2016 Olympic and Paralympic Games Environmental Assessment Report

Rio de Janeiro, Brazil
October 2013

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Acknowledgements

The contents of this report were made possible by a collective of individuals and experts from both New Zealand and Brazil. First I would like acknowledge Professor Paul Laursen and the HPSNZ Performance Physiology team who edited this report and provided support throughout this project. Thank you to Martin Dowson and Richard Young, at HPSNZ, for initiating this investigation and who have offered their continued support and advice, to Jake Wilkins, from the NZOC, who collaborated with HPSNZ on this initiative and provided contact and logistics support in Rio, to Dale Smith and Maria Callou from the Rio Rugby Club who were an immense help during my stay in Rio through translating, transport and logistics assistance, to Jaqueline Gil (NZ Embassy, Brasilia) and Marion Klintworth (Conceptum Sport Logistics, Brazil) for their local knowledge and guidance during my stay in Rio. Thank you to the environmental experts at the State Environmental Institute (INEA) in Rio de Janeiro, specifically Dr Aline Lefol (air quality scientist) and Bruno Cunha (meteorologist) who have provided an insider's view of the Rio environment, the staff at Cronolab who performed the water sample analysis, as well as New Zealand environmental experts who assisted in the interpretation of the reported findings at the National Institute of Water & Atmospheric Research, specifically Dr Guy (Urban Air Quality and Health Manager) and Jennifer Gadd (Urban Aquatic Scientist). Finally, I would like to acknowledge the HPSNZ Prime Minister Scholarship which was granted to fund this trip.

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Sincerely,

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Abbreviations

BOD – biological oxygen demand

CO – carbon monoxide

DOC – dissolved organic compounds

INEA - The State Environmental Institute (Instituto Estadual do Ambiente)

ND – not detected

NE – not established

NO_2 – nitrogen dioxide

SO_2 – sulphur dioxide

PM_{10} – particulate matter with a diameter of < 10 µm

TPH – total petroleum hydrocarbons

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PART 1: Report Overview

The next Summer Olympic and Paralympic Games will be held in Rio de Janeiro, where the environmental conditions will be considerably different from what athletes will be accustomed to in New Zealand. During the Olympic period in 2013, an environmental investigation was undertaken across the four Olympic Zones within the Rio de Janeiro area. The measurements taken examined weather conditions, air quality and water quality, both at and around specific sport venues. It was found that the daily temperature high ranged from between 20^{o}C to 35^{o}C, with humidity decreasing during the day as temperature increased. Rainfall levels (mean for August is ~40 mm) and wind speed (2-10 km/h) were generally low during this period. Air quality at sport venues was generally good, while pollution levels were quite high, and in some instances higher than New Zealand threshold limits, in and around traffic. The quality of tap water and restaurant ice was shown to be unsuitable for human consumption. At outdoor water sports venues, the water quality was poor, increasing the risk of infection. Most of the environmental measures taken in this report, during the Olympic period, are expected to be similar during the Paralympic Games, with day time temperatures slightly higher.

The key recommendations following the environmental results gained are:

1) Plan and prepare for heat using heat acclimatisation and cooling strategies if performance in your sport can be impaired in hot temperatures (≥ 27^{o}C).
2) Limit athlete's time in and around traffic outdoors. Travel in air conditioned vehicles and consider that travelling long distances in Rio's heavy traffic could be fatiguing for athletes.
3) Only consume bottled water. Do not drink tap water or restaurant ice.
4) Teams competing at outdoor water venues are recommended to follow the specific safety guidelines surrounding water exposure and use found in this document.

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Recommendations

Environmental:

- While the Rio Olympic Games will be held during Brazil's 'winter', it could still be quite hot (low to mid 30's) and appropriate heat acclimatisation and cooling strategies should be in place to maximise athlete performance in sports where heat can be a factor (Appendix B).
- Appropriate sun safety should be considered (e.g. sun screen use, seeking shade when possible, etc.). Specific guidelines to come.
- Air pollution is high around areas of traffic, placing those athletes who are predisposed to respiratory illnesses (up to 20% in an elite population) at elevated risk of exacerbating respiratory symptoms (e.g. asthma, allergic rhinitis). This will have an impact on performance.
- Athletes should be screened for atopy, asthma and exercise-induced broncospasm (by team physician/physiologist) and those already diagnosed should ensure effective management strategies are in place.
- Limit exposure to traffic while walking outside of venues and during travel. Exposure time to these conditions should not exceed 60 min where possible.
- Ensure athletes are transported in sealed air-conditioned cars and remember to turn the cars air conditioner to recirculate before departure.
- The size of Rio de Janeiro, along with the density of people and traffic, make transportation between Olympic Zones, and even within Zones, time-consuming (e.g., 90 min drive from Barra to Copacabana, which is only 34 km in distance). Be aware of the potential fatigue of such travel conditions for athletes.
- Tap water and restaurant ice should not be consumed, even if it has been boiled. Boiling water will not remove metals or other chemical contaminants in the drinking water. Drink bottled water only and only use bottled water to brush teeth.
- For athletes competing in water sports, avoid swallowing sea/fresh water. Showering and/or washing one's face post-training and competition is advised to remove any residual bacteria on the body from water contact. Wet wipes may be a practical option for cleaning one's face as the quality of tap water is questionable.
- Immediately and thoroughly clean scratches or wounds with bottled water (do not use tap water if possible) and cover with water proof barrier dressings. When possible, avoid subsequent contact with bathing water (fresh and sea water) until healed.
- Athletes should consult with their physician for any vaccines needed. The water quality results reported herein suggest that athletes should ensure they have completed appropriate vaccinations (as recommended by the medical team) at least 3 months in advance of travelling to Rio.

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Introduction

The next Summer Olympic Games and Paralympic Games will be held in Rio de Janeiro from the 5th to 21st of August and 7th to 18th of September, 2016, respectively. As environmental conditions in Rio will be markedly different from what athletes will be accustomed to in New Zealand, it was deemed important to quantify the conditions to assist with planning and preparation for the Games. In response, High Performance Sport New Zealand, along with the New Zealand Olympic Committee supported a trip to collect venue-specific environmental data over the period of the 29th July to the 11th of August, 2013. An assessment of the environmental measures, potential challenges for New Zealand athletes and teams and recommended precautions are addressed in this report.

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PART 2: The Rio Environment

This section provides an overview of the general climate and environmental conditions in Rio de Janeiro, both historically and during the investigation period. While Rio de Janeiro faces several environmental challenges in terms of air and water quality, significant efforts are being made by government and environmental institutes to improve conditions for the 2016 Summer Games. The State Environmental Institute (INEA; Instituto Estadual do Ambiente) is leading this initiative through daily monitoring and reporting of air and water quality at several locations throughout Rio. Specifically, 16 new air quality control stations have been installed near Olympic venues as part of their plan to restore or improve conditions for the games. Through careful monitoring and planning, INEA is working together with Rio de Janeiro local and state governments to implement sustainable solutions and improve some of the environmental problems. For instance, they are working to re-direct traffic and increase road capacity to offset air pollution near Olympic venues, as well as install proper waste disposal systems throughout the poor neighbourhoods of Rio de Janeiro in an effort to prevent waste runoff into water sources. As the trend over the last 13 years has been a slight decline in air and water quality, it is currently unknown if these efforts to improve air and water quality will have a significant impact by 2016. Both daily and historical reports for air and water quality at locations throughout Rio can be viewed through the INEA website, www.inea.rj.gov.br

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Weather

Background:

Rio de Janeiro is located on the Atlantic Coast of Brazil at Lat-22°54'30''S and Long-43°11'47''W, just north of the Tropic of Capricorn. It is considered to have a tropic savannah climate with both wet/hot (summer) and dry/cool (winter) seasons. July and August fall within the winter season, which is characterised by low average rainfall (28 mm; ~ 6 days of rain in August), winds (10 km/h) and higher than average pressure (1016 hPa); all of which makes the weather more stable and predictable compared with other times of the year. Weather data over the last 6 years reports the temperature in August as an average low of 18°C (15-23°C), mean of 23°C (19-27°C) and a high of 26°C (20-37°C) (National Institute of Meteorology), however, average values do not reflect the large range of temperatures that are likely to be experienced. While the average daytime high in August is typically 26°C (between 20-37°C) the majority of days can actually reach above 27°C (Figure 1), which was supported by our data collected during the investigation. The variation in temperature was highlighted over a 10-day measurement period from the 9th to the 18th of August 2013, where the high temperature reached over 30°C on several days, followed by a drop in the temperature to the mid-20's (Figure 2). This demonstrates that while the Games will be held in Rio's 'winter', temperatures in the mid-30's could be experienced. Ambient temperatures ≥ 27°C are known to cause increased physiological strain due to heat stress and subsequent exercise performance impairments over a variety of sport modes and durations, such as endurance, intermittent sprint (i.e.

team sport) and potentially middle distance events (rowing, canoe, middle-distance running). Therefore heat acclimatisation protocols and cooling strategies should be planned to support performance outcomes for the 2016 Games.

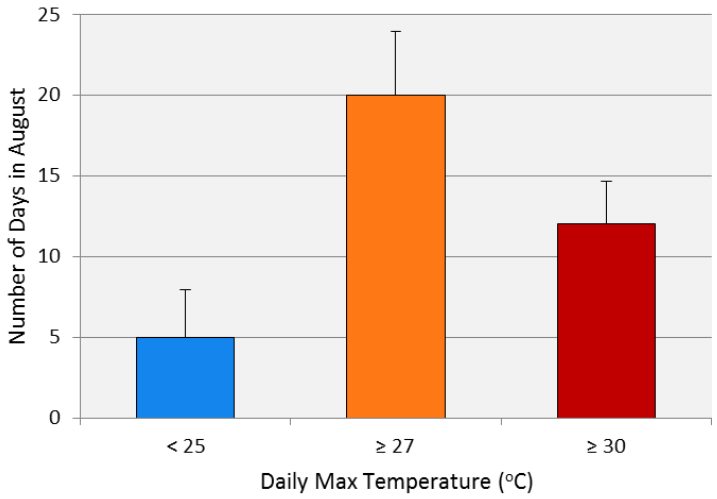

Figure 1. Average number of days during the month of August within different ranges of daily high temperatures (°C) from 2008-2013.

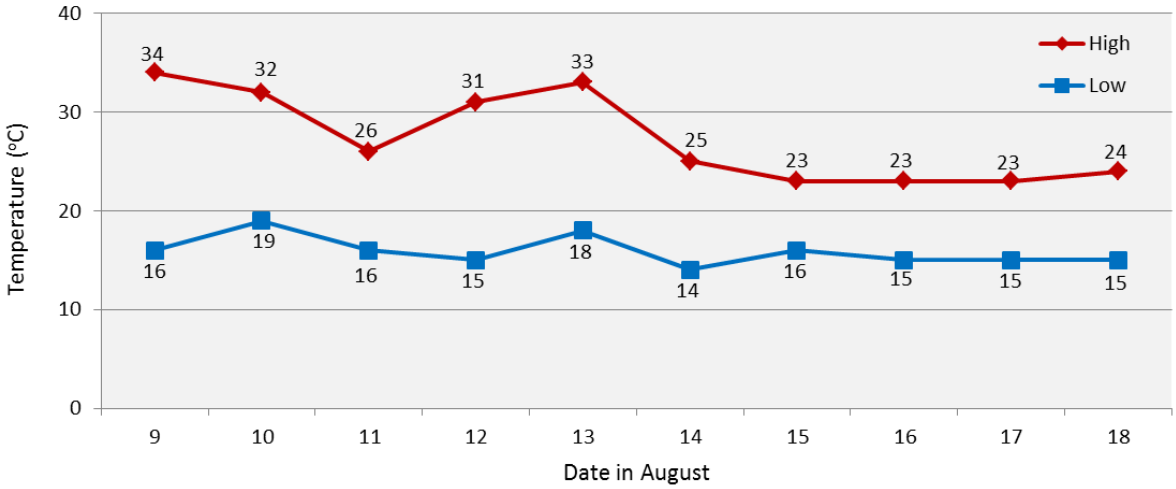

Figure 2. Ten day trend of high and low temperatures (°C) based on 24-h daily measurements for Rio de Janeiro from the 9th -18th of August, 2013.

Observations:

During the 2-week investigation, regular environmental measurements were taken, including temperature, humidity, wind speed and wind direction. These were recorded each day across 9 different venues using a Kestrel 4500 handheld weather station. Some key observations during this period were noted:

1. In general, as temperature increases throughout the day, humidity decreases. This permits greater heat loss through sweating (evaporative cooling).

2. Heat index readings indicate that while a daily high could reach 33°C, it could feel 2-6°C hotter (i.e., 35-39°C), as highlighted in Figure 2. Heat index combines the influence of solar radiation, temperature, wind and humidity, to provide an overall indication of the body's total heat load experienced and should be considered when managing the impact of heat on performance rather than temperature alone.

3. Wind speed was generally low (1.7- 12.3 km/h), as was rain fall (20mm over 4 days in August 2013).

4. Non-coastal sport venues located within the Maracanã and Deodoro Zones can be 5-10°C warmer than the Copacabana Zone (Figure 3), which is cooler due to the prevailing coastal breezes.

5. The daily temperature highs measured during the trip were greater than those reported on popular western weather websites, like 'Weather Underground'. Local websites seemed to provide more accurate live weather conditions and forecasts. For best forecasts see: http://www.inmet.gov.br/portal/index.php?r=tempo/previsaoPorTipo&type+capitais

6. To examine historical weather data for Rio de Janeiro see: http://www.inmet.gov.br/portal/index.php?r=tempo/graficos. Live and historic weather data is available for specific Olympic Zones and instructions on how to access this information can be found in Appendix A.

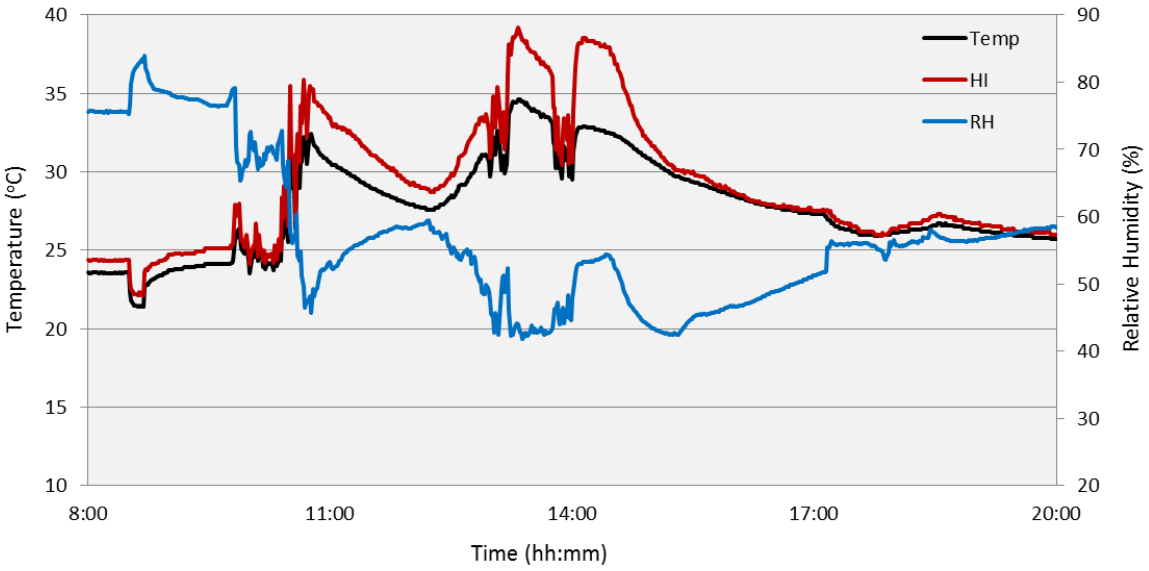

Figure 2. Average temperature (Temp; (°C)), heat index (HI; (°C)) and relative humidity (RH; (%)) over a 12 h period around Copacabana and Maracanã, Rio de Janeiro on the 6th of August, 2013.

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Paralympic Considerations:

The 2016 Paralympic Games will be held in September, ~ 1 month after the Olympics and falls within the end of the Brazilian winter and the beginning of the spring season. There is a trend for daily temperatures to be higher in September compared to August, as highlighted in Figure 3, which depicts a comparison of temperatures during the Olympic and Paralympic periods based on 2013 records. In the Deodoro Zone, the mean daily high was 26.7^{o}C and 30.5^{o}C in August and September respectively, with the majority of days hitting 30^{o}C or higher during the Paralympic period. The Copacabana Zone shows a similar increase in temperature (mean daily high in August = 24.1^{o}C; September = 27.6^{o}C) and also highlights that on any given day, Deodoro can be up to 8^{o}C warmer compared with Copacabana (Figure 3). Wind speed and atmospheric pressure appears to be similar to August conditions, while rainfall in September can be slightly higher (40 - 70 mm). Overall, Paralympic athletes, coaches and support staff should be prepared for even warmer conditions compared to the Olympic period.

Recommendations:

- Plan for it to be hot (≥ 27^{o}C)
- Ensure proper heat acclimatisation strategies are in place (Appendix B)
- Ensure that cooling strategies are planned for (Appendix B)
- Appropriate sun safety should be considered (eg. sun screen use, seeking shade when possible, etc.). Specific guidelines to come.

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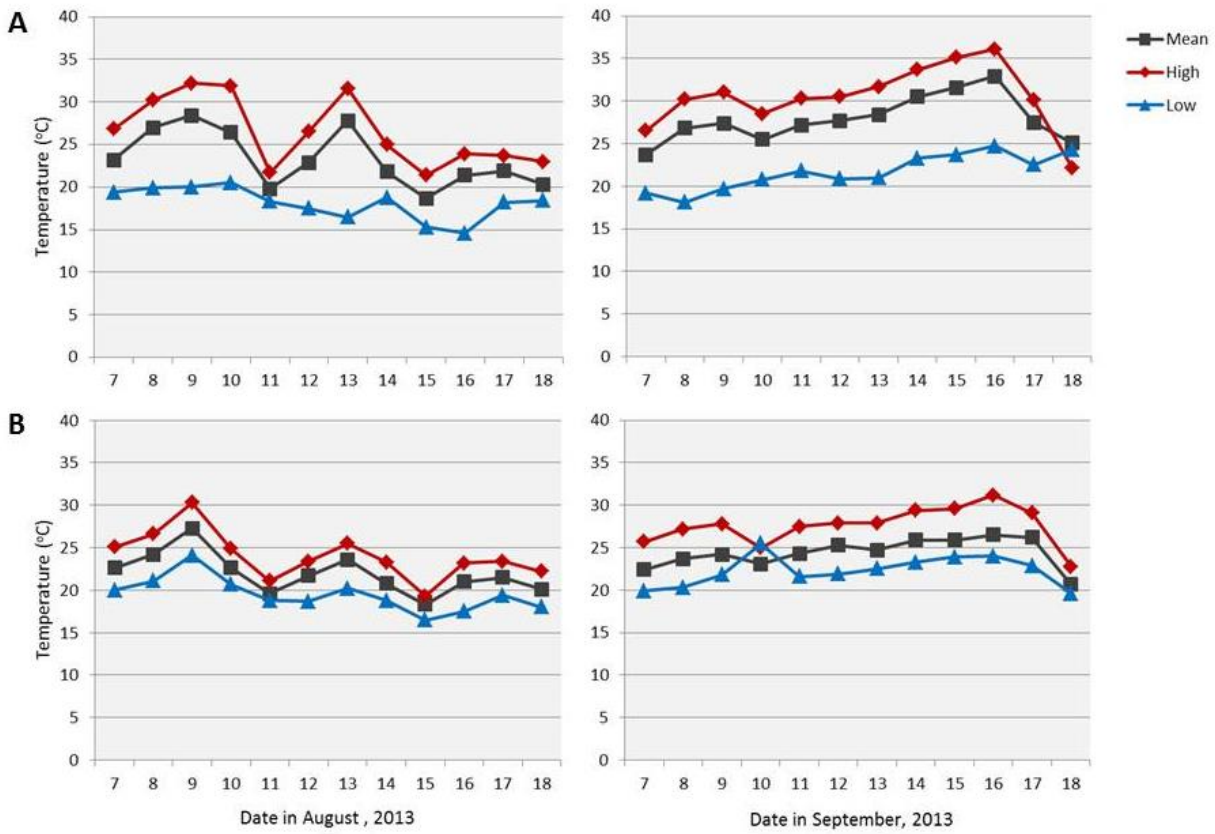

Figure 3. Daily (8 am – 6 pm) high, low and mean temperatures (^{o}C) during August versus September 2013 in the Deodoro Zone (A) and Copacabana Zone (B).

Air Quality

Background:

Rio de Janeiro is the second largest city of Brazil, and boasts a population of roughly 12 million inhabitants. It should come as no surprise then that exposure to heavy traffic and fuel emission pollution is difficult to escape. Indeed, air pollution levels in Rio are roughly four times greater compared to those in New Zealand. However, conditions in Rio are better than in recent past Games' locations, including Beijing in 2008 and New Delhi in 2010 (World Bank, 2009). Table 1 provides a comparison between locations based on particulate matter in the air that are < 10 µm in diameter (PM_{10}); a global air pollution standard measurement. High levels of PM_{10} cause sunlight to refract and this is viewed as smog (Figure 3). The World Health Organisation has set the PM_{10} exposure limit to 50 µg/m^3 as exposure to levels above this can lead to trapping of particulate matter in human airway passages leading to irritation, bronchoconstriction and subsequent asthma-like symptoms including, wheezing, shortness of breath, coughing and chest tightness; all symptoms that negatively impact exercise performance (WHO, 2005). Those athletes who already suffer from respiratory tract conditions or disease such as exercise induced asthma could be at a greater risk of experiencing these symptoms when training or competing in such conditions.

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Table 1. Comparison of city air quality based on PM_{10} (µg/m3) measurements (World Bank Report, 2009)

City	PM_{10} (µg/m^3)
Auckland	15
London	29
Rio de Janeiro	64
Beijing	121
New Delhi	198

Figure 3. Heavy smog (high PM_{10} levels) in Guanabara Bay, Rio de Janeiro.

Measurements:

Five main air pollutants were measured to determine air quality at each visited Olympic venue and during travel by car. These included carbon monoxide (CO; petrol by-product), sulphur dioxide (SO_2; diesel, power generation, industry and shipping by-product), nitrogen dioxide (NO_2; petrol and diesel by-product), volatile organic compounds (VOC; industrial chemicals and fuel emissions) and PM_{10}. Each parameter was measured continuously at each venue with handheld devices (VRAE, MiniRAE and DustTrak, respectively) and the values were compared to New Zealand National Environmental Standards for Air Quality found in Table 2 (Ministry for the Environment, 2011). It is important to note that the safety exposure limits are based on an average exposure over a given period of time. The standard sampling periods for CO, NO_2 and PM_{10} are 8, 1 and 24 h, respectively. As it was not possible to measure air quality parameters over extended periods of time, the results in this report offer a 'snap shot' of what the conditions could be like. These limitations should be considered when making comparisons to New Zealand safe exposure limits.

Table 2. National Environmental Standards for Air Quality in New Zealand

Contaminant	Thershold Concentration	Number of Exceedances Allowed
CO	8.7 ppm	1 in a 12-month period
NO_2	0.106 ppm	9 in a 12-month period
SO_2	0.134 ppm	None
PM_{10}	50 µg/m^3	1 in a 12-month period
VOC's	not established	9 in a 12-month period

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Observations:

Measures of air quality were within the New Zealand standards for threshold limits to polltants (Ministry for the Environment, 2011) at most venues and therefore are likely to be safe; however, in areas of traffic and while travelling by car, several parameters were above these limits and may be of concern for individuals expected to spend extended periods of time in such locations. Figure 5 shows the toxic gas and VOC air concentration during a drive from Copacabana, one of the four Olympic zones, to Barra, where the Olympic Village and Olympic Park are located. Sulphur dioxide levels were near zero, which was consistent throughout the trip. VOC levels averaged at 0.57 ppm and peaked at 2.07 ppm. By comparison, commuting around Auckland typically registered a reading of zero. CO was high (peaking at 6.8 ppm) but below the maximal exposure levels of 8.7 ppm. Average NO_2 concentration was 4.5 times greater (0.48 ppm) than the exposure limit of 0.106 ppm, and average PM_{10} during the drive was 110 $\mu g/m^3$ (not depicted), which is more than double the threshold limits in New Zealand. HPSNZ staff who have visited Rio have reported experiencing headaches, slight nausea and irritated throats when traveling through congested traffic in unsealed vehicles. Therefore, minimising exposure to traffic and traveling in sealed air-conditioned vehicles is recommended.

Paralympic Considerations:

The air quality measurements taken during the recent trip in August, 2013, can be considered representative of what the expected conditions would be in September, during the Paralympic period. There are no apparent factors that would cause air quality to improve or deteriorate between these months; therefore, the observations and recommendations surrounding air quality are the same for both Olympic and Paralympic athletes.

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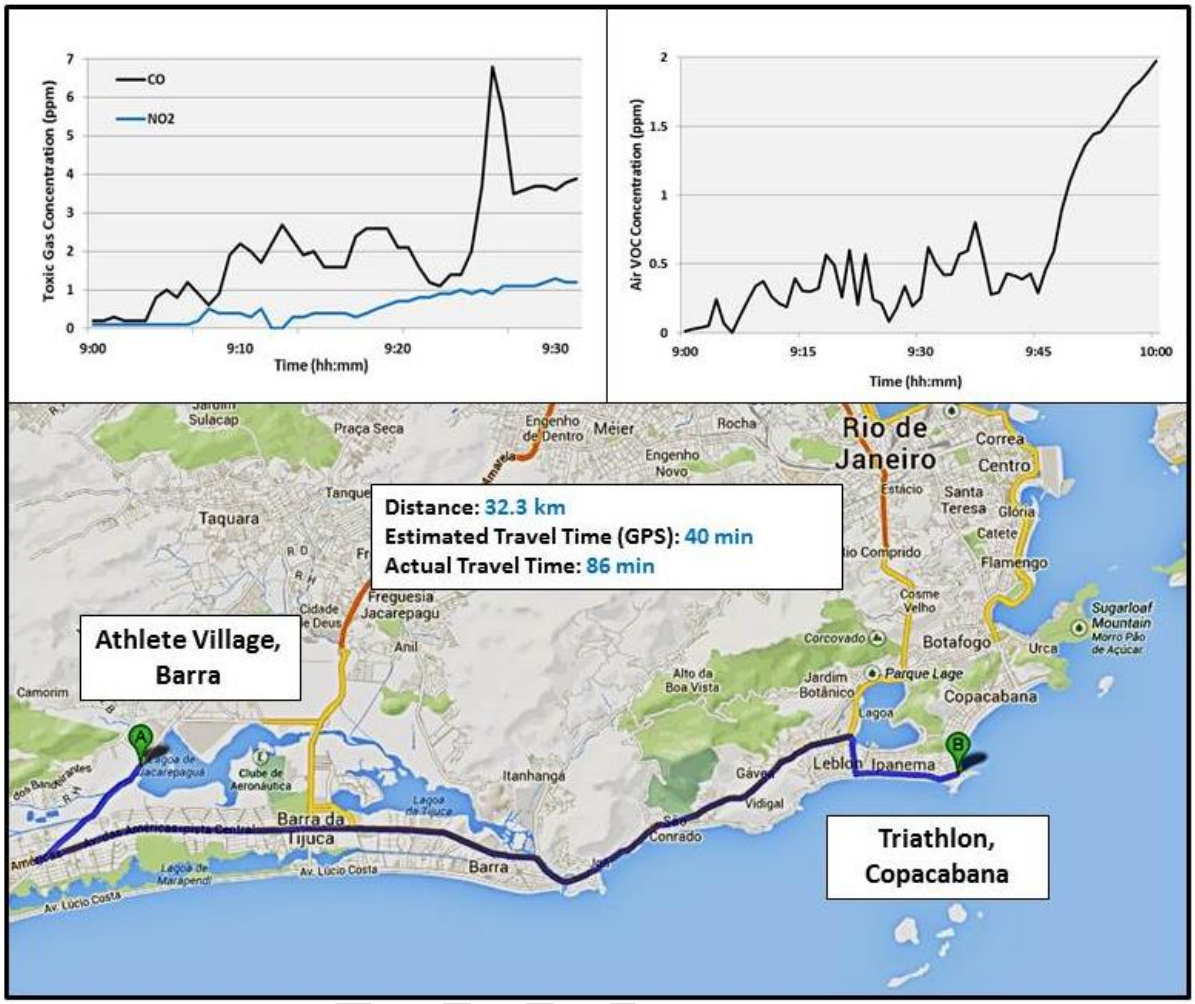

Figure 5. Air pollutants measured during car travel from Copacabana to Barra, Rio de Janeiro on the 1st of August, 2013. Safe exposure levels for CO and NO_2 are 8.7 and 0.106 ppm respectively. VOC levels while driving through Auckland were 0 ppm.

Recommendations:

- Athletes should be screened for atopy, asthma and exercise-induced broncospasm (by team physician/physiologist) and those already diagnosed should ensure effective management strategies are in place.
- Limit exposure to traffic while walking outside of venues and during travel. Exposure time to these conditions should not exceed 60 min where possible.
- Ensure athletes are transported in sealed air-conditioned cars and remember to turn the air conditioner to recirculate before departure.

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Water Quality

Background:

The poor water quality in Rio de Janeiro has been a longstanding concern and is a result of rapid industrialisation, urbanisation, and poor waste and sewage disposal (Lima & Legey, 2010). Areas that are affected include the Rio Harbour (Guanabara Bay), local beaches, and lagoons. Tap water, although heavily treated, is still not safe to consume. Exposure of such water to New Zealand athletes, coaches and support members at the 2016 Olympics could put individuals at risk of waterborne-illness and wound infection with potential to cause suboptimal performance or result in an inability to compete.

Measurements:

The water quality at both sport venues and drinking water at local accommodation and restaurants were targeted in this investigation. The sport venues included the Rio harbour area of Guanabara Bay (yachting), Lagoa Rodrigo de Freitas (kayak and rowing) and Fort Copacabana (triathlon, open-water swim and marathon swim). Water samples were collected and analysed by a local commercial water quality lab in Barra, Rio de Janeiro. All values were compared against the 'Drinking-water Standards for New Zealand (Ministry of Health, 2008) and the New Zealand 'Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas' (Ministry for the Environment, 2003). Table 3 shows the water quality values from tap water and restaurant ice in Rio de Janeiro. Several variables were shown to read above the maximal acceptable value based on New Zealand guidelines, and highlighted values (Table 2) indicate that the measured water source is not suitable for human consumption and could pose health risks. High lead and selenium levels are only a concern with chronic exposure (WHO, 2011[a] & 2011[b]). The high salinity and chloride levels are likely due to waste water leaks into the water pipes (Vieira et. al, 2012), which causes a highly unpalatable water taste. Sulphate levels (780-960 mg/l) were close to those that can cause acute catharsis, dehydration and in some cases diarrhoea at 1000 – 1200 mg/l (WHO, 2004). Both dissolved organic carbons (DOC) and biological oxygen demand (BOD) were measured at alarmingly high levels, as these should read close to zero in treated drinking-water. DOC and BOD presence is a result of plant decay through microorganisms, urban runoff and sewage contamination. Microorganisms associated with BOD levels can carry pathogenic bacteria leading to possible gastrointestinal or respiratory infections if consumed or inhaled (USEPA, 2012). The presence of TPH suggests industrial or storm water discharges into the Rio water supply, some of which could be toxic. Taken together, individuals who consume this water could be at risk of contracting a water-borne illness, while those with wounds are subject to infection if exposed to such water. Such risks have the potential to impair performance or withdrawal from competition at the Rio Olympics. Due diligence regarding water consumption and use will be needed to ensure athletes stay healthy at the 2016 Games.

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Table 3. Water quality measurements taken from tap water and restaurant ice in Rio de Janeiro.

Chemical Agent	Maximum Acceptable Value	Limit of Quantification	Beach Tap Water	Hotel Tap Water	Restaurant Ice
pH	6.5-8.5	4	6.43	6.68	6.57
Salinity (%)	NE	0.01	1.37	1.39	1.37
Aluminium (mg/l)	0.1	0.05	0.059	0.062	ND
Arsenic (mg/l)	0.01	0.05	ND	ND	ND
Copper (mg/l)	2	0.05	0.056	0.058	0.014
Iron (mg/l)*	0.2	0.05	0.278	0.303	ND
Lead (mg/l)	0.01	0.01	0.02	0.024	0.013
Mercury (mg/l)	0.007	0.0002	ND	ND	ND
Selenium (mg/l)	0.01	0.005	0.042	0.047	ND
Zinc (mg/l)*	1.5	0.01	0.013	0.012	0.018
Fluoride (mg/l)#	1.5	0.01	1.18	1.19	1.31
Chloride (mg/l)*	250	1.00	7609	7705	7609
Sulphate (mg/l)*	250	1.00	840	960	780
DOC (mg/l)	2	1.00	210	240	280
BOD (mg/l)	0.4	3	48.3	55.6	47.55
Fecal Coliforms	absent	absent	absent	absent	absent
TPH (µg/l)	NE	1	ND	1.61	ND

BOD = biological oxygen demand; DOC = dissolved organic compunds; ND = not detected; NE = not established; TPH = total petroleum hydrocarbons; Highlighted cells indicate that water is not safe for human consumption. *Based on aesthetic guidelines; safe to drink but appearance, taste or odour may not be satisfactory. #Based on dental guidelines; values ≤ 2 mg/l are not harmful.

Paralympic Considerations:

For the most part, the water quality measurements taken in August, during the Olympic period, can be considered representative of what the expected conditions would be in September during the Paralympic period. Recommendations of water use are the same for drinking water and athletes competing at outdoor water venues. The only difference is that the greater chance of rain during the month of September could cause the water quality at outdoor water sport venues to deteriorate due to sewage run-off from nearby slums and also bottom-sediment disruption. However, whether it is raining or not, the same level of safe water use and management should be enforced.

Recommendations:

- Do not drink tap water, even if it has been boiled. Boiling water will not remove metals or other chemical contaminants in the drinking water.
- Do not consume ice in drinks at restaurants.
- Drink bottled water only.
- Use bottled water only for oral hygiene purposes.
- For athletes in water sports, avoid swallowing sea/fresh water where possible. If some water is taken into the mouth accidently, athletes are advised to spit it out.
- Athletes competing in water sports should keep their hands away from their eyes, nose, mouth and ears when possible.
- Showering and/or washing one's face post-training and competition is advised to remove any residual bacteria on the body from water contact. Wet wipes may be a practical option for cleaning one's face as the quality of tap water is poor.
- Immediately and thoroughly clean scratches or wounds with bottled water (do not use tap water if possible) and cover with water proof barrier dressings. When possible, avoid subsequent contact with bathing water (fresh and sea water) until healed.

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PART 3: Olympic Zones

The Olympic venues will be spread across 4 zones and include, Barra, Copacabana, Deodoro and Maracanã. The maps below highlight specific venue locations (Figure 5) as well as distances and approximate travel times between the Olympic Village in Barra, compared with the other 3 zones (Figure 6).

Figure 5. Sport specific venue locations for the Rio 2016 Olympics.

COMPLIANCE

Figure 6. Vehicle travel distances and approximate times between the Olympic Village and the other Olympic zones. Transport time ranges are based on GPS predictions (minimum time) and experienced travel times (maximum time) during the 2013 environmental investigation.

The above figure depicts the distances and approximate travel times from the Olympic Village to each Olympic Zone (Figure 6). The times are based on current road conditions with the minimum time representing GPS predictions, while the maximum time was based on the travel duration experienced during this investigation. Currently, transportation improvements are being made for the Rio Games, with Olympic transit lanes and new train lines being constructed, therefore, reduced travel times should be expected compared with what was experienced. This does not discount the fact that the Olympic Village, where most New Zealand athletes will be based, is quite far from the other 3 zones (~ 20-40 km). Long travel distances combined with high pollution levels during travel (Figure 5) could place added stress on athletes and impair normal recovery practices. Therefore, it is advised that sporting bodies plan to incorporate recovery strategies during travel from their venue back to the Village or look for alternative accommodation closer to their event location where applicable. The following section expands the detail for specific sport venues and their measured environmental conditions during the investigation.

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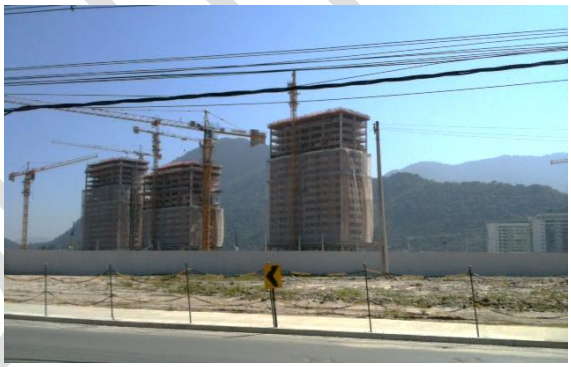
Barra

Olympic Park

The Olympic Park, located only 4 km from Olympic Village, will host the most events during the games. Events will include Track Cycling, Court and Racket Sports, Aquatics, Gymnastics and Weightlifting, as well as Swimming, Track Cycling, Paracycling, Wheelchair Rugby and Boccia for the Paralympics. Both Olympic Park and Olympic Village are heavily under construction at present. As these sites are ~ 10 km back from the coast, winds are generally low and the heat index can be greater compared with coastal areas (Table 4). Air quality within the actual Park and Village should pose no threat to athlete's health; however, individuals should limit their time outside of these venues as NO_2 and dust levels (PM_{10}) were higher around the perimeter of the Olympic Park (Table 5). Environmental data was collected near the Olympic Park on the 1st and 5th of August, 2013 from 11:15-12:15 and 14:00-15:00, respectively.

Outside the Olympic Park in Barra.



Construction at the Olympic Village site.

Table 4. Weather conditions at the Olympic Park site in Barra, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
1/08/2013	Clear	31.5	30.1	28.5	41.5	3.2	SW
5/08/2013	Cloud	21.1	20.9	20.8	82.4	4.7	SW

Table 5. Air pollutant levels at the Olympic Park site in Barra, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} ($\mu g/m^3$)	Comments
	CO	SO_2	NO_2			
1/08/2013	0.55	0	0.18	0.026	85	Outside venue and near traffic.
5/08/2013	0	0	0.090	0	35	Outside venue and away from traffic.
Exposure Limit	8.7	0.134	0.106	NE	50	

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

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Copacabana

Copacabana is the main tourist hub of Rio de Janeiro and boasts some of the city's iconic attractions, beaches, the famous Lagoa or lagoon and the Rio Harbour. As a result, there are plenty of accommodation and restaurant options. This zone will host a number of events including Road Cycling, Kayak, Rowing, Triathlon, Yachting and Beach Volleyball.

Fort Copacabana

(Triathlon, Marathon Swim)

Fort Copacabana is located at the far west end of Copacabana beach, which stretches 3.5 km. This venue will host the Triathlon for both Olympic and Paralympic Games, and the Marathon Swim for the Olympics. It was visited on the morning of the 29th July, 2013 (9:00 -11:00) and the 7th August, 2013 (14:00-15:00). During the 2-week investigation, the average daytime high ranged from the low-20's to mid-30's. Fog is common in the mornings and as the sun rises over the water, the entire horizon is illuminated, which could make it challenging for 'sighting' during morning open water swims. The sea temperature in August ranges from 20-22°C, while wave height was reported as 0.6-2.2 m; although this typically overestimates the actual waves near the Fort, which are generally smaller. Higher PM_{10} values are likely related to sand and salt particles in the air (Table 7). Overall air quality is rated as good in this area and is likely due to a consistent and light sea breeze. Despite this, the 8 lanes of traffic which run parallel to the beach, certainly make one aware of the heavy vehicle exhaust in the area.

Measuring PM_{10} levels near Fort Copacabana.

Table 6. Weather conditions, beach side at Fort Copacabana, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
29/07/2013	Clear	25.3	23.8	22.2	58.0	3.3	WSW
7/08/2013	Clear	23.3	22.7	22.3	82.3	7.1	WNW

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Table 7. Air pollutant levels along the beach at Fort Copacabana, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's	PM_{10}	Comments
	CO	SO_2	NO_2	(ppm)	(ug/m^3)	
30/07/2013	0.01	0.00	0.01	0.00	67	Along the beach and parallel roads.
6/08/2013	0.12	0.00	0.01	0.08	93	Along the beach.
Exposure Limit	8.7	0.134	0.106	NE	50	

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

Water samples were collected from Copacabana Beach at 9:00 on the 5th August, 2013. The samples were taken at ~ 100 m out from the likely beach start for the open water and triathlon swims, and at a depth of ~ 60 cm. Weather conditions were cloudy, 23.8°C, 76% RH, and sea temperature was 22°C. Table 8 highlights that several measured variables were above New Zealand maximum acceptable values' for drinking-water, and while athletes will not intentionally drink this water, it is important that they avoid swallowing and inhaling water during swimming. Inhalation of water droplets is an exposure route for water borne viruses that can lead to respiratory illness, and with the extremely high levels of measured DOC and BOD athletes could be at risk of illness. The presence of fecal coliforms was detected, which is a result of human and animal feces from sewage contamination, and can lead to infection and disease (Hepatitis A and B, tetanus and polio) if levels are high. Unfortunately, unless a specific quantity is known we cannot make conclusions in regards to the associated health risks and exposure recommendations. As we were not aware that the method of assessment performed by the employed lab was simply a positive or negative test and therefore faecal coliform concentration at these sites needs reassessment before conclusions can be made. Further recommendations include having athletes shower and/or wash their face with wet wipes post-training and competition to remove any residual bacteria on the body from water contact. Also, avoid water exposure for individuals with scratches or wounds with water proof dressings and possibly seeking alternative training locations, such as swimming pools, although the water quality at pools in Rio is not currently known.

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Table 8. Water quality values from the sea at Fort Copacabana, Rio de Janerro.

Chemical Agent	Maximum Acceptable Value	Limit of Quantification	Fort Copacabana
pH	6.5-8.5	4	7
Salinity (%)	NE	0.01	1.42
Chloride (mg/l)*	250	1.00	7849
Sulphate (mg/l)*	250	1.00	860
DOC (mg/l)	2	1.00	324
BOD (mg/l)	0.4	3	50.23
Fecal Coliforms	absent	absent	present
TPH (µg/l)	NE	1	1.22

BOD = biological oxygen demand; DOC = dissolved organic compunds; ND = not detected; NE = not established; TPH = total petroleum hydrocarbons; Highlighted cells indicate that water is not safe for human consumption. *Based on aesthetic guidelines; safe to drink but appearance, taste or odour may not be satisfactory.

Lagoa Rodrigo de Freitas

(Canoe, Rowing)

Lagoa Rodrigo de Freitas is located ~ 4 km from Copacabana Beach and will host both Canoe and Rowing events for the Olympic and Paralympic Games. This lagoon has an average depth of 2.8 m, a circumference of 7.8 km and a water surface area of 2.2 km^2. The water is a mix of both fresh and sea water, with salinity changes dependant on rainfall levels. The lagoon has a history of pollution problems from both water and land waste sources. Currently the lagoon is extensively used for rowing, sailing, fishing, commercial paddle boats, and water ski sports. In an attempt to improve the lagoon's condition, it will be closed to public and commercial use for a 6-month period prior to the Games, during which time environmental scientists will do what they can to restore its condition. Weather (Table 9) and air pollutant (Table 10) data were collected near the existing rowing club house on the lagoon's edge on 31th July (9:30-10:30) and 7th August, 2013 (9:50-10:50). Air pollution is not a concern at this venue and the daily air temperature during the 2-week visit was 19 – 30^{o}C.

Dock at Olympic rowing/kayak venue (left) and an aerial view of Lagoa Rodrigo de Freitas (right).

Table 9. Weather conditions from Lagoa Rodrigo de Freitas in Copacabana, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction (degrees)
		Max	Mean	Min			
31/07/2013	Clear	23	22.1	20.6	64.9	7.9	WNW
7/08/2013	Clear	25.4	24.0	22.4	72.5	3.6	NE

Table 10. Air pollutant levels at Lagoa Rodrigo de Freitas in Copacabana, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} ($\mu g/m_3$)
	CO	SO_2	NO_2		
31/07/2013	0.002	0	0.004	0.020	37
7/08/2013	0.038	0	0.002	0.005	54
Exposure Limit	8.7	0.134	0.106	NE	50

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

Water was collected at ~ 500 m from the regatta course finish line at a depth of ~ 60 cm on two consecutive days. The first set of samples was collected on the 4th of August, 2013 (15:30) after an 8-day period of no rain, and where the bottom sediment was generally settled. Weather conditions were clear, 29°C and 49% RH. The second set of samples were taken on the 5th of August, 2013 (11:00) after it had been raining for several hours. Rain can cause water pollutant levels to rise due to sewage run-off from nearby slums and also bottom-sediment disruption. This was confirmed by the increased number of metal types (Table 11) that were detected in the 'unsettled sediment' samples, which indicates a variety of potential pollution sources. As with the sea-water samples from Fort Copacabana, athletes training and competing at the lagoon are advised to avoid water contact with their face and should shower and/or wash their face (with wet wipes) after on-water sessions due to the high levels of DOC and BOD. Further recommendations for individuals with scratches or wounds include avoiding water contact to injured areas through water-proof wound protection and appropriate disinfection following on-water sessions.

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Table 11. Water quality values from Lagoa Rodrigo de Freitas in Copacabana, Rio de Janerro.

Chemical Agent	Maximum Acceptable Value	Limit of Quantification	Lagoa (Settled Sediment[a])	Lagoa (Unsettled Sediment[b])
pH	6.5-8.5	4	6	6
Salinity (%)	NE	0.01	1.51	1.24
Aluminum (mg/l)	0.1	0.05	ND	0.059
Arsenic (mg/l)	0.01	0.05	ND	ND
Copper (mg/l)	2	0.05	0.121	0.06
Iron (mg/l)*	0.2	0.05	0.375	0.317
Lead (mg/l)	0.01	0.01	0.054	0.017
Mercury (mg/l)	0.007	0.0002	ND	ND
Selenium (mg/l)	0.01	0.005	ND	0.048
Zinc (mg/l)*	1.5	0.01	ND	0.013
Flouride (mg/l)#	1.5^	0.01	1.83	1.54
Chloride (mg/l)*	250	1.00	8375	6844
Sulphate (mg/l)*	250	1.00	1020	760
DOC (mg/l)	2	1.00	240	206
BOD (mg/l)	0.4	3	46.69	47.76
Fecal Coliforms	absent	absent	present	present
TPH (µg/l)	NE	1	1.6	1.29

BOD = biological oxygen demand; DOC = dissolved organic compunds; ND = not detected; NE = not established; TPH = total petroleum hydrocarbons; Highlighted cells indicate that water is not safe for human consumption. [a]After 10 d period of no rain; [b]After several hours of rain. *Based on aesthetic guidelines; safe to drink but appearance, taste or odour may not be satisfactory. #Based on dental guidelines; values ≤ 2 mg/l are not harmful.

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Flamengo Park

(Road Cycling, Race Walking)

Flamengo Park is a large urban parkland near Rio Centro (CBD) stretching from Botafogo Beach to Marina de Gloria (Yachting venue). The park will host the Cycling Time Trial and Road Race, and Race Walking for the Olympic and Paralympic Games, as well as the Marathon for the Paralympics. Weather (Table 12) and air pollution (Table 13) measurements were taken on the 31st July, 2013 (13:30 -14:30) and 8th of August, 2013 (11:00 -12:00). While it is an attractive green space, people should use caution when visiting Flamengo Park, as many treed areas are home to many crack cocaine-addicted individuals, whose behaviour can be unpredictable and dangerous. Furthermore, needle stick injuries are a possibility if used needles are improperly disposed of in this area. A local policeman warned us of this during data collection, and after spending an hour there, it was apparent that individuals should not visit this area alone or at night.

Table 12. Weather conditions at Flamengo Park in Copacabana, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
31/07/2013	Clear	25	23.9	23	70.6	12.3	NNW
8/08/2013	Clear	27.8	26.2	25.2	64.8	5.5	NNW

Table 13. Air pollutant levels at the Flamengo Park in Copacabana, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} ($\mu g/m^3$)
	CO	SO_2	NO_2		
31/07/2013	0.12	0	0.070	0.17	22
8/08/2013	0.30	0	0.034	0.12	18
Exposure Limit	8.7	0.134	0.106	NE	50

NE = not established.

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Marina de Gloria

(Yachting)

Marina de Gloria is home of Yachting for the 2016 Olympics and Paralympics, and is located at the NE end of Flamengo Park. On the 4th of August 2013, environmental measurements were taken around one of the future Olympic race courses located in Guanabara Bay during a Laser regatta. Weather (Table 14) and air quality measurements (Table 15), were taken on the 31st of July and 8th of August, and collected from a section of the park which borders Marina de Gloria. Air quality measured in the bay was affected by fuel emissions from coach and official boats during the regatta, which explains the high NO_2 levels.

Docked boats at Marina de Gloria.

Table 14. Weather conditions at Guanabara Bay, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
4/08/2013	Clear	27.8	26.0	24.8	71.4	10.2	SW

Table 15. Air pollutant levels in Guanabara Bay, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)
	CO	SO_2	NO_2	
4/08/2013	0.44	0	0.11	0
Exposure Limit	8.7	0.134	0.106	NE

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

Water samples were measured specifically at Lat 22°55'1.94 S and Long 43°9'5.08 W, within the bay. Sea temperature at the time of water collection was 22°C and weather data can be found in Table 14. Table 16 highlights that several measured variables were above New Zealand maximum acceptable value's for drinking-water, specifically levels of DOC, BOD, TPH and fecal coliform presence. While athletes will not intentionally drink this water, it is important that they avoid swallowing any while sailing and avoid water contact to scratches or wounds through appropriate water-proof protection, along with disinfection following on-water sessions. Showers after on-water sessions are also advised for athletes, along with cleaning their faces with wet wipes. Failure to do so could result in possible gastrointestinal or respiratory infection (if swallowed or inhaled) and wound infection.

Table 16. Water quality values from Guanabara Bay, Rio de Janerro.

Chemical Agent	Maximum Acceptable Value	Limit of Quantification	Guanabara Bay
pH	6.5-8.5	4	6
Salinity (%)	NE	0.01	1.35
Chloride (mg/l)*	250	1.00	7466
Sulphate (mg/l)	250	1.00	900
DOC (mg/l)	2	1.00	120
BOD (mg/l)	0.4	3	57.94
Fecal Coliforms	absent	absent	present
TPH (µg/l)	NE	1	1.57

BOD = biological oxygen demand; DOC = dissolved organic compunds; ND = not detected; NE = not established; TPH = total petroleum hydrocarbons; Highlighted cells indicate that water is not safe for human consumption. *Based on aesthetic guidelines; safe to drink but appearance, taste or odour may not be satisfactory.

Surface water in Guanabara Bay (left) and at the Rio Yacht Club (right).

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Deodoro

Deodoro Olympic Park

(X-Park, Rugby 7's, Field Hockey, Equestrian, Shooting)

Deodoro is a middle-class neighbourhood that borders the largest military village in South America. The Deodoro Olympic Park will be located within the military village and will include Rugby 7's, Field Hockey, Modern Pentathlon, Equestrian and Shooting for the Olympics, as well as Equestrian and Shooting for the Paralympics. The 'X-Park' is also to be constructed in this area and will host Mountain Biking, BMX and Slalom Kayak events. To date, no visible construction has begun and access to any venue site is not permitted unless you are accompanied by military personnel. Deodoro sits ~20 km from the coast and is positioned between two mountain ranges. Due to its geographic location, the winter months (July-September) are characterised by cooler morning temperatures, warmer daytime highs and low wind. Both visits, on the 1st and 8th of August, showed that the overall heat load was the greatest in Deodoro compared with other Olympic zones (Table 17). As such, athletes competing in this region will need to prepare for the heat (See Appendix B).

Table 17. Weather conditions in Deodoro, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
1/08/2013	Clear	34.8	32.9	31.2	41.0		
8/08/2013	Clear	32.1	30.7	29.9	39.0	4.9	SW

Rugby 7's field in Deodoro.

Hockey field in Deodoro.

Air quality results show higher levels of pollution when driving through and around Deodoro. Fortunately, acceptable levels of air quality are expected at the sport venues, as we found at the Rugby 7's field (Table 18). Athletes are recommended to limit their time spent outside of their venue when in Deodoro, especially in areas of heavy traffic, as the toxic gas concentration in the air was highest when traveling through this region (Figure 7).

Table 18. Air pollutant levels around future Olympic venues in Deodoro, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's	PM_{10}	Comments
	CO	SO_2	NO_2	(ppm)	($\mu g/m_3$)	
1/08/2013	3.75	0	2.02	2.04	121	Traveling through Deodoro by car
8/08/2013	0.025	0	0	0.021	2.9	Rugby 7's field
Exposure Limit	8.7	0.134	0.106	NE	50	

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

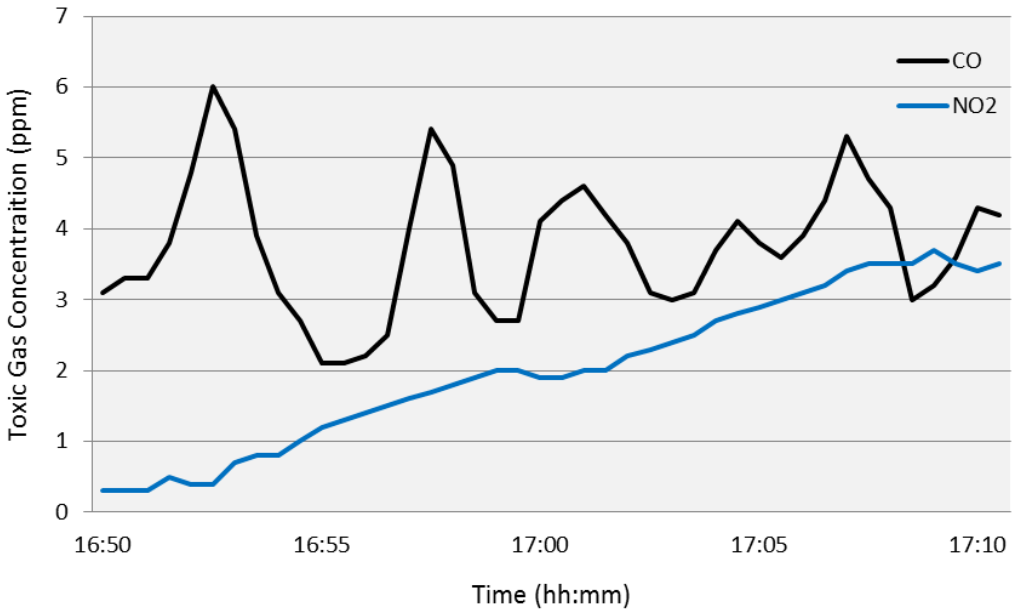

Figure 7. Toxic gas concentration (ppm) driving through Deodoro, Rio de Janeiro on the 1st of August, 2013 (16:50-17:10). Safe exposure levels are 8.7 ppm and 0.106 ppm for CO (based on an 8-h running average) and NO_2 (based on a 1-h running average), respectively.

Future site of the Deodoro X-Park.

Rugby and Hockey venues border a state highway

Maracanã

The Maracanã Zone consists of three main facilities, which will accommodate Athletics and Football during the 2016 Games. The region is densely populated and getting around can be time-consuming, even when traveling short distances. Inland from the coast, Maracanã is another zone that can be hotter than forecasted, as the heat load is intensified by urban material heat retention from concrete and asphalt. Overall, athletes competing in the Maracanã Zone are recommended to be prepared for the heat (Appendix B) and to limit exposure to air pollutants in the areas outside the venues.

João Havelange Stadium

(Athletics)

João Havelange Stadium will be the main centre for Athletics for both Olympic and Paralympic Games. Weather (Table 19) and air quality (Table 20) measurements were taken on the 30th July (10:10 - 11:10) and 6th August, 2013 (13:00 – 13:30). Both visits were characterised by warm temperatures (highs of 27.8-32.6°C) and low wind. Dust or PM_{10}, was the only air pollutant of concern and is likely a consequence of being in a highly urbanised area.

Table 19. Weather conditions at João Havelange Stadium, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
30/07/2013	Clear	27.8	24.7	22	53.5	2.9	SW
6/08/2013	Clear	32.6	31.3	30.2	47.9	2.2	SW

Table 20. Air pollutant levels outside João Havelange Stadium, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} ($\mu g/m_3$)
	CO	SO_2	NO_2		
30/07/2013	0.011	0	0.007	0	67
6/08/2013	0.12	0	0.013	0.083	93
Exposure Limit	8.7	0.134	0.106	NE	50

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

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Maracanã Stadium

(Football)

Maracanã Stadium will host both opening and closing ceremonies for both Olympic and Paralympic Games, as well as Football for the Olympics. It is undergoing heavy renovations at present, in preparation for the future Olympic Games and World Cup events. Weather (Table 21) and air quality (Table 22) measurements were taken on the 30th July (11:40 - 12:40) and the 6th August, 2013 (9:50 – 10:50am). Like João Havelange Stadium, this area was warm (high of 27.8 – 32.2°C), with low wind (1.7 – 2.8 km/h). PM_{10} levels (59 and 105 mg/m^3) exceeded recommended limits of 50 mg/m^3, however, will likely be improved once construction in the area is completed.

Outside view of Maracanã Stadium.

Table 21. Weather conditions at Maracanã Stadium, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
30/07/2013	Clear	27.8	25.2	22.6	50.3	2.8	SW
6/08/2013	Clear	32.2	26.9	24	63.7	1.7	NE

Table 22. Air pollutant levels at Maracanã Stadium, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} (µg/m^3)
	CO	SO_2	NO_2		
30/07/2013	0.099	0	0.088	0.001	59
6/08/2013	0.10	0	0.003	0.034	105
Exposure Limit	8.7	0.134	0.106	NE	50

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

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Sambadrome

(Marathon Finish, Archery)

Sambadrome (or Sambódromo in Portuguese) is located between Maracanã Stadium and the CBD of Rio de Janeiro. It is normally used for Samba parades and competitions during the world-famous *Carnival*, but during the Olympics it will host the Marathon finish as well as Archery for both Olympics and Paralympics. Only one visit (6th of August, from 13:45 - 14:15) was made during the investigation, as it is not located in a safe neighbourhood. The Samadrome borders an impoverished area with high rates of crack cocaine addiction. Therefore, individuals are not recommended to visit this area alone or without local knowledge.

Table 23. Weather conditions at the Sambadrome, Rio de Janeiro.

Date	Sky Conditions	Temperature (°C)			RH (%)	Wind Speed (km/h)	Direction
		Max	Mean	Min			
6/08/2013	Clear	32.2	31.6	30.8	44.9		

Table 24. Air pollutant levels at the Sambadrome, Rio de Janeiro.

	Toxic Gases (ppm)			VOC's (ppm)	PM_{10} ($\mu g/m_3$)
	CO	SO_2	NO_2		
6/08/2013	3.02	0	0.90	0.35	113
Exposure Limit	8.7	0.134	0.106	NE	50

Highlighted cells indicate that the values were above threshold limits for the sampled period. NE = not established.

As the Sambadrome is in the heart of a highly urbanised area, both heat (possibly due to pavement radiation) and poor air quality were observed. No visible construction was apparent, yet the average PM_{10} level was more than double (113 $\mu g/m^3$) the limit of 50 $\mu g/m^3$ and NO_2 was nearly 9 times greater than the New Zealand threshold guidelines. Furthermore, some of the highest values of CO and NO_2 air concentrations were recorded traveling through the Maracanã Zone by car from Maracanã Stadium to the Sambadrome (Figure 8). It is recommended therefore that athletes limit time spent outside these venues or traveling around this region, as prolonged exposure periods could cause respiratory tract irritation.

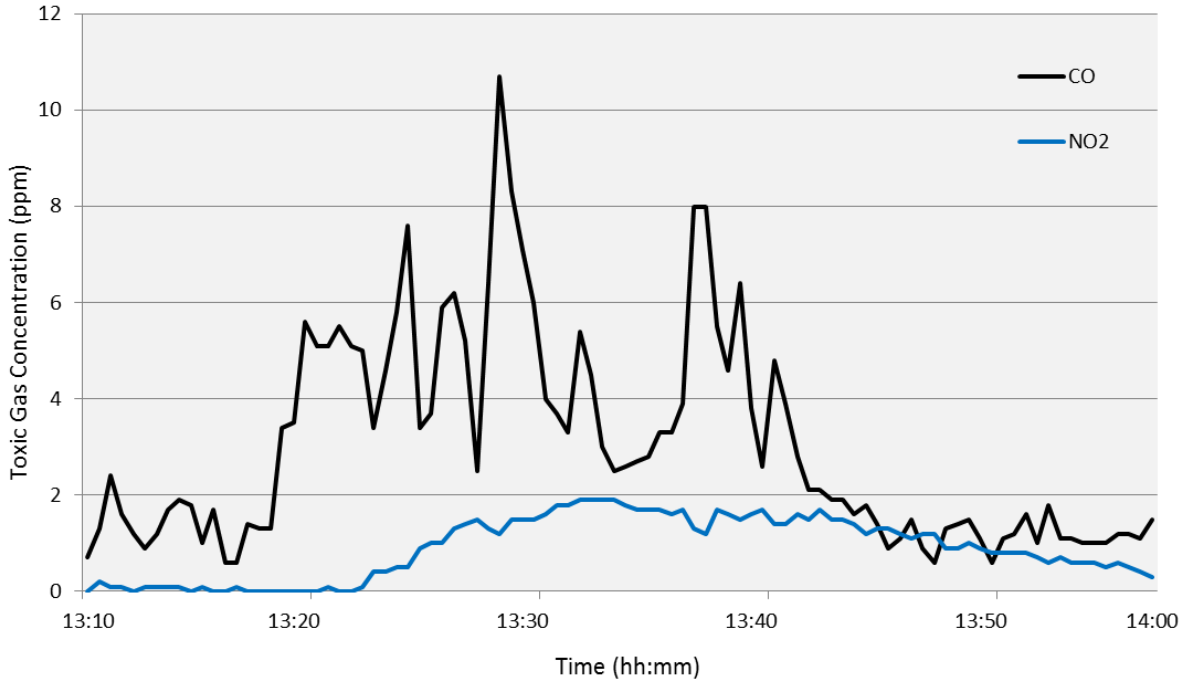

Figure 8. Toxic gas concentration (ppm) driving from Maracanã Stadium to the Sambadrome, Rio de Janeiro (13:10 – 13:40), and at the Sambadrome on the 6th of August, 2013. Safe exposure levels are 8.7 ppm and 0.106 ppm for CO (based on an 8 h running average) and NO_2 (based on a 1 h running average) respectively.

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Future Directions

Over the next 3 years, leading up to the 2016 Olympic Games, HPSNZ will continue to monitor the environmental conditions in Rio de Janeiro between July and September of each year. Changes in weather conditions, air pollution levels and water quality will be noted and reported appropriately. Contact with INEA will also be maintained to ensure our data and information is coming from accurate, local sources. Furthermore, collaboration with NSO's will begin to devise plans that address the recommendations within this report so potential environmental adversities during the games can be prepared for and managed.

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Appendix A

Zone Specific Weather Data

The weather conditions between the different Olympic Zones in Rio de Janeiro can vary. Furthermore, English or Western weather sites appear to underestimate daily high temperatures. Live and historical weather data is available online for some specific sport venues and for each Olympic Zone. Instructions for how to navigate these websites is found in this appendix. The best website to view Rio de Janeiro's weekly forecast is found directly below. There does not appear to be a resource for zone specific weather forecasts.
http://www.inmet.gov.br/portal/index.php?r=tempo/previsaoPorTipo&type+capitais

Fort Copacabana:

- Accurate live and historical data can be found at http://www.inmet.gov.br
- First translate to English (the option to translate should appear automatically).
- For live conditions, go to the '*Stations and Data'* tab and under '*Meteorological Data'* select *'Automatic Stations'*.
- Zoom in on Rio and select the station located at Fort Copacabana (between Ipanema and Copacabana Beach) and it will show you the live conditions.
- For historical conditions, go to the '*Stations and Data'* tab and under '*Data in Graphics'* select '*Automatic Stations'*.
- Under the *Stations (Estação)* tab, scroll down and select '*Rio de Janeiro – Forte de Copacabana'* and the year you wish to view. You can then see all the weather trends for that year or season presented graphically.
- Please note, conditions at this station are presented as UTC time, which is 3 h ahead of Rio de Janeiro. Therefore, subtract 3 h from any of the presented times.

Deodoro:

- Accurate live and historical data can be found at http://www.inmet.gov.br
- First translate to English (the option to translate should appear automatically).
- For live conditions go to the '*Stations and Data'* tab and under '*Meteorological Data'* select *'Automatic Stations'*.
- Zoom in on Rio and select the station located in Deodoro, just off 'Av. Brasil' and it will show you the live conditions.
- For historical conditions go to the '*Stations and Data'* tab and under '*Data in Graphics'* select '*Automatic Stations'*.
- Under the *Stations (Estação)* tab scroll down and select '*Rio de Janeiro – Vila Militar'* and the year you wish to view. You can then see all the weather trends for that year or season presented graphically.
- Please note, conditions at this station are presented as UTC time, which is 3 h ahead of Rio de Janeiro. Therefore, subtract 3 h from any of the presented times.

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Maracanã:

- A weather station in central Rio will best represent the conditions in the Marcanã Zone.
- For historical weather data go to the link below and enter a date range. Conditions at this station are presented as UTC time, which is 3 h ahead of Rio de Janeiro. Actual Rio times are recorded at 9:00 (12:00 UTC), 15:00 (18:00 UTC) and 21:00 (00 UTC) each day. http://www.inmet.gov.br/sim/sonabra/dspDadosCodigo.php?ODM3NDM=
- Historical weather data for this area is also presented graphically and can be viewed at http://www.inmet.gov.br/portal/index.php?r=tempo/graficos. This site may remain in Portugeuse but simply select the state and city (Rio de Janeiro – RJ), select the month and year and select which variables you are interested in viewing, such as temperature (temperaturas), relative humidity (umidade relative do ar) and accumulated rain fall (chuva acumulada em 24 h). Finally select 'show graphs' (Mostrar Graficos) to view your selected results.

Barra:

- The best weather data for the Barra Zone is recorded at a nearby airport which can be viewed from the link below: http://www.redemet.aer.mil.br/consulta_msg/meteograma.php?ID_REDEMET=m7k5a5dhppc4r9dr8v4k6gqiv0
- Enter the airport code SBJR and select 'Consultar'. The data from this site only displays weather conditions from the previous 96 h.

Flamengo Park and Marina de Gloria:

- The closest weather stations to these venues is recorded at a nearby airport which can be viewed from the link below: http://www.redemet.aer.mil.br/consulta_msg/meteograma.php?ID_REDEMET=m7k5a5dhppc4r9dr8v4k6gqiv0
- Enter the airport code SBRJ and select 'Consultar'. The data from this site only displays weather conditions from the previous 96 h.
- As Flamengo Park and Marina de Gloria are close to central Rio more extensive historic data can be found at the links suggested above for the Maracanã Zone.

Both daily and historical reports for air and water quality at locations throughout Rio can be viewed through the INEA website*, www.inea.rj.gov.br. If you are interested in accessing past or future air and/or water quality of a specific Olympic Zone, or if you are having difficulty using the above weather websites, contact Julia Skleryk (julia.skleryk@hpsnz.org.nz).

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Appendix B

Heat Management

Exercise in hot environments (≥ 27^{o}C) results in an increase in core body temperature, which is known to impair exercise performance over a variety of modes and durations, such as endurance, intermittent sprint (i.e. team sport) and some middle distance events. Four key strategies can help athletes to manage the effects of heat during competition include 1) acclimatising to the hot conditions, 2) pre and during-exercise cooling, 3) ensuring adequate hydration with cold fluids, and 4) ensuring sufficient carbohydrate sources are available to support the exercise.

1) Heat Acclimatisation

Acclimatising the body to the temperatures it will perform in prepares an individual to deal with the competition environment more efficiently. Ultimately, improving an athlete's ability to train and compete in hot and/or humid environments. As each sport has different needs and individual athletes will respond differently to the heat, it is highly recommended to consult your HPSNZ team Performance Physiologist and Performance Nutritionist prior to implementing a heat acclimatisation plan.

The adaptations that occur with acclimatisation include:

- ↓ core and skin temperature at rest and during exercise (feeling more comfortable in the conditions)
- ↓ heart rate for a given exercise intensity (more efficient)
- ↑ plasma volume (water part of your cardiovascular system; benefits aerobic fitness)
- ↑ sweat rate (allowing greater cooling ability)
- Glycogen (carbohydrate) sparing (ability to exercise longer)

Some guidelines for implementing a successful acclimatisation protocol for athletes:

- Perform heat training sessions for a minimum of 5 consecutive days: e.g. in a heat chamber or outside in a hot environment (30-35^{o}C). Further adaptations can be seen with 7-10 consecutive days in the heat.

- Heat adaptations/benefits can be maintained for up to 2-3 weeks from the time of the last heat exposure/session. Acclimatisation protocols do not need to be timed directly before a team's or athlete's departure time.

- Normal training sessions can be performed in the heat and should last ~ 60 - 90 min. Heat training sessions are best scheduled in the afternoon, when air (ambient) and core body temperatures are naturally higher.

- Typically, normal training sessions can be performed in the heat, bearing in mind that these conditions are an added strain on an athlete's system, so some adjustments may be

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required. These may include increasing fluid availability and adjusting exercise intensity and/or skill level. Initial sessions in the heat should be of low-to-moderate intensity and skill level and as athletes adjust to the conditions increases can be made typically after 2-3 training sessions in the heat.

- If an alternative hot environment is not available partial heat adaptations are also seen with post-exercise sauna use (up to 30 min). Sauna sessions should be scheduled immediately after the last training session on the day.

- As each sport has different needs and individual athletes will respond differently to the heat, it is highly recommended to consult your HPSNZ team Performance Physiologist to optimally implement a sport specific heat acclimatisation plan. Furthermore, your HPSNZ team Performance Nutritionist should be consulted for appropriate hydration, recovery and refuelling adjustments, which are necessary for training in the heat.

2) Pre and During-Exercise Cooling

Commencing exercise with lower core and skin temperatures with pre-exercise cooling gives the body a buffer before the detrimental effects of hyperthermia occur. Specifically, precooling results in lower core body (& potentially skin) temperatures and heart rate, both before and during exercise. The benefit of precooling is that exercise in the heat feels easier.

Below are recommendations for implementing cooling strategies:

- Successful pre-cooling techniques include external (cold water immersion and the application of ice-towels / cooling garments) and internal (consuming ice slurries) cooling. The greatest benefits are seen with a combination of both these techniques. Athletes are encouraged to test and practice strategies well in advance of their competitions. Access to safe and clean water is a consideration in choosing the most suitable strategy.

- Generally, a minimum of 15 min is required for cold water immersion. Ice slurry ingestion and ice-towels / cooling garments require more time (~30 min). Longer protocols tend to achieve a lower starting body temperature; however, logistics will often dictate what can actually be implemented in the field.

- Cooling during exercise can also reduce the rise in core body temperature. Drinking ice slurry or cold fluids is a successful strategy, as are the use of ice towels, or even dipping hands and forearms (up to the elbows) into cold water.

3) Keep Hydrated with Cold Fluids

After arriving in a hot environment or performing heat acclimatisation protocols, it's important to pay particular attention to fluid intake to maintain hydration. If an individual has not been drinking enough, headaches could develop, which indicates that fluid intake should be increased. Be aware that severe over-hydration can also trigger headaches, in which case more fluids would not be

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recommended. Drinking cold fluids (4-15°C) or ice slurries *during* exercise may also enhance performance by keeping the body cool and making exercise feel easier. Research suggests drinking according to thirst during exercise is the best hydration strategy to maximise performance, for athletes acclimatised to the conditions. Athletes are encouraged not to ignore the signals of thirst and be well prepared. Furthermore, ensure all water used for drinking, immersion and making ice or drinks (e.g.; ice slurry) are from a **safe source**.

4) Consider Carbohydrate Intake

Exercise in the heat (≥ 27°C) results in greater glycogen (carbohydrate) usage, potentially causing increased glycogen depletion and resulting in fatigue. If exercise is prolonged (i.e., greater than 90 min, such as hockey, soccer matches including the warm-up, triathlon, marathon, and race walking), consuming sufficient carbohydrate during exercise may help to lower the glycogen depletion rates and improve exercise performance in the heat. Athletes are encouraged to have good glycogen stores prior to their event.

Other Heat Beating Tips:

- Athletes are encouraged to stay cool while sleeping. Sleeping in hot environments will not provide further benefits and could impair sleep quality. If air conditioners are used at night the ideal temperature range is between 20-23°C. If set too low (< 20°C) poor sleep quality and increased risk of illness could result.

- The National Training Centre in Auckland's North Shore has access to a heat chamber and saunas, which may be available to carded athletes in specific circumstances. An appointment is needed with your team Performance Physiologist or Paul Laursen (HPSNZ Physiology Manager; paul.laursen@hpsnz.org.nz).

Take Home Points

* Athletes should train in the environment they will compete in
*Use cooling strategies before/during competition with techniques that have been tested
* Ensure there are always cold fluids available
*Carbohydrate stores should be topped up before and during the event

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