COMEAP/2018/04 WORKING PAPER 3

COMMITTEE ON THE MEDICAL EFFECTS OF AIR POLLUTANTS

Results of London Underground workers exposure to respirable dust: 2005-2017

1.   This paper prepared by Mr Nick Wilson and Dr Olivia Carlton (both Transport for London (TfL)) summarises the results of routine monitoring undertaken by TfL between 2005 and 2017

2.   Note: This is a draft working paper for discussion. It does not reflect the final view of the Committee and should not be cited.

COMEAP Secretariat

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Paper prepared by Dr Olivia Carlton and Mr Nick Wilson: January 2018

Introduction

The air underground in the London Underground infrastructure is known to be high in particulate matter (PM). London Underground has monitored dust levels underground for many years. This has been to provide evidence that exposures of employees are within the limits set by the Health and Safety Executive (HSE) in the document, EH 40. This paper gives an account of the monitoring, along with results.

Routine occupational exposure monitoring

The dust in the London Underground is primarily classified by the HSE as nuisance dust. The elements of the dust measured routinely iron, crystalline silica, zinc, chromium, copper, nickel and manganese, all of which have specific exposure limits. Airborne fibre monitoring is also undertaken from time to time. This is to ensure that asbestos levels are within required limits.

Measures are made of total inhalable and respirable dust. The former is everything that can be inhaled through the nose and mouth. The latter is that fraction of dust which gets into the small air vessels of the lung. The measure made is a gravimetric one (a measure of weight of dust per unit volume). The limits set are to protect workers over the course of their working life, assuming continuous workplace exposure for 40 hours per week, 52 weeks per year.

Table 1. Workplace Exposure Limits (HSE)

Substance	Workplace Exposure Limit (8 hour reference Period)
Inhalable Dust	10mg/m3
Respirable Dust	4mg / m3
Iron	1mg / m3 (salts) 5mg /m3 (Oxide / fume)
Nickel	0.1mg/m3 (water soluble forms) 0.5mg/m3
Copper	1mg / m3 (dusts) 0.2mg/m3 (water soluble dusts)
Manganese	0.5mg/m3
Chromium	0.5mg/m3 (0.05mg/m3 Cr VI)
Zinc	1mg / m3 (salts or fume)
Silica (Respirable)	0.1mg/m3

Monitoring methods.

The types of staff whose exposure is regularly monitored are train operators and station staff. A mix of personal exposure monitoring and static monitoring is undertaken, the former using equipment worn by a member of staff with air inflow placed in their breathing zone, the latter using equipment placed on a platform or in a train cab.

Results of routine occupational exposure monitoring

Table 1 Appendix A provides an overview of personal and static respirable dust monitoring undertaken on train operators (i.e. train drivers) between 2005 and 2017. 1. Personal exposure monitoring provides a better measure of actual occupational exposure. However, most of the information about exposure for station staff comes from static monitoring. Personal exposure levels are usually lower than static monitoring results because the static monitoring is undertaken on platforms for the full work shift.

Train Operator exposures to nuisance dust have, in the main, decreased in the period from 2005 to 2017, with considerable variability, year on year. The results range from an average exposure of 0.9mg/m^3 on the Bakerloo Line in 2007 to 0.2 mg/m^3 in 2017 on the Central Line. In recent years, average train operator exposures on the Bakerloo Line have been below 0.7mg/m^3 and on all other deep tube lines below 0.4 mg/m^3.

For station staff, monitoring results show relatively steady average results for nuisance dust from 2005 to 2017 in deep tubes, at a level between 0.5 and 0.6 mg/m^3 but with large differences at different stations in different years (see Table 2 Appendix A). For example, monitoring at Baker Street station showed average levels just above 0.2 mg/m^3 in 2013, contrasting with levels above 1.1 mg/m^3 just two years later in 2015, reducing to approximately 0.45 mg/m^3 in 2017. These results are mainly from static monitoring, which usually gives higher results than personal exposure monitoring. Typically, station staff will only spend 1-2 hours on the platforms, with the rest of the shift spent at the gate lines or in the station office where dust levels are much lower.

Crystalline silica as quartz results

Crystalline silica as quartz levels are routinely measured. Levels since 2008 have been below the limits of detection for the equipment used except for one sample in 2017. This was a Piccadilly Line Train Operator exposure for a shift and was measured at 0.03mg/m^3. The workplace exposure limit is 0.1 mg/m^3 (long term 8 hour time weighted average). [Results available upon request].

Other elements

Other elements, namely chromium, copper, iron, manganese, nickel and zinc have been measured since 2015. The results are reported as weight of each element on the filter and concentration in air expressed as mg/m^3. All results are well below the workplace exposure limits. Concentrations of iron are much higher than other

elements. This is because the air underground contains iron from the friction action of brakes on wheels and wheels on rails. The uncorrected zinc results giving weight of zinc on the filter are misleading, because there is zinc in the filter. The corrected results and air concentrations are very low. [Results available upon request].

The "clean up" and results of associated monitoring

Concern was expressed by the Mayor of London's office in 2017 about air quality underground, as part of the Mayor's focus on air quality in London. As a result, a major clean of 46 stations on the Northern, Victoria, Bakerloo and Piccadilly Lines was undertaken during summer 2017. This included cleaning some sections of tunnels on the Northern Line between stations. Appendices B and C provide a summary of the monitoring results before and after cleaning, respectively.

The results were variable – Table 2 gives the average of all line results. This indicates that the clean-up was successful and particularly effective in removing PM_1. However, a more detailed review of the results shows far more effect in those areas where the whole tunnel section was cleaned as well as the station, compared to the stations which were cleaned with no clean of tunnel section (Table 3). These results have skewed the overall average shown in Table 2. Please see Appendices 2 and 3 for more detail.

Table 2. All Lines combined. Clean up results 2017

Criteria	Pre Clean results (average)	Post Clean Results (average)	Percentage Change
Respirable Dust (4 Rail Results) mg/m3	0.551	0.535	**-2.9%**
Respirable Dust (TFL Results) mg/m3	0.299	0.269	**-10%**
PM 10 µg/m3	333	303	**-9%**
PM 2.5 µg/m3	277	242	**-12.6%**
PM 1.0 µg/m3	255	201	**-21.2%**

Table 3. Northern Line clean up results

Cleaning Criteria	Pre Clean Result (Respirable Dust)	Post Clean Result (Respirable Dust)	Percentage Change
Whole tunnel sections cleaned as well as station and Tunnel approaches	0.675	0.376	**-44.3%**
Stations and station approaches cleaned only	0.293	0.269	**-8.2%**

Discussion

The air underground in the London Underground infrastructure is high in PM. This is because of the generation of dust caused by the friction action of train brakes on wheels and wheels on rails, combined with dust generated by the clothes, hair and skin of the millions of people, in close proximity to each other, using the system.

The results of regular monitoring of occupational exposure of London Underground employees to air underground consistently show levels well within workplace exposure limits. The results vary from year to year, particularly on stations (as opposed to train operator personal monitoring during shifts) and this is likely to be due to activity, such as construction and maintenance, taking place locally before the monitoring.

Train operator exposures have fallen from those in 2005 to those in 2017, with variation over the years. Whether this is down to improved cabin filters or lower tunnel dust levels is open to question. The efficiency of the cabin filters is going to be a confounding factor when trying to draw inference from operator exposures to assess levels that passengers are exposed to in the carriages.

Station staff dust exposures have remained similar from 2005 to 2017, but with large differences in different years. These are a poor measure of staff exposure because they are predominantly static samples from platforms.

All the elements measured (chromium, copper, iron, manganese, nickel and zinc) give results well within workplace exposure limits. The highest concentration, by a large margin, are for iron.

Making a comparison between occupational exposure levels and those levels set as a maximum for public health purposes reveals that occupational health exposures are permitted at a much higher level, although the comparisons are not entirely valid. Public health exposure levels are set assuming life time exposure, 24 hours a day, and take into account the most vulnerable citizens. Occupational exposure limits

assume 8 hour exposure for 40 hours a week for a working lifetime, for people of working age.

PM is measured for occupational exposure in terms of respirable dust. For public health purposes, it is measured as PM_{10} and $PM_{2.5}$. Respirable dust is the equivalent, approximately, of PM_4.

Transport for London's (TfL's) view up until now, informed by research undertaken by the Institute of Occupational Medicine (IOM) in the early 2000s, has been that it is not appropriate to assume that the health effects associated with PM air pollution above ground, expressed as PM_{10} and $PM_{2.5,}$ are similar to those associated with exposure to airborne PM in the subway systems at similar levels. This is because the particulate below ground has a very different composition to the air above ground.

Measures made by TfL of various elements (chromium, copper, iron, manganese, nickel and zinc) raise no cause for concern in relation to occupational exposure and are not similar to the measures made recently by researchers from Kings College. However, King's College London used a different analytical approach and cannot be directly compared to TfL measurements.

TfL awaits the advice of COMEAP and will consider what (if any) changes need to be made when that advice becomes available.

END OF PAPER

2005-2017 Air Quality Monitoring for Respirable Dust: LU Train Operators and Platform Staff

Table 1: Summary of respirable dust exposures (8 hour time weighted average; mg/m^3) for operators (train drivers) for the period 2005-2017

Line	2005	2007	2008	2010	2011	2013	2015	2016	2017	Line Type
Central	0.278	0.61	0.130	0.280	0.163	0.230	0.303	0.290	0.173	Deep Tube
Jubilee	0.148	0.163	0.110	0.157	0.130	0.317	0.130	0.183	0.277	Deep Tube
Northern	0.441	0.286	0.197	0.407	0.187	0.212	0.397	0.367	0.170	Deep Tube
Piccadilly	0.300	0.373	0.250	0.257	0.170	0.242	0.197	0.443	0.253	Deep Tube
Victoria	0.536	0.533	0.310	0.503	0.170	0.297	0.377	0.357	0.250	Deep Tube
Bakerloo	0.416	0.900	0.280	0.247	0.240	0.323	0.390	0.670	0.330	Deep Tube
Circle	0.290	0.21	0.127	0.277	0.183	0.426	0.06	0.06	0.083	Sub Surface
District	-	-	-	-	-	-	0.173	0.097	0.04	Sub Surface

Each result is the arithmetic average for each line for each year.
With the exception of the Victoria line all the lines have open air sections
A typical work shift for an operator is 6-7 hours.
Operator cabin filtration will offer the operator some level of protection from dusts. This varies between vehicle models. Recent tests on the Piccadilly Line showed that the cabin filtration reduced respirable dust levels by approximately 50%.

Table 2: Summary of respirable dust exposures (static and personal 8 hour time weighted average; mg/m^3) for platform staff for the period 2005-2017

Station	2005	2007	2008	2010	2011	2013	2015	2016	2017
Hampstead	0.670	0.680	0.545	0.55	0.537	0.494	0.470	0.403	0.707
Baker Street	1.134	0.477	0.363	0.45	0.648	0.225	1.118	0.475	0.477
Euston Square	0.728	0.193	0.455	0.853	0.590	0.500	0.418	0.343	0.265
Aldgate East	0.396	0.532	0.278	0.437	0.488	0.478	0.534	0.412	0.418
Elephant & Castle	0.388	0.06 (Gatelines only)	0.334	0.288	0.178	0.412	0.650	0.340	0.265
Oxford Circus	0.688	-	-	-	-	-	0.521	0.479	0.864
Piccadilly Circus	0.590	0.680	0.748	0.51	0.370	0.400	0.292	0.740	0.722
Tottenham Court Road	0.207	0.466	0.416	0.568	0.536	0.210	0.233	0.892	0.718
Vauxhall	0.506	0.763	0.344	0.302	0.44	0.342	0.183	0.473	0.835
Kings Cross	-	0.460	0.380	0.630	0.44	0.236	-	0.263	0.374
Colliers Wood	-	-	-	0.28	-	-	-	-	-
Morden	-	-	-	0.04	-	-	-	-	-

Paddington	-	-	-	-	-	0.562	0.605	-	0.695
Waterloo	-	-	-	-	-	-	0.477	0.705	0.566
Archway	-	-	-	-	-	-	-	0.363	-

The data in each box is the arithmetic average of the sampling for each station for each year.
The data is taken from a mix of locations in stations – primarily Platforms and Gate lines. Static testing on platforms will give the highest results.

2017 Platform and Tunnel Cleaning Programme Pre-Clean Results

Table 1: Summary of platform and tunnel cleaning – pre-clean monitoring results

Station	Line & Platform	Date	Respirable (mg/m³)	PM 10 (µg/m³)	PM 2.5 (µg/m³)	PM 1.0 (µg/m³)
Seven Sisters	Victoria (NB Platform)	26.05.17	0.266	280	256	239
Finsbury Park	Victoria (SB Platform)	30.05.17	0.381	398	365	337
Seven Sisters	Victoria Plat 4	02.06.17	0.43	-	-	-
Finsbury Park	Victoria Plat 4	30.05.17	0.53	-	-	-
Highbury & Islington	Victoria Sb Platform	07.06.17	0.230	266	209	199
Kings Cross	Victoria NB Platform	09.06.17	0.257	312	216	205
Warren Street	Victoria Platform 4	31.05.17	0.15	-	-	-
Oxford Circus	Victoria Platform 5	01.06.17	0.40	-	-	-
Green park	Victoria Platform 4	02.06.17	1.13	-	-	-
Victoria	Victoria Platform 4	20.06.17	0.80	-	-	-
Pimlico	Victoria NB Platform	02.06.17	0.235	266	215	206
Pimlico	Victoria Platform 2	04.06.17	0.27	-	-	-
Finsbury Park	Piccadilly SB Platform	30.05.17	0.368	389	348	317
Finsbury Park	Piccadilly		0.36	-	-	-

	Platform 1	05.06.17				
Arsenal	Piccadilly Platform 1	06.06.17	1.14	-	-	-
Holloway	Piccadilly Platform 2	07.06.17	0.12	-	-	-
Caledonian Road	Piccadilly Platform 1	08.06.17	0.52	-	-	-
Kings Cross	Piccadilly (westbound)	31.05.17	0.315	345	289	256
Russell Square	Piccadilly Platform 1	09.06.17	0.29	-	-	-
Covent Garden	Piccadilly Platform 2	10.06.17	0.77	-	-	-
Leicester Square	Piccadilly WB Platform	06.06.17	0.205	264	175	164
Piccadilly Circus	Piccadilly WB Platform	07.06.17	0.303	386	258	242
Green park	Piccadilly WB Platform	13.06.17	0.369	457	316	298
Hyde Park Corner	Piccadilly (EB – Platform 1)	12.06.17	0.207	227	190	169
Knightsbridge	Piccadilly EB Platform	13.06.17	0.265	260	243	215

Charing Cross	Northern Line Platform 5	06.06.17	0.81	-	-	-
Station	**Line & Platform**	**Date**	**Respirable (mg/m³)**	**PM 10 (µg/m³)**	**PM 2.5 (µg/m³)**	**PM 1.0 (µg/m³)**
Embankment	Northern Line Platform 3	30.05.17	0.364	385	346	316
Embankment	Northern Line Platform 4	30.05.17	0.353	373	331	300
Embankment	Northern Line Platform 3	07.06.17	1.15	-	-	-
Waterloo	Northern Line Platform 1	08.06.17	0.26	-	-	-
Kennington	Northern Line Platform 3	09.06.17	0.48	-	-	-
Bank	Northern Line Platform 4	10.06.17	0.02	-	-	-
Moorgate	Northern Line Platform 7	11.06.17	0.30	-	-	-
Bank	Northern Line NB Plat(4)	31.05.17	0.256	272	243	223
London Bridge	Northern Line SB Platform	01.06.17	0.294	314	280	257
Borough	Northern Line SB Platform	15.06.17	0.205	218	195	181
Oval	Northern Line SB Platform	07.05.17	0.274	321	291	284

Stockwell	Northern Line SB Platform	06.05.17	0.258	310	280	259
Clapham North	Northern Line SB Platform	08.06.17	0.123	141	111	105
Clapham Common	Northern Line SB Platform	09.06.17	0.398	452	357	338
Clapham South	Northern Line NB Platform	07.06.17	0.403	471	356	336
Balham	Northern Line SB Platform	05.06.17	0.277	293	262	239
Tooting Bec	Northern Line SB Platform	08.06.17	0.357	379	337	306
Tooting Broadway	Northern Line SB Platform	15.06.17	0.281	296	245	207
Elephant & Castle	Northern Line. NB Platform	06.06.17	0.243	282	216	205
Baker Street	Bakerloo Line Platform 8	26.05.17	0.280	303	261	235

2017 Platform and Tunnel Cleaning Programme Pre-Clean Results

Table 1: Summary of platform and tunnel cleaning – pre-clean monitoring results

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Seven Sisters	Victoria (NB Platform)	13.07.17	0.352	395	323	258
Seven Sisters	Victoria Platform 4	10.07.17	0.82	-	-	-
Finsbury Park	Victoria (SB Platform)	12.07.17	0.324	364	294	230
Finsbury Park	Victoria Platform 4	11.07.17	0.63	-	-	-
Highbury & Islington	Victoria SB Platform	11.07.17	0.215	231	204	188
Kings Cross	Victoria NB Platform	10.07.17	0.207	235	188	153
Warren Street	Victoria Platform 4	12.07.17	0.47	-	-	-
Oxford Circus	Victoria Platform 5	13.07.17	0.78	-	-	-
Green park	Victoria Platform 4	14.07.17	0.31	-	-	-
Victoria	Victoria platform 4	15.07.17	0.33	-	-	-
Pimlico	Victoria Platform 2	13.07.17	0.215	231	204	188
Pimlico	Victoria Platform 2	16.07.17	0.49	-	-	-
Finsbury Park	Piccadilly	05.07.17	0.360	418	320	248

	SB Platform					
Finsbury Park	Piccadilly Platform 2	03.07.17	0.33	-	-	-
Arsenal	Piccadilly Platform 1	04.07.17	0.83	-	-	-
Holloway	Piccadilly Platform 2	05.07.17	0.72	-	-	-
Caledonian Road	Piccadilly Platform 1	02.08.17	0.86	-	-	-
Kings Cross	Piccadilly WB Platform	03.07.17	0.250	313	211	159
Russell Square	Piccadilly Platform 1	07.07.17	0.86	-	-	-
Covent Garden	Piccadilly Platform 2	08.07.17	0.26	-	-	-
Leicester Square	Piccadilly WB Platform	07.07.17	0.207	266	174	134
Piccadilly Circus	Piccadilly WB Platform	06.07.17	0.286	360	241	183
Green park	Piccadilly EB Platform	06.07.2017	0.320	400	269	201
Hyde Park Corner	Piccadilly Platform 1	04.07.17	0.288	320	259	226

Knightsbridge	Piccadilly EB platform	07.07.17	0.263	302	234	203
Charing Cross	Northern Line Platform 5	27.07.17	0.36	-	-	-
Embankment	Northern Line Platform 3	26.07.17	0.59	-	-	-
Station	**Line & Platform**	**Date**	**Respirable (mg/m³)**	**PM 10 (µg/m³)**	**PM 2.5 (µg/m³)**	**PM 1.0 (µg/m³)**
Waterloo	Northern Line	25.07.17	0.50	-	-	-
Kennington	Northern Line Platform 3	24.07.17	0.44	-	-	-
Moorgate	Northern Line Platform 7	29.07.17	0.31	-	-	-
Bank	Northern Line Platform 4	30.07.17	0.28	-	-	-
Bank	Northern Line (NB Platform)	25.07.17	0.276	318	247	194
London Bridge	Northern Line SB Platform	26.07.17	0.281	292	273	250
Borough	Northern Line SB Platform	27.07.17	0.287	337	253	195
Oval	Northern Line SB Platform	28.07.17	0.272	267	206	148
Stockwell	Northern Line SB Platform	24.07.17	0.324	340	310	286
Clapham North	Northern Line SB Platform	26.07.17	0.144	158	138	115

Clapham Common	Northern Line SB Platform	27.07.17	0.324	371	311	275
Clapham South	Northern Line NB Platform	25.07.17	0.248	261	187	143
Balham	Northern Line SB Platform	27.07.17	0.210	217	203	187
Tooting Bec	Northern Line SB Platform	NA	NA	NA	NA	NA
Tooting Broadway	Northern Line SB Platform	24.07.17	0.247	284	219	167
Elephant & Castle	Northern Line NB Platform	25.07.17	0.304	317	290	267
Baker Street	Bakerloo Line Platform 8	21.07.17	0.257	276	242	216