Gathering the evidence and identifying opportunities for future research in climate, heat and health in South Africa: The role of the South African Medical Research Council

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Background. A changing climate is likely to have widespread and varying impacts on ecosystems and human health. South Africa (SA) is particularly vulnerable to the impacts of climate change, given the projected increases in temperature, and changes in the amount and patterns of rainfall. Moreover, SA's vulnerability is exacerbated by extreme inequality and poverty. To prepare for the impacts of climate change and to ensure timeous adaptation, a perspective is given on essential heat and health research in the country.
Objectives. To gather studies conducted by the South African Medical Research Council (SAMRC)'s Environment and Health Research Unit (EHRU) to illustrate the range of possible research key areas in the climate, heat and health domain and to present future research priorities.
Methods. Studies conducted by the SAMRC's EHRU were gathered and used to illustrate the range of possible research key areas in the climate, heat and health domain. Using national and international published and grey literature, and tapping into institutional research experiences, an overview of research findings to date and future research priorities were developed.
Results. Heat and health-related research has focussed on key settings, for example, schools, homes and outdoor work places, and vulnerable groups such as infants and children, the elderly and people with pre-existing diseases. The need to address basic needs and services provision was emphasised as an important priority.
Conclusions. High and low temperatures in SA are already associated with mortality annually; these impacts are likely to increase with a changing climate. Critical cross-sectoral research will aid in understanding and preparing for temperature extremes in SA.

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Climate change is the biggest global health threat of the 21st century.[1] Unprecedented global warming associated with anthropogenic activities has catalysed a 'greenhouse effect' which has led to changes in earth systems[2] that are increasingly deemed irreversible.[3-5] Extreme weather events are predicted to increase (or are already increasing) in severity and frequency.[6] These climatic changes threaten environmental conditions required to support human health and wellbeing, including air that is safe to breathe, water that is available and clean to drink, food that is of nutritional value and shelter from the elements.[7] Associations exist between exposure to high ambient temperatures during a heatwave, for instance, with heat having particularly harmful effects on cardiovascular and respiratory health.[1]

The changing availability and compromised quality of water associated with a changing climate may lead to increases in water-related diseases such as cholera.[8] Increased droughts, flooding and proliferation of pests are considered the main threats to food security.[9] Extreme weather and climate events can displace and compel people to migrate because of the destruction of their homes (for example by storm surges), rendering the local environmental uninhabitable.[10]

In this article, studies conducted by the South African Medical Research Council's (SAMRC) Environment and Health Research Unit were gathered and used to illustrate the range of possible research key areas in the climate, heat and health domain. Using national and international published and grey literature, and tapping into institutional research experiences, an overview of research findings to date, and future research priorities, are presented.

Why is South Africa (SA) more vulnerable than many other nations to the ramifications of climate change?

Scientific models and projections indicate that southern Africa will be particularly affected by climate change. Local temperatures are expected to increase, on average, by a rate that is double the projected average for the globe.[11,12] SA may also become increasingly prone to lowered precipitation, droughts (such as the episode that gripped the Western Cape in 2017 - 2018), heatwaves and flooding.[13,14] Widespread poverty and inequality that are amongst the worst in the world also contribute to SA being considered comparatively vulnerable to climate change.[15] Detrimental environmental and health consequences of climate change will be disproportionately borne by the poorest in society, in part because of their lower levels of resilience and capacity to adapt to climate change.[16]

Role of the SAMRC in climate, heat and health research in South Africa

The SAMRC Environment and Health Research Unit (EHRU) has focused on environmental health hazards experienced by societal groups that have endured the highest burdens of poverty and inequality for decades. For example, the EHRU has researched the environmental health hazards faced by communities living in urban informal settlements and rural villages, those living close to mining operations[17] and other pollution sites, children exposed to lead,[18] manganese, mercury and arsenic in soil, petrol, paint and cottage industries, [19] and through their ingestion of food, water and medicines. These are also the same groups whose vulnerability to climate change will be highest, and whose adaptive capacity will be lowest. Progressively over the past decade, alongside increased awareness of the extent and devastating impacts of global climate change, the EHRU has expanded its emphasis to climate change and health with attention to the most vulnerable in society.

Increasing heat and heatwaves

Increasing trends in daily maximum and minimum extreme temperature indices across parts of SA over the past few years exist.[20] Specifically, the Lowveld in the north-east (Limpopo, Mpumalanga), along the east coast (northern and coastal parts of KwaZulu-Natal (KZN)) and the dry interior (Northern Cape) have experienced relatively warmer temperatures and are prone to hot daily extremes.[20] These findings are supported by projections from various climate models including the Conformal-Cubic Atmospheric Model (CCAM) run by the Council for Scientific and Industrial Research (CSIR). Under a business-as-usual scenario, increases of more than 3^0C over the central and northern interior of SA for 2070 - 2100 compared to 1975 - 2005 have been projected. Coastal areas are expected to experience a smaller increase of about 2^0C.[21]

While data challenges currently make it difficult to estimate deaths attributable to heatwaves, there is anecdotal evidence of the impact of heatwaves on health in SA. Over a period of a few days in 2016, a heatwave with maximum temperatures well over 40°C broke local temperature records over half a century and caused the deaths of at least 11 people in SA's North-West (NW) Province, with the elderly being particularly vulnerable.[22] In that same year, heatwaves resulted in records for the highest documented temperature being broken in 21 SA towns and cities.[22] In 2018, a further 12 all-time-high temperature records were broken across the Gauteng, North-West, Mpumalanga and KZN provinces.[23] Scientific predictions of rising heat in SA, together with deadly heatwaves occurring in France and elsewhere, as well as local research and anecdotal evidence, formed the basis for a decision within the EHRU to build a programme of research to characterise the health impacts of heat in SA to inform interventions for thermal comfort and heat protection. The EHRU has just begun intervention-based work in relation to heat and health and these studies will be published in due course.

The impact of temperature on national mortality

Scientists within the EHRU have worked with partners internationally to understand the impacts of ambient temperature on mortality in SA .[24] A time-series analysis was undertaken using daily temperature data and a national dataset of 8.8 million deaths between 1997 and 2013. Results showed relative risks for all-age, all-cause mortality on very cold and hot days (1st and 99th percentile of temperature distribution) were 1.14 (1.10 - 1.17) and 1.06 (1.03 - 1.09), respectively, when compared with the minimum mortality temperature and showing a greater impact on mortality from cold relative to hot temperatures. Strongest associations were in children aged <5 years, in the elderly (>64 years), and for cardiorespiratory effects. Heat effects tended to occur immediately after exposure but diminished quickly, while cold effects were delayed but relatively persistent. A total of 3.4% of deaths in SA were attributable to non-optimum temperatures during the 15-year period.

Risk of exposure to heat in specific settings: Housing, schools, clinics, the workplace

Indoor thermal conditions are an important determinant of cardiovascular and respiratory health problems.[25] The EHRU has conducted temperature monitoring studies in key SA settings (Fig. 1) including homes, schools, health facilities and places of work. We found that mean **indoor dwelling temperatures** were often higher than outdoor temperatures and frequently exceeded international and national recommendations

Fig. 1. Settings in which the EHRU has conducted temperature and health-related research projects: (A) dwellings in Limpopo, (B) schools in Johannesburg; (C) clinics in Limpopo; and (D) workers in Northern Cape. (Photos courtesy of C Y Wright (A, C and D) and S Bidassey-Manilal (B).)

for optimal thermal comfort (21^{0}C and 24^{0}C, respectively).[26,27] Mean indoor summer temperatures also often exceeded 27^{0}C; the minimum temperature above which optimal body functioning is detrimentally affected. In **schools** in the City of Johannesburg, indoor classroom temperatures varied between 21°C at night to 34°C midday during late summer months.[28] Temperature inside a shipping container classroom exceeded 40°C. There was a statistically significant relationship (controlling for school cluster effect and time of day) between classroom temperatures ≥32°C and students who reportedly felt tired and had difficulty breathing. A similar finding was seen in 8 **primary health-care facility waiting rooms** in Limpopo province.[29] On average, the clinic waiting room monthly temperature (measured for 6 months over summer) was 31°C, with a maximum temperature ≥38°C. Indoor temperatures were warmer by 2 to 4°C compared with outdoor temperatures, with the highest mean temperature outdoors recorded in December at 26°C. Mean maximum monthly outdoor temperatures were ~30°C.

Heat exposure among environmentally exposed **outdoor workers** was assessed as part of a multi-country study known as HOTHAPS (High Occupational Temperature, Health and Productivity Suppression).[30] Road construction workers in Upington, Northern Cape, where temperatures regularly exceed 40°C, reported a wide range of ill-health effects that they perceived to be associated with heat-related effects including sleeplessness, irritability and exhaustion that prohibited productivity and output during hot weather.[30] Reported impacts of working in high heat included increased thirst, excessive perspiration, dry, itchy or 'sore' skin, tiredness, dry nose, blister formation, sinus problems, teary, burning or strained eyes, exhaustion, malaise, dehydration, headaches, backache, leg pains, nose bleeds and dizziness. There was agreement that pre-existing chronic ill-health conditions, such as hypertension and diabetes, could exacerbate the effects of working in hot weather and worsen their chronic ill health conditions. There was also a reported perception that working in very hot conditions affected their sleep, which in turn affected their mental well-being increasing their irritability and fuelling aggression toward their family members.

Assessing vulnerability to heat

In partnership with scientists at the CSIR, the EHRU participated in an exercise to identify, within each of SA's nine provinces, the municipalities that have historically been most vulnerable to increasing temperatures. Within the NW province's Bonjala Platinum District Municipality, Rustenburg was simulated to be one of the hottest places vulnerable to increasing temperature (Fig. 2). One of the ways in which the country, provinces and towns can prevent adverse health impacts from temperature, especially heat, is to implement heat-health vulnerability assessments[31] and formulate heat-health plans. The EHRU has been working with the Rustenburg Local Municipality to prepare a heat-health vulnerability assessment tool for the town's population. The assessment tool will identify population sub-groups and settings at greatest risk of heat exposure and adverse heat-related health impacts in Rustenburg. On completion, it is hoped that the Rustenburg heat-health vulnerability assessment will serve as a simple model that may be followed by other SA cities and towns as suggested in the National Department of Health Climate Change and Health Adaptation Plan.[32]

Weather-based early warning systems for infectious diseases

Climate change has the potential to change the distribution of infectious diseases. In a research collaboration between Japan and SA named the infectious Disease Early Warning System (iDEWS), a sophisticated infectious disease climate-based outbreak prediction model, incorporating environmental and climate parameters, was made to predict the likelihood of outbreaks of malaria and diarrhoeal diseases with a lead time of around six months.[33] Such warnings of a high likelihood of a disease outbreak may be used by local health departments to conduct public awareness campaigns around the early signs and symptoms of diseases in high risk areas, ensure that enough staff are on duty and that there are adequate stocks of key medications.

Opportunities and the way forward

The public health opportunities and co-benefits of climate change mitigation and adaptation in SA exist but need further development, implementation and monitoring/evaluation.[34,35] Fig. 3 illustrates ways in which we can begin to identify opportunities for research, collaboration and multi-stakeholder engagement to take up this challenge.[36] These ways to curb and mitigate negative health impacts caused by a changing climate should target climate change adaptation efforts that tackle poverty, inequality, lack of access to health services as well as education gaps. All successful attempts should place emphasis on collaboration to ensure that health is integrated into global, national and local responses to climate change and that these responses are felt by those who are most affected.

Ensuring wide public awareness campaigns about the risks associated with climate and weather is important in SA. Indigenous knowledge should form a solid foundation upon which adaptation strategies at community level are conceptualised and implemented. So too should a climate change ut across all sectors of society and all levels in different institutional arrangements. A climate change lens is critical in all projects

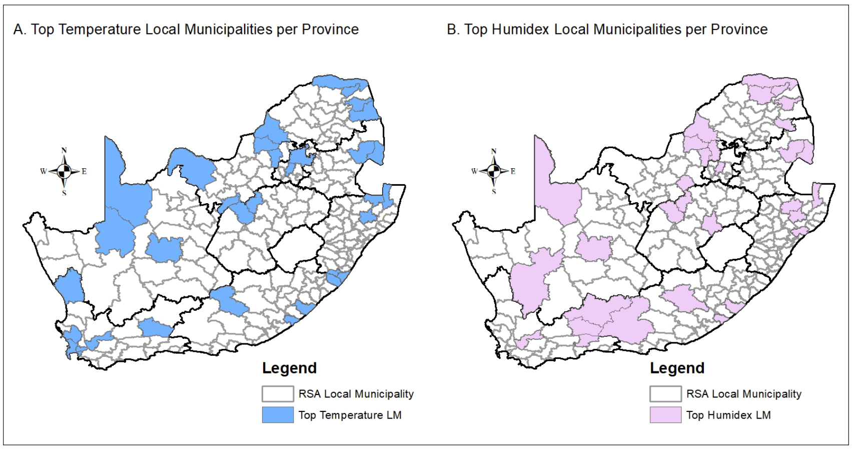

Fig. 2. Modelled estimates of the top hottest towns in South Africa using the December-January-February 3-month average of the historical monthly 99th percentile for (A) maximum temperature and (B) maximum Humidex (considering temperature and relative humidity). The historical (1979 - 2008) 99th percentile temperature and humidex was simulated over South Africa with CCAM using ERA-Interim input at a 50 km resolution.

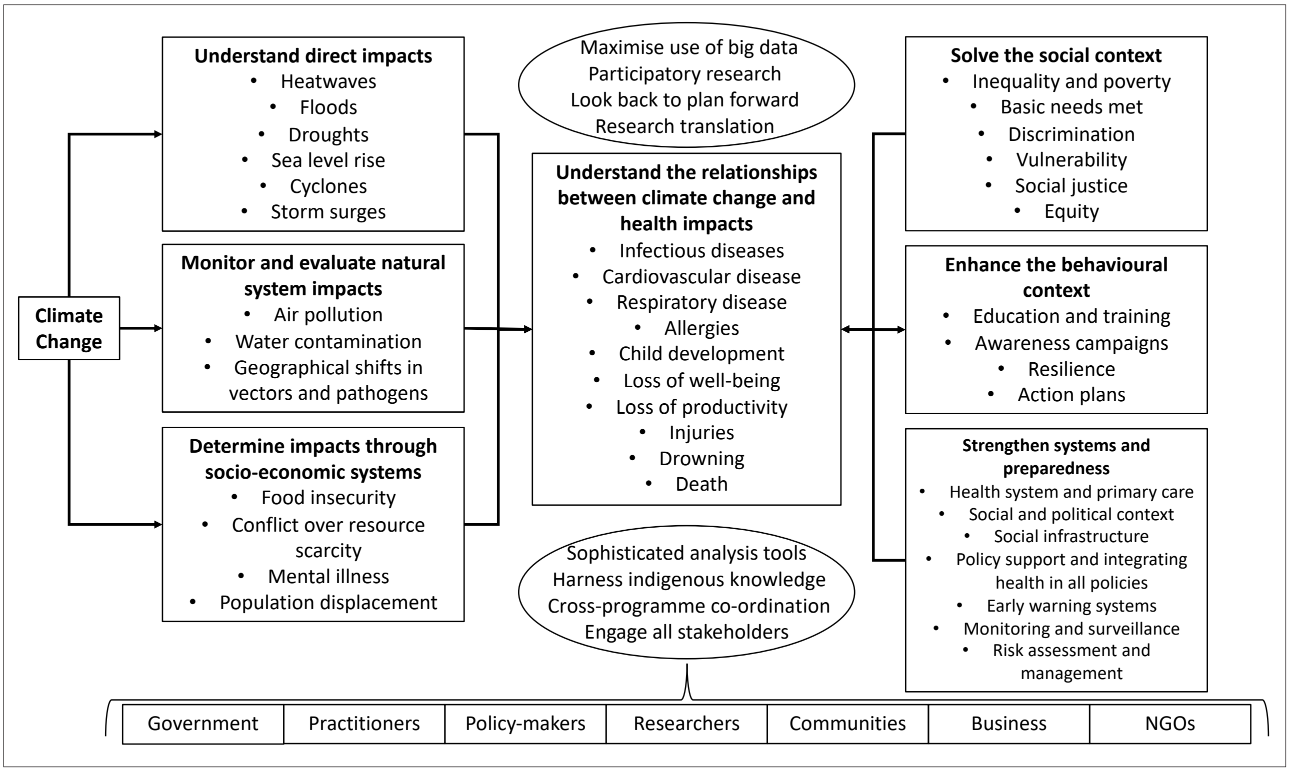

Fig. 3. Possible research priorities for climate, heat and human health in South Africa.

and programmes going forward, including those working among communities.

Drawing in practitioners in environmental health is important. For example, environmental health practitioners (EHPs) play an important role in implementing climate change-related adaptation actions in communities. Shezi *et al.*[37] conducted a study to assess the climate change-related perceptions, knowledge and preparedness among a sample of SA EHPs. Most EHPs (*n*=57) acknowledged that they had noticed climate change effects such as drought, impacts on health (i.e. malaria and cholera), flooding and damage to infrastructure. Several adaptation measures were highlighted by the EHPs, including scaling up the planting of trees to provide shade during heat waves (61%), promoting vegetable gardening (59%), instituting community-based early warning systems for adverse weather events (56%), raising standards for storm water drainage (55%), provision of public drinking water (38%), water fountains in schools (42%) and shade in school playgrounds (45%). These are practical, implementable steps that can alleviate the adverse risks of a changing climate in communities. Internationally, simple interventions have been successfully implemented, e.g. New York City promotes green infrastructure and 'cool' roofs[38] and health workers in Bhutan collect weather data as part of climate-sensitive disease surveillance.[39]

Opportunities to tackle climate change and health adaptation also arise from collecting data that can be used for research, planning and model predictions toward prevention. Hospital record-keeping in electronic format can help identify hotspot areas and diseases of concern, as well as highlight new relationships and risks to the health of communities. For example, on 16 October 2014, an unprecedented dust storm swept across a large swathe of the country. Health impacts of dust storms include increased hospitalisation due to respiratory and cardiovascular illnesses.[40-42] This dust storm, up to now exceptional in SA, provides an important opportunity to study, and begin to prepare for the public health implications of unusual weather events. Within this context, an EHRU study to investigate the impact that the dust storm had on hospital visits has begun. In communities unaccustomed to dust storms, public awareness of the actions needed to protect health during dust storms is needed.

Conclusions

The reality of climate change and its impacts on human health are being experienced around the world, including SA. Efforts to address these impacts for disease prevention must be multisectoral and multidisciplinary. The SAMRC EHRU has begun to consider practical adaptation and coping mechanisms needed in all sectors of society and at all levels of governance to prepare for climate change health-related impacts. Collaboration between researchers, policy-makers, society and all relevant stakeholders is essential. The proposed research roadmap emphasises meeting fundamental basic needs and addressing poverty and inequalities among vulnerable groups in SA within the changing climate context. Building the blocks upon which communities and government can then prepare for and prevent adverse health impacts arising from a changing climate is a research imperative.

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1. Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change. Lancet 2009;3(1):1693-1733. https://doi.org/10.1016/S0140-6736(09)60935-1

2. De Matteis A. Decomposing the anthropogenic cause of climate change. Environ Dev Sust 2019;21(1):165-179. https://doi.org/10.1007/s10668-017-0028-4
3. Lontzek TS, Cai Y, Judd KL, Lenton TM. Stochastic integrated assessment of climate tipping points indicates the need for strict climate policy. Nat Clim Change 2015;5(1):441-444. https://doi.org/ 10.1038/nclimate2570
4. Zickfeld K, Solomon S, Gilford DM. Centuries of thermal sea level rise due to anthropogenic emissions of short-lived greenhouse gases. Proc Nat Acad Sci USA 2017;114(4):657-662. https://doi.org/10.1073/pnas.1612066114
5. Beniston M, Stephenson DB, Christensen OB, et al. Future extreme events in European climate: An exploration of regional climate model projections. Climatic Change 2007;81(Suppl 1):71-95. https://doi.org/10.1007/s10584-006-9226-z
6. Wilgen van BJ, Goodall V, Holness S, Chown SL, McGeoch MA. Rising temperatures and changing rainfall patterns in South Africa's national parks. Int J Climatol 2016;36(2):706-721. https://doi.org/10.1002/joc.4377|
7. Serdeczny O, Adams S, Baarsch F, et al. Climate change impacts in Sub-Saharan Africa: From physical changes to their social repercussions. Reg Environ Change 2017;17(1):1585-1600. https://doi.org.10.1007/s10113-015-0910-2
8. Wu Z, Lu Y, Zhou S, Chen L, Xu B. Impact of climate change on infectious diseases: Empirical evidence and human adaptation. Environ Intern 2016;86(1):14-23. https://doi.org/10.1016/j.envint.2015.09.007
9. Masipa TS. The impact of climate change on food security in South Africa: Current realities and challenges ahead. J Disast Risk Studies 2017;9(1):a411. https://doi.org/10.4102/jamba.v9i1.411
10. Black R, Bennett SG, Thomas SM, Beddington JR. Migration as adaptation. Nature 2011;478(1):447-449. https://doi.org/10.1038/478477a
11. Hoegh-Guldberg O, Jacob D, Taylor M, et al. Impacts of 1.5°C global warming on natural and human systems. In: Masson-Delmotte V, Zhai P, Pörtner H-O, et al., eds. Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable development, and efforts to eradicate poverty. Geneva: Intergovernmental Panel on Climate Change, 2018. https://www.ipcc.ch/sr15/ (accessed 21 October 2019).
12. Engelbrecht FA, Adegoke J, Bopape M-J et al. Projections of rapidly rising surface temperatures over Africa under low mitigation. Environ Res Letters 2015;10(8),085004. https://doi.org/10.1088/1748-9326/10/8/085004.
13. Pohl B, Macron C, Monerie P-A. Fewer rainy days and more extreme rainfall by the end of the century in southern Africa. Scientific Rep 2017;7(1):46466. https://doi.org/10.1038/srep46466
14. Otto FEL, Wolski P, Lehner F, et al. Anthropogenic influence on the drivers of the Western Cape drought 2015-2017. Environ Res Letters 2018;13(12):124010. https://doi.org/10.1088/1748-9326/aae9f9
15. Chersich MF, Wright CY, Venter F, Rees H, Scorgie F, Erasmus B. Impacts of climate change on health and wellbeing in South Africa. Int J Environ Res Public Health 2018;15(9):884. https://doi.org/10.3390/ijerph15091884
16. Wright CY, Garland RM, Norval M, Vogel C. Human health impacts in a changing South African climate. S Afr Med J 2014;104(8):568-573.
17. Nkosi V, Wichmann J, Kuku V. Mine dumps, wheeze, asthma, and rhinoconjunctivitis among adolescents in South Africa: Any association? Int J Environ Health Res 2015;26(6):583-600. https://doi.org/10.1080/09603123.2014.989493
18. Mathee A, Khan T, Naicker N, Kootbodien T, Naidoo S, Becker P. Lead exposure in young school children in South African subsistence fishing communities. Environ Res 2013;126:179-183. https://doi.org/10.1016/j.envres.2013.05.009
19. Teare J, Kootbodien T, Naicker N, Mathee A. The extent, nature and environmental health implications of cottage industries in Johannesburg, South Africa. Int J Environ Res Public Health 2015;12(2):1894-1901. https://doi.org/10.3390/ijerph120201894
20. Kruger A, Sekele S. Trends in extreme temperature indices in South Africa: 1962 - 2009. Int J Climatol 2013;33:661-676. https://doi.org/10/1002/joc.3455
21. Engelbrecht F, McGregor J, Engelbrecht C. Dynamics of the conformal-cubic atmospheric model projected climate-change signal over southern Africa. Int J Climatol 2009;29:1013-1033. https://doi.org/10.1002/joc.1742
22. Brophy, S. SA summer heat breaks 21 records: What's going on with the weather? https://www.traveller24.com/News/Alerts/sa-summer-heat-breaks-records-whats-going-on-with-the-weather-20160113 (accessed 21 October 2019).
23. Head, T. SA Heatwave: 12 new temperature records have been set as mercury soars. https://www.thesouthafrican.com/sa-heatwave-temperature-records-september-2018/ (accessed 21 October 2019).
24. Scovronick N, Sera F, Acquaotta F, et al. The association between ambient temperature and mortality in South Africa: A time-series analysis. Environ Res 2018;161:229-235. https://doi.org/10.1016/j.envres.2017.11.001
25. Vardoulakis S. Human exposure: Indoor and outdoor. Issues Environ Sci Technol 2009;28:85-107. https://doi.org/10.1039/9781847559654
26. Kapwata T, Gebreslasie M, Mathee A, Wright CY. Current and potential future seasonal trends of indoor dwelling temperature and likely health risks in rural southern Africa. Int J Environ Res Pub Health 2018;15:952. https://doi.prg/10/3390/ijerph15050952
27. Naicker N, Teare J, Balakrishna Y, Wright CY, Mathee A. Indoor temperatures in low cost housing in Johannesburg, South Africa. Int J Environ Res Pub Health 2017;14:1410. https://doi.org/10.3390/ijerph14111410
28. Bidassey-Manilal S, Wright CY, Engelbrecht JC, Albers PN, Garland RM, Matooane M. Students' perceived heat-health symptoms increased with warmer temperatures. Int J Environ Res Public Health 2016;13(6):566. https://doi.org/10.3390/ijerph13060566
29. Wright CY, Street RA, Cele N, et al. Indoor temperature in patient waiting rooms in eight rural primary health care centres in northern South Africa and the related potential risks to human health and wellbeing. Int J Env Res Pub Health 2017;14(1):43. https://doi.org/10.3390/ijerph14010043
30. Mathee A, Oba J, Rose A. Climate change impacts on working people (the HOTHAPS initiative): Findings of the South African pilot study. Global Health Action 2010;3(1):1-9. https://doi.org/10.3402/gha.v3i0.5612
31. Health Canada. Water, Air and Climate Change Bureau Healthy Environments and Consumer Safety Branch Climate change impacts on working people (the HOTHAPS initiative): Findings of the South African pilot study. Adapting to Extreme Heat Events: Guidelines for Assessing Health Vulnerability 2011. https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/adapting-extreme-heat-events-guidelines-assessing-health-vulnerability-health-canada-2011.html (accessed 21 October 2019).
32. National Department of Health (NDoH). National Climate Change and Health Adaptation Plan. Pretoria: NDoH, 2014. http://www.health.gov.za/index.php/shortcodes/2015-03-29-10-42-47/2015-04-30-08-29-27/2015-04-30-08-32-49/category/435-climate-change?download=2609:national-climate-change-and-health-adaptation-plan (accessed 21 October 2019).
33. Department of Science and Technology (DST). South Africa and Japan Boost Fight Against Infectious Diseases. Pretoria: DST, 2014. https://www.dst.gov.za/index.php/media-room/communiques/1034-south-africa-and-japan-boost-fight-against-infectious-diseases
34. Younger M, Morrow-Almeida HR, Vindigni SM, Dannenberg AL. The built environment, climate change, and health: Opportunities for co-benefits. Am J Prev Med 2008;35(1):517-526. https://doi.org/10.1016/j.amepre.2008.08.017
35. World Health Organization. Health Co-benefits of Climate Change Mitigation. Housing Sector. Health in the Green Economy. Geneva: WHO, 2011. https://www.who.int/hia/green_economy/transport_sector_health_co-benefits_climate_change_mitigation/en/ (accessed 21 October 2019).
36. Campbell-Lendrum D, Bertollini R, Neira M, Ebi K, McMichael A. Health and climate change: A roadmap for applied research. Lancet 2009;373(9676):1663-1665. https://doi.org/10.1016/S0140-6736(09)60926-0
37. Shezi B, Mathee A, Siziba W, et al. Environmental Health Practitioners potentially play a key role in helping communities adapt to climate change and avoiding public health impacts. BMC Public Health 2019;19(1):54. https://doi.org/10.1186/s12889-018-6378-5
38. United States Environmental Protection Agency (US EPA). New York Adapts to Deal with Projected Increase of Heat Waves. Climate Change Adaptation Resource Center. Washington: US EPA, 2019. https://www.epa.gov/arc-x/new-york-city-adapts-deal-projected-increase-heat-waves (accessed 21 October 2019).
39. Ebi KL, Otmani Del Barrio M. Lessons learned on health adaptation to climate variability and change: Experiences across low- and middle-income countries. Environ Health Perspect 2017;125(6):065001. https://doi.org/10.1289/EHP405
40. Yang B, Bräuning A, Zhang A, Dong A, Esper J. Dust storm frequency and its relation to climate changes in Northern China during the past 1000 years. Atmospheric Environment 2007;41(40):9288-9299. https://doi.org/10.1002/joc.3370110405
41. Tam WWS, Wong TW, Wong AHS, Hui DSC. Effect of dust storm events on daily emergency admissions for respiratory diseases. Respirology 2012;17(1):143-148. https://doi.org/10.1111/j.1440-1843.2011.02056.x
42. Yang CY, Cheng MH, Chen CC. Effects of Asian dust storm events on hospital admissions for congestive heart failure in Taipei, Taiwan. J Toxicol Environ Health 2009;72(5):324-328. https://doi.org/10.1080/15287390802529880