


REVIEW

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# Sustainability in dialysis therapy: Japanese local and global challenge

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## Abstract

Human-induced climate change is considered the greatest health threat of the 21st century. The health effects of climate change are becoming increasingly apparent, and there is substantial evidence indicating increased risk of kidney injury due to heat illness and other climate change-related meteorological abnormalities. On the other hand, healthcare itself is responsible for environmental burdens and has been estimated to generate between 3 and 10% of total national CO<sub>2</sub> equivalent emissions. Dialysis has been estimated as one of the major contributors to healthcare's carbon footprint. Especially in Australia and the UK, nations that have high awareness regarding environmental research, "Green Nephrology" has emerged as a new discipline. From both of these countries, a series of papers have been produced outlining the carbon footprint of hemodialysis, the results of surveys of specialists' awareness of environmental issues, and proposals for how to save resources in dialysis therapy. Following on from this, several national and international nephrology societies have committed themselves to a range of initiatives aiming at "greening" the kidney sector. In Japan, where water and electricity supplies currently are stable, we occasionally are reminded of the potential for shortages of water and energy and of waste disposal problems. These issues particularly come to the fore in times of disasters, when hemodialysis patients need to be evacuated to distant dialysis facilities. Irrespective of the current state of resource availability, however, continuous efforts and the establishment of resource-saving procedures as a part of Japanese culture are highly desirable and would contribute to environmentally friendly healthcare. Japan needs to build awareness of these issues before the country faces a catastrophic situation of resource shortages. This review is intended as a call to action regarding environmental sustainability in kidney healthcare in Japan and the world.

**Keywords:** Hemodialysis, Peritoneal dialysis, Carbon footprint, Chronic kidney disease, Heat illness

## Background

Human-induced climate change is considered the greatest health threat of the 21st century. The average annual temperature in the world has risen at a rate of 0.72 °C per 100 years since the latter half of the 19th century [1]. By the end of this century, global average annual temperature is expected to rise by a further 0.3–1.7 °C if we urgently and fully reduce Greenhouse gas (GHG) emissions, versus 2.6–4.8 if we continue with business as

usual [1]. A temperature rise near the upper end of this range is not likely to be compatible with continuing human health and prosperity or indeed civilization as we know it. Notably, the magnitude of temperature increase is greater in countries at higher latitudes like Japan compared to those closer to the equator [2]. The average annual temperature in Japan has seen repeated fluctuations but overall has risen by 1.2 °C per 100 years since the beginning of the industrial era [2]. In the 21st century, Japan is predicted to experience further temperature rise of 0.5 to 1.7 °C if maximum efforts are made to reduce GHG emissions versus 3.4 to 5.4 °C if we continue to live as usual. Consequent to the increasing temperature

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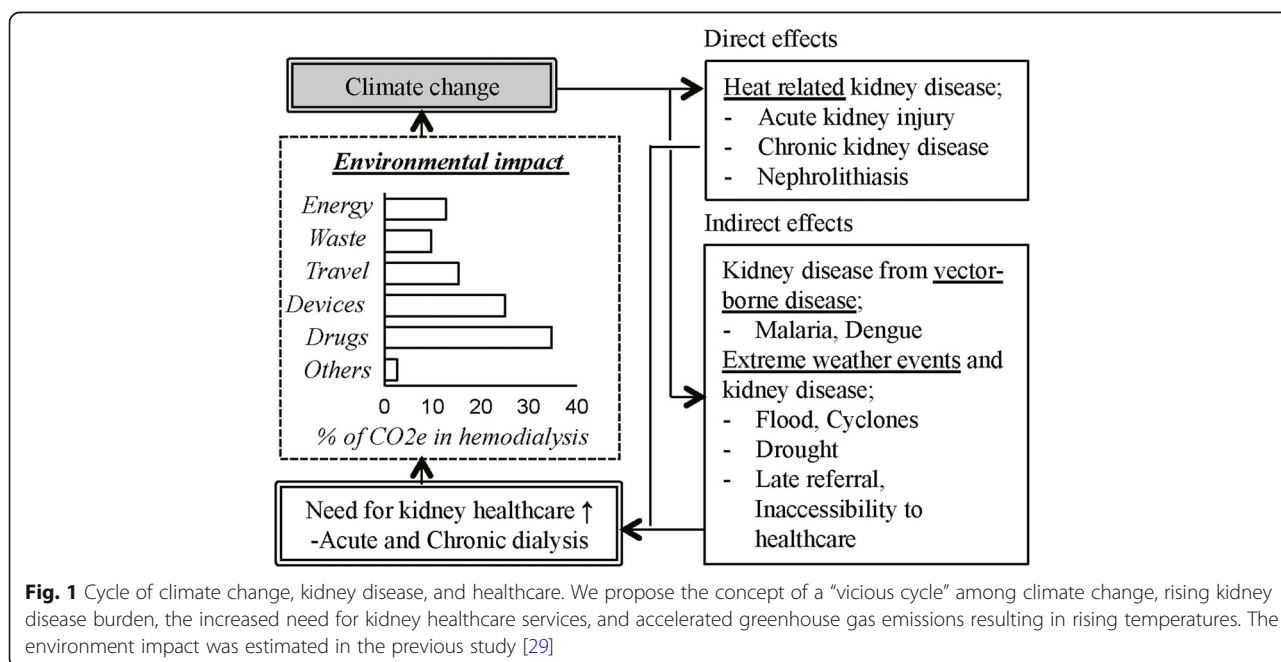
from climate change, heavy rains and floods have been increasing, while the number of rainy days has been decreasing [2]. Although there are some disagreements by people in industry, and some individuals who appear to be unconcerned with climate change, there is consensus among the scientific community and growing understanding among the public that climate change is in fact an existential threat and that extreme weather will continue to increase in Japan, as in most other world regions. Moreover, environmental problems are sometimes difficult for medical professionals to understand in the clinical setting. In daily practice, medical professionals rarely consider the direct effect of greenhouse gas emissions on their patients. In turn, climate change is expected to have a wide range of adverse effects on human health [3].

### Climate change and kidney disease

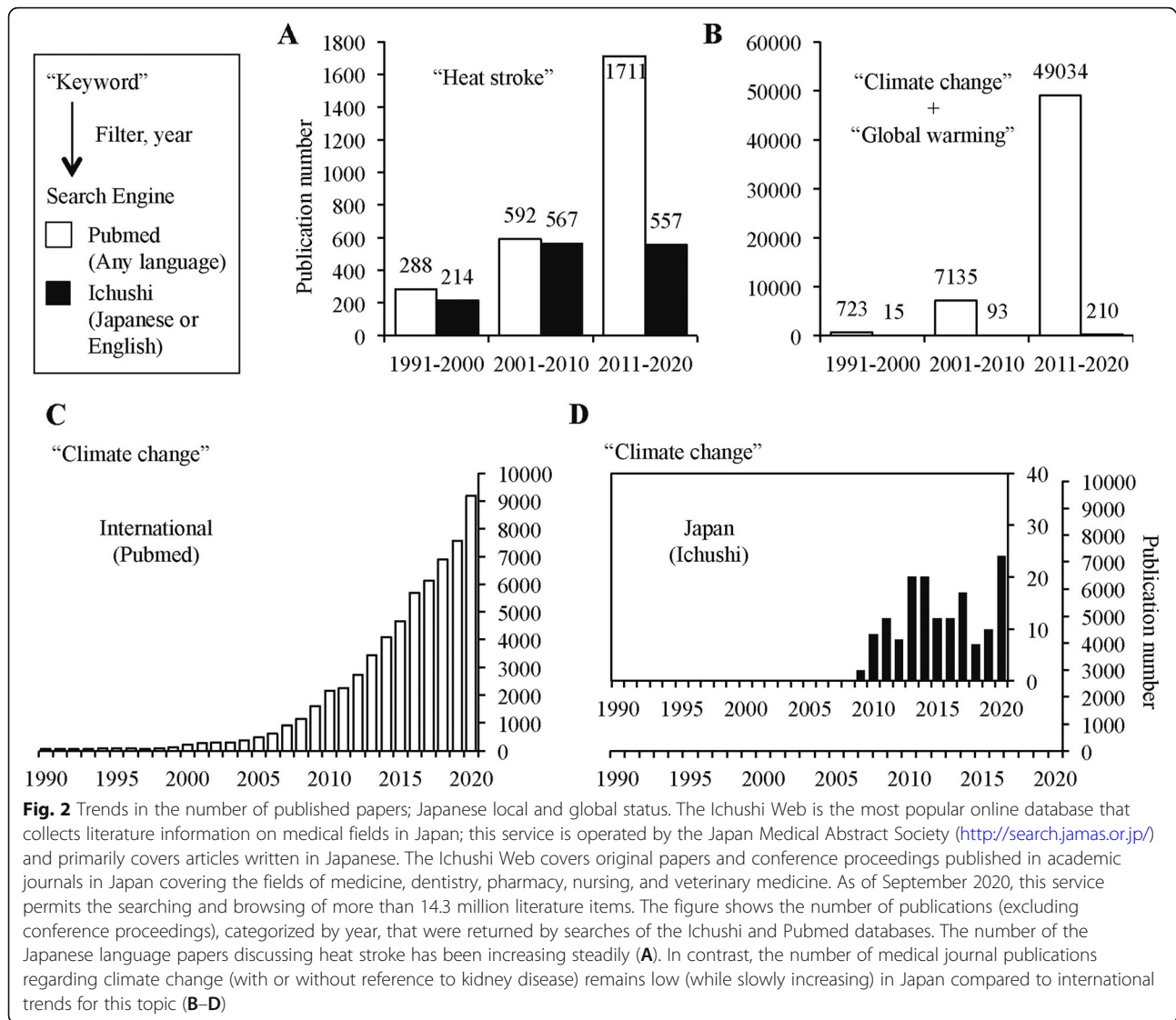
Climate change has been shown to impact kidney health [4–6] (Fig. 1). The pathways linking climate change with kidney health can be either direct or indirect [4]. For instance, heatwaves directly create risks of acute kidney injury (AKI) and nephrolithiasis because extreme heat increases the insensible loss of body water and salt. This loss can lead to fluid deficit, vasoconstriction, reduced kidney perfusion, and a compensatory reduction in urine volume. In turn, this can lead to AKI and/or urinary supersaturation with stone-forming salts and kidney stone formation [6, 7]. Extreme heat combined with strenuous work and water deficit also have been shown to correlate with early-onset chronic kidney disease (CKD), although there is still controversy regarding

whether heat is the primary driver of CKD in these cases or an exacerbator of damage caused via an alternative mechanism [6, 8, 9]. Indirect risks are mediated through pathways such as increased frequencies or magnitudes of storms, floods, or droughts, and effects on social structures such as decreases in habitable areas and increases in ethnic conflicts [4, 5]. In turn, kidney injury can be incurred by altered distribution and prevalence of vector-borne diseases such as malaria and dengue, water shortage, pollution, poor hygiene, and climate-induced disruptions to healthcare provision.

While numerous epidemiological studies from various world regions have investigated the association between ambient temperature and morbidity including with respect to kidney function [10–15], the academic evidence for a relationship between temperature and kidney injury in Japan remains sparse. It is known that the annual number of deaths from heat stroke has risen sharply in Japan from fewer than 200 in the 1990s to approximately 1800 in the decade beginning 2010 [16]. Responding to this change, the number of Japanese language papers discussing heat stroke has increased steadily (Fig. 2A). In contrast, the number of medical journal publications regarding climate change, regardless of kidney disease, has increased only slowly in Japan and overall has remained low compared to the rest of the world (Fig. 2B–D). This observation implies that the Japanese medical community still lacks awareness of the links between climate change and health hazards; indeed, a certain percentage of Japanese healthcare professionals still consider environmental problems as “Fire on the other side of the river” (idiomatically, “None of my business”).



**Fig. 1** Cycle of climate change, kidney disease, and healthcare. We propose the concept of a “vicious cycle” among climate change, rising kidney disease burden, the increased need for kidney healthcare services, and accelerated greenhouse gas emissions resulting in rising temperatures. The environment impact was estimated in the previous study [29]



### Kidney healthcare is responsible for environmental burdens

Compared to the impacts of environmental changes on health, the impacts of healthcare on our climate and the environment more broadly have received less attention [17]. However, there is gradually increasing recognition that healthcare is responsible for substantial carbon emissions and that it is therefore accelerating climate change. Country-level studies in the UK [18], the USA [19, 20], Canada [21], Japan [22], China [23], and Australia [24] have reported that healthcare sector emissions contribute between 3 and 10% of the total carbon footprint in these countries. A recent report has suggested that if global healthcare were a country, it would be the fifth-largest emitter on the planet [25]. We propose the existence of a “vicious cycle,” with climate change leading to rising disease burden, increased need for healthcare services, and accelerated greenhouse gas

emissions from healthcare, which then lead to further temperature rise (Fig. 1).

Among healthcare services, therapy for end-stage kidney disease has been estimated to be a major contributor to healthcare’s carbon footprint [26–28]. As the number of patients with end-stage kidney disease continues to increase, resource-hungry dialysis processes proliferate [26]. Several investigators have attempted analyses of the carbon footprint created by dialysis therapy (Table 1). The carbon footprint of conventional hemodialysis (HD) in Australia has been estimated to be 10.2 t CO<sub>2</sub>e per patient per year [29]. This is more than two-thirds of the mean annual per capita CO<sub>2</sub> emission estimate in Australia. Interestingly, the largest share of carbon emissions in this study arose from pharmaceuticals and medical equipment, with building energy use, water, and waste making substantially smaller contributions [29]. In contrast, the overall carbon footprint of

**Table 1** Representative carbon footprint studies, green surveys, and position papers in kidney healthcare

Author, publication year	Summary of findings, annotation	Reference
Connor, 2010	In the Dorset Renal Service, which covers a population of 865,000, activity data were collected for building energy use, travel, and procurement. The provision of hemodialysis and peritoneal dialysis to 277 patients results in 1,965 t CO <sub>2</sub> e, equating to 7.1 t CO <sub>2</sub> e per dialysis patient.	[27]
Connor, 2011	This study compared carbon footprints of the differing modalities and treatment regimens of maintenance hemodialysis. In home hemodialysis, dialyzing more frequently and for longer hours compared to in-center patients tended to increase emissions.	[28]
Lim, 2013	In Victoria, Australia, the annual per-patient carbon footprint of satellite hemodialysis was calculated to be 10.2 t CO <sub>2</sub> e, based on activity data in 2011.	[29]
Chen, 2017	The carbon footprint of 68 subjects receiving peritoneal dialysis treatment was examined. Packaging consumption constituted the largest fraction of the overall carbon footprint, which totaled 1.4 t CO <sub>2</sub> e per patient per year.	[30]
Nansai, 2020	Carbon footprint of general healthcare in Japan was estimated by environmental input-output (EIO) and disaggregated to obtain the kidney disease-related value. Studies from other countries and international EIO investigations do not disaggregate by kidney-care section-specific data. National (Japanese) carbon footprint for “renal, urethral, and reproductive disease” was 2.12 million metric tons CO <sub>2</sub> e.	[22]
Pollard, 2014	This study used a bottom-up consumption model to estimate the carbon footprint of acute care with dialysis machines in the UK, primarily counting electricity use. For a typical patient in a critical care unit (CCU) for 2 days, a renal replacement machine consumed 9.60 kWh/200 W.	[39]
Bendine, 2020	Monthly eco-reporting was implemented in NephroCare centers in France in 2005. The indicators included electricity and water consumption as well as the generation of care-related waste. During the 2005-2018 study period, power and water consumption declined by 30% and 52%, respectively. Waste decreased from 1.8 to 1.1 kg per session.	[40]
Conner, 2010	A Green Nephrology survey of 58 kidney care units in England, Scotland, and Wales was conducted to support a clinical transformation to lower carbon kidney healthcare by identifying fruitful areas for attention.	[36]
Barraclough, 2019	A green nephrology survey was conducted across 83 kidney healthcare units in Victoria, Australia. Nurse unit managers of public dialysis facilities responded to 107 questions relevant to the environmental sustainability of dialysis services.	[37]
Moura-Neto, 2019	This paper was a call-to-action for sustainability in dialysis in Brazil.	[32]
Piccoli, 2020	A position statement was developed by the Italian Society of Nephrology, focusing primarily on dialysis management. It identified ten first affordable actions.	[33]

peritoneal dialysis (PD) has been estimated as only 1.4 t CO<sub>2</sub>e, a value that is substantially lower than that of HD [30]. However, in this study, the carbon emissions impact of pharmaceutical use and of transportation of PD fluids from the point of manufacture to the point of care were not considered; as a result, 80% of the carbon footprint of PD was attributed to packing materials such as plastic bags and cardboard. Therefore, more precise assessments are needed to determine whether PD is more environmentally friendly than HD.

### What are nephrologists doing to achieve “greener” dialysis?

Clearly, kidney care and dialysis have negative environmental impacts, ranging from the local to the global scale. Especially in Australia and the UK, countries that have high awareness of environmental issues, advocates of “Green Nephrology” have promoted environmentally-friendly practices for dialysis, actively produced a series of papers to demonstrate the carbon footprint of kidney healthcare, and distributed the results of surveys investigating specialists’ awareness regarding the conservation of resources in dialysis therapy (Table 1). Following on

from such individual Green Nephrology programs, several international and nationwide nephrology societies have committed to a range of initiatives aimed at “greening” kidney healthcare [6, 31]. The European Renal Association - European Dialysis and Transplant Association has organized a number of green nephrology meetings involving representatives of national and regional nephrology groups and industry stakeholders [31]. During Kidney Week 2018, a first global meeting on Green Nephrology was held with the support of the International Society of Nephrology. Subsequently, both Brazil [32] and Italy [33] have taken action to expand local activities in support of green dialysis. In Japan, however, promotions and initiatives for environmentally friendly kidney healthcare and dialysis therapy have not yet developed. Given Japan’s status as the country harboring the second largest dialysis population in the world, practical and cultural shifts in kidney care (e.g., the establishment of resource-saving dialysis processes) are needed. In context of the need of financial resources to realize eco-friendly dialysis, some capital investment may be required for solar power generation and water reuse [6, 26]. However, these activities are just a part

and complementary to Green Nephrology. The medical care we ultimately aim for is one that does not burden the economy. We are convinced of achieving eco-friendly renal health care with cost-effective way such as preventing renal diseases, stopping unnecessary medications and excessive dialysis prescriptions, and reuse possible dialysis plastic supplies.

### **Experience of resource shortage during natural disasters in Japan**

In recent years, heavy rainfall has been on the rise, and there are concerns about extreme weather-related disasters. In Japan, we have occasionally (and suddenly) become aware of shortages of water and energy and of waste disposal problems, particularly in the context of major disasters such as Typhoon Faxai in September 2019 and Hagibis in October 2019. Particularly, Hagibis caused more than 90 deaths and left more than 270,000 households across the country without power. Although no official statement has been issued, some local press reported that hundreds of patients on chronic dialysis needed to be evacuated due to water shortages and power blackouts. Another kind of disaster, earthquakes (e.g., the Great East Japan Earthquake in 2011 [34] and the Han-Shin Awaji Earthquake in 1995 [35]), are not extreme weather-related events, but do occur more frequently in Japan than elsewhere and do force HD patients to evacuate to distinct dialysis facilities, in part due to shortages of water and electricity. These experiences could serve as an opportunity for kidney healthcare professionals to consider what options will be available if/when climate-related disasters hit and dialysis materials and resources are depleted. We need to be aware of catastrophic situations that will lead to resource shortages even in Japan, which is no exception to these worldwide concerns, and ensure that thorough preparedness planning for disasters is undertaken.

### **Conclusion: How can kidney healthcare professionals prepare for the future?**

As discussed above, Japan, like most other world regions, is likely to see increasing health impacts from climate change. There is moral imperative for Japan to consider ways to achieve more planet friendly dialysis therapy and to undertake preparedness planning for climate change-related emergencies. Possible actions to take include encouraging staff and patients to save water and energy where possible and dialysis units to install water- and energy-saving systems [6]. It would be also environmentally beneficial to evaluate the weight and types of waste generated from different dialysis machines and consumables sets and to undertake efforts to optimize waste segregation and recycling [6].

It is an undeniable fact that we do not have any precise measure of the CO<sub>2</sub> emissions and other environmental impacts of dialysis practices in Japan. Surveys of environmental attitudes and knowledge of greener dialysis processes in Japan are needed to understand the current situation domestically, as has been done in other countries [6, 36, 37]. In the context of kidney healthcare, including dialysis, various countries differ considerably in their practice patterns and geographical issues. In Japan, over 97% of dialysis is conducted as in-center HD, supplemented by much lower percentages of patients treated by home dialysis and by unsatisfactorily low numbers of transplantation surgeries [38]. Moreover, Japan is an island country and has low food and energy self-sufficiency, making the nation dependent on overseas resources. Therefore, it is not easy to apply research results obtained from other countries, which have different practice patterns and resource management compared to Japan. Research specific to the Japanese context must be conducted.

#### **Abbreviations**

GHG: Greenhouse gas; RCP: Representative concentration pathway; CKD: Chronic kidney disease; HD: Hemodialysis; CO<sub>2</sub>e: CO<sub>2</sub> equivalent; PD: Peritoneal dialysis; CCU: Critical care unit

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#### **Authors' contributions**

KN wrote the first draft of the manuscript, and KB supervised it. AU and NI read and advised about the content of the manuscript of the final version. All authors read and approved the final manuscript.

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#### **Competing interests**

The authors declare that the review/research work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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