Medical Research Archives

European Society of Medicine

OPEN ACCESS

Published: September 30, 2023

Citation: Ravichandran P., 2023. A Model for Plastic Neutrality in Dialysis: Converting Surrogate Plastic Waste to Sinkable Pebbles, Medical Research Archives, [online] 11(9). https://doi.org/10.18103/mra.v11i9.4380

DOI
https://doi.org/10.18103/mra.v11i9.4380

ISSN: 2375-1924

RESEARCH ARTICLE

A Model for Plastic Neutrality in Dialysis: Converting Surrogate Plastic Waste to Sinkable Pebbles

Palani Ravichandran

Email: ravirekha@hotmail.com

ABSTRACT

Dialysis plastic waste is a growing problem in India, with an estimated 3 million kilograms generated each year. Effective disposal of dialysis plastic waste is not uniformly addressed, and there is a need for sustainable solutions.

This study evaluated a plastic pebble model made from surrogate plastic equivalent to twice that generated during dialysis. The model was evaluated for its potential to offset dialysis plastic waste and its role in achieving sustainability in dialysis. Additionally, the model was used to advocate for and carry forward a campaign for plastic neutrality in dialysis.

The amount of dialysis plastic waste generated in one month by 25 patients was quantified. The sinkable plastic pebble aggregate model was created by purchasing waste plastic, double the quantity of calculated DPW, from the market. The purchased plastic was then repurposed into sinkable plastic pebble aggregate to mimic blue metal.

Various sample products were made in the form of slabs and bricks using sinkable plastic pebble aggregate, and compared to those made from blue metal and fired bricks. The stability and strength of the different products were compared, and the costs were analysed. The methodology was further used for advocacy and to campaign for plastic neutrality.

The results showed that the sinkable plastic pebble aggregate model is a feasible and effective way to reduce plastic waste in dialysis. It is cost-effective, contributes to a circular economy, and helps reduce mining for blue metal and fertile soil for bricks. The model can also advocate for the use of plastic-neutral materials in dialysis to reduce environmental pollution.

To conclude Sinkable plastic pebble surrogate model is a promising solution for offsetting plastic waste in dialysis. It is cost-effective, environmentally friendly, and it helps to campaign for plastic neutrality in dialysis. Further study is needed to assess its impact on a larger scale.

Keywords: green dialysis, plastic waste, Sustainable dialysis, circular economy, plastic neutrality, environment pollution

Introduction

Kidney care is a major contributor to climate change, and we all have a role to play in making it more sustainable. The Sustainable Development Goals (SDGs) call for action on this issue, and the Global Environmental Evolution in Nephrology and Kidney Care GREEN-K initiative is working to promote environmentally sustainable kidney care through advocacy, education, and collaboration [1]. Ignoring the environmental dimension of sustainable development can impact food production, clean water, extreme weather, and vector-borne diseases. Failure to engage in climate action will further damage global kidney health [2].

Dialysis is a life-saving treatment, but it also has a negative impact on the environment that could affect the health and well-being of billions of people [3]. Dialysis produces a significant amount of plastic waste [4]. In India, an estimated 200,000 people undergo dialysis each year, generating an estimated 3 million kilograms of plastic waste annually [5]. This plastic waste includes dialyzers, tubing, and other disposable supplies. Plastic waste is a major environmental problem, especially in low-income and developing countries. It can pollute waterways, harm wildlife, and contribute to climate change [6,7,8,9].

Patients in India do benefit from government-sponsored free dialysis under various schemes. Up to 20.75 million dialysis sessions have been done under the Pradhan Mantri Dialysis scheme alone so far [10]. However, the method of disposal of dialysis waste (DPW) can lead to environmental problems and contribute to many illnesses if not properly disposed [11]. Very often, courts intervene and issue directions to follow the norms, which only shows the gaps in the system [11,12].

Sustainable dialysis has several benefits, including reducing the environmental impact, saving money, and improving patient care [13,14]. The challenges of disposing of medical plastic waste are significant, but there are a number of promising practices and policies that could help to reduce the environmental impact of dialysis [15,16]. Advocacy for plastic neutrality in dialysis is the promotion of practices and policies that aim to produce zero net plastic waste in the dialysis process [17,18,19].
The disposal of medical plastic waste is a challenge, as there are no recommended models or long-term, sustainable guidelines for safe disposal. This could lead in the future to stricter regulations and penalties for improper disposal, and make it more difficult to provide dialysis services [14].

Reusing plastic and using it in construction or road making are two methods that have been adopted for its disposal 20. This would reduce the amount of plastic waste going to landfills and incinerators, and create a new market for repurposed plastic. However, these methods are not widely used, and dumping or using plastic as landfill is still the norm [21].

New technologies, such as biodegradable materials and water minimization, can help to reduce dialysis waste. However, these technologies are not yet widely available. Additionally, the number of people who need renal replacement therapy (RRT) is increasing every year. This means that even if new technologies are developed, they may not be able to offset the waste generated by RRT.

To date, no workable or time-tested model for disposing of dialysis waste has been developed. Although many studies have been conducted, no single model is available to emulate that can be used to advocate for awareness creation and influence policy makers.

We need to develop a model for disposing of DPW that is both acceptable to stakeholders and meets the principles of the circular economy that includes energy fuel or waste to construction [22,23].

This study is to develop a model to assess offsetting strategies for plastic neutrality and sustainability in RRT. The model will be apprised for its ability to reduce plastic waste, cost-effectiveness, and acceptability to stakeholders. It will also be analysed for its potential to reduce plastic waste in RRT and promote plastic neutrality. The study's findings could help raise awareness of environmental impacts and lead to more sustainable practices.

Methods

1) To assess the plastic waste generated in hemodialysis and peritoneal dialysis, the plastic waste generated by 25 end-stage renal failure patients on dialysis will be estimated and calculated per dialysis session, and the plastic waste generated per month will be expressed.
2) Surrogate plastic waste will be sourced from the used plastic market in a quantity that is one and a half to twice the amount of calculated DPW. The plastic will be a mixture of high-density polyethylene (HDPE), polypropylene (PP), low-density polyethylene (LDP), and non-recyclable plastic in the following proportions: 70% HDPE, 20% PP, 5% LDP, and 5% non-recyclable plastic
3) Shredding, extrusion, and conversion to sinkable plastic pebble: DPW will be shredded using a

plastic shredder and extruded in an extruder. The extruded plastic mass will then be reprocessed into sinkable plastic pebbles by adding salt to mimic the shape of blue metal, with a size of 2-6 centimetres.
4) The control group included three types of products: a slab, pavement blocks, and bricks. The slab and pavement blocks will be made using cement, sand, and blue metal in a 1:2:2 ratio. The kiln-baked bricks will be purchased from the market. The slab will be made using a mould with dimensions 10.5 x 13 x 2 inches, pavement blocks with dimensions 6 x 4.5 x 2 inches, and fired kiln bricks with dimensions 9 x 4.5 x 2 inches. Same-sized products will also be made from plastic pebbles, replacing blue metal.
6) The cost and strength of the plastic pebble, slabs, pavement blocks, and bricks will be analyzed after a 3-month curing period. The cost will include the cost of materials, the cost of hiring a plastic unit, and the cost of labor. The cost will be compared to the market cost of blue metal and the cost of making the control products. The strength will be measured by the compressive strength and flexural strength, which will be done in a government-approved standard laboratory.
7) Advocacy of this model: Various platforms, such as social media, small group meetings, and awareness handouts, will be used for advocacy. Direct interaction with dialysis staff and nurses will be conducted. Feedback from more than 30 senior nephrologists will be collected using a questionnaire shown in Table 1.

Statistical analysis used was two-sample t-test and chi square test.

Table 1

Questionnaire for Senior Nephrologists
Do you prescribe both hemodialysis and peritoneal dialysis to your patients? (Yes/No)
Do you perform more than 300 dialysis sessions per month? (Yes/No)
Do you dispose dialysis waste as per the prescribed norms? (Yes/No)
Do you follow sustainability in dialysis, which means to protect the environment by safe disposal of dialysis waste? (Yes/No)
Are you aware that the Indian government has formulated certain rules in biowaste disposal, and that dialysis waste is included? (Yes/No)
Are you aware of how the dialysis plastic waste is finally disposed of, and are you tracking it? (Yes/No)
Do you know that plastic waste that is disposed of can be a source of pollution and can lead to more kidney disease? (Yes/No)
Does your CAPD patient dispose plastic bags after each exchange in a sealed red bag or in the trash? (Yes/No)
Is the nephrologist responsible for the safe disposal of CAPD plastic waste? (Yes/No)
If you need to spend Rs 80 for each dialysis to repurpose dialysis waste that can help in circular economy, would you participate? (Yes/No)
Law stipulates that before bioplastic waste is disposed of, it must be shredded and sterilized. Are you aware of this? (Yes/No)
Does your dialysis unit have a shredder? If not, how is shredding done (manually or don't know)? (Yes/No)
Does your unit maintain a dialysis waste generation register? (Yes/No)

Results

Table 2 shows the details of the dialysis plastic waste (DPW) generated in one month. Of the 25 patients, 20 were on twice-weekly dialysis and generated 204 kilograms of plastic waste from 160 dialysis sessions. The remaining 5 patients on CAPD generated 112.5 kilograms of DPW from 450 exchanges per month.

The surrogate plastic waste purchased from the market was 634 kilograms, which offset the 316.5 kilograms of DPW generated by the 25 patients in one month. The cost was ₹37,560 (US$450) or approximately ₹60 (US$0.6) per HD session and ₹20 (US$0.25) per CAPD session to offset the plastic waste. There was no significant difference in the plastic waste generated between HD and CAPD.

Table 2. Details of the plastic waste generated, surrogate plastic used, and cost.

Type of Dialysis	Pt number N=25	Session per month	DPW generated per month	Market surrogate Plastic purchased	Cost of Plastic purchased	Cost of surrogate plastic per session	DPW disposal
HD	20pts	160	204 kg	408 Kg	28,560 Re	60 Re	Red Bag To licence holder
CAPD	5 pts 3 time exchange/d	450 (3x30x5)	112.5kg	226kg	9,000 Re	20 Re	Home disposal
Total	25 Pts	610	316.5Kg	634Kg	37,560 Re	---	-------

Table 3. Details of products made from surrogate plastic.

Product type	Size	Weight mean		Comp.St. random	P Value	Density compared to water
P.Pebble Blue Metal	2-3Cm 2-3 cm	2-4Gms 6-10Gms		- -	-	Sinks Sinks
Slab P.Pebble Blue Metal	 10.5x13x2 in 10.5x13x2 in	 9.1Kg(n=25) 10.12Kg(n=22)		 217N/mm2 218N/mm2	NS	-
Pav. Block P.Pebble Blue metal	 6x4.5x2 in 6x4.5x2 in	 1.3Kg(n=30) 2Kg(n=22)		 283N/mm2 234N/mm2	NS	_
 Plastic Brick Fired Brick	 9x4.5x2 in n=30 9x4.5x2in n=40	Dry 3.1Kg 2.9Kg	Wet 3.2Kg 3.3Kg	Dry 12N/mm2 3N/mm2	P<0.005	_

Abbreviations: P: Plastic CM: Centimeter gms: Gramme Comp St: Compression strength Pav: Pavement In: inches N/mm Newton/millimetre Kg: Kilogram

All DPW generated in the HD unit was disposed of in accordance with the Indian government's regulations. However, in CAPD, the patients disposed of the waste plastic bags and accessories in their household trash.

As shown in Table 3, the size of the plastic pebble was matched to that of the same-sized blue metal, and both were denser than water. The weight of the blue metal was more than four times heavier than that of the plastic pebble. Table 4 shows the products made from the plastic pebbles. Products made from sinkable plastic pebble (see Figure 1) included slabs with dimensions of 10.5 × 13 × 2 inches (n = 25) (see Figure 2), slabs with dimensions of 6 × 4.5 × 2 inches (n = 30) (Figure 1), and slabs made from blue metal with dimensions of 10.5 × 13 × 2 inches (n = 22) and 6 × 4.5 × 2 inches (n = 22). Bricks made from plastic with dimensions of 9 × 4.5 × 2 inches (n = 30) were compared to fired kiln bricks with dimensions of 9 × 4.5 × 2 inches (n = 40).

Fig 1: Image of Sinkable Plastic Pebble mimicking blue metal

Table 4 shows cost and utility analysis of the plastic related products

Cost Analysis	Purchase/Making cost	Sale Price	Additional cost of offset	Uses Of Product	USP
Pebble Plastic	130 /kg	Re ¼ of blue metal	Rs 80 /Kg, per dialysis session	• concrete cont. • Horticulture • Roads	Light weight Cheaper Can be quantified for plastic neutrality
Blue Metal	30/Kg	4 times costly than plastic pebble volume wise	-	• Concrete • Roads	Mining pollution Transport dust and water pollution
Flamed Brick	Rs 3/brick	Rs 8/brick	-	• Building • const	Mining of earth, loss of agriculture land, energy for baking
Plastic Pebble brick	Rs 6/Brick	Rs 12/brick	Rs 30 per dialysis	• Building • const	No burning, economy stronger than flame brick

Fig 2: Slabs and Brick made from Plastic Pebble

The slabs made from plastic pebble were on average 1.5 kilograms lighter than the blue metal slabs, and the pavement slabs made from plastic pebble were on average 350 grams lighter than those made from blue metal. The brick made from plastic pebble weighed 3.1 kilograms in dry condition and 3.2 kilograms after being wetted with water, compared to the weight of the baked kiln brick, which weighed 2.9 kilograms in dry condition and 3.3 kilograms in wet condition. The compressive strength of the slabs was comparable after two months, but the fired brick was 2 newtons per square millimeter compared to the brick made from plastic pebble, which had a compressive strength of 12 newtons per square millimeter ($p < 0.05$).

The cost of the surrogate plastic, plus shredding, extrusion, and reshaping into plastic pebble was ₹130/kg (less than US$2) or ₹80 per dialysis session. The cost of blue metal, compared in volume to volume, was three times cheaper than the sinkable plastic. The cost of the pebble brick was the same as the market price of the baked brick, and the cost of the slabs was cheaper than those made from blue metal. Plastic sinkable pebbles can be used in horticulture to reduce water evaporation from pots, in road making, and in place of blue metal in all its uses.

Table 5 shows the results of the questionnaire response. One hundred and forty senior nephrologists participated. More than 90% were aware of the law governing the plastic waste disposal and were willing to participate in any model that results in the sustainability of dialysis and the circular economy. More than 75% of nephrologists stated that CAPD patients dispose of their plastic waste in regular trash, and 72.5% of nephrologists agreed that nephrologists must be held responsible for dialysis waste disposal. Almost all dialysis units do not have a shredder or sterilize their dialysis plastic waste prior to disposal. Manual shredding was also used in 55% of units.

Table 5. The questionnaire was answered by 125 senior nephrologists.

Question No	Yes	No
1. Do you prescribe both hemodialysis and peritoneal dialysis to your patients	55%	45%
2. Do you perform more than 300 Dialysis sessions per month	98.2%	1.8%
3. Do you dispose dialysis waste as per the prescribed norms	82.5%	17.5%
4. Do you follow sustainability in dialysis which means to protect environment by safe disposal of dialysis waste	92.5%	7.5%
5. Are you aware that the Indian government has formulated certain rules in bio waste disposal and it includes dialysis waste	90%	10%
6. Are you aware how the dialysis plastic waste is finally disposed and are you tracking it	70%	30%
7. Do you know plastic waste that is disposed can be a source of pollution and can lead to more kidney disease	82.5%	17.5%
8. Does your CAPD patient dispose plastic bags after each exchange in sealed red bag or trash	75% Trash can	25% Red bag sealed
9. Is nephrologist responsible to safe disposal of CAPD plastic waste	72.5%	27.5%
10. If you need to spend Rs 80 for each dialysis to repurpose dialysis waste that can help in circular economy will you participate	70%	30%
11. Law stipulates before bio plastic waste is disposed it must be shredded and sterilized are you aware of this	67.5%	32.5%
12. Does you dialysis unit have shredder if not how is shredding done Manual or don't know?	55% Manual	45% Don't Know
13. Does your unit maintain dialysis waste generation register	80%	20%

Discussion

The global dialysis population is growing, and it is predicted that chronic kidney disease will become the fifth most common cause of death globally by 2040. In order to meet the increasing demand for dialysis treatment, there is a need to develop new processes, incentives, and competencies to reduce the carbon footprint associated with clinical trials in nephrology. Emphasizing the minimization of the environmental impact of dialysis treatment is crucial and active promotion of sustainable development is key to future kidney health [1,2].

There is a need to better understand the environmental impact of dialysis treatment and develop green nephrology strategies to reduce this impact by taking necessary steps [14]. This urgency is essential to ensure that dialysis treatment remains available to those who require it [15], while also minimizing its environmental impact due to plastic waste [4].

Currently medical plastic waste generation is a problem [21]. The amount of plastic waste generated by dialysis will continue to rise alongside the increasing number of patients [24]. Consequently, there is an urgent need to develop innovative solutions to address the issue of dialysis plastic waste management [25].

Though there are efforts that focus on creating sustainable dialysis machinery and accessories using recycled or biodegradable materials, it is still in research stage [17]. Additionally, it is crucial to increase recycling rates of waste from dialysis procedures and promote circular economy models [26], develop innovative technologies that minimize plastic waste [27]. These initiatives align with the medical principle of prioritizing patient health while also promoting environmental responsibility with motto of "do no harm" to Kidney health [28].

In the present study, the calculation of dialysis plastic waste was similar to that published by Cherain et al. [25]. The average amount of plastic generated in hemodialysis was less than that in CAPD. However, when single-use dialyzers and tubings were taken into account, there was not much difference in the waste generated. On average, the plastic component of waste is always above 1 kg and can vary between 1.5 and 3 kg, depending on whether the dialyser is single-use or reusable.

A significant aspect of our study was determining who would bear the cost of recycling or disposing of the plastic waste. The burden of safe disposal of waste falls on dialysis prescribers and performers. If a circular economy model [26] is to be implemented using surrogate plastic, each additional cost would increase the dialysis charges by less than 10% of the existing charges. This would go a long way in the campaign not only for climate change and kidney health, but also in changing the future landscape of dialysis [29,30] and rethink on cost effectiveness of various forms of dialysis [31].

The UN Carbon Offset Platform allows companies to offset their carbon emissions by funding projects that reduce greenhouse gas emissions [32]. However, there is currently no similar model for plastic offsetting in medical plastic waste [33]. Critics argue that plastic offsetting should be subjected to the same scrutiny as carbon offsetting because they believe that corporate polluters could use plastic offsetting to buy their way out of environmental responsibility especially in CAPD users who dispose the waste into dustbins [34]. In the present offset model used in this study, double the calculated waste was sourced to cover up for variations in the calculation of DPW. This means that for every kilogram of plastic waste generated by dialysis patients, two kilograms of plastic waste were sourced to offset this waste. CAPD patients in this study produced more plastic waste than hemodialysis patients due to their daily exchanges. This is because CAPD patients need to replace their peritoneal dialysis fluid several times a day, generating a significant amount of plastic waste that is often disposed of in regular trash cans. A lack of compliance with the Biomedical Waste Management Rules, 2016, is evident, as Bailie et al.'s study found that 80% of CAPD patients discarded their waste in garbage bags, posing environmental and sanitation worker risks [35]. This study highlights the need for guidelines to be established to address the inconsistent methods of disposal of CAPD waste and the potential for infection. Guidelines must be established to address these concerns as soon as possible.

The cost of purchasing plastic waste from the market involves sorting, transporting, storing, and supporting the livelihoods of those in the informal sector [36]. Recycling dialysis waste plastic after shredding and sterilization is recommended by some countries, but in India and similar other developing and low income countries it is economically unviable and if implemented by law may lead to increase in dialysis cost as investment needs to be made on additional manpower and space for shredder and sterilisers [37].

At present, all hospital plastic waste is considered as end-of-life plastic waste and can only be used for roads, construction, or pyrolysis. The only method employed to dispose plastic waste are landfill, or incineration [38,39]. Even in countries like Malaysia only 12-20% plastic waste can be handled by incinerators and land fill is still the method employed which is cheaper than cost involved in incineration. Pyrolysis is not available in most major cities, making it a costly process [40].

Although many studies recommend the cradle-to-cradle model for circular economy 4[1], a design philosophy that aims to create products that can be returned to the earth or recycled into new products at the end of their life, no such model has been widely adopted. This model has numerous benefits over the traditional cradle-to-grave model, which sends waste to landfills or incinerators [40,42]. However, it cannot be used in countries where the law treats hospital plastic waste as end-of-life plastic. When plastics are exposed to prolonged sunlight or UV light, they disintegrate into powdery microplastics, which are major environmental pollutants that can enter the food chain [43].

In our present study, we were able to produce a product called sinkable plastic pebbles, which have a wide range of applications. We also showed how the cradle-to-cradle model can be implemented by using sinkable plastic pebbles to replace blue metal in making various products. The products made with sinkable plastic pebbles were equally or even stronger than the same products made from blue metal. For example, the plastic pebbles were able to replace kiln-baked bricks, and they were even stronger than the bricks and did not absorb water. Though many study has shown products made directly from recycled plastic they still have a shortened life and comes back to circulation [44]. Thus, this pebble model has the advantage of using it for various construction purpose and economically viable.

These plastic pebbles help reduce the environmental impact of traditional building materials by reducing the need for mining and quarrying. Though many studies still are not provided specific guideline for use of plastic in construction [45,46], but come to common conclusion that it is emerging economy [47] and answer to future sustainability models [48]. Overall, plastic pebbles have the potential to create sustainable building practices and generate revenue for recycling and plastic manufacturing. However, the study is limited because it is only a model and has not been tested over time or in large quantities. Further research is needed to determine their long-term durability and performance in various applications.

The study did not include the cost of equipment used or the long-term benefits of extending the model to more centers. Further study is planned to assess these factors.

Advocacy and Action for Dialysis Waste

A survey of 140 senior nephrologists found that more than 80% are willing to join the campaign for sustainability in dialysis. This includes educating patients on continuous ambulatory peritoneal dialysis (CAPD) to dispose of their plastic waste properly, and developing innovative solutions for recycling and reusing dialysis waste.

The survey also found that more than 75% of patients on CAPD dispose their plastic bag waste into regular trash. This is a major problem, as plastic waste can take hundreds of years to decompose. Additionally, almost all dialysis units do not have mechanical shredders, so patients who do try to recycle their plastic waste often have to use scissors, which can contaminate the waste. These findings highlight the need for urgent action to address the problem of dialysis waste and use a model to advocate for safe disposal [49].

Nephrologists, patients, and healthcare providers all have a role to play in ensuring that dialysis waste is disposed of properly. By working together, we can create a more sustainable future for dialysis patients and the planet.

Conclusion

The sinkable plastic pebble model found in this study is a useful model to advocate for plastic neutrality in dialysis. It can be adopted to promote sustainability in dialysis and has the potential to not only help reduce the burden on incineration and landfill of plastic waste, but also provide a circular economy, especially in developing countries. Though initial results are promising, further larger studies are needed to formulate guidelines

Conflict Of Interest Statement: There is no conflict of interest in this study

Funding Statement: No fund was received or any sponsor obtained for this study

Acknowledgement: The abstract was presented in the Nephrology association of Tamilnadu and Puducherry (NATPU) and adjudged best in the nephrology meet.

References:

1. Stigant CE, Barraclough KA, Harber M, Kanagasundaram NS, Malik C, Jha V, Vanholder RC. Our shared responsibility: the urgent necessity of global environmentally sustainable kidney care. Kidney Int. 2023;104(1):12-15. doi: 10.1016/j.kint.2022.12.015. PMID: 36642093.
2. Sustainable development is key to improving global kidney health. Nat Rev Nephrol. 2021;17(1):1-3. doi:10.1038/s41581-020-00380-5.
3. Bharati J, Jha V. Global dialysis perspective: India. Kidney360. 2020 Aug 19;1(10):1143-1147. doi:10.34067/KID.0003982020. PMID: 35368789; PMCID: PMC8815477.
4. Niyitanga Evode, Sarmad Ahmad Qamar, Muhammad Bilal, Damià Barceló, Hafiz M.N. Iqbal. Plastic waste and its management strategies for environmental sustainability. Case Studies in Chemical and Environmental Engineering. 2021;4(2):100142. doi:10.1016/j.cscee.2021.100142.
5. Hoenich NA, Levin R, Pearce C. Clinical waste generation from renal units: implications and solutions. Semin Dial. 2005 Sep-Oct;18(5):396-400. doi:10.1111/j.1525-139X.2005.00078.x. PMID: 16191180.
6. Agar JW. Green dialysis: the environmental challenges ahead. Semin Dial. 2015 Mar-Apr;28(2):186-92. doi:10.1111/sdi.12324. Epub 2014 Nov 30. PMID: 25440109.
7. Piccoli GB, Cupisti A, Aucella F, Regolisti G, Lomonte C, Ferraresi M, Claudia D, Ferraresi C, Russo R, La Milia V, Covella B, Rossi L, Chatrenet A, Cabiddu G, Brunori G; On the Behalf of Conservative treatment, Physical activity and Peritoneal dialysis project groups of the Italian Society of Nephrology. Green nephrology and eco-dialysis: a position statement by the Italian Society of Nephrology. J Nephrol. 2020 Aug;33(4):681-698. doi:10.1007/s40620-020-00734-z. Epub 2020 Apr 15. PMID: 32297293; PMCID: PMC7381479.
8. Yeo SC, Ooi XY, Tan TSM. Sustainable kidney care delivery and climate change - a call to action. Global Health. 2022 Aug 3;18(1):75. doi:10.1186/s12992-022-00867-9. PMID: 35922809; PMCID: PMC9351168.
9. Heidbreder LM, Bablok I, Drews S, Menzel C. Tackling the plastic problem: A review on perceptions, behaviors, and interventions. Sci Total Environ. 2019 Jun 10;668:1077-1093. doi:10.1016/j.scitotenv.2019.02.437. Epub 2019 Mar 6. PMID: 31018449.
10. Government of India. (2023). Pradhan Mantri National Dialysis Programme (PMNDP). Retrieved from https://pmndp.mohfw.gov.in/en
11. Press Information Bureau. National Digital Health Mission: PM launches Nation-wide: Mission of Digital Health for Every Indian (press release). Government of India; 2020 Aug 15. Available from: https://pib.gov.in/newsite/printrelease.aspx?relid=105411. Accessed October 10, 2021https://pib.gov.in/newsite/printrelease.aspx?relid=105411
12. Mahananda, M.. (2015). Bio Medical Waste Generation and Management Practices in V.S.S. Medical College & Hospital, Burla, Odisha, India. Energy and Environmental Engineering. 3. 15-22. 10.13189/eee.2015.030201.
13. Blessy Joseph, Jemy James, Nandakumar Kalarikkal, Sabu Thomas, Recycling of medical plastics, Advanced Industrial and Engineering Polymer Research, Volume 4, Issue 3, 2021,Pages 199-208, ISSN 2542-5048, https://doi.org/10.1016/j.aiepr.2021.06.003.
14. Barraclough KA, Agar JWM. Green nephrology. Nat Rev Nephrol. 2020 May;16(5):257-268. doi: 10.1038/s41581-019-0245-1. Epub 2020 Feb 7. PMID: 32034297.
15. Moura-Neto JA, Barraclough K, Agar JWM. A call-to-action for sustainability in dialysis in Brazil. J Bras Nefrol. 2019 Oct-Dec;41(4):560-563. doi: 10.1590/2175-8239-JBN-2019-0014. PMID: 31268113; PMCID: PMC6979574.
16. Rahat, Md. Hasibul Hasan & Massarra, Carol & Wang, George. (2022). Using Plastic Wastes in Construction: Opportunities and Challenges. 10.29007/6369.
17. Hossain, R.; Islam, M.T.; Shanker, R.; Khan, D.; Locock, K.E.S.; Ghose, A.; Schandl, H.; Dhodapkar, R.; Sahajwalla, V. Plastic Waste Management in India: Challenges, Opportunities, and Roadmap for Circular Economy. Sustainability **2022**, 14, 4425. https://doi.org/10.3390/su14084425
18. Opeolu, Olukunle. (2019). Plastic Waste Awareness and Practices among Students. A Case study of the students of the Faculty of Environmental Sciences, University of Lagos.. 10.13140/RG.2.2.29359.18081.
19. Joseph L, Paul H, Premkumar J, Paul R,Michael JS. Biomedical waste management: Study on the awareness and practice among healthcare

workers in a tertiary teaching hospital. Indian J Med Microbiol 2015;33:129-31

20. Letho Z, Yangdon T, Lhamo C, Limbu CB, Yoezer S, Jamtsho T, Chhetri P, Tshering D. Awareness and practice of medical waste management among healthcare providers in National Referral Hospital. PLoS One. 2021 Jan 6;16(1):e0243817. doi: 10.1371/journal.pone.0243817. PMID: 33406119; PMCID: PMC7787467
21. Lee BK, Ellenbecker MJ, Moure-Eraso R. Analyses of the recycling potential of medical plastic wastes. Waste Manag. 2002;22(5):461-70. doi: 10.1016/s0956-053x(02)00006-5. PMID: 12092754.
22. Energy Fuels 2021, 35, 5, 3558–3571 Publication Date:February 15, 2021 https://doi.org/10.1021/acs.energyfuels.0c04017
23. P.O. Awoyera, A. Adesina, Plastic wastes to construction products: Status, limitations And future perspective, Case Studies in Construction Materials, Volume 12, 2020, e00330, ISSN 2214-5095, https://doi.org/10.1016/j.cscm.2020.e00330
24. Geyer, R., Jambeck, J.R., Law, K.L. (2017). Future scenarios of global plastic waste generation and disposal. Palgrave Communications, 5(6), 1-14. doi:10.1057/s41599-018-0212-7
25. Cherain, Abhilash & Yadla, Manjusha. (2022). Trends of biowaste generation in hemodialysis units under the hub-and-spoke model: act and save. Journal of The Egyptian Society of Nephrology and Transplantation. 22. 29. 10.4103/jesnt.jesnt_47_20.
26. Giorgina Barbara Piccoli and others, Eco-dialysis: the financial and ecological costs of dialysis waste products: is a 'cradle-to-cradle' model feasible for planet-friendly haemodialysis waste management?, Nephrology Dialysis Transplantation, Volume 30, Issue 6, June 2015, Pages 1018–1027, https://doi.org/10.1093/ndt/gfv031
27. Vanholder R, Annemans L, Bello AK, Bikbov B, Gallego D, Gansevoort RT, Lameire N, Luyckx VA, Noruisiene E, Oostrom T, Wanner C, Wieringa F. Fighting the unbearable lightness of neglecting kidney health: the decade of the kidney. Clin Kidney J. 2021 Apr 20;14(7):1719-1730. doi: 10.1093/ckj/sfab070. PMID: 34221379; PMCID: PMC8243275.
28. Gauly A, Fleck N, Kircelli F. Advanced hemodialysis equipment for more eco-friendly dialysis. Int Urol Nephrol. 2022 May;54(5):1059-1065. doi: 10.1007/s11255-021-02981-w. Epub 2021 Sep 4. PMID: 34480255; PMCID: PMC9005388.
29. Borg, M.A., Bi, P. The impact of climate change on kidney health. Nat Rev Nephrol **17**, 294–295 (2021). https://doi.org/10.1038/s41581-020-00365-4
30. Himmelfarb J, Vanholder R, Mehrotra R, Tonelli M. The current and future landscape of dialysis. Nat Rev Nephrol. 2020 Oct;16(10):573-585. doi: 10.1038/s41581-020-0315-4. Epub 2020 Jul 30. PMID: 32733095; PMCID: PMC7391926.
31. Klomjit N, Kattah AG, Cheungpasitporn W. The Cost-effectiveness of Peritoneal Dialysis Is Superior to Hemodialysis: Updated Evidence From a More Precise Model. Kidney Med. 2020 Dec 30;3(1):15-17. doi: 10.1016/j.xkme.2020.12.003. PMID: 33605939; PMCID: PMC7873827.
32. Giorgina Barbara Piccoli and others, Eco-dialysis: the financial and ecological costs of dialysis waste products: is a 'cradle-to-cradle' model feasible for planet-friendly haemodialysis waste management? Nephrology Dialysis Transplantation, Volume 30, Issue 6, June 2015, Pages 1018–1027, https://doi.org/10.1093/ndt/gfv031
33. United Nations Framework Convention on Climate Change. United Nations Carbon Offset Platform. Available at: https://unfccc.int/climate-action/united-nations-carbon-offset-platform. Accessed December 1, 2021
34. "Ecobusiness" (2021). What is plastic offsetting and can it really help to fight the plastic crisis? Retrieved from: https://www.eco-business.com/news/what-is-plastic-offsetting-and-can-it-really-help-to-fight-the-plastic-crisis/
35. Bailie GR, Kowalsky SF, Eisele G, Schwartzman MS. Disposal of CAPD waste in the community. Perit Dial Int. 1991;11(1):72-5. PMID: 2049428.
36. Nikiema, J., Asiedu, Z. A review of the cost and effectiveness of solutions to address plastic pollution. Environ Sci Pollut Res 29, 24547–24573 (2022). https://doi.org/10.1007/s11356-021-18038-5
37. Shanker, R., Khan, D., Hossain, R. et al. Plastic waste recycling: existing Indian scenario and future opportunities. Int. J. Environ. Sci. Technol. 20, 5895–5912 (2023). https://doi.org/10.1007/s13762-022-04079-x

38. Blessy Joseph, Jemy James, Nandakumar Kalarikkal, Sabu Thomas, Recycling of medical plastics, Advanced Industrial and Engineering Polymer Research, Volume 4, Issue 3, 2021, Pages 199-208, ISSN 2542-5048, https://doi.org/10.1016/j.aiepr.2021.06.003.
39. Horejs, C. Solutions to plastic pollution. Nat Rev Mater **5**, 641 (2020). https://doi.org/10.1038/s41578-020-00237-0
40. Lee, C.J., Chang, L. & Tan, J. Environmental Sustainability Framework for Plastic Waste Management—a Case Study of Bubble Tea Industry in Malaysia. Process Integr Optim Sustain **6**, 513–526 (2022). https://doi.org/10.1007/s41660-022-00230-w
41. Wautelet, Thibaut. (2018). The Concept of Circular Economy: its Origins and its Evolution. 10.13140/RG.2.2.17021.87523.
42. Nanda S, Patra BR, Patel R, Bakos J, Dalai AK. Innovations in applications and prospects of bioplastics and biopolymers: a review. Environ Chem Lett. 2022;20(1):379-395. doi: 10.1007/s10311-021-01334-4. Epub 2021 Nov 29. PMID: 34867134; PMCID: PMC8629338
43. Ng Chi Huey, Mistoh Mohd Aizzan, Teo Siow Hwa, Galassi Andrea, Ibrahim Azreen, Sipaut Coswald Stephen, Foo Jurry, Seay Jeffrey, Taufiq-Yap Yun Hin, Janaun Jidon, Plastic waste and microplastic issues in Southeast Asia ,Frontiers in Environmental Science ; VOLUME=11, 2023 ,https://www.frontiersin.org/articles/10.3389/fenvs.2023.1142071 DOI=10.3389/fenvs.2023.1142071 ,ISSN=2296-665X
44. Ibrahim Almeshal, Bassam A. Tayeh, Rayed Alyousef, Hisham Alabduljabbar, Abdeliazim Mustafa Mohamed, Eco-friendly concrete containing recycled plastic as partial replacement for sand, Journal of Materials Research and Technology, Volume 9, Issue 3, 2020, Pages 4631-4643, ISSN 2238-7854, https://doi.org/10.1016/j.jmrt.2020.02.090.
45. P.O. Awoyera, A. Adesina, Plastic wastes to construction products: Status, limitations and future perspective, Case Studies in Construction Materials, Volume 12, 2020, e00330, ISSN 2214-5095,https://doi.org/10.1016/j.cscm.2020.e00330.
46. Vaccaro, Pietro & P. Galvin, Adela & Ayuso, J. & Lozano-Lunar, Angelica & Lopez Uceda, Antonio. (2021). Pollutant Potential of Reinforced Concrete Made with Recycled Plastic Fibres from Food Packaging Waste. Applied Sciences. 11. 8102. 10.3390/app11178102.
47. Suhaib Yahya Al-Darzi,The effect of using shredded plastic on the behavior of reinforced concrete slab,Case Studies in Construction Materials, Volume 17, 2022, e01681,ISSN 2214-5095,https://doi.org/10.1016/j.cscm.2022.e01681.
48. Islam, Kamrul & Motoshita, Masaharu & Murakami, Shinsuke. (2023). Environmental Sustainability of Bricks in an Emerging Economy: Current Environmental Hotspots and Mitigation Potentials for the Future. Sustainability. 15. 5228. 10.3390/su15065228.
49. PlasticsToday Staff. "Plastics Advocacy and the Power of One." PlasticsToday, 26 Jan. 2021, https://www.plasticstoday.com/packaging/plastics-advocacy-and-power-one