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Renal replacement therapy and environmental risks

Abstract

It is estimated that at the end of the 19th century, the number of chemical substances present in the environment was about 300,000. Today, according to the Chemical Abstract Service database (CAS, https://www.cas.org/cas-data/cas-registry), the number of known substances (most of which are man-made) is already more than 125,000,000. Although "only" about a million of these substances have concentration levels that can directly threaten people, due to the synergistic effect, their impact on our health is enormous. One of the most common diseases of civilization is kidney disease, which is mostly asymptomatic but contributes to the death of millions of people. In cases of end-stage renal failure, renal replacement therapy is necessary. Hemodialysis and peritoneal dialysis, on the one hand, save patients' lives, and on the other hand, have a major impact on environmental pollution and increasing carbon footprint. This article addresses these interrelationships.

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Keywords: chronic kidney disease, dialysis therapy, environment, carbon footprint

INTRODUCTION

The interrelationships between environmental quality and associated climate change and disease (including nephrology) are increasingly apparent and often discussed. We have better and better tools for such studies, and the thematic database is getting richer. This observation also comes from my personal experience. Throughout my professional life, I have been involved in environmental protection and analytical chemistry, in particular, in the application of ion chromatography and related techniques in the study of environmental, food, and medical samples [1–3]. On the other hand, probably as a teenager, I developed chronic kidney disease (CKD). I was diagnosed at the age of 29 with end-stage renal failure. Now, after another 32 years of life including a year of peritoneal dialysis, I am enjoying life with a kidney that was transplanted 11 years ago. I am still working at the Institute of the Polish Academy of Sciences (PAN) and, as a volunteer, with the National Association of My Kidneys (OSMN, www.moje-nerki.pl). Does all this have a common thread? In my opinion, yes. My work has given me the strength to fight the successive stages of the disease, and sometimes the disease has been an inspiration to use my experience as an analytical chemist, for example, to research my own dialysis fluids [4].

ENVIRONMENTAL QUALITY AND KIDNEY DISEASE

In November 2019, just before the outbreak of the COVID-19 pandemic, the journal *Bioscience* published an article entitled "World scientists' warning of a climate emergency" by Wilhelm Ripple et al. who, along with 11,258 signatories from 153 countries around the world, described the dramatic effects of climate change and our impact on the state of the environment [5]. According to the authors, some of the most disturbing manifestations of human activities include a steady increase in the number of humans and livestock, an increase in meat production, fuel consumption, and CO_2 emissions, as well as the widespread use of plastics and the associated presence of microplastics in the environment. The

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positives, on the other hand, include declining fertility rates in many countries of the world, an increase in the use of solar and wind energy, systematic decommissioning of the fossil fuel sector, and a growing share of greenhouse gas emissions covered by climate charges.

Opinions of various opinion-forming bodies on the subject sometimes differ, and although we have similar goals, different paths lead to them. Since 2007, I have had the honor of representing the Polish Academy of Sciences on the Environmental Steering Panel of the European Academies' Science Advisory Council (ESP EASAC, https://easac.eu/). As part of our panel's work in recent years, we have prepared and published reports on important environmental issues, including the impact of climate change on our health [6], regenerative agriculture [7], forest biomass burning [8], plastics management [9], or the impact of the COVID-19 pandemic on a sustainable future [10]. These issues are part of global trends related to environmental pollution and the impact of climate change on our health.

Every component of the environment is important, and this is especially true of air quality. An adult passes about 20 kg of air through his lungs per day. This is far more than the amount of food consumed or liquids drunk. Air pollutants, including particulate matter, metals and metalloids, organic compounds and ions, primarily associated with the burning of fossil fuels, are factors that cause an increased risk of kidney disease, among other things [11]. Heat waves have been shown to increase the risk of dehydration, kidney stone formation, and acute kidney injury, which can develop into chronic kidney disease (CKD) increasing cardiovascular risk and shortening life expectancy [12]. Immediate action and related resources are, therefore, needed to subsidize the transition to a sustainable low-carbon economy. They should also be allocated to healthcare to prepare for the challenges of current and projected climate changes. These phenomena are and will be major challenges to our health and lives. Chronic kidney disease is listed among the diseases of civilization of the 21st century among cardiovascular disease, hypertension, obesity, and diabetes. In Poland alone, CKD or its complications may account for as many as 80-100,000 premature deaths per year (https://nefroldialpol.pl/wp-content/uploads/2022/06/NDP-4-2021.pdf). Globally, nearly 850 million people live with diagnosed CKD, and by 2040, it is likely to be the fifth most common cause of death [13]. Unfortunately, in too many cases, renal replacement therapy becomes necessary. More than 21,000 patients are currently on dialysis in Poland, of whom as many as 95% require renal replacement therapies and are treated with hemodialysis and only 5% with peritoneal dialysis [15]. The best option is transplantation, which, compared to dialysis, combines optimal results and costs with an undeniably smaller environmental burden.

DIALYSIS AND THE ENVIRONMENT

The hemodialysis procedure, along with the preparation of the treatment site, requires the use of significant amounts of toxic chemicals, energy, and water. Each year, hemodialysis performed around the requires millions of liters of water, huge amounts of energy, and thousands of tons of medical waste. It is estimated that more than 600 million sessions of hemodialysis are performed worldwide each year, but such therapy is still unavailable in many developing countries. In the 1970s in Poland, patients with end-stage renal failure over 25 years old were disqualified from dialysis because there were too few dialysis centers. Fortunately, this situation has changed rapidly, and now access to dialysis is widespread and unlimited.

As a result, the concept of green dialysis has emerged, in which proper water management plays a key role. Water used for dialysis must be pretreated by treatment systems usually using reverse osmosis technique, which guarantees its quality. This is a very effective technology, but it has the serious disadvantage of disposing of very large volumes of wastewater directly into the sewerage (about 75%). However, this water could be used for a variety of other purposes, such as flushing the toilet, washing or bathing. Tarrass et al. [20] presented a novel idea of using hemodialysis wastewater as a source of phosphorus and nitrogen for soil fertilization. According to their research, almost 100% of phosphate and 25% of ammonia can be recovered from this wastewater. Another problem is the ingestion of medications by patients with mass spectrometry (MS), which contributes to environmental pollution, as the spent dialysate poured directly into the sewerage contains significant amounts of metabolites, which can be more dangerous than the medications themselves, and which are difficult for treatment plants to handle [21].

This begs the question — what percentage of the water produced by treatment plants is consumed by us? As it turns out, it is only 1%, while the rest is used for other, non-consumption purposes [22]. At the same time, more than a billion people around the world do not have access to good-quality drinking water, and nearly 3 billion are experiencing water shortages. The human population is growing at an unprecedented rate, which naturally increases the demand for water. I am now 61 years old, and I was born when there were fewer than 3 billion people on the Earth, now there are almost 8 billion people, i.e. almost 3-fold as many.

The scarcity of natural resources such as water, rising energy costs, and greenhouse gas emissions, among other things, are associated with each stage of renal replacement therapy. On the one hand, this therapy increases environmental costs ("carbon footprint"); on the other hand, it saves and sustains the lives of patients with end-stage renal failure for many years. According to reports collected from Polish dialysis centers, each hemodialysis session uses more than 500 liters of water, 7 kWh of energy and generates more than 1 kg of medical waste. Taking into account that each patient statistically requires 156 hemodialysis sessions per year, this average annual water and energy consumption exceeds 78 m^3 and 1100 kWh per patient, respectively (https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/2/4/1/zuzycie_energii_w_gospodarstwach_domowych_w_2018.pdf). By comparison, average household electricity consumption remains at 900 kWh/person/year and 117–180 liters of water per person per day (43–65 m^3/year) (https://www.eea.europa.eu/data-and-maps/indicators/household-energy-consumption/household-water-consumption). If one multiplies these figures by the number of dialysis patients worldwide, the picture of the impact of renal replacement therapy on our planet's resources becomes truly significant. Several compact dialysis systems (wearable or portable) are currently in use or under development, which, along with the environmental benefits of using less water, can also provide greater flexibility and are more user-friendly [23].

The most common source of dialysis fluid is liquid concentrate supplied in containers or plastic bags. Its consumption depends on various factors, such as the type of hemodialysis machine, the duration of the session, and the recommended flow rate, among others. Modern hemodialysis machines are equipped with modules that automatically respond to the ratio of dialysis fluid flow rate to the patient's blood flow rate, thereby minimizing the amount of dialysis fluid used. The volume of concentrates delivered to a dialysis center is a major factor in the cost of transportation from the manufacturer to the end user. High fuel prices have made transportation one of the most significant costs of treatment, as well as environmental costs.

Zawierucha et al. [24] described an economic and environmental analysis of the cost of preparing dialysate at the dialysis site compared to using liquid concentrates supplied by suppliers in plastic containers. The authors estimated the amounts of CO_2 released into the atmosphere during transport of dialysis fluids or concentrates. It was shown that the carbon footprint produced while transporting liquid concentrates can be up to four times higher than transporting dry concentrates. Utilizing the appropriate features of hemodialysis machines can significantly reduce the weight of waste and reduce the volume of dialysis fluid needed for treatment. Despite the many limitations and difficulties associated with making a correct calculation of the carbon footprint, it appears to be the most universal indicator of the impact of CO2 emissions on climate change.

The carbon footprint generated during dialysis has been the subject of several studies conducted in different countries [25]. The results vary significantly considering the amount of CO_2 released into the atmosphere during one dialysis session (from 24.5 to 65.1 kg CO_2). Wieliczko et al. [26] offer several suggestions for reducing water consumption, implementing energy-neutral policies, segregating waste, and recycling materials used in dialysis. The waste burden is largely related to the ancillary materials used (including gloves, protective clothing, food, and drug packaging). Their disposal is complicated by the presence of biohazardous or toxic materials, which often make recycling difficult or even impossible according to regulations [27]. Energy consumption associated with dialysis therapy includes, among other things, the production of filters, apparatus, and other consumables, as well as the production and heating of dialysate, monitoring, lighting, and air conditioning of the unit, and transportation of materials and patients, which unfortunately contributes to significant production of greenhouse gases and other pollutants.

The environmental impact of various dialysis methods and kidney transplantation was also compared [28]. According to the authors, the impact of dialysis was similar to that identified by other studies, and transplantation is absolutely the most environmentally friendly. The environmental argument for peritoneal dialysis over hemodialysis is that the former does not require such frequent transport of patients to dialysis stations, and the risk of infections and related complications is much lower. In addition, with peritoneal dialysis, remote monitoring of dialysis patients at home is becoming increasingly popular, reducing the frequency of their visits to the Peritoneal Dialysis Outpatient Clinic [29].

A currently fashionable and often overused term is "green." Everything is advertised as "green," but it is often difficult to prove whether this is reality or just a marketing ploy. For example, it seems debatable to call the fashion industry "green," knowing that the vast majority of microplastic in the environment does not come, contrary to popular belief, from PET bottles, but from washing clothes [30].

A completely different thing is "green" nephrology [31] or green chemistry, including analytical chemistry [32]. Green chemistry is defined as the search for, design, and implementation of chemical products and processes to reduce or eliminate hazardous waste generation. Green analytical chemistry, in turn, is a key element of chemistry, as it ensures development in other areas of chemical science [33]. The term Green Analytical Chemistry (GAC) was first used in 1981 by Anastas and Warner [34]. They developed the following principles that should be considered by analytical laboratories in planning their activities:

- direct measurement methods, which do not require preparation of samples for analysis, should be used whenever possible;
- the number and size of samples should be as small as possible;
- if possible, measurement should be performed on-site (*in situ*);
- various analytical processes and operations should be integrated;
- automatic and miniaturized methods should be used whenever possible;
- derivatization of samples before analysis should be avoided whenever possible;
- amount of waste generated should be drastically reduced, and its management should be following current regulations;
- multi-parameter methods should be used where possible;
- energy consumption should be minimized;
- use of reagents from renewable sources should be preferred;
- toxic reagents and solvents should be eliminated or replaced with non-toxic alternatives;
- safety of analytical chemists should be improved.

Simultaneous fulfillment of all of the above objectives in laboratory realities is not possible, but they provide guidelines that should aid us in selecting a particular analytical method for a given application [35]. They contribute to the introduction of new environmentally friendly technologies in accordance with the idea of sustainable development.

Nephrology patients are very often tested for a wide range of analytes (including inorganic and organic anions and cations, metals, selected organic compounds, etc.) and sample types (including blood, urine, or dialysis fluids). Consequently, millions of such analyses are performed daily in medical laboratories around the world, which undoubtedly has an impact on the environment through the consumption of chemical reagents and energy, as well as the amount of waste produced. One of the routine methods to determine such important analytes in nephrology as inorganic and organic ions is ion chromatography [36], which can be classified as a method of green analytical chemistry [37].

The estimates presented in this article [38] and the comparison between ion chromatography (IC) and other classical methods for the determination of major inorganic ions indicate that its analytical performance, availability, and widespread use, especially in laboratories performing routine analyses (including environmental ones), undoubtedly contribute to better protection of the environment and the users themselves than other methods of ion determination. In particular, several developments have greatly accelerated IC development in recent years. These include the introduction of gradient elution and high-performance suppressors, more selective and dedicated stationary phases capillary and multidimensional IC, or instrument miniaturization, as well as increasing access to combined techniques.

SUMMARY AND CONCLUSIONS

Environmental pollution and ecological problems contribute to the onset and development of kidney disease; on the other hand, renal replacement therapy has a significant adverse impact on the environment. Climate change, dwindling natural resources, and increasing demand for medical services are creating new realities and challenges that should be taken into account while planning future activities. The medical community in particular should be sensitive to environmental issues and try to reduce the impact of its activities on the environment. It is worth rethinking some procedures related to dialysis therapy and their protocols. There is a need for transparent records of environmental burdens related to consumables, equipment, and drugs, including water consumption and wastewater production, to make production processes, applications, and waste management more environmentally friendly. Dialysis facilities contribute to the consumption of massive amounts of energy and water and generate large amounts of waste. The rising costs of natural resources such as water and energy, as well as the cost of waste disposal, should prompt us to think about how to optimize the use of available resources so that dialysis is more environmentally friendly.

Conflict of interest:

The author declare no conflict of interest.

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