Population Exposure to PAH

Short Technical Report on Indoor/Outdoor monitoring of PAHs, PM2.5 and its chemical components with ancillary measurements of gaseous toxicants in the frame of the EXPAH Project (Action 3.3)

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EXECUTIVE SUMMARY

This technical report shortly describes the work carried out under actions 3.3 of the Population Exposure to PAH (EXPAH) LIFE+ project. Detailed information can be found in the extended version of this technical report. The aim of action 3.3 was to collect PAHs, $PM_{2.5,}$ additional $PM_{2.5}$ chemical composition, and ancillary gaseous toxicants data, in different living/working microenvironments in Rome. The work provides data of population exposure and supports modeling studies for a wide estimate of urban population exposure. Personal exposure measurements on children and elderly people were also included in the study. Three Institutes (CNR-IIA, INAIL, ARPALazio) carried out the field campaigns and collected the data. The methodology was based on active sampling at low volume condition on PTFE filters and gas chromatography/mass spectrometry determination of $PM_{2,5}$-bound PAH's non-volatile congeners, characterized by higher carcinogenic and mutagenic potencies. According to the experimental design, two seasonal in-field campaigns (summer and winter-spring) have been performed by sampling both indoor and outdoor living/working microenvironments. In each seasonal campaign, 20 living environments have been monitored. The main focus was on the carcinogenic PAHs, namely benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene and the mutagenic benzo(ghi)perilene.

The PAH data bases collected in Rome for the Project have been re-arranged on the basis of site and location typology (schools, houses and offices; indoor, outdoor) and year period (winter, spring/summer). The actual concentrations recorded have been compared to those observed contemporarily at the ARPA Lazio Network stations (the results if this comparison are discussed in the Extended Technical Report).

In all, six schools, two offices, and nine houses were investigated as EXPAH stationary sites. In addition, we have considered three mobile sites (two cars and an electricity powered bus). Finally, Montelibretti (office and station lying in the Rome countryside) was investigated during the preliminary phase (see technical report http://www.ispesl.it/expah/documenti/TR_2011_CNR-INAIL.pdf). All measurements foreseen by the Protocol were made.

Absolute concentrations and percent distributions (molecular fingerprints) have been determined as well as the corresponding modulations in space and time.

Fine particulate ($PM_{2.5}$), mono-aromatic VOCs (BTEX), ozone and nitrogen dioxide, organic and elemental carbon were monitored in parallel, in order to discriminate the specific PAH impact on health of exposed segments of population (the results if this study are provided and discussed in the Extended Technical Report). As for the PAHs measured in living environments, the indoor PAHs concentrations were not negligible and of likely outdoor origin. Infact a general good correlation between indoor and outdoor PAHs concentrations was found, with a scarce influence of indoor sources in the monitored living environments. In general during the winter-spring in-field campaign, lasted from December 2011 to March 2012, the average BaP detected indoors ranged from 0.94 (offices) to 1.14 (schools) ng/m^3, and the respective outdoor values ranged from 1.4 and 2.0 ng/m^3. Contemporarily, target PAHs ranged from 6.0 to 7.4 ng/m^3 (indoors), and 8.4 to 13.2 ng/m^3 (outdoors). The typical indoor/outdoor ratio was ~0.7. During the summer campaigns, lasted from May to July 2012, BaP ranged from 0.04 to 0.15 ng/m^3 indoors and 0.06

to 0.19 ng/m^3 outdoors; the target PAHs ranged 0.40÷1.35 ng/m^3 (indoors), and 0.62÷1.52 ng/m^3 (outdoors).

In the public transport system, humans seem to be exposed to PAH levels similar to those typical of outdoor air, whilst in the cars, the indoor exposure can exceed the outdoor one. Personal exposure to benzo[a]pyrene was well below the reference value of 1ng/m^3 (EU Air Quality), ranging from 0.06 ng/m^3 to 0.16 ng/m^3. The average ΣPAHs ranged between 0.45 ng/m^3 and 1.08 ng/m^3. The exposure was mainly experimented in indoor environments, such as schools and houses, and no significant differences in exposure were observed between elderly and children. All personal measurements had the same qualitative distribution of PAHs and the ratios benzo[g,h,i]perylene/benzo[a]pyrene and indeno[1,2,3-cd]pyrene /(indeno[1,2,3-cd]pyrene+benzo[g,h,i]perylene) suggesting that exposure to PAHs in indoor environments in spring and summer is primarily due to vehicular traffic emissions, particularly diesel engines.

The filters collected in three schools and one office were analysed for elements and water-soluble ions. The mass concentration was reconstructed as the sum of five macro-sources (crustal matter, sea-salt, primary anthropogenic, secondary inorganics and organics). Winter results show that $PM_{2.5}$ is mainly composed of organic and primary anthropogenic species with a lower contribution of natural sources (soil and sea-salt. In summer the contribution of the organic and the combustion sources are lower with respect to the winter period. During both the summer and the winter period of low concentration, organics and soil components showed a substantial increase in indoor air with respect to outdoor. These components are probably due to the presence and the movements (dust re-suspension) of the students inside the classrooms. During the winter high-concentration period, this increase is still visible for soil components, while for organics it is hidden by the noticeable increase in outdoor concentration that occurs during atmospheric stability periods (role of secondary reactions during the ageing of the air masses).
In addition, an increase of the contribution of crustal elements in indoor environment with respect to the outdoor mean values is observed. During the winter study the I/O ratio of $PM_{2.5}$ concentration was about 0.8, as a consequence of the low ventilation of the buildings, which reduce the infiltration of outdoor pollutants. During the summer, instead, this I/O ratio was considerably higher (>1). Sulphate was found to have good correlation between indoor and outdoor concentrations, and they can be considered a possible candidate for $PM_{2.5}$ infiltration factor.

In conclusion, the EXPAH PAHs and $PM_{2.5}$ monitoring study has provided important data about the air quality within living/working environments. It demonstrated that significant concentrations of $PM_{2.5}$ and aerosol embedded PAHs can be found in schools, houses and offices as well as in-vehicle transport systems. The main origin of these pollutants is from ambient air. It penetrates within these micro-environments being often resuspended. The infiltration factors depends on the pollutants, the environment and the season. Episodes of indoor concentrations higher than the legal limit (1 ng/m^3) have been observed for the most cancerogeneous PAH (BaP), although in the monitored periods its average value was below this limit.
The following paragraphs describe the average results obtained during the EXPAH seasonal field campaigns in the living/working environments.

NOMENCLATURE

As for site symbols, school acronyms began with "I" letter and houses with "H"; no-special labels were established for the three working places (ARP, OUR and GYM).
Symbols adopted for individual PAHs are as reported in Table here bottom:

compound	***symbol***	***compound***	***symbol***
benz[a]anthracene	BaA	chrysene+triphenylene	CH
benzo[b]fluoranthene	BbF	dibenz[a,h]anthracene	DBahA
benzo[j]fluoranthene	BjF	dibenz[a,c]anthracene	DBacA
benzo[k]fluoranthene	BkF	dibenz[a,j]anthracene	DBajA
BbF + BjF	BbjF	indeno[1,2,3-cd]pyrene	IP
BjF + BkF	BjkF	perylene	PE
BbF + BjF + BkF	BbjkF	carcinogenic PAHs	cPAHs
benzo[e]pyrene	BeP	cPAHs + BPE + CH (genotoxic PAHs)	gPAHs
benzo[a]pyrene	BaP	cPAHs + BPE *(measured by INAIL)*	PAHs1
benzo[g,h,i]perylene	BPE	BaP/PAHs conc. ratio	BaP/PAHs

Volunteers personal data, code and sampling periods.

	Home location	**Code**	**Monitoring interval**
Female	Via Card. Garampi	**VCF**	11-26/04/2012
Female	Via F. Galeotti	**VAP**	11-26/04/2012
Male	Via La Spezia	**VGP**	13/04-02/05/2012 22/09-06/10/2012
Male	Via S.B. del Tronto	**VIB**	12-28/04/2012 22/09-05/10/2012
Male	Via P. Carnera	**VVN**	17/04-09/05/2012
Male	Via Ufente	**VGT**	23/04-07/05/2012
Female	Via Genzano	**VLD**	20/07-07/08/2012
Female	Viale Moliere	**VMA**	15/07-04/08/2012
Male	Via di Tor Chiesaccia	**VSL**	15/10-03/11/2012

&1. PAH measurements in schools

1.1. Winter

Table 1.1 shows the average, minimum and maximum concentrations of PAH congeners measured at all sites by CNR and INAIL during the winter season (N=18). Table 1.2 provides the in/out concentration ratios at the same sites.

Table 1.1. Average PAH contents in $PM_{2.5}$ at schools of Rome in winter. A) outdoor; B) indoor. Data reported as ng/m^3.

A) OUDOOR	**average**	**minimum**	**maximum**
BaA	0.69	0.62	0.73
BbjkF	2.99	1.83	4.13
BaP	1.50	1.36	1.69
IP	1.47	1.29	1.85

DBA	0.19	0.17	0.23
BPE	1.39	0.98	1.68
cPAHs	6.68	5.01	7.86
PAHs1	8.24	6.33	9.54

B) INDOOR	average	minimum	maximum
BaA	0.35	0.11	0.46
BbjkF	2.13	0.44	3.53
BaP	1.13	0.30	1.58
IP	1.15	0.52	1.62
DBA	0.16	0.07	0.23
BPE	1.23	0.40	1.71
cPAHs	4.32	1.00	6.80
PAHs1	6.15	1.84	8.29

Table 1.2. Average PAH indoor/outdoor concentration ratios at schools of Rome in winter

compound	average	minimum	maximum
BaA	0.50	0.19	0.68
BbjkF	0.71	0.23	1.03
BaP	0.76	0.22	1.16
IP	0.82	0.33	1.27
DBA	0.89	0.35	1.34
BPE	0.93	0.32	1.24
cPAHs	0.64	0.19	0.86
PAHs1	0.76	0.27	1.11

Table 1.3 reports the average percent distribution of PAH group at the schools investigated

Table 1.3. Percent distribution of PAH congeners at schools in winter, outdoors and indoors

compound	outdoor		indoor	
	average	std. dev.	average	std. dev.
BaA	8.6	1.1	5.7	0.6
BbjkF	35.2	7.5	32.4	7.7
BaP	18.2	2.5	17.9	2.9
IP	18.4	4.1	20.3	6.1
DBA	2.4	0.4	2.9	0.5
BPE	17.1	1.3	20.9	2.4
cPAHs	80.4	2.9	66.3	12.7

1.2. Spring

Table 1.4 shows the average, minimum and maximum concentrations of PAH congeners measured at all sites by CNR and INAIL during the spring season (N=18). Table 1.5 provides the in/out concentration ratios at the same sites.

Table 1.4. Average PAH contents in $PM_{2.5}$ at schools of Rome in spring. A) outdoor; B) indoor. Data reported as ng/m^3.

A) OUDOOR	average	minimum	maximum
BaA	0.08	0.04	0.17
BbjkF	0.35	0.21	0.47
BaP	0.12	0.07	0.21
IP	0.15	0.10	0.23
DBA	0.03	0.02	0.04
BPE	0.23	0.13	0.34
cPAHs	0.58	0.28	0.87
PAHs1	0.81	0.42	1.21

B) INDOOR	average	minimum	maximum
BaA	0.05	0.02	0.10
BbjkF	0.27	0.12	0.36
BaP	0.10	0.07	0.16
IP	0.12	0.08	0.20
DBA	0.03	0.02	0.06
BPE	0.17	0.10	0.31
cPAHs	0.46	0.21	0.71
PAHs1	0.63	0.30	1.02

Table 1.5. Average PAH indoor/outdoor concentration ratios at schools of Rome in spring

compound	average	minimum	maximum
BaA	0.72	0.58	1.02
BbjkF	0.79	0.61	1.01
BaP	0.84	0.59	1.10
IP	0.79	0.60	0.89
DBA	0.92	0.60	1.55
BPE	0.76	0.43	0.92
cPAHs	0.81	0.72	0.99
PAHs1	0.80	0.64	0.97

Table 1.6. Percent distribution of PAH congeners at schools in spring, outdoors and indoors

compound	outdoor		indoor	
	average	std. dev.	average	std. dev.
BaA	10.5	4.1	9.1	3.4
BbjkF	45.2	7.3	44.3	6.5
BaP	16.6	6.8	16.9	6.8
IP	20.1	6.5	20.6	8.3
DBA	4.5	1.3	4.9	0.6
BPE	28.7	5.1	27.3	7.2
cPAHs	71.3	5.1	72.7	7.2

&2. PAHs measurements at houses

2.1. Winter

Tables 2.1-2.2 show the average concentration values (N=12) for indoor and outdoor environments and in/out ratios, respectively, recorded at the sites. Table 2.3 shows the PAH percent distribution.

Table 2.1. Average concentrations of PAHs at Rome houses in winter. Data are reported in ng/m^3 units. A) Outdoor burdens; B) indoor burdens

A)	average	minimum	maximum
BaA	0.61	0.25	0.82
BbjkF	4.20	2.38	5.65
BaP	1.46	0.63	1.89
IP	1.95	1.27	2.33
DBA	0.20	0.00	0.31
BPE	2.65	2.23	3.05
cPAHs	8.4	4.5	10.8
PAHs1	11.1	6.8	13.8

B)	average	minimum	maximum
BaA	0.21	0.13	0.34
BbjkF	2.40	1.94	3.07
BaP	0.98	0.79	1.33
IP	1.39	1.17	1.64
DBA	0.17	0.14	0.20
BPE	1.78	1.41	2.44
cPAHs	5.2	4.2	6.5
PAHs1	6.9	5.6	8.4

Table 2.2. Average in/out concentration ratios of PAHs at Rome houses in winter

IN/OUT	average	minimum	maximum

BaA	0.51	0.39	0.61
BbjkF	0.67	0.50	0.91
BaP	0.83	0.57	1.23
IP	0.81	0.69	0.96
DBA	0.77	0.73	0.84
BPE	0.74	0.56	0.83
cPAHs	0.72	0.58	0.96
PAHs1	0.71	0.57	0.86

Table 2.3. Percent distribution of PAHs at the houses of Rome in winter

compound	**outdoor**		**indoor**	
	average	**st. dev.**	**average**	**st. dev.**
BaA	4.9	1.4	3.0	0.8
BbjkF	37.7	1.2	34.4	3.0
BaP	12.4	2.0	13.6	1.3
IP	18.0	0.5	20.5	0.8
DBA	1.7	1.1	2.6	0.3
BPE	25.3	4.4	25.9	3.9
cPAHs	74.7	4.4	74.1	3.9

2.2. Spring/summer

Tables 2.4-2.5 show the average concentration values (N=15) for indoor and outdoor environments and in/out ratios, respectively, recorded at the sites. Table 2.6 shows the PAH percent distributions.

Table 2.4. Average concentrations of PAHs at Rome houses in spring-summer. Data are reported in ng/m^3 units. A) Outdoor burdens; B) indoor burdens

A)	**average**	**minimum**	**maximum**
BaA	0.074	0.019	0.199
BbjkF	0.297	0.168	0.539
BaP	0.118	0.031	0.266
IP	0.164	0.073	0.353
DBA	0.026	0.000	0.051
BPE	0.212	0.083	0.424
cPAHs	0.68	0.33	1.34
PAHs1	0.89	0.42	1.74

B)	**average**	**minimum**	**maximum**
BaA	0.038	0.016	0.075
BbjkF	0.215	0.121	0.371

BaP	0.087	0.022	0.219
IP	0.125	0.070	0.322
DBA	0.021	0.000	0.045
BPE	0.171	0.080	0.326
cPAHs	0.49	0.30	1.02
PAHs1	0.66	0.41	1.35

Table 2.5. Average in/out concentration ratios of PAHs at Rome houses in spring-summer

IN/OUT	average	minimum	maximum
BaA	0.63	0.38	0.96
BbjkF	0.76	0.53	1.00
BaP	0.80	0.57	1.35
IP	0.83	0.54	1.35
DBA	0.88	0.58	1.88
BPE	0.86	0.61	1.29
cPAHs	0.77	0.56	1.09
PAHs1	0.79	0.58	1.14

Table 2.6. Percent distribution of PAHs at the houses of Rome in spring-summer

compound	outdoor		indoor	
	average	st. dev.	average	st. dev.
BaA	7.9	3.4	6.0	2.2
BbjkF	34.7	7.0	33.4	7.3
BaP	12.7	3.4	13.0	4.0
IP	18.1	3.8	18.8	3.7
DBA	2.9	1.0	3.2	1.2
BPE	23.7	3.2	25.6	3.0
cPAHs	76.3	3.2	74.4	3.0

&3. PAHs in offices

3.1. Winter

Tables 3.1-3.2 show the average concentration values (N=6) for indoor and outdoor environments and in/out ratios, respectively, recorded at the office sites.

Table 3.1. Average concentrations of PAHs at Rome offices in winter. Data are reported in ng/m^3 units. A) Outdoor burdens; B) indoor burdens

A)	average	st.dev.
BaA	0.80	0.11
BbjkF	5.44	4.07
BaP	2.01	0.38
IP	2.38	0.49
DBA	0.40	0.22
BPE	2.37	1.13
cPAHs	11.0	5.3
PAHs1	13.4	6.4

B)	average	st.dev.
BaA	0.22	0.11
BbjkF	2.21	0.00
BaP	1.09	0.44
IP	1.31	0.20
DBA	0.14	0.19
BPE	1.45	0.03
cPAHs	5.0	1.0
PAHs1	6.4	1.0

Table 3.2. Average in/out concentration ratios of PAHs at Rome offices in winter

B)	average	st.dev.
BaA	0.34	0.13
BbjkF	0.59	0.38
BaP	0.58	0.31
IP	0.56	0.22
DBA	0.58	0.82
BPE	0.68	0.35
cPAHs	0.55	0.32
PAHs1	0.57	0.32

Table 3.3. Percent distribution of PAHs at the offices of Rome in winter

compound	outdoor		indoor	
	average	st. dev.	average	st. dev.
BaA	6.1	2.7	3.3	1.3
BbjkF	36.5	11.1	35.4	6.4
BaP	16.0	4.9	16.3	4.3
IP	19.8	4.8	20.1	0.8
DBA	2.6	0.2	2.0	2.8
BPE	19.0	1.4	22.9	2.8
cPAHs	81.0	1.4	77.1	2.8

3.2. Spring

Tables 3.4-3.5 show the average concentration values for indoor and outdoor environments and in/out ratios, respectively, at the offices (N=6). Table 3.6 shows the PAH percent distributions.

Table 3.4. Average concentrations of PAHs at Rome offices in spring. Data are reported in ng/m^3 units. A) Outdoor burdens; B) indoor burdens

A)	average	st.dev.
BaA	0.06	0.03
BbjkF	0.36	0.09
BaP	0.12	0.09
IP	0.18	0.13
DBA	0.04	0.00
BPE	0.19	0.12
cPAHs	0.76	0.35
PAHs1	0.94	0.46

B)	average	st.dev.
BaA	0.04	0.01
BbjkF	0.20	0.03
BaP	0.08	0.05
IP	0.09	0.06
DBA	0.03	0.01
BPE	0.13	0.09
cPAHs	0.43	0.15
PAHs1	0.57	0.24

Table 3.5. Average in/out concentration ratios of PAHs at Rome offices in spring

B)	average	st.dev.
BaA	0.86	0.41
BbjkF	0.56	0.06
BaP	0.68	0.10
IP	0.53	0.02
DBA	0.73	0.15
BPE	0.71	0.08
cPAHs	0.60	0.08
PAHs1	0.62	0.05

Table 3.6. Percent distribution of PAHs at the offices of Rome in spring

compound	outdoor		indoor	
	average	st. dev.	average	st. dev.
BaA	5.9	0.7	7.6	1.9
BbjkF	40.9	10.1	37.0	9.6
BaP	12.2	3.6	13.1	3.0
IP	17.5	5.2	14.8	4.9
DBA	4.6	2.3	5.7	3.5
BPE	18.9	2.8	21.8	7.1
cPAHs	81.1	2.8	78.2	7.1

&4. PAHs measurements at motor vehicles

4.1 Winter

Table 4.1 summurizes the results of sampling performed in winter at indoor and outdoor vehicles environments. A: Bus; B: Cars. N=10 for bus, N=6 for cars.

Table 4.1. Average PAHs congeners, Minimum, maximum, relative standard deviation. BaP/gPAHs is also reported.

A. BUS	WINTER							
	INDOOR				OUTDOOR			
	Avg	Min	Max	SD %	Avg	Min	Max	SD %
BaA	0.61	0.38	1.10	35	0.70	0.53	0.98	22
BbjkF	1.19	0.69	1.84	30	1.20	0.76	1.57	21
BaP	0.76	0.46	1.39	38	0.65	0.40	0.83	23
IP	0.78	0.47	1.41	34	0.69	0.43	0.91	24
DBahA	0.11	0.07	0.23	43	0.10	0.08	0.14	24
BPE	0.66	0.48	1.02	25	0.62	0.41	0.85	20
gPAHs	4.11	2.73	6.55	29	3.97	2.77	5.23	20
BaP/gPAHs	0.18	0.16	0.21	-	0.16	0.14	0.19	-

B. CARS	WINTER							
	INDOOR				OUTDOOR			
	Avg	Min	Max	SD %	Avg	Min	Max	SD %
BaA	0.56	0.26	0.70	29	1.05	0.25	1.88	55
BbjkF	1.27	0.58	1.92	37	1.89	0.49	3.00	56
BaP	0.92	0.41	1.54	44	1.32	0.30	2.25	59
IP	0.71	0.38	1.13	40	0.92	0.22	1.40	55
DBahA	0.17	0.07	0.29	42	0.19	0.07	0.47	76
BPE	0.94	0.39	1.86	56	1.34	0.28	2.92	69
gPAHs	4.57	2.19	7.31	39	6.72	1.61	11.0	57
BaP/gPAHs	0.20	0.18	0.22	-	0.19	0.18	0.22	-

4.2 Summer

Table 4.2 summurizes the results of sampling performed in summer at indoor and outdoor vehicles environments. A: Bus; B: Cars. N=10 for bus, N=7 for cars.

Table 4.2. Average PAHs congeners, Minimum, maximum, relative standard deviation. BaP/gPAHs is also reported.

A. BUS	SUMMER							
	INDOOR				OUTDOOR			
	Avg	Min	Max	SD %	Avg	Min	Max	SD %
BaA	0.10	0.05	0.23	53	0.11	0.07	0.16	25
BbjkF	0.24	0.13	0.59	70	0.22	0.14	0.52	52
BaP	0.09	0.04	0.24	77	0.09	0.05	0.29	85
IP	0.12	0.05	0.23	55	0.11	0.06	0.28	53
DBahA	0.01	0.00	0.05	316	0.01	0.00	0.09	316
BPE	0.12	0.06	0.28	55	0.13	0.07	0.22	34
gPAHs	0.67	0.33	1.51	62	0.67	0.41	1.54	49
BaP/gPAHs	0.13	0.11	0.18	-	0.12	0.10	0.19	-

B. CARS	SUMMER							
	INDOOR				OUTDOOR			
	Avg	Min	Max	SD %	Avg	Min	Max	SD %
BaA	0.07	0.03	0.11	42	0.11	0.03	0.17	50
BbjkF	0.22	0.14	0.30	24	0.24	0.16	0.30	21
BaP	0.12	0.10	0.14	15	0.13	0.09	0.19	26
IP	0.14	0.09	0.18	27	0.15	0.11	0.22	23
DBahA	0.01	0.00	0.04	171	0.01	0.00	0.06	265
BPE	0.08	0.05	0.12	30	0.13	0.07	0.22	26
gPAHs	0.64	0.46	0.82	20	0.67	0.41	1.54	20
BaP/gPAHs	0.19	0.15	0.22	-	0.12	0.10	0.19	-

4.3 Indoor to Outdoor evaluation

In Figure 4.1 the scatter plot of the indoor versus outdoor gPAHs concentrations of bus is reported. The good correlation (R^2=0.88) indicates that from PAHs sampling results the infiltration factor can be obtained.

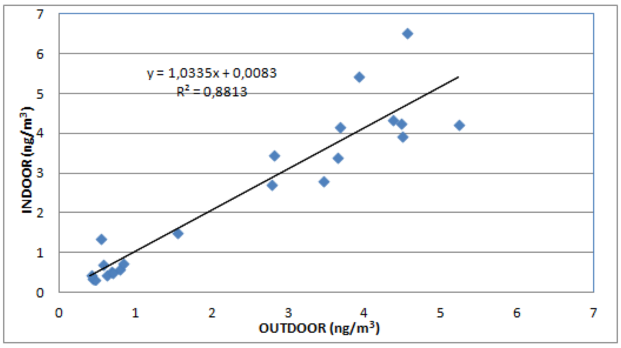

Fig. 4.1 BUS: gPAHs, Indoor vs Outdoor

In Figure 4.2, A and B, the scatter plots of the indoor versus outdoor gPAHs concentrations of cars are reported. The good correlations (R^2=0.95 and R^2=0.92, for car 1 and 2, respectively) indicates that also for cars, from PAHs sampling results the infiltration factor can be obtained.

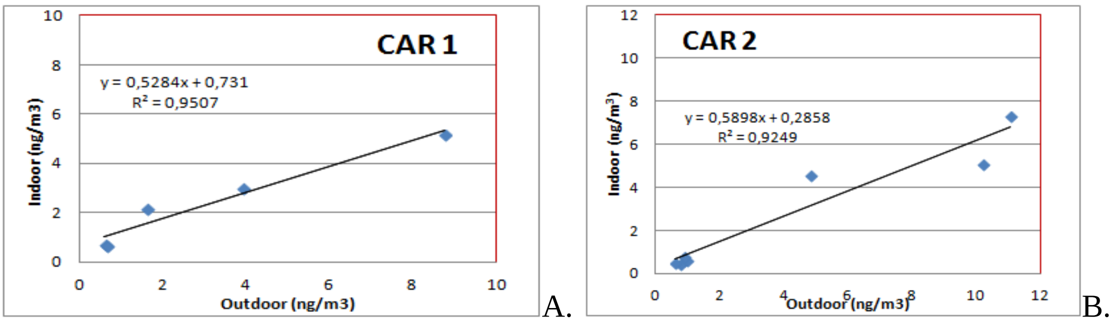

Fig. 4.2 CAR1 (A); CAR2 (B): gPAHs, Indoor vs Outdoor

&5. PAHs exposure measurements on volunteers.

5.1 Spring

Table 5.1 summarizes the results obtained from measurements of volunteers exposure to PAHs from April to May (Spring measurements). The mean concentrations were obtained over 15 daily measurements (N=15). Data are reported in ng/m^3 units. The average, minimum, maximum and relative standard deviation of the mean values (N=6) are also reported.

Table 5.1. PAHs mean values for exposure measurements on volunteers

	BaA	BbjkF	BaP	IP	DBA	BPE	PAHs1	BaP/PAHs1
VCF	0.05	0.23	0.10	0.13	0.02	0.14	0.67	0.15
VTR	0.04	0.22	0.11	0.15	0.02	0.11	0.65	0.16
VVN	0.03	0.15	0.07	0.10	0.02	0.08	0.45	0.16
VAP	0.03	0.21	0.08	0.14	0.02	0.13	0.61	0.13
VIB	0.05	0.22	0.12	0.13	0.03	0.11	0.66	0.19
VGP	0.07	0.29	0.16	0.18	0.02	0.13	0.86	0.18
AVERAGE	*0.05*	*0.22*	*0.11*	*0.14*	*0.02*	*0.12*	*0.65*	*0.16*
Min	*0.03*	*0.15*	*0.07*	*0.10*	*0.02*	*0.08*	*0.45*	*0.13*
Max	*0.07*	*0.29*	*0.16*	*0.18*	*0.03*	*0.14*	*0.86*	*0.19*
STD DEV %	*36*	*21*	*29*	*20*	*18*	*18*	*20*	*13*

In some cases, the difference in exposure during the day hours and the night ones have been also registered. Figure 5.1 shows the day and night profile for some volunteers during the spring in-field campaign.

Fig. 5.1. Day and night gPAhs profile for volunteers in spring.

5.2 Summer/Autumn

Table 5.1 summarizes the results obtained from measurement of volunteers exposure to PAHs from July to early November (Summer/Autumn measurements). The mean concentrations were obtained over 15 daily measurements (N=15). Data are reported in ng/m^3 units. The average, minimum, maximum and relative standard deviation of the mean values (N=5) are also reported.

Table 5.2. PAHs mean values for exposure measurements on volunteers

	BaA	BbjkF	BaP	IP	DBA	BPE	PAHs1	BaP/PAHs1
VIB	0.04	0.20	0.06	0.08	0.02	0.09	0.49	0.13
VGP	0.08	0.27	0.10	0.13	0.03	0.16	0.77	0.13
VSL	0.06	0.34	0.16	0.22	0.06	0.23	1.08	0.15
VLD	0.04	0.21	0.07	0.10	0.03	0.12	0.58	0.12
VMA	0.04	0.19	0.06	0.10	0.02	0.10	0.51	0.12
AVERAGE	0.05	0.24	0.09	0.12	0.03	0.14	0.68	0.13
Min	0.04	0.19	0.06	0.08	0.02	0.09	0.49	0.12
Max	0.08	0.34	0.16	0.22	0.06	0.23	1,08	0.15
STD DEV %	37	26	48	44	58	40	36	10

Also in summer/autumn in-field campaign some results can be referred to day and night measurements. Figure 5.2 shows the relative profiles.

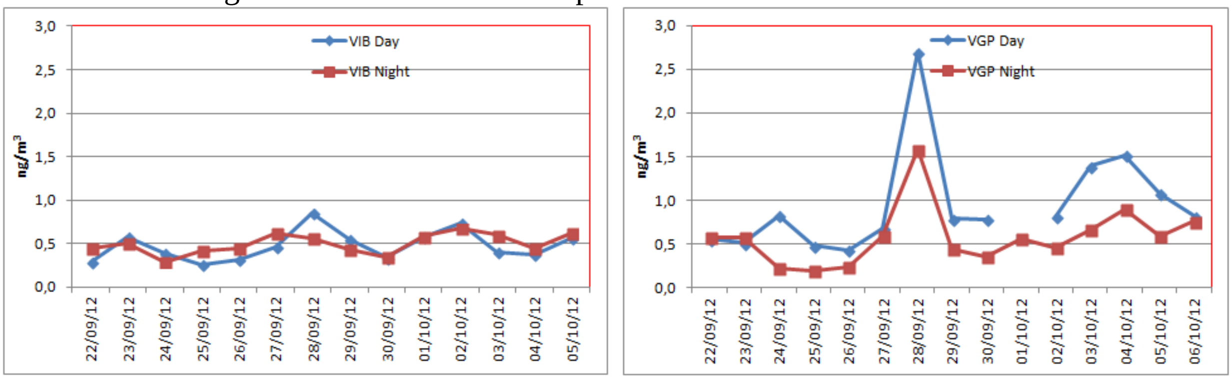

Fig. 5.2. Day and night gPAhs profile for volunteers in summer/autumn.

&6. $PM_{2.5}$ at schools, houses and offices

6.1 Schools

The mean PM contents (N=3) in the air of schools recorded in winter are provided in Table 6.1, while the IN/OUT ratios are reported in Table 6.2. Tables 6.3 and 6.4 show the corresponding data recorded in spring.

Table 6.1. Average outdoor and outdoor concentrations of airborne $PM_{2.5}$ in schools of Rome in winter. A) Nov. 28 ÷ Dec. 22, 2011; B) Feb. 14 ÷ Mar. 09, 2012. Data in μg/m³

A)	OUT		IN	
	average	st.dev.	average	st.dev.
Nov 28	47	8	39	4
Nov 29	59	8	50	8
Nov 30	50	4	38	4
Dec 01	56	8	48	10
Dec 02	49	6	39	10
Dec 03	14	4	12	2
Dec 04	31		25	5
Dec 12	16	4	13	1
Dec 13	16	4	14	1
Dec 14	10	2	8	4
Dec 15	11	0	13	2
Dec 16	21	2		
Dec 17	22	3	10	5
Dec 18	16	7	11	2
Dec 19	30	2	24	3
Dec 20	19	3	16	2
Dec 21	9	2	6	2
Dec 22	59	8	51	8
B)	**OUT**		**IN**	
	average	**st.dev.**	**average**	**st.dev.**
Feb 14	21	2	9	10
Feb 15	19	1	17	10
Feb 16	30	9	12	7
Feb 17	25	11	16	10
Feb 20	15	7	11	2
Feb 21	12	3	9	4
Feb 22	18		9	4
Feb 23	31	4	19	6
Feb 24	30	15	21	6
Feb 27	24	9	9	4
Feb 28	23	5	13	1
Feb 29	34	3		
Mar 1	36	19	21	7
Mar 2	38	2	23	4
Mar 5	23		19	
Mar 6	16		15	
Mar 7	13		11	
Mar 8	13		11	
Mar 9	19		15	

Table 6.2. Average indoor/outdoor concentrations ratios of $PM_{2.5}$ in schools (winter)

Date	IN/OUT		date	IN/OUT	
	average	st.dev.		average	st.dev.
Nov 28	0.79	0.09	Feb 14	0.27	0.21
Nov 29	0.86	0.09	Feb 15	0.78	0.40
Nov 30	0.76	0.03	Feb 16	0.63	0.42
Dec 01	0.84	0.06	Feb 17	0.46	0.32
Dec 02	0.85	0.13	Feb 20	0.62	0.29
Dec 03	0.86	0.17	Feb 21	0.74	0.48
Dec 04	0.65		Feb 22	0.74	0.48
Dec 12	0.89	0.17	Feb 23	0.63	0.32
Dec 13	0.98	0.32	Feb 24	0.60	0.17
Dec 14	0.83	0.41	Feb 27	0.56	0.34
Dec 15	1.22	0.21	Feb 28	0.66	0.18
Dec 16			Feb 29	0.65	0.20
Dec 17	0.46	0.21	Mar 1	0.54	0.26
Dec 18	0.71	0.26	Mar 2	1.04	0.83
Dec 19	0.82	0.06	Mar 5	0.80	
Dec 20	0.84	0.03	Mar 6	0.91	
Dec 21	0.71	0.14	Mar 7	0.80	
Dec 22	0.86	0.09	Mar 8	0.80	
			Mar 9	0.97	

Table 6.3. Average (N=3) outdoor and outdoor concentrations of airborne $PM_{2.5}$ in schools of Rome in spring. May 14 ÷ Jun. 01, 2012. Data in $\mu g/m^3$

date	OUT		IN	
	average	st.dev.	average	st.dev.
May 14	10	3	12	7
May 15	10	2	13	5
May 16	10	5	9	3
May 17	13	14	12	7
May 18	10	4	20	21
May 21	7	1	11	4
May 22	9	4	11	3
May 23	8	2	13	2
May 24	13	3	18	4
May 25	13	2	17	5
May 28	17	1	20	6
May 29	13	3	19	6
May 30	17	5	20	9
May 31	15	3	19	7
Jun 01	13	5	18	4

Table 6.4. Average indoor/outdoor concentrations ratios of $PM_{2.5}$ in schools (spring)

date	IN/OUT	
	average	st.dev.
May 14	1.13	0.42
May 15	1.39	0.68
May 16	1.09	0.41
May 17	1.23	0.80
May 18	2.38	2.68
May 21	1.53	0.55
May 22	1.42	0.62
May 23	1.58	0.40
May 24	1.40	0.22
May 25	1.33	0.22
May 28	1.17	0.27
May 29	1.50	0.42
May 30	1.27	0.54
May 31	1.30	0.53
Jun 01	1.68	1.17

6.2. Houses

The mean PM contents in the air of houses recorded in winter (N=4) are provided in Table 6.5, while the IN/OUT ratios are reported in Table 6.6. Tables 6.7/6.8 and 6.9/6.10 show the corresponding values recorded in spring and summer, respectively.

Table 6.5. Average outdoor and outdoor concentrations of airborne $PM_{2.5}$ in the houses of Rome in winter (Jan. 16 to Feb. 03, 2012). Data in µg/m^3

date	OUT		IN	
	average	st.dev.	average	st.dev.
Jan 16	27	2	30	7
Jan 17	44	6	39	12
Jan 18	62	4	52	20
Jan 19	54	15	54	28
Jan 20	29	7	38	15
Jan 23	35	2	37	6
Jan 24	15	3	26	6
Jan 25	10	0	21	6
Jan 26	24	5	28	7
Jan 27	45	2	47	16
Jan 30	23	6	31	10
Jan 31	30	2	33	4
Feb 01	13	4	29	11
Feb 02	29	4	39	21
Feb 03	13		35	

Table 6.6. Average indoor/outdoor concentrations ratios of $PM_{2.5}$ in houses (winter)

Date	IN/OUT	
	average	st.dev.
Jan 16	1.03	0.07
Jan 17	0.88	0.16
Jan 18	0.84	0.34
Jan 19	1.09	0.38
Jan 20	1.37	0.69
Jan 23	1.09	0.10
Jan 24	1.56	0.13
Jan 25	1.77	0.34
Jan 26	1.14	0.17
Jan 27	1.12	0.43
Jan 30	1.56	0.76
Jan 31	1.17	0.06
Feb 01	2.36	
Feb 02	1.44	0.75
Feb 03	3.20	

Table 6.7. Average (N=5) outdoor and outdoor concentrations of airborne $PM_{2.5}$ in the houses of Rome in spring (Apr. 14 to Apr. 28, 2012). Data in $\mu g/m^3$

date	OUT		IN	
	average	st.dev.	average	st.dev.
Apr 14	17	18	16	4
Apr 15	15	5	16	7
Apr 16	12	3	16	4
Apr 17	16	4	17	5
Apr 18	10	3	12	4
Apr 19	8	2	10	3
Apr 20	8	3	12	9
Apr 21	10	2	11	3
Apr 22	10	3	14	6
Apr 23	12	3	11	3
Apr 24	11	3	11	2
Apr 25	11	3	10	2
Apr 26	16	4	18	9
Apr 27	19	6	16	3
Apr 28	24	5	20	7

Table 6.8. Average indoor/outdoor concentrations ratios of $PM_{2.5}$ in houses (spring)

Date	IN/OUT	
	average	st.dev.
Apr 14	1.63	0.89
Apr 15	1.12	0.34
Apr 16	1.31	0.29
Apr 17	1.08	0.28
Apr 18	1.24	0.29
Apr 19	1.34	0.56
Apr 20	1.36	0.51
Apr 21	1.17	0.41
Apr 22	1.38	0.37
Apr 23	0.94	0.22
Apr 24	1.03	0.23
Apr 25	1.00	0.45
Apr 26	1.13	0.56
Apr 27	0.91	0.21
Apr 28	0.82	0.25

Table 6.9. Average (N=4) outdoor and outdoor concentrations of airborne $PM_{2.5}$ in the houses of Rome during summer. A) Jun. 06 ÷ Jun. 26, 2011; B) Jun 29 ÷ Jul. 19, 2012. Data in $\mu g/m^3$

A)	OUT		IN	
	average	st.dev.	average	st.dev.
Jun 6	12	5	11	4
Jun 7	14	3	11	2
Jun 8	15	2	12	2
Jun 11	13	1	13	4
Jun 12	12	2	9	2
Jun 13	12	2	11	2
Jun 14	11	3	11	4
Jun 15	16	5	13	3
Jun 18	20	4	18	4
Jun 19	21	3	17	1
Jun 20	18	5	15	2
Jun 21	23	6	18	1
Jun 22	21	3	17	6
Jun 25	16	1	18	5
Jun 26	17	1	11	4

B)	OUT		IN	
	average	st.dev.	average	st.dev.
Jun 29	17	3	18	4
Jul 02	14	1	19	9
Jul 03	17	11	20	9
Jul 04	14	3	16	6
Jul 05	23	5	21	9
Jul 06	14	4	29	22
Jul 09	33	39	18	5
Jul 10	14	0	19	6
Jul 11	14	0	25	11
Jul 12	15	3	18	11
Jul 13	14	7	18	11
Jul 16	9	2	13	8
Jul 17	15	9	15	9
Jul 18	14	2	21	8
Jul 19	13	3	14	1

Table 6.10. Average indoor/outdoor concentrations ratios of $PM_{2.5}$ in houses (summer)

Date	IN/OUT		date	IN/OUT	
	average	st.dev.		average	st.dev.
Jun 6	0.93	0.12	Jun 29	0.92	0.15
Jun 7	0.84	0.05	Jul 02	1.39	0.74
Jun 8	0.75	0.13	Jul 03	1.84	1.42
Jun 11	0.97	0.27	Jul 04	1.19	0.55
Jun 12	0.78	0.25	Jul 05	1.10	0.60
Jun 13	0.91	0.12	Jul 06	2.31	1.65
Jun 14	1.04	0.30	Jul 09	1.01	0.61
Jun 15	0.96	0.24	Jul 10	1.32	0.43
Jun 18	0.96	0.38	Jul 11	1.83	1.04
Jun 19	0.83	0.15	Jul 12	1.17	0.79
Jun 20	0.91	0.27	Jul 13	1.31	0.81
Jun 21	0.81	0.18	Jul 16	1.58	1.16
Jun 22	0.85	0.38	Jul 17	1.27	0.97
Jun 25	1.14	0.27	Jul 18	1.40	0.59
Jun 26			Jul 19	1.10	0.36

6.3. Offices

Table 6.11 shows the $PM_{2.5}$ concentrations at offices in winter, and Table 6.12 the corresponding IN/OUT ratio values. Table 6.13 reports the symmetric data collected in spring.

Table 6.11. Outdoor and indoor $PM_{2.5}$ at offices in winter. Data in µg/m^3.

date	OUT	IN	date	OUT	IN
Jan 16	31	12	Feb 14	22	22
Jan 17	63	21	Feb 15	22	22
Jan 18	77	29	Feb 16	21	27
Jan 19		16	Feb 17	32	30
Jan 20		17	Feb 20	13	20
Jan 23		17	Feb 21	9	16
Jan 24	21	11	Feb 22	14	29
Jan 25	15	9	Feb 23	13	29
Jan 26	37	21	Feb 24	32	31
Jan 27	60	20	Feb 27	15	18
Jan 30	25	5	Feb 28	22	21
Jan 31	51	16	Feb 29	29	27
Feb 01		9	Mar 1	35	35
Feb 02	30	11	Mar 2	35	31
Feb 03	14	10			

Table 6.12. Indoor/outdoor concentration ratios of $PM_{2.5}$ at offices in winter.

date	IN/OUT	date	IN/OUT
Jan 16	0.39	Feb 14	1.00
Jan 17	0.34	Feb 15	0.99
Jan 18	0.38	Feb 16	1.29
Jan 19		Feb 17	0.93
Jan 20		Feb 20	1.52
Jan 23		Feb 21	1.83
Jan 24	0.55	Feb 22	2.04
Jan 25	0.60	Feb 23	2.22
Jan 26	0.58	Feb 24	0.97
Jan 27	0.32	Feb 27	1.19
Jan 30	0.19	Feb 28	0.97
Jan 31	0.32	Feb 29	0.93
Feb 01		Mar 1	1.00
Feb 02	0.35	Mar 2	0.88
Feb 03	0.74		

Table 6.13. Outdoor and indoor $PM_{2.5}$ at offices in spring. Concentrations in $\mu g/m^3$.

date	OUT		IN		IN/OUT	
	average	st.dev.	average	st.dev.	average	st.dev.
May 14	12		8	0.4	0.65	
May 15	8	2	10	2	1.27	0.09
May 16	22	19	9	1	0.69	0.64
May 17	4		7	2	1.98	
May 18	10	2	10	3	1.05	0.50
May 21	8	8	6	1	1.49	1.57
May 22	9	2	5	1	0.54	0.23
May 23	10	3	8	3	0.82	0.48
May 24	14	2	13	5	0.92	0.51
May 25	13	4	12	0.0	1.00	0.30
May 28	20	8	13	3	0.73	0.45
May 29	14	3	12	3	0.86	0.38
May 30	16	3	11	3	0.71	0.32
May 31	17	6	13	2	0.86	0.44
Jun 1	12	2	14	2	1.13	0.34

&7. $PM_{2.5}$ at motor vehicles

Tables 7.1 shows the averaged (N=10) $PM_{2,5}$ results for winter and summer, respectively, monitored at the Bus. Indoor and outdoor values are reported. Data in $\mu g/m^3$.

Table 7.1. BUS. Winter - Summer $PM_{2,5}$. Data in $\mu g/m^3$.

	WINTER		SUMMER	
	IN	OUT	IN	OUT
Average	74	49	26	24
Min	67	34	20	15
Max	90	68	33	31
SD%	11	21	18	21

Tables 7.2 shows the averaged $PM_{2,5}$ results for winter and summer (N=6 and N=7), respectively, monitored at both the Car1 and Car 2. Indoor and outdoor values are reported. Data in $\mu g/m^3$.

Table 7.2. $PM_{2.5}$ mean values monitored at cars.

	WINTER		SUMMER	
	IN	OUT	IN	OUT
Average	34	34	26	34
Min	10	26	15	24
Max	51	51	38	40
SD%	46	33	29	16

&8. $PM_{2.5}$ for volunteers measurements

Table 8.1 show the mean $PM_{2.5}$ values monitored during the spring (A) and summer/autumn 2012 (B) for volunteers, with minimum, maximum and relative standard deviation values. N ≅ 15. Data in $\mu g/m^3$.

Table 8.1. $PM_{2.5}$ monitored for volunteers.

A. SPRING	VAP	VCF	VGP	VIB	VTR	VVN
Average	25	17	26	21	14	16
Min	11	11	20	13	7	8
Max	43	25	31	28	19	30
SD%	43	23	14	29	29	45
B. SUMMER/AUTUMN	VLD	VMA	VGP	VIB	VSL	
Average	18	13	21	19	35	
Min	13	7	10	12	20	
Max	22	24	33	25	64	
SD%	18	30	32	24	44	

&9.*Chemical composition of $PM_{2.5}$*

The average chemical composition of $PM_{2.5}$ at the three schools during the two periods are shown in Figures 9.1 (winter) and 9.2 (spring/summer). The analytical data have been re-arranged so as to evaluate the strength of the main PM macro-sources: soil (brown), sea-spray (blue), combustion processes (black), secondary formation of inorganic species (yellow), primary and secondary production of organic matter (green).

Figure 9.1. Average concentrations of the five macro-sources at schools (winter).

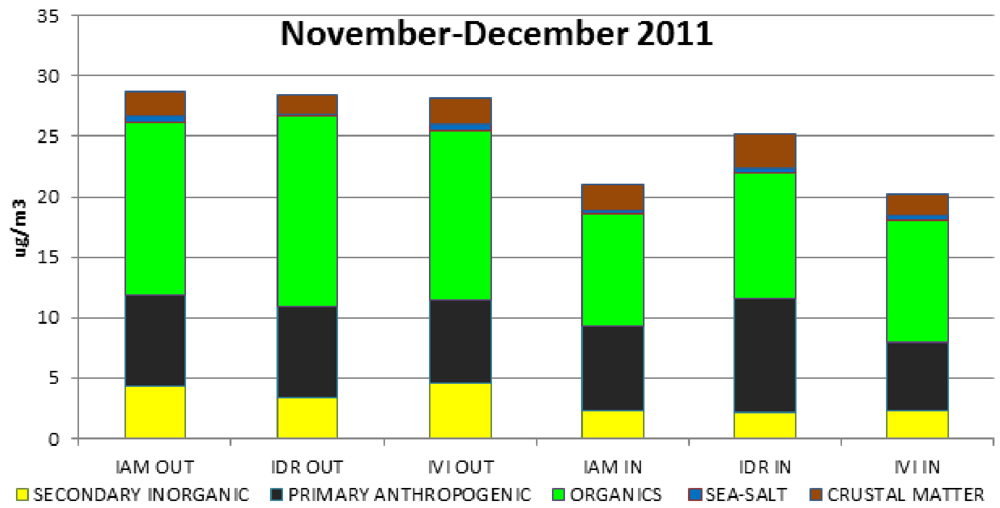

Figure 9.2. Mean concentrations of the five macro-sources at schools (spring/summer).

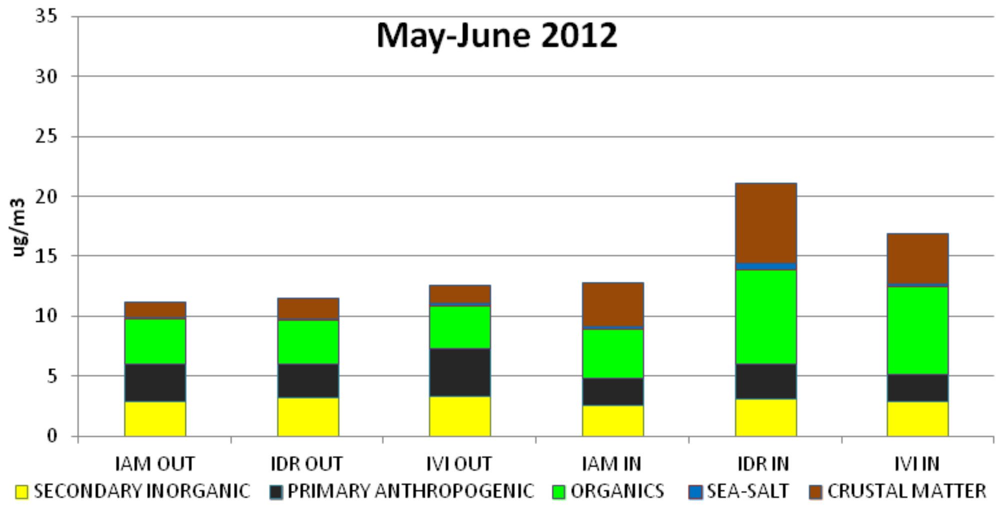

Figure 9.3 reports the scatter plot of indoor and outdoor sulfate concentrations during the two periods. When forcing the intercept to zero,the slope was 0.725 during the winter and 0.917 during the summer, showing that sulfate can be useful to calculate the infiltration factors.

Figure 9.3. Scatter plot of IN/OUT sulphate concentrations in winter and summer