Saharan dust – a carrier of persistent organic pollutants, metals and microbes to the Caribbean?

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Abstract: An international team of scientists from government agencies and universities in the United States, U.S. Virgin Islands (USVI), Trinidad & Tobago, the Republic of Cape Verde, and the Republic of Mali (West Africa) is working together to elucidate the role Saharan dust may play in the degradation of Caribbean ecosystems. The first step has been to identify and quantify the persistent organic pollutants (POPs), trace metals, and viable microorganisms in the atmosphere in dust source areas of West Africa, and in dust episodes at downwind sites in the eastern Atlantic (Cape Verde) and the Caribbean (USVI and Trinidad & Tobago). Preliminary findings show that air samples from Mali contain a greater number of pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) and in higher concentrations than the Caribbean sites. Overall, POP concentrations were similar in USVI and Trinidad samples. Trace metal concentrations were found to be similar to crustal composition with slight enrichment of lead in Mali. To date, hundreds of cultureable microorganisms have been identified from Mali, Cape Verde, USVI, and Trinidad air samples. The sea fan pathogen, *Aspergillus sydowii,* has been identified in soil from Mali and in air samples from dust events in the Caribbean. We have shown that air samples from a dust-source region contain orders of magnitude more cultureable microorganisms per volume than air samples from dust events in the Caribbean, which in turn contain 3-to 4-fold more cultureable microbes than during non-dust conditions. Rev. Biol. Trop. 54 (Suppl. 3): 9-21. Epub 2007 Jan. 15.

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Since the appearance of disease epizootics on coral reefs 30 years ago, the number of recognized diseases on reefs has increased, as have incidence of and mortality from disease. Diseases have been reported on coral reefs both close to and remote from human activities and populations throughout the Western Atlantic, and increasingly, throughout the world. Of the 29 diseases currently recognized on coral reefs, the causative agents of only a few have been identified (Garrison *et al.* 2005). The basic processes driving the disease epizootics and the lack of recovery on reefs remain essentially unknown. *Aspergillus sydowii,* a common soil fungus, was the first coral pathogen to be identified and was proven to cause sea fan disease (gorgonian aspergillosis) throughout the Western Atlantic (Smith *et al.* 1996, Geiser *et al.* 1998). A periodic source of soil was thought to be essential for gorgonian aspergillosis to occur, as the fungus was not known to reproduce in seawater (Smith *et al.* 1996). Thus, the presence of sea fan disease on reefs of carbonate islands lacking soil begs the question: What is the source of soil and the pathogenic fungus?

Every year, billions of tons of eroded mineral soils (dust) are carried from the Saharan Desert and the Sahel, via the Saharan Air Layer, to the Americas, the Caribbean, Europe and the Near East. The quantity of soil eroded, lifted into the atmosphere and transported long distances varies with global climate, tropical sea surface temperatures, regional meteorology, surface composition, and land use in the dust source region (e.g., Nickling and Gillies 1993, Tegen and Fung 1994, 1995, Tegen *et al.* 1996). Saharan dust has been transported across the Atlantic for millions of years, depositing nutrients (primarily phosphorus) to the Amazon Basin (Swap *et al.* 1992), red-clay soils to the limestone islands of the Caribbean (Muhs *et al.* 1990), freshwater diatoms and phytoliths to the seafloor off the coast of West Africa (e.g., Maynard 1976), and iron that periodically triggers red-tides in the Gulf of Mexico (Lenes *et al.* 2001, Walsh and Steidinger 2001). When the dust reaches the Caribbean, the average dust particle is less than 2.5 µm in diameter. African desert locusts (*Schistocerca gregari*) periodically make the journey from West Africa to the Windward Islands of the Lesser Antilles in Saharan dust air masses (Rosenberg and Burt 1999). At times, a continuous cloud of Saharan dust extends from West Africa to Central America, South America and north to the southeastern U.S. (Fig. 1). Could Saharan dust be a source of soil and pathogens to the Caribbean region? We hypothesized that Saharan dust (also referred to as African dust) carries viable microorganisms, including pathogens, nutrients such as iron, persistent organic pollutants, and metals across oceans and that these contaminants play a role in the degradation of downwind ecosystems, including Caribbean coral reefs (Shinn *et al.* 2000, Garrison *et al.* 2003). Over the past forty years, the quantity of dust transported from Africa to the Americas has been shown to have increased (e.g., Prospero and Nees 1986). At the same time, the composition of the dust air masses may have changed due to pesticide use, changes in land use, and the burning of synthetic materials and biomass (fuel) in the dust source regions and in the areas over which dust air masses pass (Garrison *et al.* 2003). Here we present preliminary data on the POPs and metals associated with African dust air masses in the Caribbean and a source region in Africa, and review microbial research findings from our international team of scientists studying this complex topic.

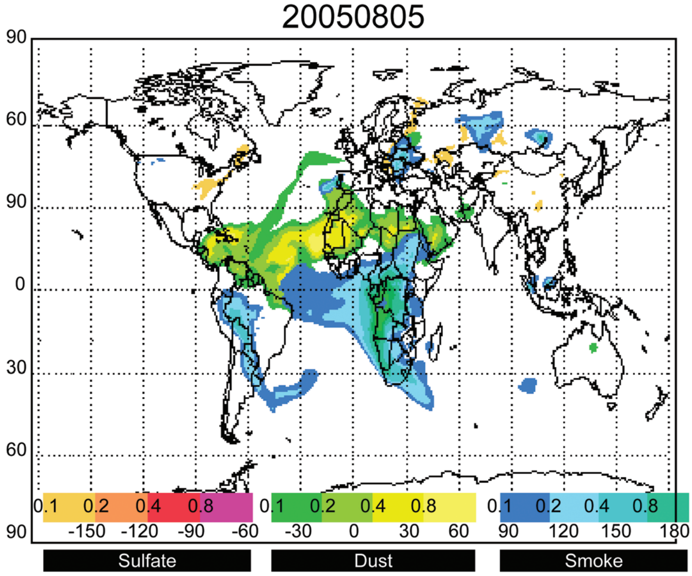

Fig. 1. Navy Aerosol Analysis and Prediction System Global Aerosol Model (Naval Research Laboratory, Monterey, CA): aerosol optical depth on 5 August 2005. Dust from the Sahara (green to yellow in color) extends from West Africa to Central America, covering the tropical Atlantic and Caribbean Sea.

Fig. 1. Análisis de Aerosoles de la Naval y Sistema de Predicción Modelo Global de Aerosoles (Laboratorio de Investigación Naval, Monterey, California, EEUU): profundidad óptica del aerosol el 5 de agosto de 2005. El polvo del Sahara (color verde a amarillo) se extiende desde África oeste hasta América Central, cubriendo el Atlántico tropical y el Mar Caribe.

MATERIALS AND METHODS

Sampling: African dust samples were collected periodically from August 1997 to the present for microbial analysis and from December 2001 for chemical analysis. Sampling sites were established in a dust source region (Bamako, Republic of Mali) and downwind in the eastern Atlantic (Cape Verde) and the Caribbean (St. John and St. Croix, USVI; Trinidad) (Table 1). Data presented here from downwind sites are from air samples collected only when the wind was from the east to southeast and Saharan dust was observed in the atmosphere; presence of Saharan dust was confirmed by the presence of reddish-brown particles with high Fe content on filters. Samples for microbial analysis reported here were collected by vacuum filtering 0.2 to 0.4 m^3 air (12 min sampling period at 0.018 to 0.033 $m^3\ min^{-1}$) using pre-sterilized filter housings containing 47 mm, 0.2 µm pore-size filter membranes (Griffin *et al.* 2001); samples were sent to two microbiology laboratories (USGS, St. Petersburg, FL and the Marine Microbial Ecology Laboratory, University of South Carolina Aiken) for analyses. Samples for persistent organic-pollutant analysis were collected by filtering 150 to 1 000 m^3 air through 90 mm glass-fiber filters (GF/F; particle phase) and two solvent-extracted polyurethane-foam plugs (PUF, vapor phase) in Teflon cartridges; samples were frozen and sent to two analytical laboratories (USGS National Water Quality Laboratory, NWQL, and the Simonich Environmental Chemistry Laboratory, Oregon State University) for POP analysis and to one contract laboratory for dioxins and furans analyses. Samples for metals analysis were collected by filtering 200-1 000 m^3 air through 90 mm quartz-fiber filters (QF/F; preconditioned at 600ºC for 5 hr) and sent to a USGS laboratory (Denver) for analysis.

Analyses: Samples were analyzed for viable microorganisms, persistent organic pollutants [pesticides, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs)], metals, stable isotopes, minerals, and particle-size distribution. Mineralogy and particle-size distribution were determined for two samples only, due to the relatively large quantities of sample required for those analyses and the normally low quantity of particles collected.

Microorganisms and Metals: Microorganisms collected on filters were cultured and colonies isolated, identified, and in some cases tested for pathogenicity, as detailed in

TABLE 1
The locations of 2001-2004 Saharan dust sampling sites

CUADRO 1
Ubicación de los puntos de muestreo de polvo Sahariano del 2001-2004

	Bamako, Mali	Bamako, Mali	Sabbat Point, St. John	Lind Point, St. John	Grass Point, St. Croix	Galera Point, Trinidad
Sampling site	American International School (AISB)	Emetteur Kati	Windward coast	meteorology station, leeward side of island	SE windward side of island	Lighthouse, NE Trinidad
Sampling period	Dec 2001 – May 2003	Feb 2004 - present	Feb 2001 – July 2002	July 2002 – Dec 2004	June – Dec 2004	Feb 2004 - present
Latitude	12.5º N	12.7º N	18.3º N	18.3º N	17.7º N	10.8º N
Longitude	8.0º E	8.0º W	64.7º W	64.8º W	64.6º W	59.9º W
Elevation	380 m	554 m	25 m	53 m	12 m	70 m

Griffin *et al.* (2001) and Weir-Brush *et al.* (2004). Metals were analyzed by using inductively coupled-plasma mass spectrometry (ICP/MS; U.S. Environmental Protection Agency 1999), instrumental neutron activation analysis (INAA, Baedecker 1987) and/or graphite-furnace atomic-absorption spectrometry (GF-AAS).

Persistent organic pollutants: Analysis of persistent organic pollutants was conducted using standard or modified USGS NWQL methods and as described in Killin *et al.* (2004). Air samples were solvent extracted using a soxhlet apparatus or accelerated-solvent extraction, and compounds were separated using various adsorption chromatography or solid-phase extraction procedures as needed. Gas chromatography with electron-impact mass spectrometry (GC/EIMS) methods were used to determine a suite of current-use pesticides and degradates (Foreman *et al.* 2000, Majewski *et al.* 2000) and selected PAHs, phthalate plasticizers, and other organic compounds (Zaugg *et al.* 2002). Gas chromatography with either electron-capture detection or electron-capture negative-ionization mass spectrometry was used to determine chlorinated pesticides and PCBs (Patton *et al.* 1989). Dioxins and furans (PCDD/Fs) were analyzed by a contract laboratory using USEPA TO-9A and 8290 methods (U.S. Environmental Protection Agency 1998, 1999).

Quality control: Field-blank samples were collected at each site for each sample type. Triplicate microbial samples and a control were routinely collected. Duplicate POP samples were collected to the extent funding and sampling equipment allowed. Laboratory method blanks and spike recovery experiments were performed in all laboratories to control for contamination and to characterize method performance for POP analytes.

PRELIMINARY RESEARCH FINDINGS

Microorganisms: As of August 2005, preliminary identification has been made of >300 taxa of microorganisms cultured from air samples collected at St. Croix, St. John, and Trinidad during dust and non-dust conditions. Identifications are ongoing. Air samples collected during dust events in the USVI contain approximately 3-4 times as many cultureable microorganisms per volume as do air samples collected during non-dust conditions (Griffin *et al.* 2003, Griffin and Smith unpublished data). Of those microorganisms identified to date, 25% are known plant pathogens and 10% are known opportunistic pathogens of humans (Griffin *et al.* 2001, 2003). Air in Mali (a source region) contains orders of magnitude more microorganisms per volume than air sampled in the downwind areas (USVI and Trinidad) and a higher microbial species richness (Kellogg *et al.* 2004, Smith unpublished data). Of the hundreds of microorganisms cultured and isolated from Sahara and Sahel (Mali, West Africa) air samples, DNA sequencing has been used to identify 50 taxa of bacteria (and three genera of fungi; Kellogg *et al.* 2004), and preliminary identifications have been made on >100 additional taxa of bacteria and fungi (Smith unpublished data). Of the cultureable bacteria identified thus far from source regions, 10% are known animal pathogens, 5% are plant pathogens, and 27% are opportunistic human pathogens (Kellogg *et al.* 2004). The pathogenic strain of the fungus (*A. sydowii*) proven to cause sea fan disease and mortality of sea fans throughout the Caribbean region (Smith *et al.* 1996, Geiser *et al.* 1998) has been isolated by Smith from: 1) lesions of diseased sea fans; 2) air samples collected in the USVI during African dust conditions but not from non-dust periods (Weir-Brush *et al.* 2004, Smith unpublished data); 3) soil from the Sahel (Mali; Smith unpublished data); and 4) sediment from the

Gulf of Paria (SE Caribbean) near the mouth of the Orinoco River (Smith unpublished data).

Persistent organic pollutants: Nine pesticides, 17 PAHs, and nine PCBs have been identified in air samples from a dust-source region in the African Sahara/Sahel (Mali) and downwind sites in the U.S. Virgin Islands (St. Croix and St. John) and Trinidad (Tables 2a & 2b). One pesticide (Profenofos) and four PAHs were detected only in dust-source region samples (Tables 2a & 2b). Of the more than 100 analytes screened for in the samples, three pesticides [Chlorpyrifos, Endosulfan I, and hexachlorobenzene (HCB)] were detected in samples from each of the sites (Table 2a). Components of chlordane were detected from all Atlantic sites, and DDE (a breakdown product of DDT) was identified in Mali, St. John, and Trinidad samples. To date, DDT has been detected only in samples from Mali. Air samples from Mali contained a greater number of pesticides, PCBs, and PAHs (Tables 2a and 2b) and in higher concentrations than the Caribbean site samples with the exception of the pesticide Dacthal (Garrison unpublished data). The higher concentration of Dacthal in one St. John sample indicates local use of the pesticide. Local or regional use is also indicated by the frequency of occurrence of chlordane and dieldrin (and preliminary concentration data) from Lind Point (St. John) samples (Table 2a). Overall, POP concentrations were similar in USVI and Trinidad samples. Unexpectedly, dioxins and furans were detected only in the Mali samples, and none were detected in any of the Caribbean or Cape Verde samples. Only nine of the 139 PCB congeners screened for were detected in Mali and Caribbean samples, with seven in Mali and five in Caribbean samples (Table 2b). Similarly, a greater number of PAH analytes were detected in Mali samples (Table 2b). Interestingly, anthracene, a product of biomass combustion that is used to determine residence time of PAHs in the atmosphere, was detected only in samples from Mali (Table 2b). Chemicals from the breakdown of PUF sampling media interfered with PAH detection in a few of the samples collected early in the project, thereby decreasing the total number of samples analyzed for PAHs. All of the POPs detected are known toxins, carcinogens, immune system suppressants, or are known or suspected endocrine disruptors (Table 3). Pesticide, PCB, and PAH results are not yet available for 2005 samples (Cape Verde, St. Croix, and Trinidad).

Metals: Lead concentrations were elevated in all samples collected at the AISB site in Bamako, Mali. Concentrations of all other metals in dust aerosols at source and downwind sites were found to be similar to the Earth's crust and soils.

DISCUSSION

All of the POPs and trace metals detected in this study can be transported through the atmosphere and are known to sorb to soils. Preliminary patterns of POP occurrence (Tables 2a & 2b) and concentrations in air found in this study suggest that Saharan dust air masses are the likely source of atmospheric POPs at the downwind Caribbean sites; supporting data will be published in the near future. The striking similarity in the suite of organics detected at all sites and, in most cases, the much lower concentrations at downwind sites, support an African-Caribbean atmospheric transport link. Preliminary data from the Lind Point site indicate local or regional upwind use of Dacthal, although this current-use pesticide was detected only once at the site (Table 2a) and at a higher concentration than in Mali or other sites. Initial findings from the Lind Point site also indicate a possible regional upwind source of Dieldrin and Chlordane, although concentrations were higher in Mali samples. Use of these pesticides was banned in the U.S. years ago (Dieldrin in 1987 and Chlordane in 1988) because they are highly toxic and known to persist in the environment for decades. Detecting pesticides that were banned in the U.S. years ago was not a surprise: chlordane is exported for use in a few

TABLE 2a

Fraction of samples with pesticides or dioxins/furans detected in blank-corrected air samples (2001 - 2004) from a dust-source region (Mali) and downwind sites in the Caribbean [St. John and St. Croix (USVI) and Trinidad]

CUADRO 2a

Fracción de las muestras con pesticidas o dioxinas/furanos detectados en muestras de aire corregidas con un blanco (2001-2004) de un sitio fuente de polvo (Mali) y sitios en la dirección del viento en el Caribe [St. John y St. Croix (USVI) y Trinidad]

	Bamako, Mali	Sabbat Point, St. John	Lind Point, St. John	Grass Point, St. Croix	Galera Point, Trinidad
Pesticides					
Number of samples	19	6	9	6	12
Controls	5	2	6	3	5
cis - chlordane	0.20	1.00*	0.77	0.17	
trans - chlordane	0.58	1.00*	0.88	0.83	0.09
cis - nonachlor		1.00*	0.56	0.17	
trans – nonachlor	0.37	0.67*	0.88	0.33	
Chlorpyrifos	0.84	1.00	0.88	1.00	0.67
Dacthal	0.11		0.11	0.33	0.09
o,p'-DDD	0.05				
p,p'-DDD	0.16				
p, p'-DDE	0.84		0.11		0.09
p, p'-DDT	0.16				
Diazinon	0.37		0.11		
Dieldrin	0.53		0.67		
Endosulfan I	1.00	1.00	0.77	1.00	0.83
Endosulfan II	1.00		0.67	0.17	0.09
Endosulfan sulfate	1.00				0.09
Hexachlorobenzene	0.68	1.00	0.56	1.00	0.83
Profenofos	0.21				
Dioxins and furans					
Number of samples	5	2	1	0	1
Controls	2	1	1	0	1
All TCDD	0.60				
All HxCDD	0.60				
1, 2, 3, 4, 6, 7, 8 - HpCDD	0.60				
other HpCDD	0.60				
OCDD	0.60				
2, 3, 7, 8 - TCDF	0.60				
other TCDF	0.60				
All PeCDF	0.60				
1, 2, 3, 4, 7, 8 - HxCDF	0.20				
other HxCDF	0.60				
1, 2, 3, 4, 6, 7, 8 – HpCDF	0.60				

* indicates detected but below quantification limits. To facilitate interpretation, cells were left empty for POPs "not detected."

* indica detecciones por debajo de los límites de cuantificación. Para facilitar la interpretación, se dejaron vacías las celdas donde los POPs no fueron detectados.

TABLE 2b

Fraction of samples with polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) detected in blank-corrected air samples (2001 – 2004) from a dust-source region (Mali) and downwind sites in the Caribbean [St. John and St. Croix (USVI) and Trinidad]

CUADRO 2b

Fracción de las muestras con bifenilos policlorinados (PCBs) e hidrocarburos policíclicos aromáticos detectados en muestras de aire corregidas con un blanco (2001-2004) de un sitio fuente de polvo (Mali) y sitios en la dirección del viento en el Caribe [St. John y St. Croix (USVI) y Trinidad]

	Bamako, Mali	Sabbat Point, St. John	Lind Point, St. John	Grass Point, St. Croix	Galera Point, Trinidad
PCBs					
Number of samples	19	6	9	6	12
Controls	5	2	6	3	5
101					0.08
110					0.08
118	0.32		0.33	0.16	0.33
138	0.47				0.33
153	0.32		0.22	0.33	0.17
174	0.05				
180	0.21				
183	0.37				
187	0.26				
TOTAL PCBs		0.50			
PAHs					
Number of samples					
Controls	15	6	9	5	4
	4	2	6	3	1
Acenaphthene	0.07				
Anthracene	0.60				
Anthraquinone	0.60				
Benzo(a)anthracene	0.40		0.11		0.50
Benzo(b)fluoranthene	0.40		0.11		0.75
Benzo(k)fluoranthene	0.33		0.11		0.50
Benzo(a)pyrene	0.33				0.25
Benzo(e)pyrene	0.40		0.44		0.50
Benzo(ghi)perylene	0.13		0.22		0.25
Chrysene+Triphenylene	0.40			0.60	0.50
Dibenz(a,h)anthracene	0.07				
Fluoranthene	0.67	1.00*	0.77	0.80	0.7
Fluorene	0.27				1.00
Indeno(1,2,3-cd)pyrene	0.33		0.22		0.25
Phenanthrene	0.67	1.00*	0.88	1.00	1.00
Pyrene	0.67	1.00*	0.88	1.00	1.00
Retene	0.27		0.44	1.00	0.50

* indicates detected but below quantification limits. To facilitate interpretation, cells were left empty for POPs "not detected."

* indica detecciones por debajo de los límites de cuantificación. Para facilitar la interpretación, se dejaron vacías las celdas donde los POPs no fueron detectados.

countries; DDT is currently approved for use against agricultural pests and disease vectors (e.g. mosquitoes) in areas such as Mali; and, POPs and their degradates can persist in the environment for decades. Unfortunately, due to extreme logistical difficulties and funding constraints, we do not have time-series samples of a dust air mass as it traverses the Atlantic from Mali to the Caribbean.

The PAH anthracene is an indicator of recent combustion of biomass, and the anthracene/phenanthrene ratio is often used to date the relative "age" of the air mass. The absence of detectable anthracene in the Caribbean samples and its presence in Mali indicates the air masses sampled in the Caribbean had "aged" and/or traveled some distance since the combustion occurred and that locally-generated PAH contamination is unlikely. The lack of anthracene combined with the presence of other longer-lived PAHs, presence of reddish-brown particulates, meteorological data (strong easterly winds), and back trajectory atmospheric models all indicate the air masses sampled in the Caribbean originated in western Africa.

The PCBs most commonly detected in the air samples from this study (PCB 118, 138 and 153) were also the predominant congeners reported in marine organisms and sediment from French Frigate Shoals, North West Hawaiian Islands (Miao *et al.* 2000) and in other marine studies (Bavel *et al.* 1996, Hope *et al.* 1997). These PCBs are known to suppress immune systems (de Stewart *et al.* 1996), resist degradation by invertebrates and fish, and bioaccumulate in marine and terrestrial organisms (Bright *et al.* 1995). The authors of these studies suggested long-range atmospheric as a probable source of PCBs to these remote areas. The similarity in the types of PCBs found in the atmosphere over the eastern Caribbean and in coral reef-associated organisms in the remote Pacific is a coincidence that needs to be investigated.

Deposition from long-distance transport is considered the major pathway by which persistent organic pollutants enter the oceans (Atlas and Giam 1986). Little is known of the acute or chronic effects of chlordane, DDT and degradates, diazinon, dieldrin, dioxins and furans, endosulfans, HCB, PAHs, or PCBs on coral reef plants or animals, although concentrations in marine-organism tissue have been reported. Chlorpyrifos, a widely used pesticide and potent neurotoxin to a wide range of organisms (Table 3), is reported to interfere with reproduction and settlement of coral larvae in ppb concentrations (Richmond 1997). DDT at concentrations of 2 ppb in seawater shuts down photosynthesis in phytoplankton (Wurster 1968), an effect with serious implications to global biosphere function. Each of the pesticides, PCBs and PAHs identified in dust air masses in this study is a top priority pollutant, known to be highly dangerous to humans and other organisms (e.g., http://oaspub.epa.gov/wqsdatabase/wqsi_epa_criteria.rep_parameter): each persists in the environment, bioaccumulates, is toxic and/or carcinogenic, or interferes with physiological processes at very low concentrations (Table 3). A potentially significant and relatively unexplored research topic is the synergistic effect of combinations of organochlorine pesticides. Enhanced toxicity, exceeding the sum of individual toxicities, has been reported (Soto *et al.* 1994). Thus, it is possible that the "stews" of POPs associated with dust may be more highly toxic than individual concentrations predict.

Mercury, lead, cadmium, nickel, copper, and zinc are recognized trace-metal pollutants. Lead was the only trace-metal pollutant we found in concentrations exceeding normal crustal composition, and this occurred only in samples collected at the first Mali site, situated in a river valley. The elevated lead concentration most likely came from the ongoing use of lead as a gasoline additive in Mali (Diara 1997) and appeared to remain localized in the river valley. Pb is still used as a gasoline additive in Trinidad and Tobago. However, the low levels of Pb in the Trinidad samples and the similarity to USVI sample concentrations indicate that the air masses sampled were not contaminated by local sources. Metal concentrations within normal crustal composition do not rule out toxicity effects, especially from potent biocides such as

TABLE 3

Class, use, toxicity, persistence in the environment, and status of persistent organic pollutants detected in 2001-2004 dust air samples

CUADRO 3

Clase, uso, toxicidad, persistencia en el ambiente y estatus de contaminantes orgánicos persistentes detectados en muestras de polvo de 2001-2004

	Class of compound	**Use**	**Toxicity**	**Persistence**	**Status**
Chlordanes	Organochlorine pesticide	Termites, other insect pests	Carcinogen, liver toxin, neurotoxin, endocrine disruptor.	Half-life > 20 yrs.	Banned 1988 USA; exported
Chlorpyrifos (Dursban, Lorsban)	Organophosphate pesticide	Termites, mosquitoes, and insecticide for lawns, ornamentals and crops	Neurotoxin, suspected teratogen and endocrine disruptor; potent toxin to aquatic organisms.	Half-life of days in the environment.	Current use
Dacthal	Herbicide with contaminants: HCB & 2, 3, 7, 8 – TCDD (most toxic dioxin)	Lawns, crops	Low toxicity but contaminants highly toxic; see HCB and dioxins/furans.	See for dioxins/ furans and HCB.	Current use
Diazinon	Organophosphate pesticide	Farms, crops, ranch insecticide	Cholinesterase inhibitor; neurotoxin; immune suppression suspected.	Half-life < 3 mos in the environment.	Current use
Dieldrin	Organochlorine pesticide	Insect pests of crops, termites; wood preservative	Bioconcentrates in animals, plants, and soils; neurotoxin; endocrine disruptor.	Highly persistent; ubiquitous at low concs; half-life ~ 5 yr.	Banned 1987 USA
DDT (DDE, DDD)	Organochlorine pesticide	Mosquitoes, disease-carrying insects, crop insects	Bioacculmulates in animals; carcinogen, neurotoxin, disrupts reproduction.	DDT and degradates (DDD and DDE) persist for years.	Banned 1972 USA
Endosulfan	Organochlorine pesticide	Insects on crops; wood preservative	Neurotoxin, endocrine disruptor; possible immune-system suppressant.	Half-life 10 da in environment; may persist years in soil.	Current use

TABLE 3 (Continued)

Class, use, toxicity, persistence in the environment, and status of persistent organic pollutants detected in 2001-2004 dust air samples

CUADRO 3 (Continuación)

Clase, uso, toxicidad, persistencia en el ambiente y estatus de contaminantes orgánicos persistentes detectados en muestras de polvo de 2001-2004

	Class of compound	**Use**	**Toxicity**	**Persistence**	**Status**
HCB	Organochlorine fungicide	Combustion and manufacturing product	Carcinogenic, oncogenic, teratogenic, fetotoxic, mutagenic, endocrine disruptor, immunosuppressor (mammals).	Bioacculmulates in animals and plants; half-life in environment 7.5 yrs.	Banned
Profenofos	Organophosphate insecticide	Insect and mite pests of crops (cotton)	Cholinesterase inhibitor; highly toxic to marine organisms	2 – 43 days in soil and water, respectively.	Current use
Dioxins/furans	Organochlorine	Combustion product	Probable human carcinogens, immunosuppressors, fish toxin, endocrine disruptor.	Half-life in the environment to 10-12 yrs.	Contaminants
PCBs	Organochlorine	Transformers, product additives	Toxic to fish, probable human carcinogen; endocrine disruptors, immunosuppressors.	10 da – 18 mo in environment.	Contaminants
PAHs	Polycyclic aromatic hydrocarbons	Combustion products	Photo-induced toxicity; probable teratogens; growth and photosynthesis inhibitors.	Half-lives in the environment range from hours to years.	Contaminants

Reference: Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/)
Referencia: Agencia para Sustancias Tóxicas y Registro de Enfermedades (http://www.atsdr.cdc.gov/)

Cu and Cd. Bioavailability of the metals is an important factor. Transport time, presence of other pollutants (hydrolyzed SO_2, NO_x), and chemical reactions on the surface of particles all have been shown to affect bioavailability of metals associated with aerosols, usually by increasing solubility (Fan *et al*. 2006).

The timing of dust deposition, whether via dry or wet deposition mechanisms, is an important consideration that has received little attention. In the Caribbean, synchronized coral spawning usually occurs in August, falling within the period of greatest Saharan dust activity (June – September) in the Caribbean region. Coral gametes are buoyant, rising to the surface for fertilization. The deposition of Saharan dust, with accompanying persistent organic pollutants, metals, and nutrients, to the marine surface layer could produce a fairly hostile environment for gametes and embryos, and potentially interfere with fertilization and embryo survival.

Long-distance atmospheric transport of microorganisms has been well documented (for a comprehensive review, Gregory 1973) and known pathogens, primarily of plants, are among these aeromicrobes (Brown and Hovmøller 2002). Most of these pathogens are fungi, whose dispersal spores are resistant to desiccation and provide protection from ultraviolet light and other harsh environmental conditions. Plant and animal pathogens are among the hundreds of different bacteria and fungi we have identified from dust and non-dust air samples to date (Griffin *et al.* 2001, 2003, Kellogg *et al.* 2004, Weir-Brush *et al*. 2004). Identification of hundreds of new isolates is ongoing.

Our preliminary research findings show promising correlations between the POPs and microorganisms in dust-event samples from the source region in Africa and downwind sites in the Caribbean. However, no direct or causal link has yet been proven. Results from ongoing fieldwork and laboratory analysis will provide the data needed to complete rigorous analysis of the POP, metals, and microbial datasets.

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RESUMEN

Un grupo internacional de agencias gubernamentales y universidades de los Estados Unidos, las Islas Vírgenes (EUA), Trinidad y Tobago, la República de Cabo Verde y la República de Mali (África Oeste), está trabajando en conjunto para elucidar el papel que el polvo del Sahara puede estar jugando en el deterioro de los ecosistemas caribeños. El primer paso ha sido identificar y cuantificar los Contaminantes Orgánicos Persistentes (POPs, por sus siglas en inglés), los metales traza y los microorganismos viables presentes en la atmósfera de las áreas fuente de polvo de África occidental y en áreas ubicadas en la dirección del viento, como el Atlántico este (Cabo Verde) y el Caribe (IVEUA y Trinidad y Tobago), durante los episodios de transporte de polvo. Resultados preliminares indican que las muestras de aire de Mali contienen mayor número y mayores concentraciones de pesticidas, bifenilos policlorinados (PCBs) e hidrocarburos policíclicos aromáticos (PAHs) que las de los sitios del Caribe. Las concentraciones de POPs fueron similares en las muestras de USVI y de Trinidad. Se encontró que las concentraciones de metales traza fueron similares a las de la composición de la corteza, con un ligero enriquecimiento de plomo en Mali.

Hasta la fecha, cientos de microorganismos cultivables han sido identificados en las muestras de Mali, Cabo Verde, IVEUA y Trinidad. Hallamos el patógeno de los abanicos de mar, *Aspergillus sydowi*, en las muestras de aire de Mali y en las muestras del Caribe durante polvaredas. Hemos demostrado que las muestras de aire provenientes de una región fuente de polvo, contienen más microorganismos cultivables por volumen -en órdenes de magnitud- que las muestras de aire tomadas en polvaredas en el Caribe, las cuales a su vez contienen tres a cuatro veces más microorganismos cultivables que aquellas tomadas cuando no hay polvaredas.

Palabras clave: polvo africano, Caribe, patógenos de corales, contaminantes orgánicos persistentes, polvo del Sahara.

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