CHAPTER 4

KIDNEY HEALTH IN A WARMING WORLD: THE IMPACT OF CLIMATE CHANGE ON RENAL FUNCTION

Adnan ÖNÜN [1]
Emre AYDIN [2]

INTRODUCTION

Global warming is defined as the increase in the average temperatures of the atmosphere and oceans. This process is primarily triggered by the rise in greenhouse gas emissions such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) originating from human activities, including the use of fossil fuels, industrial production, and deforestation. Greenhouse gases trap solar radiation by preventing it from escaping back into space after reflecting off the Earth's surface, thereby creating a "greenhouse effect" and contributing to planetary warming.

Undoubtedly, global warming has adverse environmental, economic, social, and health-related consequences. Rising temperatures are associated with an increased incidence of heatstroke, dehydration, and cardiovascular diseases. Changing climate conditions have expanded the geographical distribution of vector-borne diseases such as malaria and dengue fever. Furthermore, elevated air pollution levels have led to a rise in respiratory illnesses, including asthma and chronic obstructive pulmonary disease (COPD). The risk of acute kidney injury and chronic kidney disease, driven by dehydration and heat stress, has also become a growing public health concern in today's world.

Climate change has a direct impact on humanitarian emergencies such as heatwaves, wildfires, floods, tropical storms, and hurricanes, with an observable increase in their scale, frequency, and intensity. Research indicates that approximately 3.6 billion people currently reside in regions that are highly vulnerable to the effects of climate change. Between 2030 and 2050, climate change is projected to cause an additional 250,000 deaths

[1] Dr., Dicle University Faculty of Medicine, Department of Internal Medicine, adnanonun@gmail.com, ORCID iD: 0009-0008-9403-7061

[2] Assoc. Prof. Dr., Dicle University, Faculty of Medicine, Department of Internal Medicine, emreaydin83@hotmail.com, ORCID iD: 0000-0001-7657-3065

DOI: 10.37609/akya.3817.c1713

with chronic illnesses, to combat heatwaves. The importance of adequate fluid intake to prevent dehydration must be emphasized, particularly in hot regions, by ensuring accessible and safe water sources. Additionally, reducing industrial waste and particulate emissions is an essential step in preserving kidney health.

In summary, combating climate change is a vital component of kidney disease prevention. Measures taken at both individual and societal levels will help secure the health of future generations. Raising public awareness and effectively implementing policy interventions are of paramount importance for human health and the sustainability of ecosystems.

REFERENCES

1. Shah AD. Climate change and kidney health: an urgent call to action. Curr Opin Nephrol Hypertens. 2024 Jan 1;33(1):77.
2. Glaser, Jason; Lemery, Jay; Rajagopalan, Balaji; Climate Change and the Emergent Epidemic of CKD from Heat Stress in Rural Communities: The Case for Heat Stress Nephropathy. Clinical Journal of the American Society of Nephrology 11(8):p 1472-1483, August 2016.
3. Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med. 1999 May;16(4):269-77.
4. Conti S, Masocco M, Meli P, Minelli G, Palummeri E, Solimini R, Toccaceli V, Vichi M. General and specific mortality among the elderly during the 2003 heat wave in Genoa (Italy). Environ Res. 2007 Feb;103(2):267-74.
5. Wen B, Xu R, Wu Y, Coêlho MSZS, Saldiva PHN, Guo Y, Li S. Association between ambient temperature and hospitalization for renal diseases in Brazil during 2000-2015: A nationwide case-crossover study. Lancet Reg Health Am. 2021 Oct 31;6:100101.
6. Moyce S, Joseph J, Tancredi D, Mitchell D, Schenker M. Cumulative Incidence of Acute Kidney Injury in California's Agricultural Workers. J Occup Environ Med. 2016 Apr;58(4):391-7.
7. Correa-Rotter R, Wesseling C, Johnson RJ. CKD of unknown origin in Central America: the case for a Mesoamerican nephropathy. Am J Kidney Dis. 2014 Mar;63(3):506-20.
8. Kjellstrom T, Butler AJ, Lucas RM, Bonita R. Public health impact of global heating due to climate change: potential effects on chronic non-communicable diseases. Int J Public Health. 2010 Apr;55(2):97-103.
9. Lieberman HR. Hydration and cognition: a critical review and recommendations for future research. J Am Coll Nutr. 2007 Oct;26(5 Suppl):555S-561S.
10. Friel S. Climate change, food insecurity and chronic diseases: sustainable and healthy policy opportunities for Australia. N S W Public Health Bull. 2010 May-Jun;21(5-6):129-33.
11. Rogers DJ, Randolph SE. Climate change and vector-borne diseases. Adv Parasitol. 2006;62:345-81.
12. Stookey JD, Pieper CF, Cohen HJ. Hypertonic hyperglycemia progresses to diabetes faster than normotonic hyperglycemia. Eur J Epidemiol. 2004;19(10):935-44.
13. Webb P. The physiology of heat regulation. Am J Physiol. 1995 Apr;268(4 Pt 2):R838-50.
14. Crandall CG, Wilson TE. Human cardiovascular responses to passive heat stress. Compr Physiol. 2015 Jan;5(1):17-43.
15. Sawka MN, Leon LR, Montain SJ, Sonna LA. Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. Compr Physiol. 2011 Oct;1(4):1883-928.
16. Kenny GP, Jay O. Thermometry, calorimetry, and mean body temperature during heat stress.

Compr Physiol. 2013 Oct;3(4):1689-719.
17. Cheung SS, McLellan TM, Tenaglia S. The thermophysiology of uncompensable heat stress. Physiological manipulations and individual characteristics. Sports Med. 2000 May;29(5):329-59.
18. Amorim, Fabiano ve ; Schlader, Zachary b,c .Isı stresi altında böbrek: bir durum. Nefroloji ve Hipertansiyonda Güncel Görüş 34(2):s 170-176, Mart 2025.
19. Goldfarb DS, Hirsch J. Hypothesis: Urbanization and exposure to urban heat islands contribute to increasing prevalence of kidney stones. Med Hypotheses. 2015 Dec;85(6):953-7.
20. Soucie JM, Thun MJ, Coates RJ, McClellan W, Austin H. Demographic and geographic variability of kidney stones in the United States. Kidney Int. 1994 Sep;46(3):893-9.
21. Sadler R, Possemiers H, Prenen F, Van Landschoot L, Pollenus E, Deckers M, Knoops S, Koshy P, Matthys P, Van den Steen PE. The differential effect of Interferon-gamma on acute kidney injury and parasitemia in experimental malaria. Sci Rep. 2025 Feb 21;15(1):6402.
22. Katsoulis O, Georgiadou A, Cunnington AJ. Immunopathology of Acute Kidney Injury in Severe Malaria. Front Immunol. 2021 Apr 23;12:651739.
23. Lyke KE, Burges R, Cissoko Y, Sangare L, Dao M, Diarra I, Kone A, Harley R, Plowe CV, Doumbo OK, Sztein MB. Serum levels of the proinflammatory cytokines interleukin-1 beta (IL-1beta), IL-6, IL-8, IL-10, tumor necrosis factor alpha, and IL-12(p70) in Malian children with severe Plasmodium falciparum malaria and matched uncomplicated malaria or healthy controls. Infect Immun. 2004 Oct;72(10):5630-7.
24. Namazzi R, Batte A, Opoka RO, Bangirana P, Schwaderer AL, Berrens Z, Datta D, Goings M, Ssenkusu JM, Goldstein SL, John CC, Conroy AL. Acute kidney injury, persistent kidney disease, and post-discharge morbidity and mortality in severe malaria in children: A prospective cohort study. EClinicalMedicine. 2022 Feb 12;44:101292.
25. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, Drake JM, Brownstein JS, Hoen AG, Sankoh O, Myers MF, George DB, Jaenisch T, Wint GR, Simmons CP, Scott TW, Farrar JJ, Hay SI. The global distribution and burden of dengue. Nature. 2013 Apr 25;496(7446):504-7.
26. Wilder-Smith A, Ooi EE, Horstick O, Wills B. Dengue. Lancet. 2019 Jan 26;393(10169):350-363.
27. Cron RQ, Goyal G, Chatham WW. Cytokine Storm Syndrome. Annu Rev Med. 2023 Jan 27;74:321-337.
28. Al Kadi M, Yamashita M, Shimojima M, Yoshikawa T, Ebihara H, Okuzaki D, Kurosu T. Cytokine storm and vascular leakage in severe dengue: insights from single-cell RNA profiling.
29. Costa F, Hagan JE, Calcagno J, Kane M, Torgerson P, Martinez-Silveira MS, Stein C, Abela-Ridder B, Ko AI. Global Morbidity and Mortality of Leptospirosis: A Systematic Review. PLoS Negl Trop Dis. 2015 Sep 17;9(9):e0003898.
30. Felzemburgh RD, Ribeiro GS, Costa F, Reis RB, Hagan JE, Melendez AX, Fraga D, Santana FS, Mohr S, dos Santos BL, Silva AQ, Santos AC, Ravines RR, Tassinari WS, Carvalho MS, Reis MG, Ko AI. Prospective study of leptospirosis transmission in an urban slum community: role of poor environment in repeated exposures to the Leptospira agent. PLoS Negl Trop Dis. 2014 May 29;8(5):e2927
31. Haake DA, Levett PN. Leptospirosis in humans. Curr Top Microbiol Immunol. 2015;387:65-97.
32. Rajapakse S. Leptospirosis: clinical aspects. Clin Med (Lond). 2022 Jan;22(1):14-17.
33. Miller MR, Raftis JB, Langrish JP, McLean SG, Samutrtai P, Connell SP, Wilson S, Vesey AT, Fokkens PHB, Boere AJF, Krystek P, Campbell CJ, Hadoke PWF, Donaldson K, Cassee FR, Newby DE, Duffin R, Mills NL. Inhaled Nanoparticles Accumulate at Sites of Vascular Disease. ACS Nano. 2017 May 23;11(5):4542-4552. doi: 10.1021/acsnano.6b08551. Epub 2017 Apr 26. Erratum in: ACS Nano. 2017 Oct 24;11(10):10623-10624.
34. Tavera Busso I, Mateos AC, Juncos LI, Canals N, Carreras HA. Kidney damage induced by subchronic fine particulate matter exposure. Environ Int. 2018 Dec;121(Pt 1):635-642.

35. Bowe B, Xie Y, Li T, Yan Y, Xian H, Al-Aly Z. Particulate Matter Air Pollution and the Risk of Incident CKD and Progression to ESRD. J Am Soc Nephrol. 2018 Jan;29(1):218-230.
36. Bowe B, Xie Y, Yan Y, Al-Aly Z. Burden of Cause-Specific Mortality Associated With PM2.5 Air Pollution in the United States. JAMA Netw Open. 2019 Nov 1;2(11):e1915834
37. Bowe B, Xie Y, Li T, Yan Y, Xian H, Al-Aly Z. Estimates of the 2016 global burden of kidney disease attributable to ambient fine particulate matter air pollution. BMJ Open. 2019 May 9;9(5):e022450.
38. Bowe B, Xie Y, Li T, Yan Y, Xian H, Al-Aly Z. Associations of ambient coarse particulate matter, nitrogen dioxide, and carbon monoxide with the risk of kidney disease: a cohort study. Lancet Planet Health. 2017 Oct;1(7):e267-e276.
39. Khlifi R, Hamza-Chaffai A. Head and neck cancer due to heavy metal exposure via tobacco smoking and professional exposure: a review. Toxicol Appl Pharmacol. 2010 Oct 15;248(2):71-88.
40. Järup L. Hazards of heavy metal contamination. Br Med Bull. 2003;68:167-82.
41. Nagajyoti PC, Lee KD, Sreekanth TVM. Ağır metaller, bitkiler için oluşum ve toksisite: bir inceleme. Environ Chem Lett. 2010;8(3):199–216.
42. Morais S, Costa FG, Pereira ML. Ağır metaller ve insan sağlığı. Oosthuizen J, editör. Çevresel sağlık – ortaya çıkan sorunlar ve uygulama. 2012. s. 227–246.
43. Solenkova NV, Newman JD, Berger JS, Thurston G, Hochman JS, Lamas GA. Metal pollutants and cardiovascular disease: mechanisms and consequences of exposure. Am Heart J. 2014 Dec;168(6):812-22.
44. Zheng N, Liu J, Wang Q, Liang Z. Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, Northeast of China. Sci Total Environ. 2010 Jan 15;408(4):726-33.
45. Djahed B, Taghavi M, Farzadkia M, Norzaee S, Miri M. Stochastic exposure and health risk assessment of rice contamination to the heavy metals in the market of Iranshahr, Iran. Food Chem Toxicol. 2018 May;115:405-412.
46. Lauwerys RR, Bernard AM, Roels HA, Buchet JP. Cadmium: exposure markers as predictors of nephrotoxic effects. Clin Chem. 1994 Jul;40
47. Singh N, Kumar D, Sahu AP. Arsenic in the environment: effects on human health and possible prevention. J Environ Biol. 2007 Apr;28
48. Guha Mazumder DN. Chronic arsenic toxicity & human health. Indian J Med Res. 2008 Oct;128(4):436-47.
49. Zuo J, Huesker K, Liu Y, Hocher JG, Zhang X, von Baehr V, Krämer BK, Hocher B. Association of whole blood heavy metal concentrations with kidney function. Sci Rep. 2025 Mar 11;15(1):8370.
50. Sharma P, Dubey RS. Bitkilerde kurşun toksisitesi. Brezilya Bitki Fizyolojisi Dergisi. 2005;17(1):35–52.
51. Wadhwa N, Mathew BB, Jatawa S, Tiwari A. Lipid peroksidasyonu: mekanizma, modeller ve önemi. Int J Curr
52. Mathew BB, Tiwari A, Jatawa SK. Free radicals and antioxidants: A review. Journal of Pharmacy Research. 2011;4(12):4340–4343.
53. El-Nekeety AA, El-Kady AA, Soliman MS, Hassan NS, Abdel-Wahhab MA. Protective effect of Aquilegia vulgaris (L.) against lead acetate-induced oxidative stress in rats. Food Chem Toxicol. 2009 Sep;47(9):2209-15.
54. Rana MN, Tangpong J, Rahman MM. Toxicodynamics of Lead, Cadmium, Mercury and Arsenic- induced kidney toxicity and treatment strategy: A mini review. Toxicol Rep. 2018 May 26;5:704-713.
55. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol. 2014 Jun;7(2):60-72.
56. Patrick L. Mercury toxicity and antioxidants: Part 1: role of glutathione and alpha-lipoic acid in

the treatment of mercury toxicity. Altern Med Rev. 2002 Dec;7(6):456-71.
57. Han JX, Shang Q, Du Y. Effect of environmental cadmium pollution on human health. Health. 2009;1(3):159–166.
58. Satarug S, Garrett SH, Sens MA, Sens DA. Cadmium, environmental exposure, and health outcomes. Cien Saude Colet. 2011 May;16(5):2587-602.
59. Castagnetto JM, Hennessy SW, Roberts VA, Getzoff ED, Tainer JA, Pique ME. MDB: the Metalloprotein Database and Browser at The Scripps Research Institute. Nucleic Acids Res. 2002 Jan 1;30(1):379-82.