Chemical (Elemental & Organochlorine) and Bacterial Communities Composition of Atmospheric Aerosols during Saharan Dust Events in the Eastern Mediterranean

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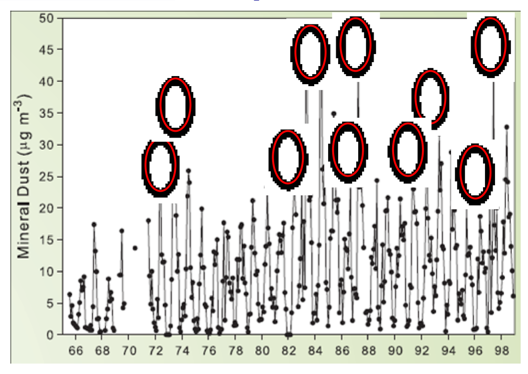
OVERVIEW

The Mediterranean receives large amounts of airborne mineral dust, emitted from the Sahara-Sahel-Chad regions, which affect the climate, human health and ecosystems. (Prospero 2007, Taylor, 2013, Krom 2004)

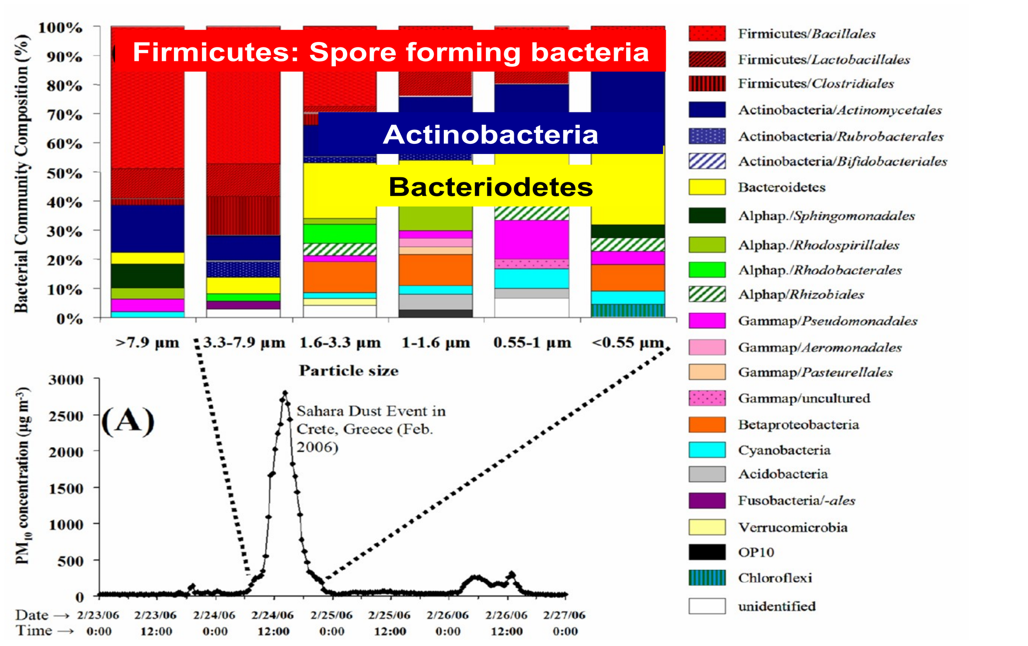
- Dust flux from the Saharan-Sahel region to the atmosphere ca. 1*10⁹ t/y
- In the last decade: amplification of dust loadings.



El Niño events have coincided with increased flux of Saharan dust across the Atlantic.

Over the 1998-to-2004 periods the Saharan dust transport over the Mediterranean has increased.

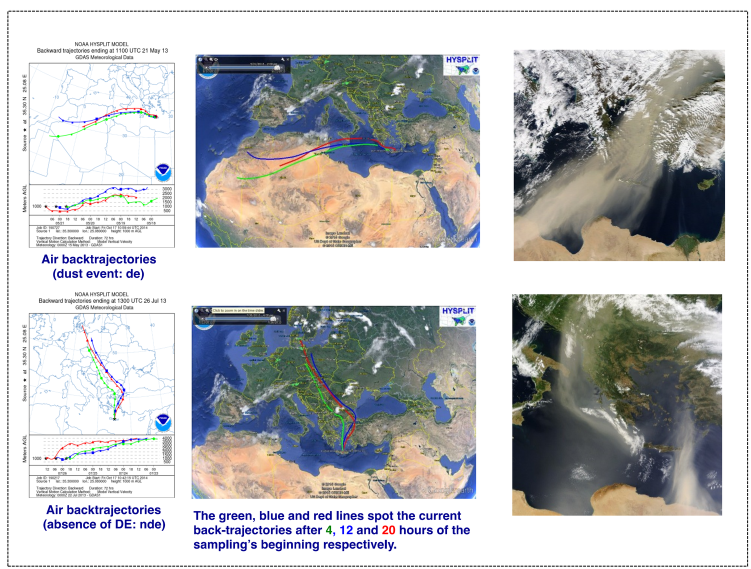
In a previous ECPL study was demonstrated that fine Saharan particles introduce a significant pulse of microorganisms. (Polymenakou et al., 2008)



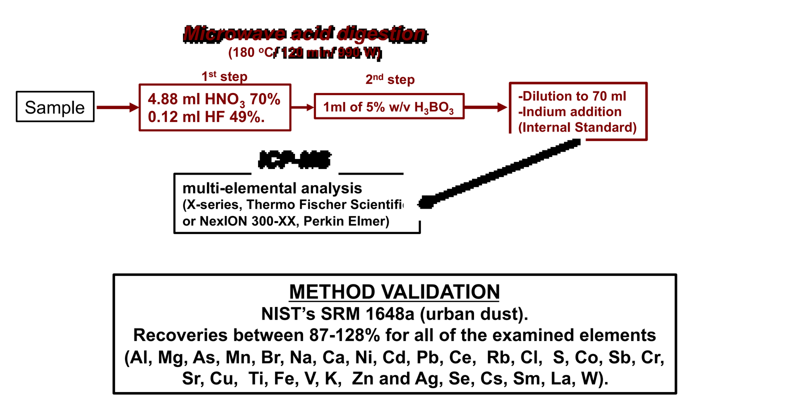
We report a two-year study (2013 & 2014) of the multi-elemental monitoring, of the occurrence of PCBs & OCPs, and of the bacterial composition of aerosols during African dust events on the Island of Crete (Greece).
24-hour sampling sessions have been conducted in a semi-rural area (35° 18'N, 25° 45'E) and PM_{10} and $PM_{2.5}$ samples have been collected.
47 major and trace elements were simultaneously determined in each sample by ICP-MS. 48 PCB congeners and the 10 most common OCPs were determined by GC-NCI/MS. Bacterial composition and diversity was studied by Illumina amplicon sequencing (by targeting the V3-V4 hyper-variable regions of the 16S rRNA gene using primers U341F and 805R). The results were thoroughly studied in view of their relationship with events affected and not affected by African dust.

EXPERIMENTAL

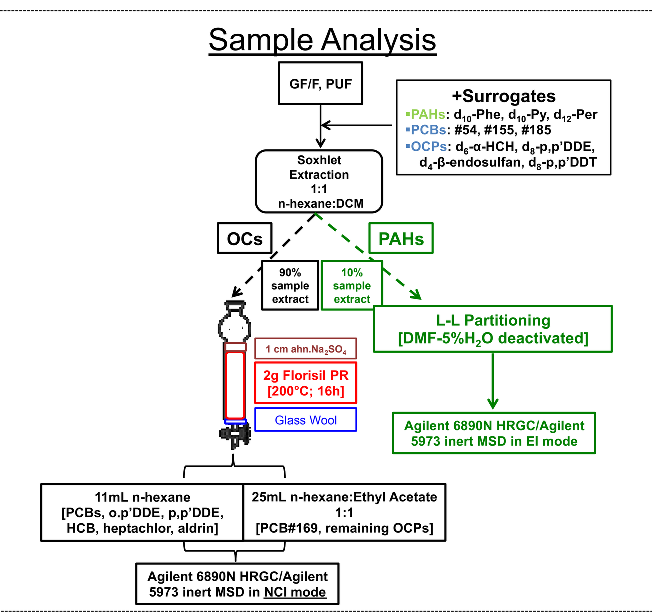
Backward trajectories were calculated with the HYSPLIT model (Draxler, 1994) *and satellite data from MODIS*



Particulate matter elemental analysis



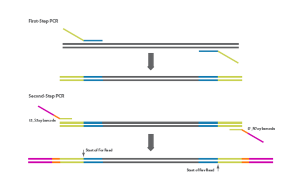
PAHs & POPs analysis



Bacterial Communities Composition analysis

- A MOBIO soil kit was used to extract DNA
- The V3-V4 region of the 16S rRNA gene was amplified
- The samples were analysed using a MiSeq amplicon sequencing approach Each sample had three biological replicates
- In total 519,707 sequences were analyzed using Qiime, Primer6, and PAST

The two step PCR approach



Sampling site during African dust event

RESULTS & DISCUSSION

Elemental composition of $PM_{2.5}$

Concentrations of major and trace elements of $PM_{2.5}$ during African dust events (n=33 samples; *BDL : below limit of detection)*

	Ca	Al	Fe	Na	Mg	K	Mn	Zn	Sr	La	Dy	Pb	Th
	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	ng/m³	ng/m³	ng/m³	pg/m³	pg/m³	ng/m³	ng/m³
min	BDL	0.03	0.04	BDL	BDL	0.06	0.18	BDL	BDL	31.63	BDL	BDL	BDL
max	9.95	5.25	2.75	2.11	1.86	1.46	42.44	50.45	25.42	2433.1	265.4	33.08	0.59
av	1.51	0.95	0.64	0.70	0.38	0.50	9.32	11.49	6.81	530.7	63.2	3.39	0.09

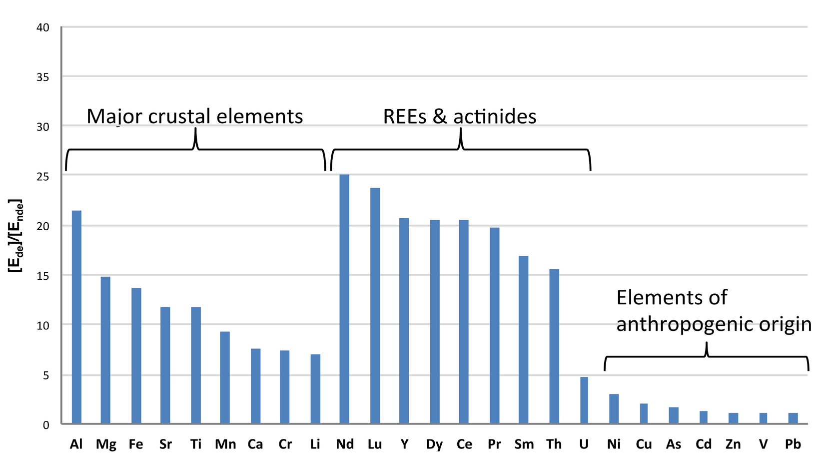
Concentrations of major and trace elements of $PM_{2.5}$ without transferred African dust (n=16 samples) *(BDL :below limit of detection)*

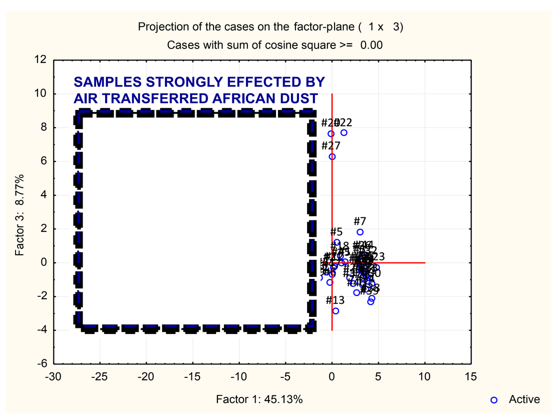
	Ca	Al	Fe	Na	Mg	K	Mn	Zn	Sr	La	Dy	Pb	Th
	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	ng/m³	ng/m³	ng/m³	pg/m³	pg/m³	ng/m³	ng/m³
min	BDL	0.03	0.03	0.10	0.01	0.091	0.012	2.714	0.172	BDL	BDL	0.637	BDL
max	1.41	0.17	0.15	0.39	0.10	0.95	3.80	48.69	2.90	198.3	15.51	6.61	0.03
av	0.31	0.08	0.08	0.22	0.04	0.34	1.63	9.96	0.90	79.4	5.00	2.10	0.01

element	Mg	Mn	Sr	Ce	Pr	Nd
R^2	0.83	0.85	0.86	0.80	0.80	0.80

R squared coefficients comparing the concentrations of elements from $PM_{2.5}$ and the total PM_{10} concentrations for 26 samples. p-value <0.05 for all cases.

$[E_{de}]/[E_{nde}]$: Ratio of selected elements' concentrations of the samples with the highest content of transferred African dust $[E_{de}]$ and the non dust event samples $[E_{nde}]$





2D PLOT OF CASES AFTER PCA ANALYSIS

Factor analysis (PCA extraction, varimax normalized)
Factor 1: African Dust Events
(Factor 2: road traffic (tire abrasion)

	Factor 1
Expl.Var	28.79
Pr	0.99
Nd	0.99
Ce	0.99
Fe	0.99
Mn	0.99
La	0.99
Cs	0.98
Y	0.97
Al	0.97
Dy	0.97
Sm	0.96
Er	0.96
Sr	0.96
Tb	0.96
Mg	0.95
Ho	0.94
Yb	0.92
Eu	0.91
Rb	0.91
Tm	0.91
Gd	0.89
Ca	0.87
Lu	0.84
Li	0.82

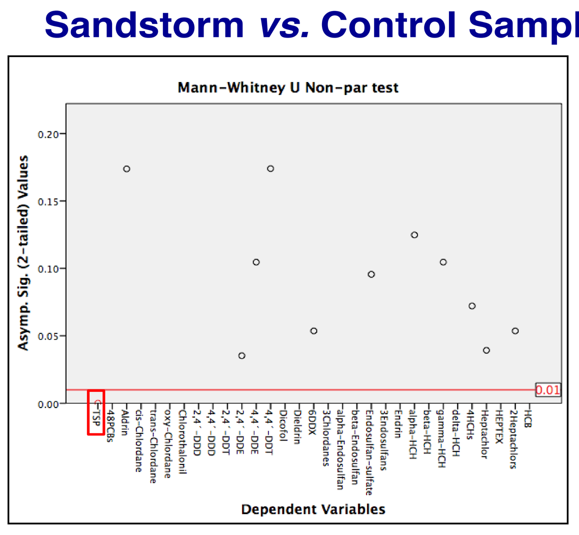
	Factor 2
Expl.Var	6.39
Zn	0.93
Ba	0.84

Green: REEs
Brown: earth's crust elements

POPs and PAHs Aerosol composition

Analyte [Gas+Partcle Phase]	%DF	1st quartile	Median	3rd quartile	Geometric Mean	CV
		[pg/m³]				
Σ_{48}PCBs		44.52	83.35	110.15	71.64	0.51
Aldrin	94	0.03	0.06	0.12	-	1.38
cis-Chlordane	100	0.38	0.49	0.61	0.55	0.82
trans-Chlordane	100	0.30	0.41	0.72	0.49	0.62
oxy-Chlordane	100	0.16	0.22	0.33	0.24	0.58
2,4´-DDD	97	0.09	0.14	0.25	-	0.86
4,4´-DDD	94	0.14	0.55	0.96	-	1.11
2,4´-DDT	94	0.45	1.10	1.78	-	0.95
2,4´-DDE	100	0.43	0.76	1.10	0.72	0.79
4,4´-DDE	100	8.64	14.37	19.40	13.99	0.51
4,4´-DDT	100	2.02	2.75	4.97	3.22	0.80
Dicofol	100	0.72	1.03	9.54	1.79	1.23
Dieldrin	97	1.64	2.25	3.92	2.44	0.85
alpha-Endosulfan	100	1.72	2.95	6.26	3.10	0.79
beta-Endosulfan	100	0.38	0.51	0.86	0.59	0.73
Endosulfan-sulfate	100	0.07	0.17	0.36	0.16	0.85
Endrin	3	<MDL	<MDL	<MDL	-	5.39
alpha-HCH	100	1.57	1.97	3.09	2.43	1.11
beta-HCH	3	<MDL	<MDL	<MDL	-	5.39
gamma-HCH	100	1.25	1.79	2.75	2.00	0.73
delta-HCH	0	<MDL	<MDL	<MDL	-	
Heptachlor	93	0.36	0.62	0.99	0.63	1.18
HEPTEX	100	0.39	0.56	0.80	0.53	0.48
HCB	100	12.40	16.44	22.61	15.92	0.44

Sandstorm *vs.* Control Samples



OCs Concentration differences between Sandstorm-Control samples statistically insignificant [p value>0.01]

Environmental Processes & Potential Sources Estimation

Rotated Component Matrix[a]

	PC1	PC2	PC3	PC4
Initial Eigenvalues	7.645	3.415	1.594	1.220
% of Variance	44.970	20.088	9.375	7.178
Cumulative %	44.970	65.058	74.433	81.612
TSP			-.760	
T	.532	.804		
RH		-.842		
WS			-.753	
AP			.780	
Aldrin			.330	.792
Σ48PCBs	.589	.671		
Σ3Chlordanes	.862	.401		
Chlorothalonil	.718	.363		
Σ6DDX	.749		.403	
Dieldrin				-.822
Dicofol	.802	.397		
Σ3Endosulfans	.817	.447		
Σ4HCHs	.826			.437
Heptachlor	.867			
HCB		-.811		
Σ2Heptachlors	.878			

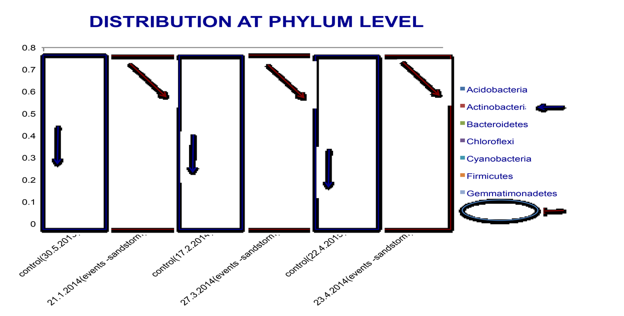
Extraction Method: Principal Component Analysis.
r values <0.3 were excluded from the table
Rotation Method: Varimax with Kaiser Normalization.

Principal Component Analysis:
- Normalized [log_{10} transformed] data
- 4 statistically significant PC factors, which are describing 82% of total data variance

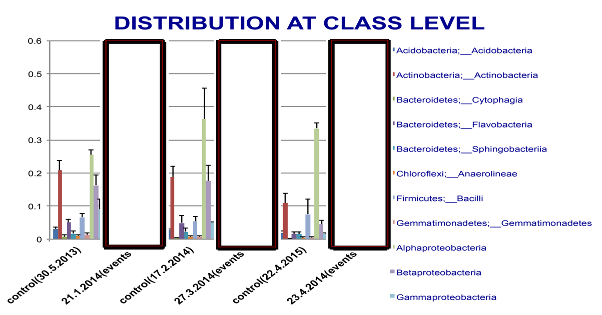
PC factors	PC1	PC2	PC3	PC4
Source Estimation	LRT, Primary Emission Sources	Re-volatilization, Secondary Emission Sources	Wind Dispersion	Aldrin Degradation To Dieldrin [soils, plant surfaces, insects?]

Bacterial communities composition of $PM_{2.5}$

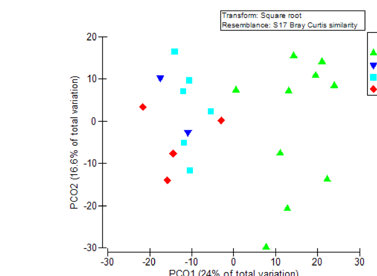
DISTRIBUTION AT PHYLUM LEVEL



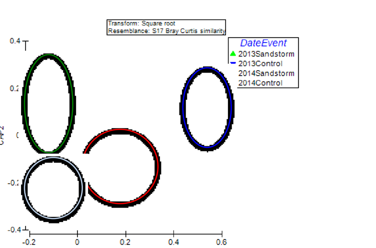
DISTRIBUTION AT CLASS LEVEL



At Phylum level: (*I*) the relative abundance of Proteobacteria is higher during the sandstorm events, (*II*) Firmicutes are reduced during sandstorms, and (*III*) in the last sandstorm Cyanobacteria are drastically reduced Bacterial community composition of sandstorm events
At Class level: (*i*) the relative abundance of Alphaproteobacteria is increasing during the sandstorm events, (*ii*) the level of Actinobacteria is reduced together with Betaproteobacteria



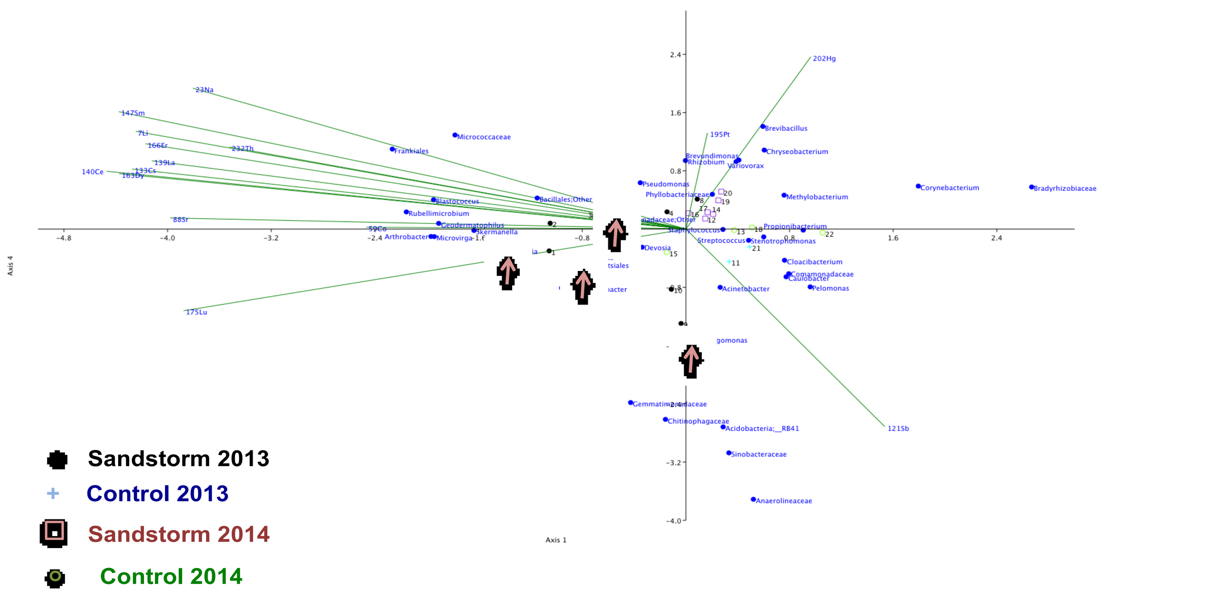
Principal coordinate analysis (PCO) of bacterial communities based on relative abundances of operational taxonomic units (OTUs) with ordinations from sandstorm events and control samples for 2013 and 2014. Variance explained by each PCO axis is given in parentheses.



Canonical analysis of principal coordinates (CAP) ordinations of bacterial communities based on relative abundances of OTUs from sandstorms and control samples from 2013 and 2014. The constrained ordinations show maximized differences among the different treatments.

R^2	No.Vars		
0.89296	15		
Variable	P	Variable	P
^{7}Li	0.001	^{140}Ce	0.001
^{23}Na	0.001	^{147}Sm	0.001
^{59}Co	0.006	^{163}Dy	0.001
^{88}Sr	0.001	^{166}Er	0.001
^{121}Sb	0.009	^{175}Lu	0.001
^{133}Cs	0.001	^{195}Pt	0.007
^{139}La	0.001	^{202}Hg	0.008
		^{232}Th	0.001

CCA: Canonical Correspondence



Canonical correspondence triplot relating bacterial operational taxonomic units (OTUS; blue dots), environmental factors (green lines), and samples (black dots: sandstorms 2013, blue cross: control samples 2013; red squares: sandstorms 2014; green circles: control samples 2014). for bacterial communities based on relative abundances of OTUs. Blue dots represent bacterial OTUs including 15 environmental factors.

Acknowledgements: The work part of the project "CHEMISAND" is implemented under the "ARISTEIA" Action of the "OPERATIONAL PROGRAMME EDUCATION AND LIFELONG LEARNING" and is co-funded by the European Social Fund (ESF) and National Resources.