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WM-Air Project Briefing: Assessment of local air quality and air pollutant emissions from football travel associated with Birmingham County Football Association

A report from the WM-Air project for Birmingham County Football Association, 26th May 2021

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Background Information

WM-Air - Clean Air Science for the West Midlands (wm-air.org.uk) - is a NERC funded initiative, led by the University of Birmingham, working in collaboration with over 20 cross sector partners, to apply environmental science expertise to support the improvement of air quality, and associated health, environmental and economic benefits, across the West Midlands. The football sector reflects a currently underexplored focus for transport and air quality research, and wider engagement.

Birmingham County Football Association (BCFA) are part of the national FA's regional network that governs, safeguards and aims to increase participation in football across all formats & abilities. Geographically BCFA cover Birmingham, The Black Country, Coventry, Warwickshire and into East Staffordshire. They have 7 professional clubs in the region but their main focus is on "grassroots football" with 1200 affiliated member clubs, 4750 teams, 1200 referees 25,000 volunteers and c.100,000 players.

BCFA are currently developing a pioneering project to understand the environmental impact football is having, and implementing ways to help the game make fundamental changes to reduce its environmental footprint. The "*Save Today, Play Tomorrow*" project will underpin their next 4 year strategy and will launch in June 2021. BCFA have also recently joined the UN's Sport for Climate Action Framework.

BCFA have already completed an in-house carbon footprint analysis for football travel over the last 6 years - estimating that the average adult player through travelling to/from football emits c.0.5 tonnes of CO_2 per season – and wanted to conduct a similar analysis for air pollutants. As such, they approached WM-Air for support with the air quality - i.e. Nitrogen Dioxide (NO_2) and Particulate Matter ($PM_{2.5}$) - aspect of the 'Save Today, Play Tomorrow' initiative. The existing climate impact analysis is linked to a "Pledge of Sustainability" that all clubs will be asked to sign up to when they affiliate for the 21/22 season.

Specifically, BCFA are interested in understanding the current air quality situation around their club venues, understanding emissions associated with football related travel to inform to specific actions concerning sustainable travel initiatives and to raise awareness of the health impacts associated with poor air quality and how this may affect player performance.

Project Overview

WM-Air is working in partnership with the BCFA to better understand links between football activities, air quality and health and to support policy actions with regards to sustainable transport.
This briefing paper specifically explores:

1) Quantifying local air quality for football locations, by overlaying BCFA club sites with annual air quality data (NO_2, $PM_{2.5}$).
2) Estimating air pollutant (NOx, $PM_{2.5}$) emissions related to football activities, (per person per year) by utilising football-related travel data (i.e. journey distances to/from football) over 6 seasons, and real-world vehicle air pollution emissions factors (EFs).

Approach and Findings

1) Local air quality

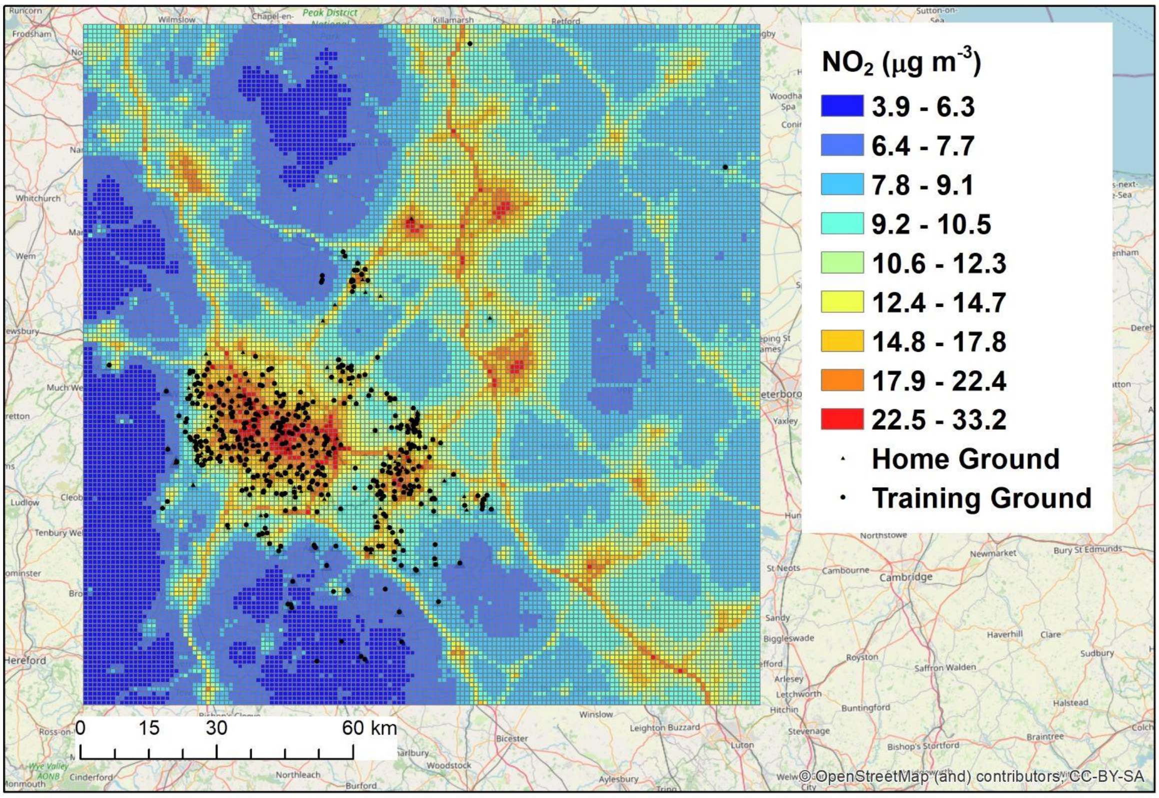
Approach

Defra annual air quality datasets for ground level NO_2 and $PM_{2.5}$ concentrations for 2019, the latest available dataset, were retrieved the UK-Air database). These data are provided at 1x1 km resolution and are widely used to support air quality policies (i.e., in planning for compliance with the legal limit for NO_2 – an annual mean of 40 µg m^{-3} – and legal standards for $PM_{2.5}$ in the UK[1]). The datasets reflect annual average background air pollutant concentrations across the 1 km^2 area, and do not capture "hot spots" of higher concentrations which may be found (for example, close to local roads), or air pollutant variations over shorter time periods. However, as football locations are mostly located a distance away from major roads, Defra air quality maps can be used here to identify which locations are located in areas of higher air pollution levels. The high-resolution WM-Air model[2] can explore more localised air pollution variability (e.g. to 10 m^2 resolution), however it only covers the seven local authority areas covered by the WMCA so for consistency reasons, it could not be used for the whole BCFA geographical footprint).

Results

Figure 1 shows annual mean concentrations for ground-level NO_2 and $PM_{2.5}$, with football locations (home grounds and training grounds) overlaid. As would be expected, higher concentrations of NO_2 and $PM_{2.5}$ are found in city centre areas and near major road links. The 'top 30' home- and training grounds located in areas with the highest NO_2 concentrations can be found in Appendix A1. As evident, there are 4 training grounds and 3 home grounds, most of which are in Birmingham, in locations where the 1km^2 annual mean background NO_2 concentrations are higher than 30 µg m^{-3}. There are 244 training grounds and 219 home grounds in locations with annual mean $PM_{2.5}$ concentrations higher than 10 µg m^{-3} (see below for health context).

[1] https://uk-air.defra.gov.uk/assets/documents/Air_Quality_Objectives_Update.pdf
[2] The WM-Air standalone ADMS-Urban (CERC, 2020) baseline model configuration for the West Midlands has been completed and constructed in collaboration with Cambridge Environmental Research Consultants (CERC). Model predictions for NO_x, NO_2, O_3, PM_{10} and $PM_{2.5}$ have been evaluated using the measurement data of 32 monitoring sites from local authorities within West Midlands and Defra's Automatic Urban and Rural Network (AURN); overall, the model performed well.



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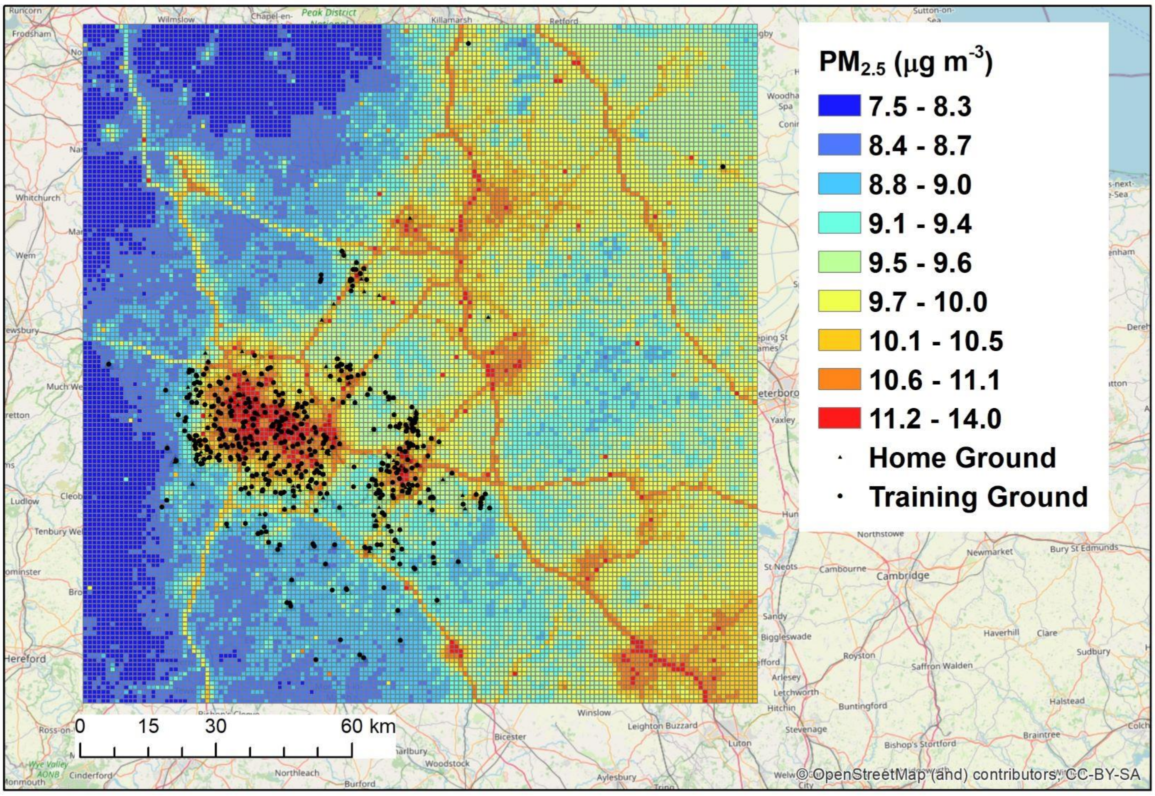


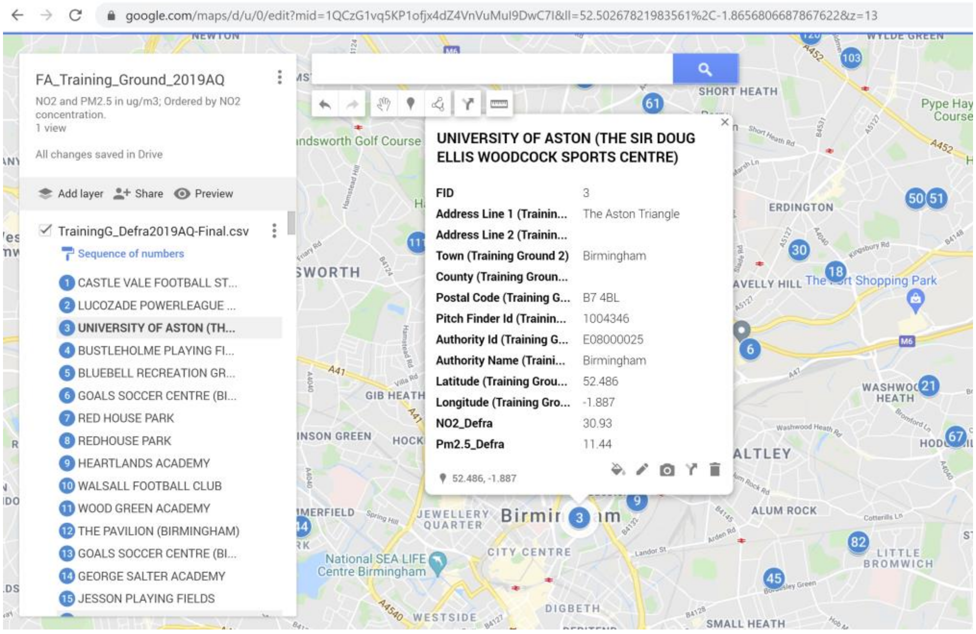
(b)

Figure 1: Air quality levels (annual mean background concentrations) for (a) NO_2 and (b) $PM_{2.5}$ (in µg m^{-3}) with football locations (black dots) (Home and Training grounds).

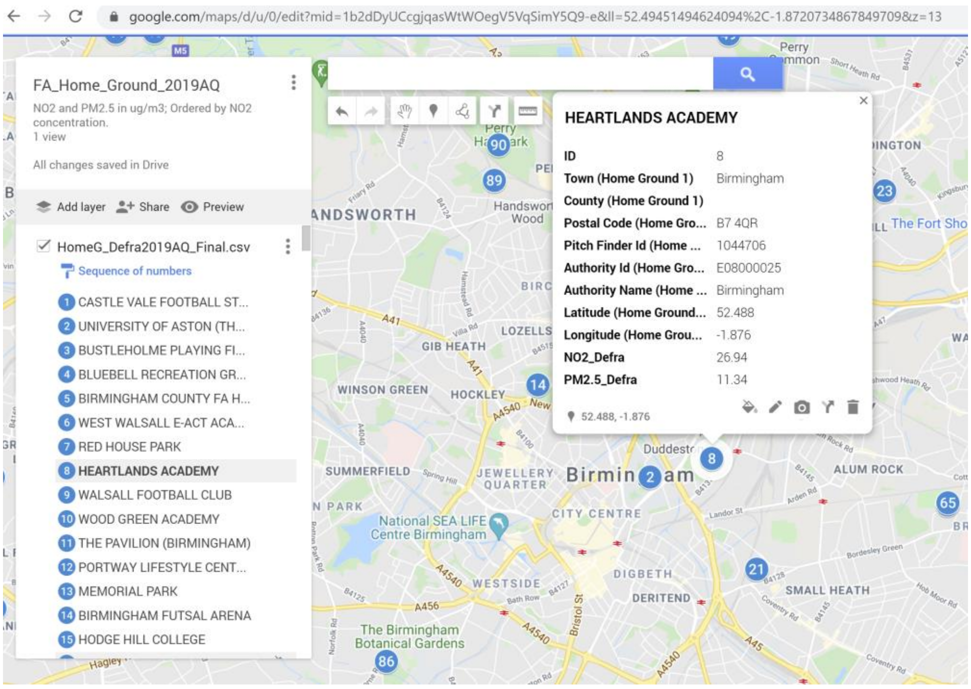
This data has also been plotted as a kml file onto a Google map, along with air quality information for all football locations, which offers a zooming capability (example screenshots are shown in Figure 2):

- Training grounds: https://www.google.com/maps/d/u/0/edit?mid=1QCzG1vq5KP1ofjx4dZ4VnVuMuI9DwC7I&usp=sharing
- Home grounds: https://www.google.com/maps/d/u/0/edit?mid=1b2dDyUCcgjqasWtWOegV5VqSimY5Q9-e&usp=sharing

The locations have been ranked in terms of the air quality in the corresponding 1 km^2 DEFRA dataset, and the estimated NO_2 and $PM_{2.5}$ annual mean concentrations can be viewed by clicking on each location. (This dataset is also supplied in the accompanying spreadsheet 'BCFA - Air Quality Data for Clubs.xsl').



(a)



(b)

Figure 2: Example Google maps layer for NO_2 and $PM_{2.5}$ (annual mean background concentrations in $\mu g\ m^{-3}$) for (a) Training ground and (b) Home ground.

Context: Health effects of air pollutants

A variety of air pollutants have known or suspected harmful effects on human health and the environment[3]. In most areas of Europe, these pollutants are principally the products of combustion from space heating, power generation or from motor vehicle traffic. Pollutants from these sources may not only prove a problem in the immediate vicinity of these sources but can travel long distances.

The key pollutants of concern in the UK are nitrogen dioxide gas (NO_2) and fine particles, particularly $PM_{2.5}$, those 2.5 μm in diameter or smaller, which can be inhaled into the lungs. NO_2 irritates the airways of the lungs, increasing the symptoms of those suffering from lung diseases; fine particles carried deep into the lungs can cause inflammation and a worsening of heart and lung diseases. In both cases effects are greater for vulnerable populations. $PM_{2.5}$ is recognised to exert health impacts even at very low concentrations – no threshold has been observed below which no damage to health is observed[4].

The air pollution levels identified for BCFA football locations are broadly typical of those found in urban areas across the UK and Europe. They may be compared with the current air quality standards, listed below – however caution is needed as the standards apply to actual measured levels at a specific location, and air pollution can vary significantly (in particular, NO_2 levels close to roadways). The figures presented in this report derive from model simulations, averaged over a 1km grid – so they may over, or under, estimate the actual levels at any specific location. It is the responsibility of Local Authorities to ensure air quality meets these objectives:

The current relevant air quality objectives in the UK are[5]:

NO_2: Annual mean concentrations not to exceed 40 $\mu g\ m^{-3}$
Hourly concentrations not to exceed 200 $\mu g\ m^{-3}$ more than 18 times per year.

$PM_{2.5}$: Annual mean concentrations not to exceed 25 $\mu g\ m^{-3}$

The World Health Organisation sets a (non-binding) guideline level[4] for $PM_{2.5}$ concentration of 10 $\mu g\ m^{-3}$ (as an annual mean). The UK government's 2019 Air Quality strategy sets an ambition to halve the UK population living in areas exceeding this WHO guideline by 2025 – for context, a recent WM-Air estimate is that approximately half of the West Midlands population live in areas where $PM_{2.5}$ concentrations exceed this (10 $\mu g\ m^{-3}$) level.

Air quality standards in the UK are currently under review, linked to the passage of the Environment Bill[6] through parliament, and our understanding is there is some appetite to adopt a more stringent objective for $PM_{2.5}$ (than the current 25 $\mu g\ m^{-3}$), reflecting the WHO position, and the medical evidence that there is no lower threshold for health effects.

2) Emissions from travel to/from football

Approach

Using the last 6 years of journey start/destination postcode data as supplied by BCFA, and real-world vehicle Emission Factors (EFs) for NOx and $PM_{2.5}$ derived from WM-Air calculations, we estimated the NOx and $PM_{2.5}$ emissions generated from travel to/from matches and training sessions for players registered to play for an affiliated Birmingham County FA club/team. Appendix A2 provides more

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[3] https://uk-air.defra.gov.uk/
[4] https://www.who.int/airpollution/publications/aqg2005/en/
[5] https://uk-air.defra.gov.uk/assets/documents/National_air_quality_objectives.pdf
[6] https://www.gov.uk/government/publications/environment-bill-2020

information about the calculation of EFs and assumptions used; the full methodology can be found in Ghaffarspand *et al*. (2020).

In order to perform this calculation we assume the following (which is consistent with the data provided from BCFA and the methodology employed for their existing carbon footprint analysis, with some additional notes in brackets):

1. *Only registered player data is included, split between open "Open Aged" (Adult) & "Youth" (U18's football). Online player registration is not mandatory until 21/22 season so the data cut is a best endeavours view.*
2. *For the purpose of this analysis it is assumed that all players drive or travel to football by* [petrol/diesel] *car* [from their home address] *(latest figures show that in 2019, 75% of UK adults drive or have access to a vehicle).* [Note, the distance travelled approach using postcode areas results in players travelling within the same postcode area having no travel distance assigned, and thus contribute zero emissions].
3. *Considerations for travel are 4 journeys per week over 52 weeks, this includes midweek training (to/from) home match day (to/from). To help factor in away travel/midweek games the analysis uses the model over 52 weeks.* [Note, this training/match pattern is also assumed for 2020/21 season, therefore COVID-19 related impacts are not explicitly modelled.]
4. *The data only includes those registered with "Non-NLS" clubs & teams, this is what we determine as "grassroots football" that make up the majority of participants within the County.*
5. *As we cannot control the integrity of the data being uploaded to the WGS (Whole Game System) it is assumed that postcode data are correct. Only those records where both of these fields of data are complete can be included in the calculations.*

Emissions Results

On average, 0.66 kg of NOx and 11.5 g of $PM_{2.5}$ are emitted per player per year - across the 6 seasons' worth of data analysed - from football-related travel. (Detailed emissions results for each journey can be found in the accompanying spreadsheet 'BCFA - AQ emissions from player data.xls'.) To put these numbers into context, if we use the average distance travelled per person by car (as either driver or passenger), per year in the UK (5,009 miles in 2019)[7], we can derive annual average emissions from car travel per person, per year of 3.42 kg of NOx and 59.9 g of $PM_{2.5}$. If we assume that travel behaviour of those involved in BCFA grassroots football is similar to the national average, the football-travel-related air pollutant emissions for those individuals would account for roughly 20% of their total road transport-related emissions each year.

As expected, the emissions data does vary considerably across the journeys undertaken, with most players travelling short distances for football, and relatively fewer players travelling from further afield. The distances travelled each week is shown in Figure 3, with almost a quarter of players travelling within the same postcode area. For this analyses, and in order to be comparable with the BCFA's CO_2 analysis, these journeys were classed as contributing zero emissions – i.e. zero km travelled - but were still included in order to calculate average emissions per player. It is reasonable to expect many of these players would indeed travel via active transport means.

The BCFA journey data shows that there are also a relatively large number of players travelling significant distances (i.e. up to ~2000 km each week) for football, therefore contributing to the highest emissions. It is understood that some of these calculated journeys are likely to arise from University students who register their home (rather than term time) address when playing locally in their University region. However, there are also players who do travel significant distances from outside the

[7]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/906276/national-travel-survey-2019.pdf

region to play. As per the BCFA CO_2 analysis methodology therefore, we have included these journeys these in the main analysis outlined above. However, if all players who appear to travel >50km to football were excluded, the average emission per player per year decreases to 0.54 kg for NOx and 9.5 g for $PM_{2.5}$ (equating to quite significant reductions of 18% and 17%, respectively).

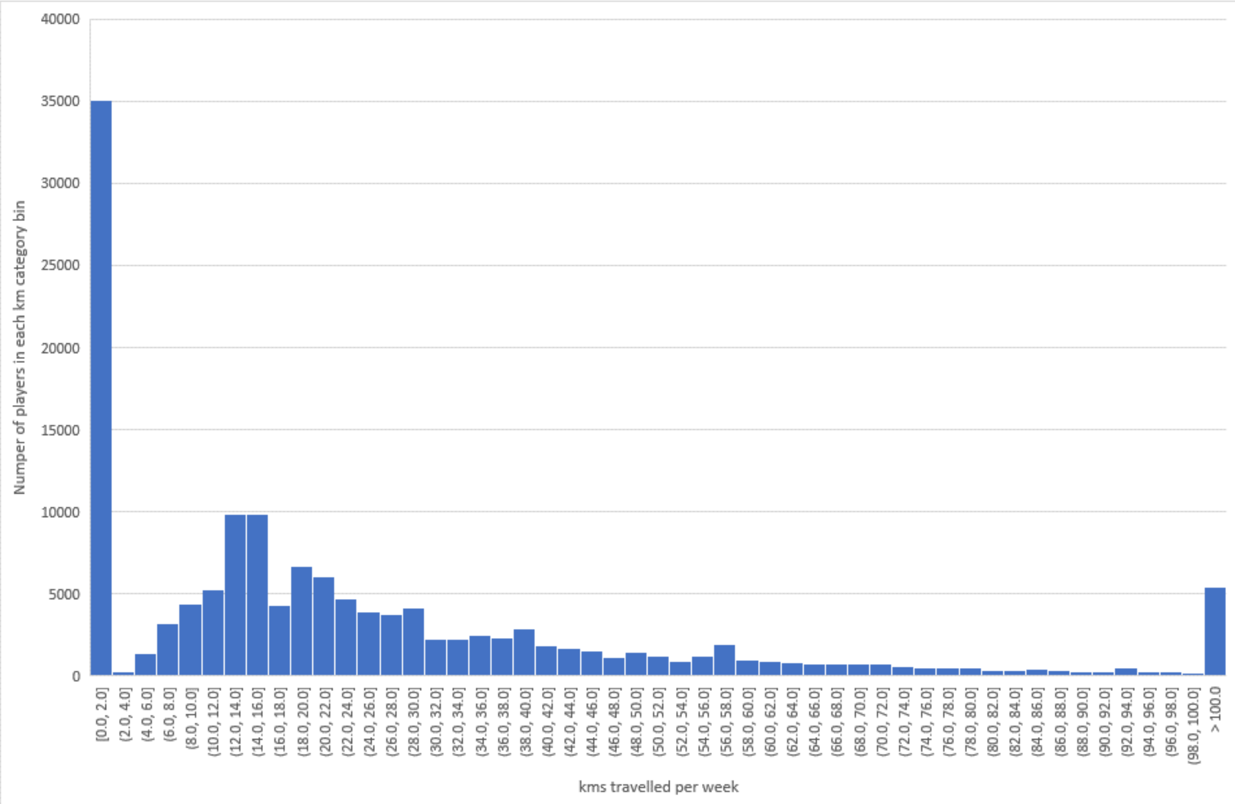

Figure 3: Histogram showing the range of distances travelled per player per week, across the entire player base (NB. Due to the way in which the travel data has been collected, journeys within the same postcode area contribute zero emissions, as per BCFA dataset).

Considerations and future work

There are a number of activities that could further develop this work (for example):

- Repeating the analysis at a higher resolution using the WM-Air model for those clubs within the model's footprint in order to identify those with the true highest ground pollution levels.
- Mapping proximity of home and training facilities to public transport routes.
- Undertake a health impact calculation using the HEAT tool to estimate reduced mortality among the study population from changing a proportion of trips to active means: https://www.heatwalkingcycling.org/#homepage
- Measuring real-time AQ to inform training times.
- Exploration of impacts on athletic performance, in particular consideration of the effects of ozone – the air pollutant gas most closely linked to elite performance, for example in athletics events - in summer months. For example, assessing football player performance against hourly air quality data (i.e. has been done in German Bundesliga).

In addition, the following suggestions could be considered for inclusion within the '*Save today, Play tomorrow*' initiative:

- Engagement activities to help communicate air pollution issues to the BCFA community, and scope for individual actions, such as active travel / ride sharing (though this may be difficult currently due to issues linked to Covid social distancing).
- Integrating incentives for sustainable travel within the pledge, similar to what has been done for CO_2 offsetting as a condition of clubs registering.
- Exploring feasibility of travel planning (which are evidence based from other sectors). This could be done electronically. All training locations should have travel details for foot/bike routes and public transport services and all clubs could make that travel information accessible to players as the preferred mode.
- Working with partner authorities in each area to provide specific services/routes.
- Upstream - planning future training locations to be in close proximity to public transport.
- Sharing best practice via the UN Sports for Climate Action initiative.

Statement concerning accuracy and limitations & use of preliminary datasets

The University of Birmingham has sought to ensure the accuracy of the information within this report. To the fullest extent permitted by law, the University accepts no liability for any loss or damage (whether direct, indirect or consequential and including, but not limited to, loss of profits, loss of data, business or goodwill) incurred by any person or organisation and howsoever caused arising from or connected with any error or omissions in this document or from any person acting, omitting to act or refraining from acting, or otherwise using the information contained in this document or its references. The University makes no representation or warranty that any information in this report will not result in the innocent infringement of third party rights and the University accepts no responsibility whatsoever for the infringement of such rights.

Appendix

Appendix A1: ***Top 30 football locations sited in the poorest air quality locations, ordered by highest NO_2 concentration. The Defra annual air quality datasets are for ground level NO_2 and $PM_{2.5}$ concentrations at 1x1km resolution for 2019, retrieved the UK-Air website (https://uk-air.defra.gov.uk/data/pcm-data).***

Table A1: Top 30 highest NO_2 concentrations (µg m^{-3}) for training ground.

ID	Name (Training Ground)	Authority Id	Latitude	Longitude	NO_2	$PM_{2.5}$
1	CASTLE VALE FOOTBALL STADIUM	Birmingham	52.516	-1.779	33.25	11.77
2	LUCOZADE POWERLEAGUE SOCCER CENTRE (BIRMINGHAM)	Birmingham	52.508	-1.865	31.7	12.28
3	UNIVERSITY OF ASTON (THE SIR DOUG ELLIS WOODCOCK SPORTS CENTRE)	Birmingham	52.486	-1.887	30.93	11.44
4	BUSTLEHOLME PLAYING FIELDS	Sandwell	52.544	-1.971	30.04	11.95
5	BLUEBELL RECREATION GROUND	Solihull	52.47695	-1.72146	29.11	11.27
6	GOALS SOCCER CENTRE (BIRMINGHAM STAR CITY)	Birmingham	52.50555	-1.85454	27.19	11.97
7	RED HOUSE PARK	Sandwell	52.54599	-1.93965	26.97	12.02
8	REDHOUSE PARK	Sandwell	52.546	-1.94	26.97	12.02
9	HEARTLANDS ACADEMY	Birmingham	52.488	-1.876	26.94	11.34
10	WALSALL FOOTBALL CLUB	Walsall	52.566	-1.991	26.83	12.22
11	WOOD GREEN ACADEMY	Sandwell	52.564	-2.004	26.62	12.01
12	THE PAVILION (BIRMINGHAM)	Birmingham	52.53	-1.885	26.18	12.04

13	GOALS SOCCER CENTRE (BIRMINGHAM PERRY BARR)	Birmingham	52.527	-1.894	26.18	12.04
14	GEORGE SALTER ACADEMY	Sandwell	52.526	-2.012	26.17	11.37
15	JESSON PLAYING FIELDS	Sandwell	52.528	-2.004	26.17	11.37
16	PORTWAY LIFESTYLE CENTRE	Sandwell	52.4988	-2.03007	25.68	11.82
17	BIRMINGHAM FUTSAL ARENA	Birmingham	52.496	-1.907	24.73	11.18
18	ERDINGTON ACADEMY	Birmingham	52.5145	-1.83822	24.71	12.05
19	SMITHS WOOD PLAYING FIELD	Solihull	52.50081	-1.74949	24.7	11.38
20	SIDNEY STRINGER ACADEMY	Coventry	52.41367	-1.50369	24.64	11.03
21	HODGE HILL COLLEGE	Birmingham	52.50133	-1.82057	24.42	11.8
22	DOUG ELLIS SPORTS CENTRE	Birmingham	52.51996	-1.89401	24.31	11.83
23	HOLFORD DRIVE COMMUNITY SPORTS HUB	Birmingham	52.52	-1.891	24.31	11.83
24	WARLEY RFC	Sandwell	52.49475	-2.00563	24.14	11.71
25	YORK ROAD SOCIAL AND SPORTS CLUB	Sandwell	52.484	-2.025	23.6	11.95
26	LONDON MIDLAND RAILWAY CLUB ASSOCIATION (WALSALL)	Walsall	52.573	-1.994	23.22	11.91
27	HOLTE SCHOOL	Birmingham	52.5006	-1.90181	23.17	11.42
28	MARL HOLE PARK	Sandwell	52.51698	-2.01018	23.17	11.45
29	SANDWELL ACADEMY	Sandwell	52.509	-1.968	23.05	11.24
30	JAFFRAY PLAYING FIELDS	Birmingham	52.51701	-1.84516	22.89	11.79

Table A2: Top 30 highest NO_2 concentrations ($\mu g\ m^{-3}$) for Home ground.

ID	Name (Home Ground)	Authority Id	Latitude	Longitude	NO_2	$PM_{2.5}$
1	CASTLE VALE FOOTBALL STADIUM	Birmingham	52.516	-1.779	33.25	11.77
2	UNIVERSITY OF ASTON (THE SIR DOUG ELLIS WOODCOCK SPORTS CENTRE)	Birmingham	52.486	-1.887	30.93	11.44
3	BUSTLEHOLME PLAYING FIELDS	Sandwell	52.544	-1.971	30.04	11.95
4	BLUEBELL RECREATION GROUND	Solihull	52.47664	-1.7211	29.11	11.27
5	BIRMINGHAM COUNTY FA HEADQUARTERS	Sandwell	52.54268	-1.96178	28.53	11.80
6	WEST WALSALL E-ACT ACADEMY	Walsall	52.58213	-2.00979	27.64	11.96
7	RED HOUSE PARK	Sandwell	52.54599	-1.93965	26.97	12.02
8	HEARTLANDS ACADEMY	Birmingham	52.488	-1.876	26.94	11.34
9	WALSALL FOOTBALL CLUB	Walsall	52.566	-1.991	26.83	12.22
10	WOOD GREEN ACADEMY	Sandwell	52.564	-2.004	26.62	12.01
11	THE PAVILION (BIRMINGHAM)	Birmingham	52.53	-1.885	26.18	12.04
12	PORTWAY LIFESTYLE CENTRE	Sandwell	52.4988	-2.03007	25.68	11.82
13	MEMORIAL PARK	North Warwickshire	52.497	-1.709	25.63	11.24
14	BIRMINGHAM FUTSAL ARENA	Birmingham	52.496	-1.907	24.73	11.18
15	HODGE HILL COLLEGE	Birmingham	52.501	-1.821	24.42	11.80
16	FOXFORD LEISURE CENTRE	Coventry	52.453	-1.479	24.37	11.48
17	DOUG ELLIS SPORTS CENTRE	Birmingham	52.51996	-1.89401	24.31	11.83
18	HOLFORD DRIVE COMMUNITY SPORTS HUB	Birmingham	52.52	-1.891	24.31	11.83
19	WARLEY RFC	Sandwell	52.49475	-2.00563	24.14	11.71
20	YORK ROAD SOCIAL AND SPORTS CLUB	Sandwell	52.484	-2.025	23.60	11.95

21	ST ANDREW'S STADIUM (BIRMINGHAM CITY FC)	Birmingham	52.476	-1.868	23.45	10.92
22	MARL HOLE PARK	Sandwell	52.51698	-2.01018	23.17	11.45
23	JAFFRAY PLAYING FIELDS	Birmingham	52.51701	-1.84516	22.89	11.79
24	SILHILLIANS SPORTS CLUB	Solihull	52.404	-1.748	22.70	10.55
25	ASTON VILLA FOOTBALL CLUB AGP	Birmingham	52.50826	-1.88596	22.53	11.49
26	VILLA PARK	Birmingham	52.508	-1.885	22.53	11.49
27	GOODYERS END PRIMARY SCHOOL	Nuneaton and Bedworth	52.46951	-1.49482	21.86	11.26
28	FOWLERS PLAYING FIELDS	Wolverhampton	52.599	-2.12	21.79	10.24
29	CAKEMORE PLAYING FIELD	Sandwell	52.47726	-2.0196	21.70	11.53
30	KING GEORGE PLAYING FIELD	Birmingham	52.516	-1.779	33.25	11.77

Appendix A2*: Derivation of Emissions Factors*

An estimated dynamic fleet composition is used for the projection of a mileage-based total fleet emission of NO_x and $PM_{2.5}$ under real-world conditions. This analyses draws upon 1. traffic composition distributions from Transport for West Midlands (TfWM); 2. fleet compositions obtained from the EDAR remote sensing campaigns within the five urban areas of UK (Ghaffarpasand et al. 2020); and 3. fleet distributions measured by Automatic Number Plate Recognition (ANPR) survey in 2016, used as estimates for the 2020 fleet. The TfWM dataset provides the estimated fleet distribution [cars, buses, LGVs, and HGVs]. The EDAR dataset, which includes over 90,000 individual vehicle characteristics (real-world emissions and vehicle information), is used to split the TfWM fleet distribution further by splitting cars into diesel and petrol engines. Finally, the ANPR dataset was used to extract EURO classification of each subset. A full explanation of the methodology can be found in Ghaffarpasand et al. (2020).

We also note the following assumptions and caveats for calculating emissions of NOx and PM2.5:

1. Vehicle fleet composition (i.e. the EURO distribution of the fleet) for the year 2020 was combined with EURO-based EFs, to provide the corresponding EFs for each EURO subsets. This information was used to calculate the weighted-average emissions factors.
2. Weighted-average Emissions Factors of 0.423850 g/km for NOx and 0.007426 g/km for $PM_{2.5}$ (See Appendix A2 for more information) were used to calculate annual NOx and $PM_{2.5}$ emissions for players based on the annual distances travelled.
3. The analysis includes journeys where a player is registered with more than one club and/or more than one season, so the total number of players is taken as 143,738 (across the 6 seasons) for calculation of overall averages, and for consistency with the BCFA's CO_2 calculations.
4. Emissions were calculated as an average over the six seasons up to and including 2020-21, but assuming a normal (non-Covid) pattern of journeys would have occurred. The final results therefore correspond to the non-Covid-impacted average over the past 6 years.
5. We could not explore total annual emissions, or emissions broken down at club-level, as the journey data was too variable across the seasons and clubs and would not give a complete picture. However if more complete journey dataset became available in due course, this would be interesting to explore in order to understanding how each club compares versus distance travelled by their players – i.e. their 'travel footprint' - and therefore their emissions.

It is important to re-emphasise the number of assumptions that were required as part of this analysis (i.e. the assumed distances travelled and the use of broad postcode areas, that all travel is via petrol/diesel car, the inclusion of the large distances travelled by a small number of players, the lack of data regarding travel to away games and midweek games etc.), and therefore the resulting limitations to the accuracy of the emissions data presented here must be considered when drawing conclusions from this work.

References

Cambridge Environmental Research Consultants (CERC): ADMS-Urban User Guide Version 5.0, available at: https://www.cerc.co.uk/environmental-software/assets/data/doc_userguides/CERC_ADMS-Urban5.0_User_Guide.pdf, 2020.

Ghaffarpasand, O., Beddows, D.C.S., Ropkins, K., Pope, F. D. (2020) Real-world assessment of vehicle air pollutant emissions subset by vehicle type, fuel and EURO class: New findings from the recent UK EDAR field campaigns, and implications for emissions restricted zones, Science of the Total Environment, 734, 139416. https://doi.org/10.1016/j.scitotenv.2020.139416

Osei, L.K, Ghaffarpasand, L. and Pope, F.D. (2021) Real-World Contribution of Electrification and Replacement Scenarios to the Fleet Emissions in West Midland Boroughs, UK, *Atmosphere*, 12, 332. https://doi.org/10.3390/atmos12030332