEA) NephroCare network are sent quarterly to the FMC headquarters, where they are centralized, consolidated and used for benchmarking, for monitoring the sustainability of the company and for complying with the internal quality system (Bad Homburg, Germany). These data, among others, have been used to establish the FMC environmental plans starting in 2007. These plans have focused on water and power consumption and on waste production in dialysis during the following periods: 2007–10, 2011–15 and 2016–18. These three different plans covered all FMC activities, including design and development, manufacturing, sales, logistic and storage and dialysis therapy. The section of these plans related to dialysis therapy activities are reported in Supplementary data, Tables SA–SC. The first plan (2007–10; Supplementary data, Table SA) focused on awareness of environmental issues related to dialysis therapy, giving directions for eco-reporting, environmental certification of dialysis units (ISO 14001), eco-efficient technologies implementation in dialysis therapy activities and in new building construction and/or existing unit refurbishing. No targets for KPIs were given in this first plan. The second plan (2011–14; Supplementary data, Table SB) gave precise targets about environment awareness in dialysis units, eco-reporting exhaustivity, water and electricity consumption, care-related waste production and ISO 14001 certification (percent of certified dialysis units). The third plan (2015–18; Supplementary data, Table SC) reproduced the second plan, with updated targets according to the data collected from the eco-reporting. These plans have framed the environmental actions at the country and unit level.

The collected data are sent back quarterly to all involved parties at the country, region and unit levels through the Balance Score Card (BSC), which includes these specific KPIs in the community section (Figure 1; see also Supplementary data for more information on the BSC). The normalization per HD session has been an important point, as the number of dialysis units and dialysis patients have increased in France during the period of this study, from 19 in 2005 to 37 in 2018. The exact number of dialysis sessions is automatically reported from the internal clinic management system, EUCLID (version 2000 until 2010 and EUCLID 5 since then), installed in all dialysis units of the EMEA region [5]. The EUCLID software is precisely informed about the dialysis sessions because it is interconnected with the dialysis machine (4008 with progressive substitution to 5008 between 2005 and 2012).

Also, carbon equivalents of power, water and waste sparing were calculated and converted in CO_2 production using the tool provided by the Association Bilan Carbone (Paris, France) [6]. Every person with validated training has access to this tool (G.B. and F.A.). The calculation, regularly updated, integrates the matter, the amount or volume, the transportation means and the distance and converts the spared amount into CO_2 tons equivalent.

RESULTS

We report here the results for NephroCare France from 2005 to 2018 through the three country-level calendar plans described above. The number of dialysis sessions performed in NephroCare during this period has been 3 608 911 HD treatments. The number of HD patients increased from 1328 in 2005 to 2642 in 2018.

Power consumption

Between 2005 and 2007, the number of dialysis units increased from 19 to 29. The electricity data record was switched from yearly to monthly collection. During this period, the power consumption decreased slightly from 23.1 to 20.0 kWh/treatment (Table 1), mainly due to improvements in data collection from trained staff and improvements in data reliability from additional metres. From 2007 to 2010, the number of dialysis sessions increased by 18% and the electricity consumption per session remained stable, with an increase in 2010 reaching 20.7 kWh/treatment (Table 1). An action plan was then implemented, including additional metres, water treatment system changes, air conditioning programming, automatic lighting with

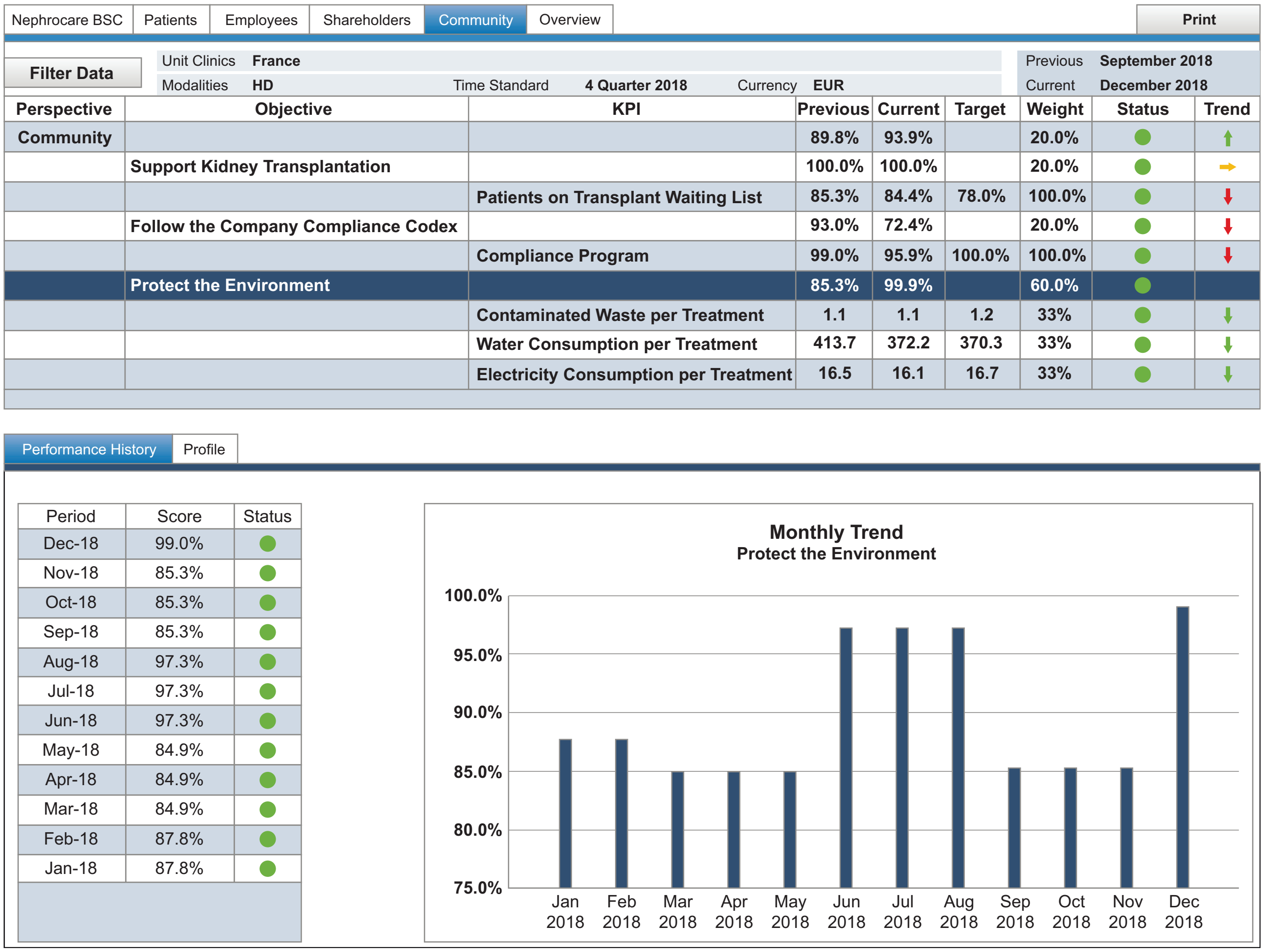

FIGURE 1: BSC displaying the December 2018 community section for NephroCare France. The score of 99% is the aggregate of the difference between the current result of each of the three KPIs and the target value for the three KPIs.

Table 1. Average power and water consumption and care-related waste production per HD session between 2005 and 2017

			Electricity		Water		Care-related waste	
Year	Patients	No. of HD sessions	kWh/session	Target	L/session	Target	kg/session	Target
2005	1328	169 335	23.11[a]	12.5	801.48[a]	415.00	1.77	1.10
2006	1440	196 445	21.34[a]	12.5	680.88[a]	415.00	1.65	1.10
2007	1462	202 009	20.00	12.5	701.36	415.00	1.69	1.10
2008	1555	214 655	20.36	12.5	602.77	415.00	1.60	1.10
2009	1716	252 364	19.50	12.5	567.80	415.00	1.61	1.10
2010	1727	254 754	20.70	11.0	551.10	369.00	1.60	0.95
2011	1810	257 985	19.12	11.0	478.03	369.00	1.42	0.95
2012	1906	274 041	19.05	11.0	434.46	369.00	1.39	0.95
2013	2163	321 337	19.27	11.0	449.91	369.00	1.32	0.95
2014	2257	342 461	18.16	11.0	437.75	369.00	1.22	0.95
2015	2325	351 346	18.05	9.5	432.05	326.00	1.18	0.80
2016	2398	360 415	17.51	9.5	377.63	326.00	1.21	0.80
2017	2599	371 828	17.25	9.5	374.65	326.00	1.14	0.80
2018	2642	399 356	16.26	9.5	381.93	326.00	1.11	0.80

The successive action plan targets are given for each of the three KPIs.
[a]Estimation because not all dedicated metres had been implemented at that time.

motion detectors, light timers and replacement of incandescent with light-emitting diode technology (Table 2). Several other improvements included the downsizing of administration offices and moving a dialysis unit to a high environmental quality building. However, some climatic conditions played against power savings, such as hot late spring periods and cold winters, increasing the use of air conditioning and heating systems. During the analysed period, the target for electricity consumption decreased from 12.5 kWh/treatment in 2005 to 11.0 kWh/treatment in 2010 and 9.5 kWh/treatment in 2015. Finally, since 2010 (20.7 kWh/treatment) the average real electricity consumption declined to 16.3 kWh/treatment at the end of 2018, corresponding to a savings 1200 MWh and a global decrease from 2005 of 29.6%. In Figure 2, the electricity consumption in NephroCare B is displayed. This unit was far above the target of the third environmental plan (9.5 kWh/session). The decision was made to update the reversible heat pump for air and water in two steps, 6 months apart. This has decreased electricity consumption by 10.9% comparing the fourth quarter of 2016 and 2018. However, it remains above the target and additional measures are to be taken.

Water consumption

Estimation of water consumption based on invoices or building metres has been progressively replaced by real data in the eco-reporting since 2007. At that time, the average consumption was 701 L/treatment. However, between 2005 and 2018, the targets for water consumption have declined from 415 L/treatment in 2005 to 369 L/treatment in 2010 and 326 L/treatment in 2015. The action plans have involved several measures to decrease the use of water for dialysis (Table 2): progressive replacement of 4008 by 5008 machines and, more importantly, several water treatment systems were replaced by updated devices with a significant improvement in efficiency in terms of the proportion of rejected water (from 60% to 20%). At the end of 2018, the average water consumption per treatment had declined at 382 L, a 52% decrease in 13 years. To illustrate the powerful influence of new-generation water treatment systems on water consumption, the case of NephroCare P is reported in Figure 3. This unit joined NephroCare France in 2013. A high level of water consumption was seen, at ∼600 L/HD session, whereas the target was set at 369 L (Table 1). After implementation of an updated water treatment system, water consumption dropped by 50%.

Table 2. Listing of measures contributing to the reduction of electricity and water consumption and care-related waste production

Electricity
Staff training for eco-reporting
5008 dialysis machine implementation
Presence detectors and lighting timers
Switch to LED bulbs
Reduced facility size[a]
Moved a unit to a high environmental-quality building
Change or tuning of air treatment systems
Water
Staff training for eco-reporting
5008 dialysis machine implementation
Change in water treatment system
Move to a new building
Care-related waste
Staff training for eco-reporting
Regular audits
Caregiver training for waste sorting

[a]In France, the surface per dialysis chair/station is strictly regulated.

Care-related waste

The targets for care-related waste per treatment have decreased from 1.1 kg in 2005 to 1.0 kg in 2010 and 0.8 kg in 2015 (Table 1). Between 2005 and 2010, the average weight per treatment of care-related waste decreased from 1.8 to 1.6 kg. In 2010, an action plan at the country level was defined, including staff training and audits, leading to an additional decrease from 1.6 to 1.4 kg/treatment between 2010 and 2012. In 2013, voiding of the rinsed circuit to the drain was used in all French NephroCare dialysis units. This procedure is automatically performed by the dialysis machine through a retrofiltration procedure, eliminating the blood-soiled saline remaining in the circuit but retaining the blood part by the membrane. This allows elimination of the care-related waste tubing full of water. Since then, the average care-related waste has decreased from 1.4 to 1.1 kg, representing a 37% decline during the period.

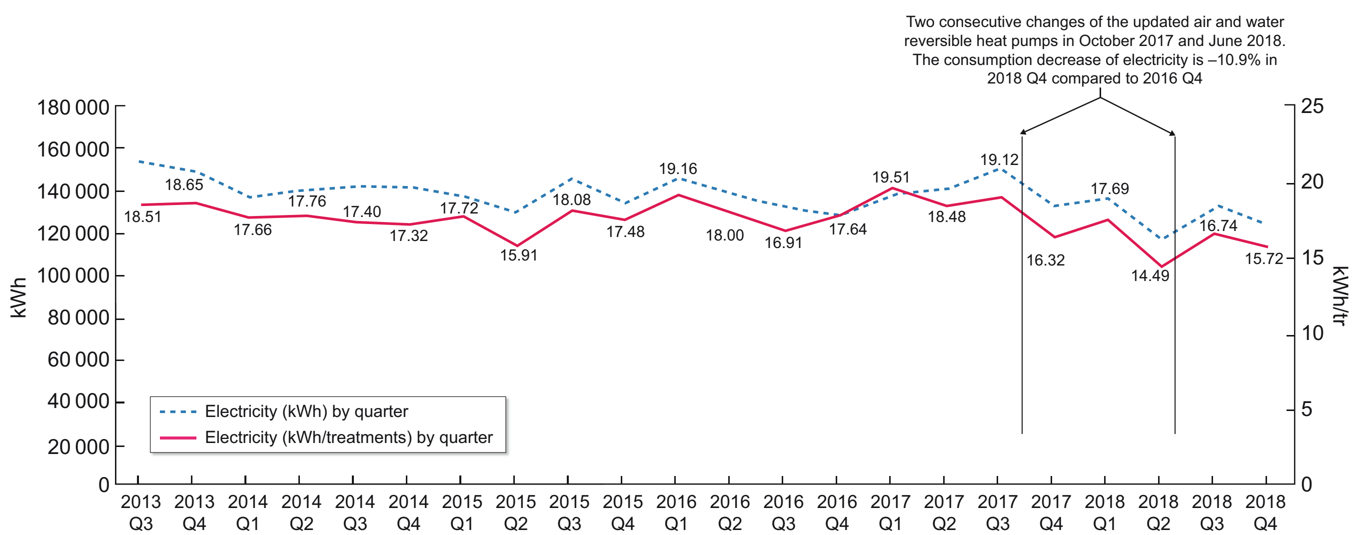

FIGURE 2: Electricity consumption in NephroCare B. The action plan consisted of changes in the reversible heat pump for air and water.

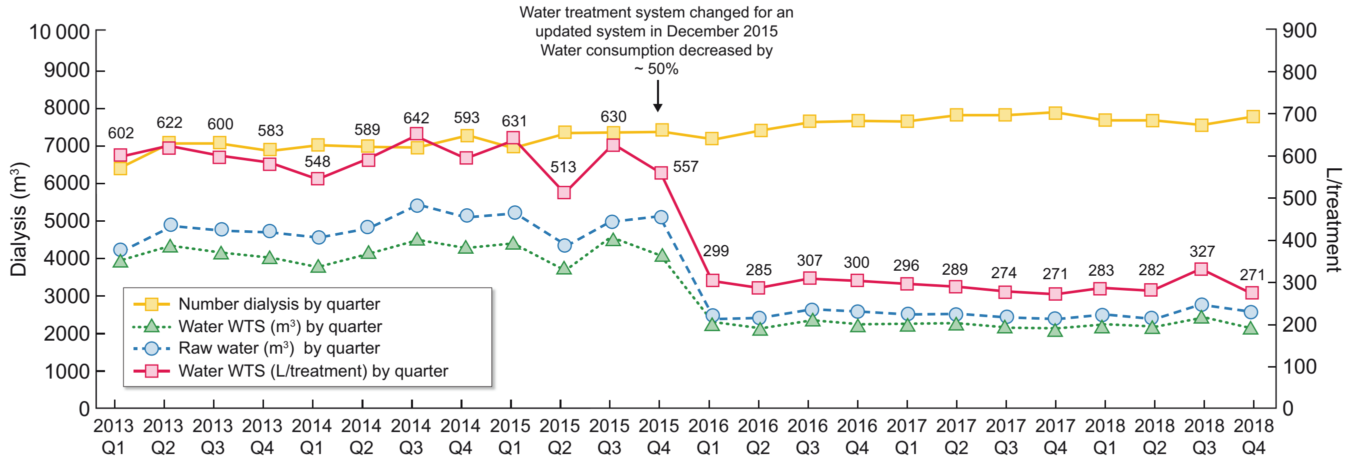

FIGURE 3: Water consumption in NephroCare P. The action plan consisted in changing the water treatment system (WTS) to a new updated one, producing a substantial decrease in water needs.

Carbon equivalent production

The above-described improvements of the three KPIs can be converted into a reduction in CO_2 production. Due to the electricity savings, the CO_2 equivalent was reduced for the analysed period from 92 400 tons, 10 000 tons for care-related wastes and 17.5 tons for water. In total, 102 440 tons of CO_2 equivalent were saved, an amount that represents the CO_2 production of a plane flying around the globe 11 500 times.

DISCUSSION

This report describes the implementation of KPIs and their regular collection to evaluate three main domains regarding the environmental impact of dialysis sessions (water, power and care-related waste); the implementation of successive environmental plans with targets and action plans when KPIs fluctuate or remain far from the targets and the importance of technology in decreasing water and electricity consumption. This approach embraces most of the statements by Agar in defining green dialysis [7]. In this work, the author warns the nephrology community about regulations ahead regarding the environment and urges us to action to be part of this important challenge.

Few data are currently available in the literature regarding water and power consumption in dialysis units. However, since 2005, the French NephroCare centres have focused on data collection. We know very precisely at the unit, region and country level how much is consumed in terms of natural and energy resources. This is a mandatory process, part of their internal policy, aimed at reducing consumption. The normalization of the dialysis session is very easy to use and makes it comparable not only with other dialysis units inside NephroCare, but also with every dialysis facility around the world. The company has always integrated in its IMS a commitment to the community. All the dialysis units in France have been certified ISO 14001 [8] since 2005, parallel with implementation of the program. In the end, it is a win–win process. The eco-reporting process has been very important for all dialysis units to obtain the 14001 ISO certification.

The progressive reduction of water and electricity consumption per session was mainly related to technology changes. The example of water treatment is striking. The current generation of reverse osmosis implemented in NephroCare units has the capacity to send to the dialysis machines 75–80% of the treated water (AquaA from FMC since 2011), whereas it was much less some years ago, with up to 60% of water rejected [9]. Also, heat disinfection of these new reverse osmosis devices instead of chemical disinfection has significantly reduced the water needed for this procedure. Looking back at the 2007–10 environmental plan (Supplementary data, Table SA), cold disinfection implementation was recommended. This shows how important it is to review plans to follow technology advances.

Moreover, implementation of 5008 dialysis machines has contributed to water savings with auto-flow (dialysate flow adjusted to the blood flow at a rate prescribed by the nephrologist [10]) and eco-flow (automatic decrease of blood and dialysate flows when the machine is waiting for the patient connection). Also, by educating the staff, the automatic machine starts for the morning shift with 'infinite' rinsing may reduce water consumption. Moreover, during this period, haemodiafiltration (HDF) has increased significantly. Each hemodiafiltration session has used roughly an additional 15–25 L of water, corresponding to the infusion volume. However, this has not blunted the general trend of a decrease in water consumption with the updating of water treatment systems needed to perform convective therapies.

Regarding power savings, it is difficult to quantify which measures are the most efficient between lighting improvement, air conditioning upgrades and dialysis technology. The reduction of dialysate consumption brings power savings since it avoids dialysate heating, with a power savings of 0.64 kW/h per session (see Appendix).

Care-related waste has benefited from implementation of the 5008. The extracorporeal circuit volume is 20% lower than with the former 4008 machines. Moreover, this gain has been also improved with the retrofiltration procedure, allowing emptying of the circuit, reducing the weight from care-related saline in the filter and tubing. The effort on care-related waste is important for the community because its treatment is costly and a source of energy consumption compared with common waste. However, and despite great progress with these KPIs, it is important to highlight the importance of regular training and audits to maintain the vigilance of caregivers about care-related waste production and reduction.

Beyond the improvements reported in this study, there are a lot of actions to be discussed and implemented to further reduce resource consumption and toxic waste production. One of the easiest measures to implement in dialysis activities is the reuse of rejected water from reverse osmosis. This has been reported in some units in France for sanitation [2] and Australia for in-centre, satellite and home dialysis [11]. In this last report, the rejected water, theoretically suitable for drinking, qualifies as 'grey water' and redirected to sporting facilities and gardens. This is of utmost importance, especially areas under frequent cycles of drought. The authors state that grey water reuse is 'feasible, simple, safe, effective, environmentally responsible. . .and inexpensive'. However, there are no data regarding recycling of spent dialysate. Active research in this field could contribute to saving a lot of water. Beyond these specificities related to dialysis, it is also a question of behaviour changes among patients, staff, physicians and managers. The paradigm change is the third level of the sustainable development pyramid (Figure 4). The spectrum of actions needed for a sustainable environment is very well illustrated in a recent survey sent to dialysis unit head nurses in Australia. Barraclough *et al.* [12] included a large number of items far beyond what we report in our experience. These items are summarized in Table 3, which shows clearly that environmental protection is a life-long commitment and a question of changing our behaviours.

Our report has strengths and limitations. The strength is the description of the environmental data collection and the normalization by HD treatment. This is the key not only to benchmark this activity inside the company, but also around the world, and to establish a strategy and plans to decrease the resources needed to perform chronic HD. However, this normalization per dialysis treatment may have limitations. Among the French NephroCare centres, there are some self-care units active only 3 days per week, usually on Monday, Wednesday and Friday. During the wintertime, the heating is not stopped on the inactive days of the week, overestimating the electricity consumption per treatment. Timers on the heating system should solve this issue. Another important limitation is the gap between the savings in water and the savings in electricity. This must be a domain of continuous research. Moreover, we lack a full carbon footprint calculation as reported by Lim *et al.* [13]. In this study, a six-chair dialysis unit was evaluated with a

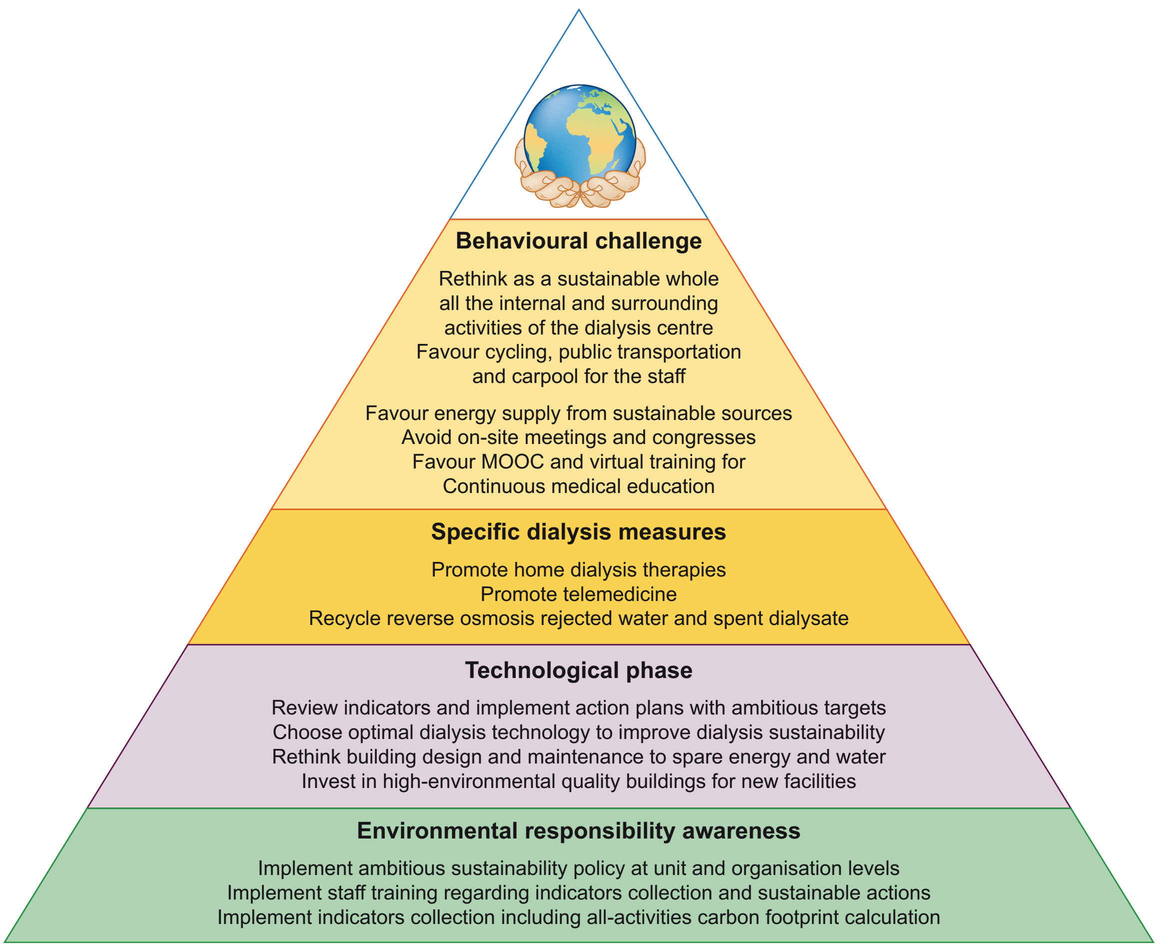

FIGURE 4: Sustainable development pyramid for dialysis activities. MOOC, massive open online courses.

Table 3. Items from the green dialysis survey [4]

Low-energy lighting
Recycling reverse osmosis water
Renewable energy use
Commingled recycling
Polyvinyl chloride plastic recycling
Staff education in waste management
Waste segregation audits
Secured bicycle parking
Shower and changing facilities for bike riders
Visioconference for meetings
Telemedicine availability
Focus of top management on environmental sustainability
Climate change action plan
Training/information on environmental sustainability

yearly estimation of 10.2 tonnes of CO_2 equivalent for the whole activity of this unit, mainly from pharmaceuticals (35.7%) and medical equipment (23.4%). It is in our plan to make these calculations at each dialysis unit and at the country level. The other limitation is the absence of KPIs regarding behavioural changes oriented towards environment sustainability. The Australian survey summarizes these new KPIs to be implemented [12].

In conclusion, the first step in the dialysis process regarding environmental sustainability is to evaluate and regularly collect precise information from defined KPIs. This is the only way to design action plans to decrease the impact of dialysis activities on the environment. Moreover, it is important to set targets through proactive plans to guide actions and fulfil commitments towards the community. A panel of additional measures related to companies' responsibilities and individual behaviours must be implemented to allow sustainable growth, because the demand for dialysis therapy is growing quickly around the world. The nephrology community must be sensitized to this challenge and must be proactive to anticipate future regulations.

SUPPLEMENTARY DATA

Supplementary data are available at ndt online.

ACKNOWLEDGEMENTS

We thank Professor John Agar for his comments. These data have been presented in part at the national meeting of the French Society of Nephrology, Dialysis and Transplantation in Lille, October 2018 and at the European Dialysis and Transplant Association meeting in Budapest, June 2019. All the authors are full-time employees of Fresenius Medical Care.

CONFLICT OF INTEREST STATEMENT

None declared.

(See related article by Blankestijn *et al*. Nephrology: achieving sustainability. *Nephrol Dial Transplant* 2020; 35: 2030–2033)

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APPENDIX

Power saving from dialysate consumption reduction: considering a reduction of dialysate consumption of 200 mL/min (12 L/h) and that heating dialysate from 25°C (osmosed water temperature) to 36.5°C requires 48.07 kJ (11.5° × 4.18 kJ), i.e. 576.84 kJ/h and 2307.36 kJ for 4 h, i.e. 0.64 kWh (1 kWh = 3600 kJ).