



# Homeland Security

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Science and Technology

**Environmental Assessment of Proposed NYC Subway Tracer  
Particle and Gas Releases for the Underground Transport  
Restoration (UTR) Project**

**Prepared for Department of Homeland Security Science and  
Technology Directorate**

**April 14, 2016**

## EXECUTIVE SUMMARY

This Environmental Assessment (EA) documents the analysis of the potential effects from proposed tests involving the release of low concentrations of particles and gases at three stations within the Metropolitan Transit Authority (MTA) New York City Transit (NYCT) subway system by the Department of Homeland Security (DHS) Science & Technology Directorate (S&T). No construction, permanent land disturbance, or land use changes would occur with implementation of the Proposed Action or the Alternatives. No appreciable risk to passengers, MTA NYCT workers, or field test personnel is anticipated.

Subways are attractive targets for terrorists to release a biological weapon due to the low physical security and rapid agent dispersion from train and passenger activity. Subway dispersion models have been created to aid in understanding where biological particles travel after a release. These models help in both pre- and post-attack planning for first responders. Pre-attack planning includes identifying ideal locations for biodetection technologies. Post-attack planning includes determining the source location for attribution, identifying exposed passengers, and aiding the remediation effort (e.g., mapping, decontamination). While the subway dispersion models are critically important for homeland defense, there is little quantitative evidence as to their accuracy due to limited testing.

DHS S&T is currently leading the Underground Transport Restoration (UTR) project, a large scale effort to increase U.S. subway system resiliency against potential aerosolized biological agent attacks. Key stakeholders taking part in the effort include the Environmental Protection Agency (EPA), major transportation authorities (e.g., MTA NYCT), the federal government (e.g., DHS Office of Health Affairs), and several national laboratories. As part of this effort, DHS S&T proposes releasing particle and gas materials (“tracers”) within the MTA NYCT subway system to help refine and/or validate the statistical confidence of subway dispersion models developed by Argonne National Laboratory (ANL) with past DHS S&T funding. The motivation for the current testing derives from previous tests and modeling extrapolation having large uncertainties with respect to the effect of fomite transport (e.g., particle attachment to passenger clothing), particulate surface deposition and particle resuspension. The current assessment will analyze the potential for impacts to human health and the environment from the proposed testing, and is being coordinated with the aforementioned stakeholders and the public ridership for information and comment. This environmental assessment is being conducted in accordance with the National Environmental Policy Act (NEPA) as outlined in 40 CFR Parts 1500-1508 and DHS Directive 023-01, Environmental Planning Program.

The tests are planned for the Spring of 2016 and must be conducted during revenue hours to understand the quantitative impact on dispersion from train cars and passenger movement. Gas material is proposed for release concurrently with particulate material. A gas simulant provides highly specific real-time concentration data (difficult to do with particulates) and the ability to correlate the UTR measurements to previous gas tracer testing conducted in the MTA

NYCT subway system. In addition, gaseous materials do not deposit on surfaces and are unaffected by mechanical filtration in train car HVAC systems thereby providing an indication of particulate losses through these actions.

In total, there are two safe particulate alternatives presented in this assessment, which would meet the needs of DHS S&T. Regardless of the particulate material, the release dissemination is proposed for subway revenue hours (i.e., operational) because the main effects being tested are the impact of the trains and passengers on dispersion model predictions. The two particulate tracer alternatives are shown below as well as a no particulate alternative:

- Particulate Tracer Alternative P1: Aerosol release of DNA oligonucleotides (oligos) encapsulated in soluble maltodextrin particles (maltodextrin with oligos is referred to commercially as DNATrax) and tagged with a fluorescent Optical Brightener (referred to as DNATrax-OB). DNATrax-OB allows for quantification using PCR and fluorimetry, but not culture methods.
- Particulate Tracer Alternative P2: Aerosol release of P1 attached to amorphous silica particles (referred to as DNATrax-OB-Silica). DNATrax-OB-Silica allows for quantification using PCR and fluorimetry, but not culture methods.
- Particulate Alternative P3: No particulate released.

Alternatives P1 and P2 present similar options; P2 uses amorphous silica as a carrier to afford tighter particle size control. Characterization work (e.g., limit of detection measurements, sizing capabilities, reaerosolization chamber tests) is ongoing to determine whether P1, P2, or a combination is preferred for releases. However, both DNATrax-OB and DNATrax-OB-Silica do not present a significant risk to the environment or human health. The no particulate alternative will not help to validate current particulate models and therefore does not meet the needs of the development effort and test.

DNATrax presented in Alternative P1 was developed for food labeling and has been classified by the Food & Drug Administration (FDA) as Generally Recognized As Safe (GRAS). The primary component maltodextrin is used in several commercially available food products such as sweetening agents (e.g., Splenda®) and protein shakes. The DNA oligo sequences, selected from natural sequences, do not produce proteins and are considered to be safe. The Optical Brightener (OB) is also considered safe and is used commercially in detergents, cosmetics and paper products. Amorphous silica, the primary component in Alternative P2, is used as an anti-caking agent and a carrier for liquid active ingredients in human and animal nutrition.

While most of these materials have been shown to be safe in many consumer food products, the material will be aerosolized in a respirable form (particle sizes from 1 – 10 µm) resulting in many passengers breathing the material into their lungs rather than ingesting. Both DNATrax-OB and DNATrax-OB-Silica usage will result in air concentrations well below OSHA Permissible Exposure Levels (PELs) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). Note that these values are created for

occupationally-exposed healthy individuals while some passengers may have respiratory illnesses and/or compromised immune systems. However, the small quantity of particulate material proposed for these tests will result in 8-hour maximum mass concentrations (i.e., next to release) that are over an order of magnitude lower than the established limits by OSHA and ACGIH, respectively, providing an additional margin of safety.

The gas tracer material should be safe at proposed release concentrations (e.g., tens of ppm), not currently present in the background, completely passive (i.e., non-reactive), and quantifiable to very low concentrations (ppt or lower). The three gas tracer alternatives are:

- Gas Alternative G1: Release of sulfur hexafluoride (SF<sub>6</sub>) gas within the subway system. Sulfur hexafluoride allows for real-time measurements using infrared spectroscopy and laboratory measurements using Gas Chromatography Mass Spectroscopy (GC-MS).
- Gas Alternative G2: Release of SF<sub>6</sub> gas and three perfluorocarbon tracers (PDCB, PMCH, and mPDCH). The three perfluorocarbon tracers allow for higher sensitivity compared to SF<sub>6</sub> due to their extremely low presence in the subway background.
- Gas Alternative G3: No gas released.

Notice that there is an alternative that would involve no gas releases. A gas simulant provides highly specific real-time concentration data (difficult to do with particulates), the ability to correlate the UTR measurements to previous gas tracer testing conducted in the MTA NYCT subway system, and a reference for particle filtration and deposition within the system since the gas simulant is not mechanically filtered (e.g., train HVAC filters) or deposited on surfaces. However, the primary objective of the current test is to evaluate particulates, rather than gases.

Seven perfluorocarbon tracers (known as PFTs) were safely used for the Subway Surface Air Flow Exchange (S-SAFE) Program (i.e., 2013 NYPD funded gas tracer study). Three of those same seven PFTs or related isomers are proposed for Alternative G2. While SF<sub>6</sub> provides real-time measurement capabilities near the release location, the sensitivity of measurements past a few stations from the release location will be limited due to the relatively high SF<sub>6</sub> concentrations that are always present in the NYC subway background (due to leakage from electric power substations). All of the proposed gases have been demonstrated as safe for this application and have been released in populated subway stations previously with no reported adverse effects. Therefore, Alternative G2 would be the preferred plan for the proposed measurements.

The indirect environmental effects caused by the potential exposure of terrestrial wildlife by movement of the material out of subway tunnels and into the open air were also evaluated. The environmental consequences posed by any of the alternatives as outlined will not have an adverse effect on terrestrial wildlife.

In accordance with Executive Order 12898, analysis of the environmental effects must also include effects on minority communities and low-income communities, when such analysis is required by the National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. section 4321 et

esq. There is no evidence that low income or minority populations would receive a higher exposure to the particulate or gas material than any other group. In the case that these groups have a higher prevalence of “sensitive” populations (e.g., asthmatics), maintaining similar levels to EPA-established National Ambient Air Quality Standards and being well below established gas thresholds illustrates that these alternatives would not disproportionately impact minority or low-income communities.

DHS S&T will post the EA with an email address for the public to comment over a 6-week period in the fall/winter, 2015. Public input submitted will be discussed and considered with respect to conclusions of the EA.

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## LIST OF ACRONYMS

AAC – Acceptable Air Concentration  
ACGIH – American Conference of Governmental Industrial Hygienists  
ANL – Argonne National Laboratory  
*Ba* – *Bacillus anthracis*  
BGM – Below Ground Model  
BRL – Below Reporting Limit  
CAS – Chemical Abstracts Service  
CDC – Center for Disease Control  
CFR – Code of Federal Regulations  
CFU – Colony Forming Unit  
CO – Carbon Monoxide  
CO<sub>2</sub> – Carbon Dioxide gas  
COPD – Chronic Bronchitis/Chronic Obstructive Pulmonary Disease  
DfT (UK) – Department for Transport United Kingdom  
DHS S&T – Department of Homeland Security Science & Technology Directorate  
DNA – Deoxyribonucleic Acid  
DNATrax – DNA Tagged Reactants for Aerosol Experiments  
DSTL – Defence Science and Technology Laboratory  
DTRA – Defense Threat Reduction Agency  
EC<sub>0</sub> – No-Effect Concentration  
EC<sub>50</sub> – 50% of Maximal Effect Observed  
eDNA – environmental DNA  
EPA – Environmental Protection Agency  
ETAD – Ecological & Toxicological Association of Dyes & Organic Pigments Manufacturers  
FDA – Food & Drug Administration  
GC-MS – Gas Chromatography Mass Spectroscopy  
GCT – Grand Central Terminal  
GRAS – Generally Recognized As Safe  
GWP – Greenhouse Warming Potential  
HH – Health Hazard  
HPV - High Production Volume  
HVAC – Heating, Ventilation & Air Conditioning  
iPPCH – Perfluoroisopropylcyclohexane  
LC<sub>0</sub> – Maximum Tolerable Dose  
LLNL – Lawrence Livermore National Laboratory  
MBTA – Massachusetts Bay Transportation Authority  
MIT LL – Massachusetts Institute of Technology Lincoln Laboratory  
MMAD – Mass Median Aerodynamic Diameter  
mPDCH – Metaperfluorodimethylcyclohexane  
MTA – Metropolitan Transportation Authority  
MTCDE – Metric Tons Carbon Dioxide Equivalent

NAAQS – National Air Quality Standards  
NEPA – National Environmental Policy Act  
NOAA - National Oceanic and Atmospheric Administration  
NYCCAS – New York City Community Air Survey  
NYCT – New York City Transit  
NYSHPO – New York State Historic Preservation Office  
OB – Optical Brightener  
OSHA – Occupational Safety and Health Administration  
PCR – Polymerase Chain Reaction  
PDCB – Perfluorodimethylcyclobutane  
PEL – Permissible Exposure Limit  
PFT – Perfluorocarbon Tracer  
PM<sub>10</sub> – Particulate Matter under 10 microns  
PM<sub>5</sub> – Particulate Matter under 5 microns  
PM<sub>2.5</sub> – Particulate Matter under 2.5 microns  
PMCH – Perfluoromethylcyclohexane  
PNOS – Particle Not Otherwise Specified  
PPM<sub>v</sub> – Parts Per Million by Volume  
PPE – Personal Protective Equipment  
PPL – Particles Per Liter of Air  
PPTV – Parts Per Trillion by Volume  
PTCH – Perfluorotrimethylcyclohexane  
ptPDCH – Perfluoroethylcyclohexane  
RCRA – Resource Conservation and Recovery Act  
SAS – Synthetic Amorphous Silica  
SDS – Safety Data Sheet  
SF<sub>6</sub> – Sulfur Hexafluoride  
S-SAFE – Subway Surface Air Flow Exchange  
SCOGS – Select Committee on GRAS Substances  
TLV – Threshold Limit Value  
TSP – Total Suspended Particulates  
TWA – Time Weighted Average  
UDP – Urban Dispersion Program  
USDA – U.S. Department of Agriculture  
UTR – Underground Transportation Restoration  
WHO – World Health Organization  
WMATA – Washington Metropolitan Area Transit Authority

## **Section 1. Purpose and Need of the Proposed Action**

A strategic goal of the U.S. Department of Homeland Security (DHS) is to prevent, detect, protect and recover from biological attacks<sup>1</sup>. Protecting and remediating critical infrastructure, such as subways, from the effects of biological weapons is a key element to achieving this goal. Early warning detection systems (e.g., BioWatch Program), rapid response strategies (e.g., stop trains, evacuation), and post-attack remediation strategies (e.g., mapping contamination) are constantly being examined for subway systems to minimize casualties and economic impact. Subway dispersion models have been created to help in these endeavors and are actively used by agencies within DHS for both pre- and post-attack planning. Pre-attack planning includes identifying ideal locations for biodetection technologies. Post-attack planning includes determining the source location for attribution, identifying exposed passengers, and aiding the remediation effort (e.g., mapping, decontamination). While the subway dispersion models are critically important for homeland defense, there is little quantitative evidence as to their accuracy due to limited testing.

Previous subway dispersion tests are shown in TABLE 1; many of the previous efforts have focused on gases and liquid aerosols. These types of measurements lack information on reaerosolization, train car mechanical filtration, and fomite transport (i.e., attachment and subsequent resuspension of particulate materials on passengers and their personal effects). Solid particulate measurements that do exist have limited spatial area results (i.e., limited to 1 – 2 stations) due to sensitivity and specificity issues (e.g., poor limit of detection). In general, all previous tests lack the spatial and temporal resolution desired for model validation.

Without meaningful validation under realistic threat scenarios, the actual measure of protection current dispersion models provide is academic rather than demonstrated. The proposed testing action will determine the accuracy and sensitivity of current subway dispersion models.

The purpose of this Environmental Assessment is to evaluate whether significant impacts to the environment may occur from the proposed dispersion testing. DHS S&T proposes to test dispersion model accuracy in the MTA NYCT subway system using small quantities of carrier particles tagged with DNA oligonucleotides (oligos) and an Optical Brightener (OB). Tagging carrier particles with oligos allows for highly specific and sensitive measurements to be made, thus fulfilling the purpose of the proposed dispersion tests. There are two choices of carrier particles currently being assessed: maltodextrin and amorphous silica. The combination of maltodextrin with oligos is a commercially available product called “DNATrax”. Both DNATrax and amorphous silica have been used for tracer testing in public spaces previously. In addition, three perfluorocarbon tracer (PFTs) and SF<sub>6</sub> gases are proposed for concurrent release. All four gas materials have previously been used for tracer testing in subways during revenue hours (i.e., passengers present). This assessment will examine the impact of using the proposed particulate and gas materials with respect to human health and environmental safety.

**TABLE 1**  
**Previous Subway Revenue-Hour Particulate and Tracer Gas Material Phenomenology Measurements**

<b>Year</b>	<b>Agency / Program</b>	<b>Sponsor</b>	<b>Gas</b>	<b>Particulate</b>	<b>Location</b>	<b>Limitations</b>
1966	U.S. Army	U.S. Army	---	<i>B. atrophaeus</i> (BG)	MTA NYCT	Lack of particle size information, limited spatial extent, no surface sampling, lack of specificity
2005	Urban Dispersion Program (UDP)*	DHS, DTRA	7 PFTs, SF <sub>6</sub>	---	MTA NYCT	No particulates
2006	MetroGuard Testing	MTA NYCT	---	Polystyrene, Urea	MTA NYCT	Limited spatial resolution (one station)
2007 – 2008	ANL, LBNL	DHS	3 PFTs, SF <sub>6</sub>	Urea	DC WMATA	Liquid aerosol droplet, lack of sensitivity/specificity
2009 – 2012	ANL, LBNL	DHS	3 PFTs, SF <sub>6</sub>	Urea, Silica	Boston MBTA	Liquid aerosol droplet, lack of sensitivity/specificity
2013	DSTL, ANL, LBNL, BNL	DfT (UK), DHS	5 PFTs, SF <sub>6</sub>	Urea	London Underground	Liquid aerosol droplet, lack of sensitivity/specificity
2013	S-SAFE* Program	NYPD	7 PFTs	---	MTA NYCT	No particulates

\*UDP and S-SAFE phenomenology measurements included BNL and ANL

## **Section 2. Text Alternatives to Meet the Need**

This section will detail the range of test simulant alternatives to determine the Proposed Action for the particulate and gas materials. The analysis of the alternatives is being conducted in accordance with the National Environmental Policy Act (NEPA) as outlined in 40 CFR Parts 1500-1508 and DHS's implementing regulation Directive 023-01, Environmental Planning Program.

The optimum condition for executing a bio-terror attack would be during rush hour, when a large number of riders are in the stations and trains are running at peak number and speed. The transport of aerosols is largely driven by the motion of trains and passengers in the system, and thus the most accurate reflection of material transport would involve testing when stations are operational.

Therefore, all particulate and gas release alternatives are proposed during revenue hours (i.e., during normal operations while passengers are present within station) in Grand Central, Times Square, and/or Penn Station. These stations were selected due to having crossing subway lines, high passenger traffic, and significant psychological importance. The area immediately around the specific release location will be roped off with field test personnel (including MTA and NYPD personnel) blocking entrance. A "release event" will include both particulate and gas materials being released at two separate stations simultaneously for 10 – 20 minutes. The amounts of particulate and gas materials released per release event will be discussed in the next few sections. Each release event will be separated by a minimum of 23 hours. A total of five release events are proposed over a week. TABLE 2 is an example of what the final release schedule will look like.

**TABLE 2**  
**Tentative Release Schedule\* (Subject to Revision)**

Release Event #	Day	Proposed Particulate & Gas Details								Sampling Window	Simulant Release Window
		Station #1	Particulates	SF <sub>6</sub>	PFT #1	PFT #2**	Station #2	Particulates	PFT #3		
1	Mon	GC	20 g	1 kg	0.5 kg	0.5 kg	TSQ	10 g	0.5 kg	9am – 3pm	11am – 12pm
2	Tues	GC	20 g	1 kg	0.5 kg	0.5 kg	TSQ	10 g	0.5 kg	9am – 3pm	11am – 12pm
3	Wed	GC	10 g	1 kg	0.5 kg	0.5 kg	TSQ	20 g	0.5 kg	9am – 3pm	11am – 12pm
4	Thurs	GC	20 g	1 kg	0.5 kg	0.5 kg	PS	10 g	0.5 kg	9am – 3pm	11am – 12pm
5	Fri	GC	10 g	1 kg	0.5 kg	0.5 kg	PS	20 g	0.5 kg	9am – 3pm	11am – 12pm

\*Note that testing may be conducted on the weekend if one of the weekday tests was postponed due to extreme weather conditions.

\*\*PFT #2 will be released on the Grand Central – 42 St 7 Platform

GC = Grand Central – 42 St 4,5,6 Platform, TSQ = Times Sq – 42 St 1,2,3 Platform, PS = 34 St - Penn Station 1,2,3 Platform

## ***2.1 Particulate Tracer Alternatives***

The particle tracer dissemination method will be short dry bursts every 30 – 60 seconds for 10 – 20 minutes. The maximum amount of particulate tracer material released within a station over ten minutes, 8 hours, and 24 hours is 20, 20, and 40 grams, respectively. The particulate release amount has been chosen because it provides enough tracer material for sampling measurements to take place several stations away from the release location but should not create a visible plume or substantially add to the visible background haze within the stations (see Section 3.2.2 Subway Indoor Air Quality). The device used to release the material in short bursts is called an “eductor”. The particulate tracer material is stored in a plastic tube that fits into the bottom of the eductor. Compressed air will be passed over a small opening in the top of the tube which aerosolizes the particulates. The particulate tracer material will be weighed and pre-filled into the eductor plastic tube in a laboratory. The filled tubes will be placed in a shatter resistant, leak-proof sealed secondary container for transport to the test site.

Mobile equipment and samples will be used to collect particulates in the subway. The majority of air samples will be collected using Portable Sampling Units (PSUs) and Dry Filter Units (DFUs). PSU devices weigh 113 lb, are approximately 5’ x 25” x 16” (HxWxD) in size, and require electrical power (110 Volts). DFU devices weigh 42 lb, are approximately 15” x 13” x 13” (HxWxD) in size, and require electrical power (110 Volts). Approximately 40 – 60 PSUs and 40 DFUs will be temporarily located within subway stations and near station vents the week of testing. Locations have been identified where power is available. The PSU and DFU devices can be locked in place using a chain and pedestrian traffic will remain unimpeded. Units will be put into position the week before testing begins and removed the week after testing. No permanent physical changes will take place to stations or outdoor locations from the use of PSUs or DFUs.

In addition, approximately 25 – 50 portable particle counters will be placed in stations near the release for real-time particle counts. Particle counters will be locked in place and plugged into outlets for power. Units will be put into position the day of testing and removed at the end of each day of testing. No physical changes will take place to station or outdoor locations where particle counters are located.

### **2.1.1 Particulate Alternative P1**

The first particulate alternative (P1) is to aerosolize DNA oligonucleotides (oligos) encapsulated in maltodextrin particles (referred to as “DNATrax”) and tagged with an Optical Brightener (OB). DNATrax (i.e., DNA oligos encapsulated inside maltodextrin) was developed by Lawrence Livermore National Laboratory (LLNL) for food labeling and has been classified by the Food & Drug Administration (FDA) as Generally Recognized As Safe (GRAS). The Safety Data Sheet (SDS) and a safety review of DNATrax by a LLNL Certified Industrial Hygienist have been included in Appendix A. DNATrax-OB, which includes encapsulation of both CI Fluorescent Brightener 220 and DNA oligos inside maltodextrin, is proposed as particulate alternative P1 for

described phenomenology tests. The SDS for CI Fluorescent Brightener 220 has also been included in Appendix A.

The primary component, maltodextrin, is already used extensively in several food and drink products (e.g., beer, protein shakes, and sweeteners such as Splenda). The SDS for maltodextrin has also been included in Appendix A. The DNA oligo sequences, selected from natural sources, do not produce proteins and are considered to be safe (refer to Section 4.1 Human Health and Safety Effects). In addition, DNA is already ubiquitous in the environment and is produced by all living matter. The optical brightener, Fluorescent Brightener 220 (SDS included in Appendix A), is used in several consumer products such as laundry detergent and paper production. Maltodextrin, CI Fluorescent Brightener 220 and DNA oligos do not present a significant risk to the environment or human health.

The DNATrax-OB particles will have a mass median aerodynamic diameter (MMAD) between 1 – 10  $\mu\text{m}$ , which is considered respirable. The DNATrax-OB particles (including the primary component maltodextrin) are not listed explicitly by OSHA; therefore it is assumed classified as “Particulates Not Otherwise Regulated” by OSHA and at a minimum would be required to remain well below the designated 8-hour Time Weighted Average (TWA) respirable Permissible Exposure Limit (PEL) of 5  $\text{mg}/\text{m}^3$ . The American Conference of Governmental Industrial Hygienists (ACGIH) recently established a Threshold Limit Value (TLV) of 3  $\text{mg}/\text{m}^3$  (respirable) and 10  $\text{mg}/\text{m}^3$  (inhalable, i.e., deposits in the nose, throat and upper respiratory tract) for “particles not otherwise specified (PNOS)”. However, the ACGIH PNOS designation applies only to particles that are insoluble or poorly soluble in water (maltodextrin is soluble in water). To be conservative, air concentrations will remain well below the lower ACGIH TLV. Given that these values are created for occupationally-exposed healthy individuals, and while some passengers may have respiratory illnesses and/or compromised immune systems, the small quantity of particulate material proposed for these tests will result in 8-hour maximum concentrations (i.e. next to release) that are 500 and 300 times lower than the established limits by OSHA and ACGIH for particles not otherwise regulated (i.e., inert or nuisance dusts), respectively. For more information, refer to Section 4.1.1 Human Health and Safety Effects from Particulate Releases.

### **2.1.2 Particulate Alternative P2**

The second particulate alternative (P2) is to aerosolize P1 attached to amorphous silica particles. Particulate Alternative P2 will be referred to as DNATrax-OB-Silica. The Safety Data Sheet (SDS) for amorphous silica has been included in Appendix A.

Amorphous silica, the primary component in Alternative P2, is used as an anti-caking agent and a carrier for liquid active ingredients in human and animal nutrition.

The DNATrax-OB-silica particles will have a mass median aerodynamic diameter (MMAD) between 1 – 10  $\mu\text{m}$ , which is considered respirable. The DNATrax-OB-silica particles are primarily amorphous silica which OSHA regulates specifically; at a minimum the mass

concentration would be required to remain well below the designated 8-hour TWA respirable PEL of 0.8 mg/m<sup>3</sup>. The ACGIH recently established a TLV of 3 mg/m<sup>3</sup> (respirable) and 10 mg/m<sup>3</sup> (inhalable, i.e., deposits in the nose, throat and upper respiratory tract) for “particles not otherwise specified (PNOS)”. Given that these values are created for occupationally-exposed healthy individuals, and while some passengers may have respiratory illnesses and/or compromised immune systems, the small quantity of particulate material proposed for these tests will result in 8-hour maximum concentrations (i.e. next to release) that are 80 and 300 times lower than the established limits by OSHA and ACGIH for particles not otherwise regulated (i.e., inert or nuisance dusts), respectively. For more information, refer to Section 4.1.1 Human Health and Safety Effects from Particulate Releases.

### **2.1.3 No Action Particulate Alternative (P3)**

The no action alternative would eliminate conducting in-situ particulate releases within the subway system. Non-revenue releases cannot be conducted in the MTA NYCT system because it is continuously operational. Gas measurements (described in the next section) by themselves have already been conducted in NYC as part of the S-SAFE and UDP Programs. This alternative will not help to validate current particulate models and therefore does not meet the needs of the development effort and test.

## ***2.2 Gas Tracer Alternatives***

The gas tracers would include sulfur hexafluoride (SF<sub>6</sub>) and/or three perfluorocarbon tracers (PFTs) that would be continuously released during the ten-minute particulate release period. The release rates and amounts are listed in TABLE 3. Because SF<sub>6</sub> is a gas at room temperature, it would be released from a low-pressure cylinder through a flow meter to monitor its release rate. The PFTs, which are liquid at room temperature, would be metered onto battery-powered, low-temperature hot plates (one for each PFT) where they would quickly evaporate. Small, battery-powered fans would be used to ensure rapid dispersal of the tracer gases.

Mobile equipment will be used to collect gas samples in the subway. The majority of gas samples will be collected from the air using gas bag samplers. The gas bag samplers are custom made portable devices that weigh approximately 15 lb, are 16” × 10” × 12” (L×W×H) in size, and are battery powered. Approximately 40 gas bag samplers will be temporarily located within subway stations and near station vents the week of testing. The gas bag samplers can be locked in place using a chain and pedestrian traffic will remain unimpeded. Units will be put into position the week before testing begins and removed the week after testing. No permanent physical changes will take place to stations or outdoor locations from the use of gas bag samplers.

In addition, approximately 10 portable gas sensors will be placed in stations near the release for real-time gas concentration measurements. Gas sensors will be locked in place and

plugged into outlets for power. Units will be put into position the day of testing and removed at the end of each day of testing. No physical changes will take place to station or outdoor locations where gas sensors are located.

**TABLE 3**  
**Tracer Gas Release Amounts and Release Rates**

Gas	CAS	Mass Released (kg)			Release Rate per Event (g/min)
		10-min*	8-hr	24-hr	
Sulfur Hexafluoride (SF <sub>6</sub> )	2551-62-4	1.0	1.0	2.0	50 - 100
Perfluorodimethylcyclobutane (PDCB)	28677-00-1	0.5	0.5	1.0	25 - 50
Perfluoromethylcyclohexane (PMCH)	355-02-2	0.5	0.5	1.0	25 - 50
Metaperfluorodimethylcyclohexane (mPDCH)	335-27-3	0.5	0.5	1.0	25 - 50

\*A gas release event will occur over a 10 – 20 minute period and will coincide with the release of the particulate tracer. The upper bound is set at 1 gas release event per day and 2 gas release events over 24-hours.

### 2.2.1 Gas Alternative G1

The first gas alternative (G1) is to use SF<sub>6</sub> alone. SF<sub>6</sub> is a biologically inert, colorless, odorless gas. The SDS for SF<sub>6</sub> has been included in Appendix A. It has been widely used as an airflow tracer for several decades in indoor and outdoor studies alike, including subway releases in Washington, DC (2007, 2008)<sup>2</sup> and Boston (2009, 2010, and 2012)<sup>3</sup> as well as aboveground releases in mid-town Manhattan during UDP (2005)<sup>4</sup>.

The OSHA PEL and the ACGIH TLV for SF<sub>6</sub> are 1,000 ppm for an 8-hour TWA. These limits were established to prevent oxygen displacement (i.e., to prevent asphyxia) rather than because of chemical toxicity. The largest 1-hour average SF<sub>6</sub> concentration measured near the SF<sub>6</sub> release location during the Boston subway tests was less than 1% of the PEL and TLV; the equivalent 8-hour concentration was more than 1,000 times less than these limits.

In addition, SF<sub>6</sub> is a greenhouse gas and has a Global Warming Potential (GWP) of 23,600<sup>5</sup>. However, the amount of SF<sub>6</sub> planned for release will have a low overall GWP impact; more discussion is provided in Section 4.3 Global Warming Potential.

Because of its stability and high dielectric constant, SF<sub>6</sub> is primarily used as an insulating gas by the electric power industry. Due to its use in electric substations, urban areas in the U.S. have considerable fugitive emission sources. For instance, in 2002 fugitive emission estimates for the U.S. amounted to approximately 720,000 kg, including 101,000 kg in NYC alone, an average of 1,942 kg per week<sup>6</sup>. In comparison, less than 20 kg total will be released in this study.

An unfortunate consequence of the fugitive emissions is that elevated background levels of SF<sub>6</sub> may compromise the tracer measurements. In January 2004, prior to the UDP study, background SF<sub>6</sub> measurements in mid-town Manhattan were made by scientists from the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory. These measurements revealed substantial SF<sub>6</sub> emissions from a substation in mid-town, with concentrations ranging as high as 5,209 pptv (immediately downwind of the substation) down to 167 pptv at a distance of 2.7 km. For this reason, SF<sub>6</sub> alone is not a recommended alternative.

The value of using SF<sub>6</sub> as a tracer is that its infrared signature permits detection in real time using portable infrared gas analyzers. Even in the presence of significant background levels, the real-time measurement capability would be invaluable for monitoring the concentration levels in stations near the release point during the tests and for obtaining high time-resolution data.

### 2.2.2 Gas Alternative G2

The second gas alternative (G2) is to use three PFTs in addition to SF<sub>6</sub>. PDCB, PMCH, and mPDCH are inert, odorless, and colorless. The SDS for PDCB, PMCH, and mPDCH has been included in Appendix A. They are fully fluorinated (saturated with fluorine), contain only carbon and fluorine, and have no unsaturated bonds. For these reasons, these compounds are extremely stable, chemically and physically. One result of their extreme stability is that they have few commercial uses and therefore their background concentration in the atmosphere is extremely low.<sup>7</sup> This permits very small amounts of the tracers to be detected. Because of this low background, PFTs have been used as airflow tracers for decades<sup>7</sup>, including the subway studies in Washington, DC and Boston, UDP and S-SAFE, described earlier.

Being extremely stable chemically also makes perfluorocarbon compounds biologically inert and therefore suitable for a wide range of medical applications such as blood extenders or blood substitutes<sup>8</sup>, wound healing<sup>9</sup>, eye surgery<sup>10,11</sup>, equipment sterilization, imaging<sup>12,13</sup>, liquid breathing<sup>14,15,16,17</sup>, and organ storage.

Because perfluorocarbons are not known to cause adverse health effects, even at high concentrations, no OSHA PEL, ACGIH TLV, or Acute Exposure Guideline Level (AEGL) have been established. For S-SAFE, a 15-min Acceptable Air Concentration (AAC) limit of 9 ppm and an 8-hr limit of 3 ppm were established<sup>18</sup> for the PFTs. These thresholds were based on the known toxicity profile of cyclohexane, which is an industrial solvent, not an inert perfluorocarbon compound. Nevertheless, based on the maximum observed concentrations near the PFT release locations in the Boston subway tests and the greater dilution of PFTs observed in the MTA NYCT subway during S-SAFE (owing to the larger stations and more frequent trains), the concentrations near the PFT release locations in this study should be 3 – 4 orders of magnitude lower than 8-hr OSHA PEL for cyclohexane (300 ppmv) and an order of magnitude lower than the AAC 8-hr limit. More discussion is provided in 4.1.2 Human Health and Safety Effects from Gas Releases.

As mentioned in the previous section, SF<sub>6</sub> is a greenhouse gas and has a GWP of 23,600<sup>5</sup>. The GWP of the particular PFTs proposed for this study are not published, but can be conservatively estimated as 10,000 based on the accepted range of GWP for PFTs as 1,000 – 10,000<sup>19</sup>. Using these GWPs for the tracers, the upper bound is estimated at 193 MTCDE (Metric Tons Carbon Dioxide Equivalent) or 424,600 lbs of CO<sub>2</sub> equivalent for the total amount of gas tracers proposed to be released during this study.

### **2.2.3 No-Action Gas Alternative**

The no action alternative would eliminate conducting in-situ gas releases within the subway system. Because the NYC subway operates 24 hours per day, 7 days per week, it is not possible to conduct these tests during non-revenue hours. Gas tracer releases have already been conducted in NYC as part of the S-SAFE and UDP Programs. Releasing similar gas tracers in this study will enable the data to be directly compared to the results of those previous studies. More importantly, the tracer gases do not deposit on surfaces and are unaffected by mechanical filtration in train car HVAC systems. Because the co-located gas

releases will assess the airflow and passive dispersion, simultaneous gas and particulate measurements would allow particulate removal processes to be directly quantified through comparison of the relative gas and particulate concentrations. Although the primary objectives of the proposed study could be attained solely with the release of particulate materials, the additional benefits of the gas tracer measurements are substantial. This is particularly true if the results do not agree with the currently existing computational models. While the No-Action Gas Alternative would still allow the primary objectives of the tests to be met, it is not recommended.

### **Section 3. Affected Environment**

Several U.S. subway systems were considered to host the measurements. The three main criteria in selecting a venue for this study were as follows:

- A large system with many underground stations and multiple subway lines;
- A system representative of many other subway systems;
- A system in which research studies on the modeling of airflows, particle transport dynamics, and assessments of normal background conditions have been previously carried out.

After preliminary discussions were held with a few subway systems, the MTA NYCT was considered to be an optimal location. The MTA NYCT is the largest U.S. subway system and contains several types of stations. They have hosted several previous chemical and biological defense related projects and have been an extremely amenable host. In addition, an extensive chemical tracer study was recently completed that can be leveraged for further information (2013 S-SAFE Program).

Within the MTA NYCT system, there are three potential subway stations chosen for releasing tracer materials: Grand Central, Time Square, and Penn Station. These stations were selected due to having crossing subway lines, high passenger traffic, and significant psychological importance.

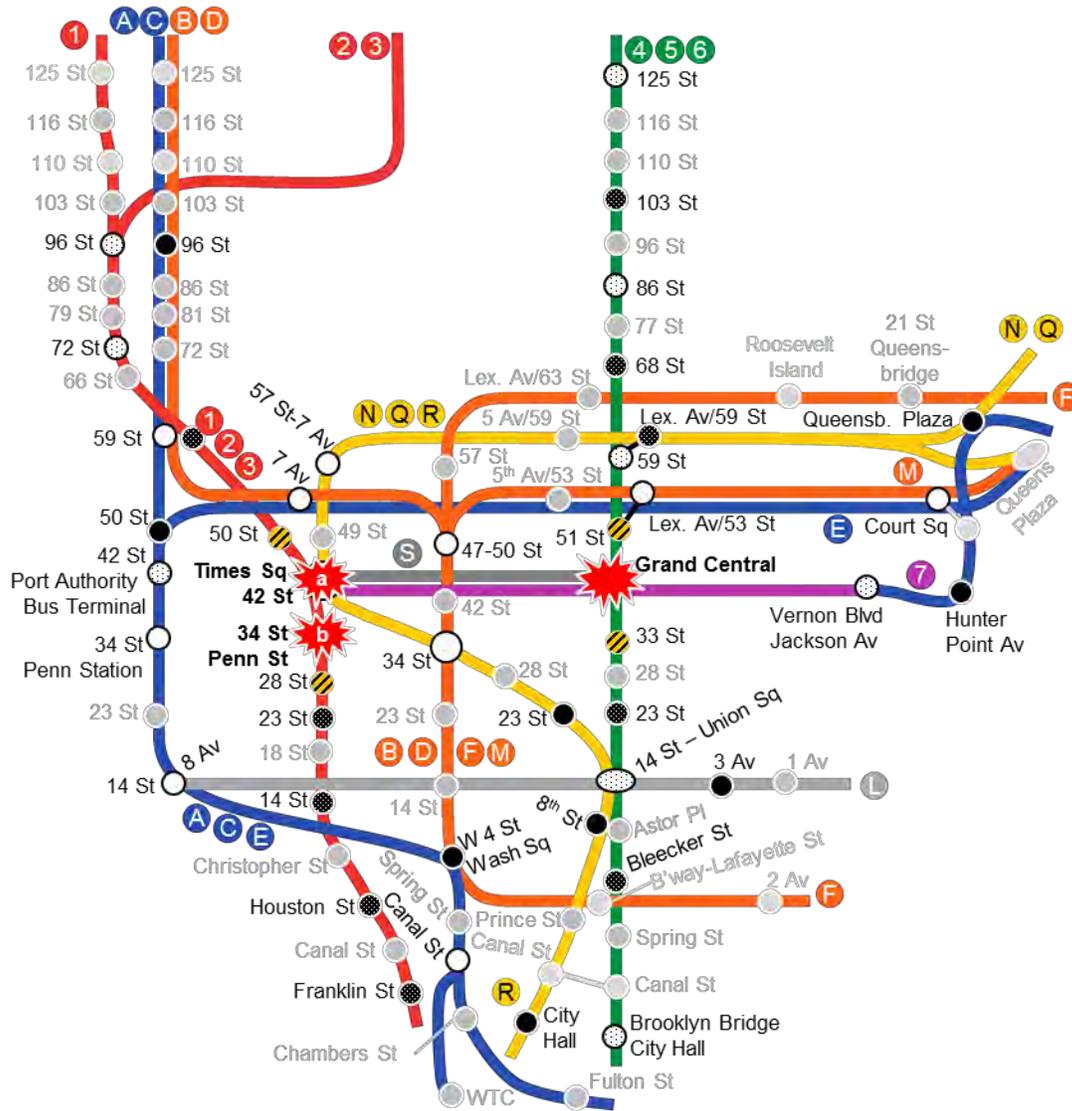
#### ***3.1 MTA NYCT Subway Overview***

The MTA NYCT subway system is the nation's largest mass transit system in terms of daily ridership (> 6 million), number of stations (468), and total track length (842 miles). It has 34 physical lines and is continuously operational (i.e., 24/7, 365 days a year).

Times Square, Grand Central, and Penn Station rank amongst the top 5 busiest stations in the MTA NYCT subway system<sup>20</sup> and were therefore chosen as possible releases sites. Grand Central is located in Midtown Manhattan at the intersection of Park Avenue and 42<sup>nd</sup> Street. The MTA platforms lie beneath Grand Central Terminal, which serves all Metro-North Railroad

lines east of the Hudson River. Penn Station is situated completely underground and is located underneath Madison Square Garden, 33<sup>rd</sup> Street, and Two Penn Plaza. The station spans three underground levels with the concourses located on the upper two levels and the train platforms located on the lowest level serving Amtrak, Long Island Railroad, New Jersey Transit and the MTA subway (1,2,3 and A,C,E platforms). Times Square station is located under Times Square and the Port Authority Bus Terminal, at the intersection of 42<sup>nd</sup> Street, Seventh and Eighth Avenues, and Broadway in Midtown Manhattan. Five different subway lines are served at Times Square station including the S, 7, (1,2,3), (N,Q,R) and (A,C,E) lines.

Sampling will occur at stations adjacent to the identified release sites (red stars shown in Figure 1), as well as platforms up to 10 – 12 stations away. Proposed stations and subway lines for sampling are listed in TABLE 4.



**Legend**

● Local train station (Air sampling* indoors)	*Sampling typically indicates: • Air: PSU and/or DFU • Surface: 8 12x12" Alum. coupons • Gas: 1 Gas box
● Local train station (Air/surface sampling* indoors)	
○ Local & express train station (Air sampling indoors)	
○ Local & express train station (Air/surface/gas sampling indoors)	
⊘ Adjacent release station (Air/surface/gas sampling* indoors & outdoors)	
★ Release station (Air/surface/gas sampling* indoors & outdoors + Release device/setup)	
● No station sampling	

Figure 1: Map of Proposed Release and Sampling Locations during Phenomenology Measurements (Subject to Revision). Red stars indicate potential tracer release locations.

**TABLE 4**

**Proposed Platform and MTA Subway Lines for Sampling (Subject to Revision)**

Station	Platform	Train	Sampling Activities
125 St	Uptown	4,5,6	Air (PSU & DFU), Surface
103 St	Uptown	6	Air (PSU & DFU), Surface
86 St	Uptown Local	4,5,6	Air (PSU & DFU), Surface
68 St Hunter College	Uptown	6	Air (PSU only), Surface
59 St	Uptown Express	4,5,6	Air (PSU & DFU), Surface
51 St	Uptown	6	Air (PSU & DFU), Surface
Grand Central 42 St	All	4,5,6	Air (2 PSU, DFU), Surface
33 St	Uptown	6	Air (PSU & DFU), Surface
23 St	Downtown	6	Air (PSU & DFU), Surface
14 St Union Sq	Mezzanine	4,5,6	Air (PSU & DFU), Surface
Bleecker St	Downtown	6	Air (PSU & DFU), Surface
Brooklyn Bridge City Hall	Downtown	4,5,6	Air (PSU & DFU), Surface
Queensboro Plaza	Downtown	N,Q	Air (DFU)
Lexington Av / 59 St		N,Q,R	Air (PSU), Surface
57 St / 7 Av	Uptown	N,Q,R	Air (PSU)
Times Square – 42 St	Uptown	N,Q,R	Air (PSU & DFU), Surface
34 St / Herald Sq	Uptown	N,Q,R	Air (PSU & DFU)
23 St	Uptown	N,R	Air (DFU)
14 St – Union Sq	Uptown	N,Q,R	Air (PSU & DFU)
8 St – NYU	Uptown	N,R	Air (PSU)
City Hall		R	Air (DFU)
47 50 Sts Rockefeller Ctr	Downtown	B,D,F,M	Air (PSU)
34 St Herald Sq	Uptown	B,D,F,M	Air (PSU & DFU)
W 4 St Wash Sq	Downtown	B,D,F,M	Air (PSU)
Hunters Point Av	W to Manhattan	7	Air (PSU)
Vernon Blvd / Jackson Av	W to Manhattan	7	Air (PSU), Surface
Grand Central		7	Air (PSU & DFU), Surface
Times Sq		7	Air (PSU & DFU), Surface
Grand Central		S	Air (PSU & DFU), Surface
Times Sq		S	Air (PSU & DFU), Surface

Station	Platform	Train	Activities
96 St	Downtown	1,2,3	Air (PSU & DFU), Surface
72 St	Downtown	1,2,3	Air (PSU & DFU), Surface
59 St Columbus Cir.	Downtown	1	Air (PSU & DFU), Surface
50 St	Downtown	1	Air (PSU & DFU), Surface
Times Square 42 St	All	1,2,3	Air (2 PSU & DFU), Surface
34 St Penn Station	Express	1,2,3	Air (2 PSU & DFU), Surface
28 St	Uptown	1	Air (PSU & DFU), Surface
23 St	Uptown	1	Air (PSU & DFU), Surface
14 St	Uptown	1,2,3	Air (PSU & DFU), Surface
Houston St	Uptown	1	Air (PSU & DFU), Surface
Franklin St	Uptown	1	Air (PSU & DFU), Surface
96 St		A,C	Air (PSU)
59 St Columbus Cir.	Express	A,C	Air (PSU)
50 St	Downtown 'E	C,E	Air (PSU)
42 St Port Authority	Downtown	A,C,E	Air (PSU & DFU), Surface
34 St Penn Station	Express	A,C,E	Air (PSU)
14 St	Uptown	A,C,E	Air (PSU)
W 4 St Wash Sq	Uptown	A,C,E	Air (PSU)
Canal St	Uptown	A,C,E	Air (PSU)
Court Sq 23 St	W to Manhattan	E	Air (PSU)
Lexington Av / 53 <sup>rd</sup> St		E	Air (PSU)
7 Av	Downtown	E	Air (PSU)
3 Av		L	Air (DFU)
14 St – Union Sq		L	Air (PSU), Surface
8 Av		L	Air (DFU)

## 3.2 Air Quality

This section describes the ambient NYC outdoor and subway air quality. An aggregation of air quality studies from several subway stations around the world has been provided for perspective.

### 3.2.1 NYC Metropolitan Outdoor Air Quality

Outdoor air quality in NYC has historically been relatively poor and the city estimates that 6% of the city's annual deaths are attributable to air pollution<sup>21</sup>. The Clean Air Act, last amended in 1990, required the EPA to develop National Ambient Air Quality Standards (NAAQS) for particulate matter with a diameter below 10  $\mu\text{m}$  ( $\text{PM}_{10}$ ) and 2.5  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ). NAAQS define primary standards, which protect the health of "sensitive" populations such as asthmatics, children, and the elderly. In addition, NAAQS defines secondary standards which protect against decreased visibility and damage to animals, crops, vegetation, and buildings. Primary and secondary levels for annual average  $\text{PM}_{2.5}$  have been set at 15  $\mu\text{g}/\text{m}^3$  and 12  $\mu\text{g}/\text{m}^3$ , respectively. A  $\text{PM}_{10}$  24-hr average of 150  $\mu\text{g}/\text{m}^3$  has been defined for primary and secondary concentrations<sup>22</sup>. The city launched an effort in 2007 to achieve the highest outdoor air quality of a major city by the year 2030. The New York City Community Air Survey (NYCCAS) reported annual average  $\text{PM}_{2.5}$  concentrations for the 2010 – 2012 period to be 14  $\mu\text{g}/\text{m}^3$ , a significant reduction from the  $\text{PM}_{2.5}$  annual average of 17  $\mu\text{g}/\text{m}^3$  recorded for 2005 – 2007<sup>23</sup>. Outdoor  $\text{PM}_{10}$  levels have remained steady for the same time period, averaging 60  $\mu\text{g}/\text{m}^3$  for 2005 – 2011<sup>24</sup>. While outdoor  $\text{PM}_{10}$  concentrations for NYC are well below primary and secondary NAAQS, outdoor  $\text{PM}_{2.5}$  concentrations still remain above secondary standards which protect against environmental harm. NYC continues to work towards reducing particulate emissions and meeting national standards.

### 3.2.2 Subway Indoor Air Quality

This section describes inherent particulate matter in air/surface samples (i.e., grime), chemical vapors (summa canister data), and typical cleaning materials found in subways. It should be emphasized that passenger entrances, ventilation shafts, and tunnels allow for a large exchange of air with the outside environment.

#### 3.2.2.1 Airborne and Surface Particulate Samples

Airborne particulate mass concentrations have been measured at several subway systems with a summary of average results in TABLE 5. Airborne particulate mass concentrations were almost always significantly higher inside subway stations than ambient air outside of the stations<sup>25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44</sup>; generally by at least a factor of 4. The exception to this was Guangzhou China where outdoor air pollution was much higher than other cities. Notice that there is a wide range of concentrations depending on the subway

system. Significant mass concentration variations were also measured between stations<sup>45</sup>, seasons<sup>27,31,46,47</sup>, and time of day<sup>44,47</sup> for the same city.

**TABLE 5**

**Average mass concentration measurements taken in different subway systems**

	Mass Concentration ( $\mu\text{g}/\text{m}^3$ )						Description
	Outdoor		Subway				
	PM <sub>2.5</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>5</sub>	PM <sub>10</sub>	TSP	
Berlin <sup>25</sup>					147		
Buenos Aires <sup>45</sup>						211	<i>Platform</i>
Budapest <sup>42</sup>					155		<i>Platform</i>
Boston <sup>48</sup>					205		Platform (Winter)
Cairo <sup>37</sup>						938	
Guangzhou <sup>49</sup>	106		44		55		
Helsinki <sup>26</sup>	10, 17		54 21				<i>Platform (Winter)</i> <i>Subway Car (Winter)</i>
Hong Kong <sup>25</sup>			33		44		
London	23.5 <sup>[27]</sup>		165 103 <sup>[27]</sup> , 375 <sup>[50]</sup>		1,250		<i>Subway Drivers Cab</i> <i>Platforms (Winter)</i>
	34.5 <sup>[27]</sup>		239 <sup>[27]</sup>	801 <sup>[29]</sup>			<i>Platforms (Summer)</i>
Mexico City <sup>51</sup>	71, 38		61				
NYC	13 <sup>[32]</sup>		62 <sup>[32]</sup> 56 <sup>[33]</sup>				<i>Platforms &amp; Cars</i> <i>Subway Workers</i>
		74			103 114		<i>Station</i> <i>Subway Car</i>
Rome <sup>40</sup>		101			166 407		<i>Subway Drivers Cab</i> <i>Platforms</i>
Seoul			66 <sup>[47]</sup> , 118 <sup>[30]</sup> 111		144 126, 137 <sup>[52]</sup>		<i>Subway Car</i> <i>Platforms</i>
	23		212		386		
Toronto <sup>53</sup>	15		159				
Washington DC <sup>36</sup>						333	

The elevated mass concentration values in the subway are thought to be influenced by passenger activity, floor cleaning, station depth, date of construction, ventilation rate, proportion of frictional to regenerative braking, train frequency, wheel type (rubber vs. steel), and the presence or absence of platform-edge doors and/or air-conditioning in subway cars and stations<sup>33,37</sup>. Analysis has been conducted on collected particulate samples to determine the constituent materials. Iron oxides (e.g., Fe<sub>3</sub>O<sub>4</sub>, Fe<sub>2</sub>O<sub>3</sub>) make up the majority of subway particulate mass (e.g., 64 – 71% in London subway<sup>28</sup>). The iron oxides generally create a passivation layer on the surface of iron. Airborne iron is primarily attributed to wear debris from the subway car wheel-rail interface and also braking (contributed 15% total mass<sup>54</sup>). TABLE 6 reports the percentage iron content from a few other cities. A NYC study found that iron content percentage varied depending on the location within the subway system (e.g., 14% for overhaul shop workers, 27% for track workers, 43% for train operators)<sup>33</sup>.

**TABLE 6**

**Percent iron in subway dust**

<b>City</b>	<b>Fe %</b>
<b>Budapest<sup>42</sup></b>	42
<b>Buenos Aires<sup>45</sup></b>	21
<b>Helsinki<sup>26</sup></b>	54
<b>London<sup>28</sup></b>	45
<b>NYC<sup>32</sup></b>	42
<b>Rome<sup>40</sup></b>	10
<b>Seoul<sup>47</sup></b>	45
<b>Stockholm<sup>41</sup></b>	40
<b>Washington DC<sup>36</sup></b>	55

Other metals found in elevated percentages to the outdoors were chromium (present in steel), manganese (present in steel), copper (present in current collector shoes rubbing against conductor rail), zinc (vehicular traffic), and barium (present in some brakes<sup>25</sup>). The metals are not generally present as elements but as compounds (e.g., oxides, chlorides, sulfides)<sup>36</sup>. Steel, manganese and chromium were found to be more than 100 times higher in the NYC subway system than outdoors<sup>32</sup>. Carbon-rich particles are generally found, attributed to carbon inclusion in steel, oils, and human debris (e.g., clothes fibers, hair, skin)<sup>36,29,25</sup>. Other non-metals found were silica quartz (e.g., 7.2% in Washington DC), attributed to concrete (i.e., construction, degradation)<sup>36</sup>, and chlorides<sup>29,38,47</sup> attributed to the use of road salts for de-icing. A Washington DC study found that subway dust from older WMATA rail lines was not significantly different than dust from newer lines<sup>36</sup>. Also of interest was that power washing only reduced mass concentrations by roughly 10%<sup>34</sup>. The same factors that affect mass concentration levels also affect the composition of subway dust. Therefore, it is important for each facility to conduct analysis on their inherent subway particles.

While some of the underground subway increase in airborne mass concentration is attributable to higher particulate density (i.e., iron), it is also attributed to an increase in total particle counts. Measurements in the Washington DC subway system found that the total particle counts (Smithsonian Station) were at least 2 – 3 times lower in magnitude immediately outside the station for all particle sizes between 0.5 – 9.4  $\mu\text{m}$ <sup>55</sup>. Compared to the outdoors, the subway environment has particles that are heavier (i.e., iron oxides) and in greater numbers. Typical subway station total particle counts (>0.5  $\mu\text{m}$ ) reached 10,000 – 100,000 Particles Per Liter (PPL) of air depending on train operation and time of day<sup>38,46,55</sup>. Fluorescent particles have been reported at <1% of total particle counts<sup>38</sup>. Also of interest is that NYC air-conditioned subway cars reduced particle counts by 75 – 90% compared to the subway station<sup>35</sup>.

With respect to airborne particle sizing, significant increases in coarser particles (i.e., >2  $\mu\text{m}$ ) have been measured for subway dust<sup>28,29</sup>. Measurements in Washington DC, found the largest subway station particle increases (compared to outdoors) in the 1.1 – 3.2  $\mu\text{m}$  particle size range<sup>55</sup>. These coarse particles typically come from grinding activities (wheel-rail interface) and other geological origins (e.g., spores, waste residues)<sup>40</sup>. Many subway particles are angular in shape which is consistent with metal surface abrasion<sup>33</sup>. A Seoul Korea study found that subway dust in the 2.5 – 10  $\mu\text{m}$  range and 1 – 2.5  $\mu\text{m}$  range were made of 77.3% and 70.9% iron, respectively<sup>56</sup>. It is thought that this increase in coarser sized particles is due to the liberation of iron particles at the wheel-rail interface and from braking systems. Park & Ha assert that many smaller particles (< 2  $\mu\text{m}$ ) are from vehicle exhausts and other sources of combustion based on measuring a strong positive correlation between PM<sub>2.5</sub> and CO concentrations<sup>57</sup>.

Bulk dust samples were collected from subway surfaces and analyzed<sup>36</sup>. Particle sizing was conducted with an average normalized distribution of 23.3% (< 2.5  $\mu\text{m}$ ), 27.2% (2.5 – 10  $\mu\text{m}$ ), 42.9% (10-25  $\mu\text{m}$ ), and 6.5% (>25  $\mu\text{m}$ ). A shift to larger particles is seen in the deposited particles. The primary constituent material (40%) was iron.

A recent NYC subway system sampling campaign was completed that examined the types of microorganisms found within stations<sup>58</sup>. The findings suggest a rich and diverse background of microorganisms in the subway environment. Hundreds of organisms classified as bacterial, viral, archaeal, and eukaryotic taxa were found in the subway (with evidence of *E. coli*, *Y. pestis* and *B. anthracis*); however most organisms were considered harmless. There were several *Bacillus* species found within the subways, with the most abundant being *B. cereus* (causes foodborne illness).

### 3.2.2.2 Vapor Samples

Summa canisters were used to collect vapor backgrounds from an operational MBTA subway station (Park Street Red Line Platform) during revenue hours and the results are shown in TABLE 7. Notice that ethanol is found in the highest concentration; with acetone, isopropyl

alcohol, toluene, and chlorodifluoromethane also found in smaller percentages. It is thought that many of these vapors are caused by human traffic and activities: colognes/perfumes (ethanol, isopropyl alcohol), shampoos (ethanol), suntan lotion (ethanol, acetone), shoe polish (acetone), leather dressings (acetone, toluene), food additives (acetone), food packaging (acetone), cosmetics (ethanol, acetone), anti-acne preparations (ethanol, isopropyl alcohol), body lotions/creams (ethanol, isopropyl alcohol), printing ink (toluene), and hairspray (ethanol, isopropyl alcohol).

Park & Ha measured CO<sub>2</sub> in the Seoul subway system at an average concentration of 1,775 ppm<sup>57</sup>. Fromme found relatively high concentrations of fluoranthene and pyrene; possibly attributed to tar-based products formerly used to preserve wooden railway ties<sup>59</sup>. As discussed earlier, SF<sub>6</sub> gas is present in the NYC background due to an electric substation in mid-town Manhattan.

**TABLE 7**  
**Summa Canister Results Collected from MBTA Park Street Red Line Station**

Compound	CAS No.	Concentration (ppbv)			
		12/15/09		6/27/12	6/28/12
		6 – 12pm	12 – 6pm	10 – 6pm	10 – 6pm
Ethanol	64-17-5	78.9	107	105	109
Acetone	67-64-1	12.7	7.71	10.4	11.6
Isopropyl Alcohol	67-63-0	3.75	6.48	4.04	12.0
Toluene	108-88-3	6.71	1.52	BRL (1.0)	BRL (1.0)
Methane, chlorodifluoro-	75-45-6	4.75	4.58		
Dichlorodifluoromethane (Freon 12)	75-71-8	0.72	0.73	BRL (1.0)	BRL (1.0)
Chloromethane	74-87-3	0.67	0.69	BRL (1.0)	BRL (1.0)
Benzene, 1-ethyl-2-methyl- (01)	000611-14-3	9.12			
m,p-Xylene	179601-23-1	BRL (0.5)	6.82	BRL (2.0)	BRL (2.0)
1,2,4-Trimethylbenzene	95-63-6	BRL (0.5)	6.44	BRL (1.0)	BRL (1.0)
1,3,5-Trimethylbenzene	108-67-8	BRL (0.5)	4.9	BRL (1.0)	BRL (1.0)
4-Ethyltoluene	622-96-8	BRL (0.5)	3.01	BRL (1.0)	BRL (1.0)
Limonene	138-86-3		2.70		
Ethylbenzene	100-41-4	BRL (0.5)	2.13	BRL (1.0)	BRL (1.0)
Isobutane	75-28-5		1.71		2.34
o-Xylene	95-47-6	BRL (0.5)	1.55	BRL (1.0)	BRL (1.0)
n-Heptane	142-82-5	BRL (0.5)	1.47	BRL (1.0)	BRL (1.0)
d-Limonene	5989-27-5	1.31			
1-Butanol	71-36-3	1.22			
Indane	496-11-7	1.10			
Hexane, 3-methyl-	589-34-4		1.19		
Hexane	110-54-3	BRL (0.5)	0.73	3.18	BRL (1.0)

\*BRL = Below Reporting Limit, Value shown in parenthesis

### 3.2.2.3 Typical Cleaning Materials

A cleaning event can create a substantially different temporary air and surface background. Typically stations are power washed with a high pressure hose on a monthly basis. TABLE 8 is a list of typical cleaning materials and their primary chemical components used by MTA NYCT, MetroNorth Railroad and Boston MBTA. Each system used almost entirely different cleaning materials.

**TABLE 8**

**Typical Subway Cleaning Solutions in NYC MTA, MetroNorth Railroad (GCT) and Boston MBTA**

City	Specific Location	Name	Manufacturer	Purpose
Boston	MBTA (General)	Neutrabrite	Spectrowax Corporation	Hard Surface Cleaner
		D-GREASE	Spectrowax Corporation	Cleaning grease and oil
		Ethylene Glycol Butyl Ether	Sigma-Aldrich	Cleaning Solution
		Five Star Glass Cleaner	Spectrowax Corporation	Wash windows
MTA	NYCT (General)	TIDE	P&G	All Purpose Cleaner / Detergent
		Power Lemon	Nationwide Chemical Co., Inc.	Disinfectant / Detergent
		Elite Professional Bleach	James Austin Company	Disinfectant / Remove Stains
		Enviro Neutral Cleaner NU	W.W. Grainger	Daily Floor & Surface Cleaner
		Sheen Stainless Steel	U.S. Industrial Lubricants / Oil Kraft	Stainless Steel Cleaner and Polish
		Window / Stainless Steel Cleaner	National Chemical Laboratories of Pa, Inc	Wash windows and stainless steel
		NCL 333 Graffiti Remover	National Chemical Laboratories of Pa, Inc	Remove Graffiti / Detergent
		NCL 430 Strawberry/Citrus Deodorant	National Chemical Laboratories of Pa, Inc	Sanitize
		ACCLAIM	Zep Inc	Anti-bacterial handcleaner
		Solopol	Evonik Stockhausen, Inc.	Hand Cleanser
		Cream Cleanser #53	Enviro-solutions Limited	Bathroom Cleaner
Earthsense #20 Washroom Cleaner	National Chemical Laboratories of Pa, Inc	Washroom Cleaner		
NYC	MetroNorth Railroad (Grand Central Terminal)	Noxon 7	Reckitt Benckiser	Metal Polish
		Water Base Stainless Steel Maintainer	Claire	Stainless steel cleaner
		Shineline Baseboard Stripper	Spartan	Clean baseboard, floor edges, stairs
		Rapid Strip	Supply One	Stripping
		EarthVital Vitalshine Zinc Free Seal & Finish	CapTree PureTech Solutions	Floor sealer and finish All
		EarthVital Easy 2 Clean Peroxide Cleaner	CapTree PureTech Solutions	Purpose Cleaner Floor shiner
		Super Spraybuff	Spartan	Cleanser Hand
		Ajax Oxygen Bleach	Colgate-Palmolive Company	Washing
		Hand Soap	Unknown	
		112 Orange	Unknown	
446	Unknown			
Hard as Nails	151 Products Ltd	Adhesive		
Rapid Stripper	Viking Criterion	Stripping		
Concur	The Fuller Brush Company	Floor Cleaner		
Super Mist Odor Counteractant	Aireactor	Odor Remover		
Vandalism Mark Remover	Edmer	Remove Graffiti		
Delta Ultra	Pollet	Cleaner / Degreaser		

## **Section 4. Environmental Alternatives of Implementing the Alternative Actions**

Information and evaluation data on the different particulate and gas materials gathered from regulatory agencies and published documents are reviewed in this section to address the potential direct or indirect effects on health, safety, and the environment due to implementation of each alternative action.

### ***4.1 Human Health and Safety Effects***

This section will discuss all human health and safety effects related to the release of gas and particulate tracers during the planned testing in the MTA NYCT subway stations. Passenger contact with all particulate and gas alternatives will occur. Contact may include inhalation, ingestion, and dermal contact. Additional potential for contact may occur following testing due to the potential for re-aerosolization of the particulate material due to air movement within the subway station. Ridership during rush hours is expected to be largely comprised of healthy working adults, but young, aged or immune-deficient or immune-compromised riders are also expected to be present during testing. A discussion of the anticipated upper bound of test material exposure will first be discussed. The individual environmental consequences of each individual gas and particulate alternative will then be discussed within their individual health related studies and the planned population exposure.

#### **4.1.1 Human Health and Safety Effects from Particulate Releases**

As stated earlier, the maximum amount of particulate tracer material released within a station over ten minutes, 8 hours, and 24 hours is 20, 20, and 40 grams, respectively. The majority of released material by weight will be in the respirable particle range of 1 – 10  $\mu\text{m}$ . For all particulate alternatives, a 10 foot radius controlled zone will be established on the platform around the release site with no access for the general public permitted while the release occurs. The material will be directed into the airspace to be rapidly mixed into the station, minimizing exposure of any one individual to tracer materials.

TABLE 9 provides particulate release concentrations near the source from previous Boston and NYC testing. Computer modeling particulate concentration results using the Below Ground Model (BGM) developed by Argonne National Laboratory (ANL) are also presented for comparison. It is anticipated that both particulate alternatives will yield similar station concentrations as shown for the Grand Central platform modeling. Notice that all previous releases and modeling results are 1 – 2 orders of magnitude lower in 8-hour Time Weighted Average (TWA) mass concentration than the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) and OSHA permissible exposure limits. It should be noted that there will be a cumulative dosage effect for riders that transit the affected subway stations daily. However, the entire duration of testing will be completed in

approximately one week and all applicable inhalation and ingestion concentrations are well below established guidelines.

A subway passenger that is near the release site for the 15 minutes immediately after dissemination would expect a daily increase in PM<sub>10</sub> mass concentration of 3.8 µg/m<sup>3</sup>. An upper bound on the increase in the daily mass concentration (i.e., over 24 hours) directly next to the release site is expected to be 7.7 µg/m<sup>3</sup>. For comparison, the EPA has set a health-based national ambient air quality standard for daily outdoor PM<sub>10</sub> content at 150 µg/m<sup>3</sup>. EPA primary standards provide health protection for the public, including the health of “sensitive” populations (e.g., asthmatics, children and elderly). Therefore, even standing next to the release location for 24 hours, the mass concentration increase is only 5.1% of the EPA outdoor guidelines.

Note that much of the material will deposit on surfaces (indoor and outdoor) as well as subway passenger effects (e.g., clothing, hair, skin). Some passengers will transport particulates to other locations (e.g., work, home) via fomite transport (i.e., particulate attachment). The amount of material transported via personal effects will likely be at doses in a similar range to the total amount inhaled. However, this is highly dependent on several factors including particle size, passenger clothing, passenger movement, and humidity. As an example, someone standing on the Grand Central 4,5,6 platform for three hours after a 10 gram release of 1-µm spherical particles (1 g/cm<sup>3</sup> density) within the station and breathing at 8.5 Liters Per Minute (LPM) could inhale up to  $45 \times 10^6$  total particles (< 24 µg) based on modeling estimates. Using the same model (assuming a deposition velocity of 0.3 m/hr averaged over all surfaces), a surface area within Grand Central 4,5,6 platform equal to the approximate total surface area of skin on a human body (1.5 m<sup>2</sup>) would have  $41 \times 10^6$  particles deposited after three hours (< 22 µg). Previous aerosol releases at South Station in Boston measured particle deposition velocities much greater on cotton coupons (18 m/hr) than stainless steel coupons (0.8 m/hr) for polystyrene latex particles (mass median diameter of 2.7 µm). The majority of this material will remain adhered to surfaces until mechanical agitation and/or wetting; most likely presenting inhalation concentrations much lower than experienced within subway stations.

**TABLE 9**  
**Measured and Expected Mass Concentrations from Subway Particulate**  
**Measurements**

	Particle	Release Quantity	Release Location	Details	Mass Concentration (mg/m <sup>3</sup> ) Time Weighted Average			
					15-min	1-hr	3-hr	8-hr
<b>Previous Tracer Tests</b>	<i>B. subtilis</i> mix1	18.7 g (burst)	Boston subway	Non-revenue (no train)	1.25	0.39	0.13	0.05
	<i>B. subtilis</i> mix1	42 g (burst)	Boston subway	Non-revenue (1 train arrival)	0.64	0.24	0.08	0.03
	Silica mix2	146 g (16 g/min)	NYC subway	Non-revenue (1 train arrival)	0.20	0.19	0.06	0.02
	Silica mix2	65 g (7.2 g/min)	Boston subway	Non-operational (no train)	0.62	0.28	0.12	0.04
	Silica mix2	55 g (5 g/min)	Boston subway	Non-operational (no train)	0.65	0.24	0.10	0.04
	Urea/OB3	30 g (1.5 g/min)	Boston subway	Revenue hours	0.70	0.44	0.20	0.08
	Pure OB4	30 g (1.5 g/min)	Boston subway	Revenue hours	0.70	0.44	0.20	0.08
	PSL microspheres5	1 g (0.05 g/min)	Boston subway	Revenue hours	0.07	0.035	0.012	0.0045
<b>Modeling</b>	DNA-Tagged Carrier	20 g (1 g/min)	NYC Grand Central	Next to Release	0.27	0.1	0.03	0.01
				Next Station (33 <sup>rd</sup> St)	0.04	0.03	0.009	0.003
<b>Limits</b>	OSHA Nuisance Dust PEL							5
	ACGIH Nuisance Dust TLV							3
	OSHA Amorphous Silica PEL							0.8

#### 4.1.1.1 Human Health and Safety Effects from Particulate Alternative P1

The first particulate alternative (P1) is to aerosolize DNA oligonucleotides (oligos) encapsulated in maltodextrin particles (referred to as “DNATrax”) and tagged with an Optical Brightener (OB). DNATrax (i.e., DNA oligos encapsulated inside maltodextrin) was developed by Lawrence Livermore National Laboratory (LLNL) for food labeling and has been classified by the Food & Drug Administration (FDA) as Generally Recognized As Safe (GRAS). DNATrax is listed as a nuisance dust on its SDS (provided in Appendix A). DNATrax-OB, which includes encapsulation of both CI Fluorescent Brightener 220 and DNA oligos inside maltodextrin, is proposed as particulate alternative P1 for the described phenomenology tests. The fluorescent tag has been added to make tracer discrimination easier for real-time biological trigger sensors utilizing fluorescence techniques. Safety information for DNATrax-OB components is summarized below.

Maltodextrin is a polysaccharide produced from starch that is often used as a food additive and has FDA Generally Recognized as Safe (GRAS) approval for ingestion. The maltodextrin SDS (provided in Appendix A) lists the OSHA PEL as 5 mg/m<sup>3</sup> (respirable fraction)<sup>60</sup>. Maltodextrin is characterized as a nuisance dust and is not known to have adverse effects on the lungs<sup>60</sup>.

DNA sequences will be chosen from the thermophilic bacterium *Thermotoga maritima* (*T. maritima*) that are non-coding (i.e., do not produce a protein) and dissimilar from DNA sequences of other common biological aerosol microorganisms. The oligos are inert and non-living. Furthermore, environmental DNA (eDNA) is already ubiquitous as byproducts (e.g., skin, hair, urine) from all organisms; therefore there is no additional impact or burden placed on the environment from use of the material. To further verify specificity of each candidate DNA signature, a final computational screening utilizing TaqSim PCR simulation program will verify that no cross-reactions are identified when the signatures are compared against all sequences in genbank, including eukaryotic sequences.

The report of the Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers (ETAD) submitted to the U.S. EPA High Production Volume (HPV) Chemicals Challenge Program<sup>61</sup>, and accepted by the EPA<sup>62</sup>, summarizes the results of published toxicology studies on CI Fluorescent Brightener 220 and related optical brighteners. According to the studies summarized in the report, these materials are generally not irritating to skin and eyes; toxicity studies in male and female Wistar rats showed that oral doses up to 15,000 mg per kg body weight (the highest level tested) resulted in no fatalities<sup>63,64</sup>. Toxicity studies of a related brightener (CI Fluorescent Brightener 263, CAS No. 67786-25-8) reported no deaths and no signs of toxicity in male and female Wistar rats, male NMRI mice, female New Zealand white rabbits, and female beagle dogs orally administered 2500, 1000, 1000 and 500 mg/kg (respectively)<sup>65</sup>. In inhalation toxicity studies, Wistar rats were exposed for 4 hours to 163, 375, 1,225 and 1,895 mg/m<sup>3</sup> of CI Fluorescent Brightener 28/113 (CAS No. 4404-43-7) (the latter being the maximum attainable concentration)<sup>66</sup>. No mortalities occurred in any group. At doses of 1,225 and 1,895 mg/m<sup>3</sup>, a transient reduction of the general condition of the rats was

observed for 4 – 6 hours. No further clinical symptoms were observed and at the end of the 14 day observation period no findings were noted in pathological examinations. In a similar study<sup>67</sup>, rats exposed to 2,900 mg/m<sup>3</sup> of CAS No. 13863-31-5 for 4 hours did not result in mortality of any of the 10 animals tested. Animals appeared healthy during the 14 days following exposure and had normal weight gains.

A review of toxicity studies for three optical brighteners, including CI Fluorescent Brightener 220, carried out by the German Institute for Consumer Health Protection and Veterinary Medicine<sup>68</sup> also concluded that they pose no risk to consumers. The SDS for CI Fluorescent Brightener is 220 is provided in Appendix A.

The DNATrax-OB particles will have a mass median aerodynamic diameter (MMAD) between 1 – 10 µm, which is considered respirable. The DNATrax-OB particles (including the primary component maltodextrin) are not listed explicitly by OSHA; therefore it is assumed classified as “Particulates Not Otherwise Regulated” by OSHA and at a minimum would be required to remain under the designated 8-hour Time Weighted Average (TWA) respirable Permissible Exposure Limit (PEL) of 5 mg/m<sup>3</sup>. The American Conference of Governmental Industrial Hygienists (ACGIH) recently established a Threshold Limit Value (TLV) of 3 mg/m<sup>3</sup> (respirable) and 10 mg/m<sup>3</sup> (inhalable, i.e., deposits in the nose, throat and upper respiratory tract) for “particles not otherwise specified (PNOS)”. However, the ACGIH PNOS designation applies only to particles that are insoluble or poorly soluble in water (maltodextrin is soluble in water). To be conservative, the lower ACGIH mass concentration will still be shown as in full compliance. As shown in TABLE 9, the maximum concentrations encountered after particle releases (i.e., next to release) are 500 and 300 times lower than the established limits by OSHA and ACGIH for particles not otherwise regulated (i.e., inert or nuisance dusts), respectively. Maltodextrin, CI Fluorescent Brightener 220 and the DNA oligos are not anticipated to present a significant risk to human health and safety.

#### 4.1.1.2 Human Health and Safety Effects from Particulate Alternative P2

The second particulate alternative (P2) is to aerosolize P1 or DNA oligos attached to amorphous silica particles. Particulate Alternative P2 will be referred to as DNATrax-OB-Silica. The fluorescent tag has been added to make tracer discrimination easier for real-time biological trigger sensors utilizing fluorescence techniques. Safety information for DNATrax-OB-Silica is summarized below with SDS’s provided in Appendix A.

Amorphous silica (SiO<sub>2</sub>, CAS: 7631-86-9), the primary component in Alternative P2, is used as an anti-caking agent (e.g., dried eggs), filler for the rubber industry, and a carrier for liquid active ingredients in human and animal nutrition. Amorphous silica is found naturally in dust from microscopic marine plant fossil skeletons (i.e., diatomaceous earth). One of the major problems with assessing the health effects from amorphous silica is contamination from crystalline silica<sup>69</sup>. Crystalline silica can cause several negative human health effects such as silicosis, tuberculosis, chronic bronchitis/chronic obstructive pulmonary disease (COPD) and

lung cancer. However, all amorphous silica that is proposed for use will be synthetically manufactured, avoiding contamination with crystalline silica. No silicosis has been found in the epidemiological studies involving workers with long-term exposure to intentionally manufactured Synthetic Amorphous Silica (SAS)<sup>69</sup>. In addition, long-term animal inhalation experiments exposed to high concentrations of amorphous silica ( $> 10 \text{ mg/m}^3$ ) showed no persistent silicotic nodules (crystalline silica clearly demonstrated this effect)<sup>69</sup>. No adverse changes were observed in Wistar rats<sup>70</sup> exposed to three different types of respirable SAS particles at  $1 \text{ mg/m}^3$  (6-hrs a day for five consecutive days).

Silica gels (minimum silica content 89.5%) are considered GRAS when used as anti-foaming agents<sup>71</sup>. Silicon dioxides are considered GRAS as substances migrating from paper and paperboard products used in food packaging<sup>72</sup>. In 2010, Cabot Corporation submitted a proposed regulation to the U.S. FDA designating the addition of up to 2% SAS in several food categories as Generally Recognized As Safe (GRAS)<sup>73</sup>. The FDA responded that:

“Based on the information provided by Cabot, as well as other information available to the FDA, the agency has no questions at this time regarding Cabot’s conclusion that SAS is GRAS under the intended conditions of use. The agency has not, however, made its own determination regarding the GRAS status of the subject use of SAS.”

In November 2014, the Evonik Corporation also determined SAS to be GRAS and submitted a new proposed regulation to the FDA for consideration<sup>74</sup>. It is currently under review by the U.S. FDA. The amorphous silica SDS lists the OSHA PEL as  $0.8 \text{ mg/m}^3$  (respirable fraction)<sup>75</sup>.

Maltodextrin is a polysaccharide produced from starch that is often used as a food additive and has FDA Generally Recognized as Safe (GRAS) approval for ingestion. The maltodextrin SDS (provided in Appendix A) lists the OSHA PEL as  $5 \text{ mg/m}^3$  (respirable fraction)<sup>76</sup>. Maltodextrin is characterized as a nuisance dust and is not known to have adverse effects on the lungs<sup>60</sup>.

DNA sequences will be chosen that are non-coding (i.e., do not produce a protein) and dissimilar from DNA sequences found in other common biological aerosol microorganisms. The oligos will be inert and are non-living. Furthermore, environmental DNA (eDNA) is already ubiquitous as byproducts (e.g., skin, hair, urine) from all organisms; therefore there is no additional impact or burden placed on the environment from use of the material. To further verify specificity of each candidate DNA signature, a final computational screening utilizing TaqSim PCR simulation program will verify that no cross-reactions are identified when the signatures are compared against all sequences in genbank, including eukaryotic sequences.

As described earlier, Fluorescent Optical Brightener 220 is used safely in several U.S. commercially available products. Amorphous silica, CI Fluorescent Brightener 220 and the attached DNA oligos/maltodextrin do not present a significant risk to the environment or human health.

Amorphous silica is regulated by OSHA and would be required to remain under the designated 8-hour Time Weighted Average (TWA) respirable PEL of 0.8 mg/m<sup>3</sup>. The DNATrax-OB-Silica particles will have a mass median aerodynamic diameter (MMAD) between 1 – 10 µm, which is considered respirable. As shown in TABLE 9, the maximum concentrations encountered after particle releases would be well below the established OSHA limit. Amorphous silica, CI Fluorescent Brightener 220 and the DNA oligos are not anticipated to present a significant risk to human health and safety.

#### **4.1.2 Human Health and Safety Effects from Gas Releases**

As stated earlier, the maximum amount of gas to be released within a station over ten minutes, 8 hours, and 24 hours are 1, 1, and 2 kilograms, respectively for SF<sub>6</sub> and 0.5, 0.5, and 1.0 kilograms for PFTs. TABLE 10 lists gas concentrations measured near the point of release during previous Boston subway tests adjusted to the release amounts in TABLE 3. The OSHA PEL and ACGIH TLV for SF<sub>6</sub> and the Acceptable Air Concentration (AAC) for PFTs are also indicated.

**TABLE 10****Maximum Observed Tracer Concentrations\* during Boston MBTA Subway Studies**

Tracer Gas	Average ppmv*			
	15-min	1-hr	3-hr	8-hr**
SF <sub>6</sub>	7.6	2.8	1.2	0.4
<i>OSHA PEL, ACGIH TLV Limit</i>	–	–	–	1,000
PDCB	5.0	3.0	1.0	0.38
PMCH	3.0	1.6	0.7	0.25
mPDCH	1.5	0.8	0.3	0.11
<i>AAC Limit</i>	9.0	–	–	3.0

\*Adjusted for the release amounts in TABLE 3

\*\*Based on 3-hour exposure measurements

Based on the maximum concentrations observed during the Boston subway tests the expected concentrations in NYC would be well within the established limits for these release amounts.

The PFTs released in the MTA NYCT subway system during the S-SAFE Program were not entirely the same as those in TABLE 3 but nevertheless provide a useful indicator of the likely maximum PFT concentrations immediately at the release point. TABLE 11 presents the average 10-minute PFT concentrations observed at the release locations in the MTA NYCT subway *while the tracer releases were in progress* during S-SAFE, adjusted to the release amounts in TABLE 3. Other PFTs, including PDCB, were released aboveground during the S-SAFE Program, but are not included here.

**TABLE 11**  
**Observed Tracer Concentrations\* during MTA NYCT Subway Studies**

Tracer Gas	Average ppmv*		
	10-min	30-min	8-hr
PMCH	7.5	---	0.012
ptPDCH**	11.5	---	0.006
iPPCH	7.9	---	0.022
PTCH	3.9	---	0.01
BGM Modeling	0.84	0.34	0.025
<i>AAC Limit</i>	<i>9.0</i>	---	<i>3.0</i>

\*Adjusted for the release amounts in TABLE 3  
\*\*ptPDCH is an isomer of mPDCH

TABLE 11 also includes the 10-min, 30-min, and 8-hr average PFT concentrations predicted by the ANL Below Ground Model (BGM) for the 50-ft section of the subway platform containing the release location. The rapid dilution of material with distance from the release point causes the 10-min average from the model of this 50-ft section to be about ten times less than the 10-min averages measured directly at the point of release. The 8-hr model prediction is comparable to the measured value for iPPCH, which was released in the same subway station assumed in the model calculation.

#### 4.1.2.1 Human Health and Safety Effects from Gas Alternative G1

Gas alternative G1 involves the release of SF<sub>6</sub> alone. It is evident from TABLE 10 that the maximum concentrations likely to be encountered in this study are far below the established limits. In addition, SF<sub>6</sub> has been released in subways in Washington, DC and Boston many times without adverse effects.

#### 4.1.2.2 Human Health and Safety Effects from Gas Alternative G2

Gas alternative G2 involves the release of three PFTs in addition to SF<sub>6</sub>. TABLE 10 indicates that, based on the PFT releases in the Boston subway, the expected maximum concentrations would be within the established AAC limits. TABLE 11 shows that the S-SAFE measurements at the PFT release locations in the MTA NYCT subway, after adjusting for the release amounts in TABLE 3, largely confirm this. The exception is the isomer of mPDCH, ptPDCH, which is slightly greater than the AAC 10-min limit. However, this limit may be exceeded for no more

than 30 minutes in one day<sup>18</sup> and may not exceed 15 ppmv. Because the PFT releases will only last 10 minutes, rapid dilution of the tracers by the subway trains will ensure that this limit will not be exceeded, as the model calculation presented in TABLE 11 suggests. Also, the measured 10-min concentrations in TABLE 11 were at the point of release; as described earlier, the release locations will be cordoned off to keep subway patrons at a distance. In addition, subway patrons are unlikely to be in the vicinity of the release for more than a few minutes while they wait for a train.

PFTs have previously been released in subways in NYC, Washington DC, and Boston without adverse effects. The SDS for each PFT proposed for release is provided in Appendix A.

#### **4.2 Environmental Effects on Wildlife**

The potential for exposure of terrestrial wildlife to the particulate and gas materials due to movement of the material with the air vented from the station, or with the train as it travels out of the station and above ground was evaluated. DNATrax-OB will not impact the surrounding environment. The primary component, maltodextrin, is already used extensively in several food and drink products (e.g., beer, protein shakes, and sweeteners such as Splenda). The DNA oligos are safe and are comprised of the same four nucleotides as all other DNA (uniqueness comes from differences in sequence)<sup>77</sup>. The particular sequence will be made to look distinctly different from known pathogens that are searched for within the DHS BioWatch air sampling program. The fluorescent brightener (CI fluorescent brightener 220) is used in several products found commonly in Manhattan (paper, clothing). It has been tested extensively on animals and has presented little to no risk. The OB is soluble in water and is removed by >75% to >95% through adsorption from sewage with direct photolysis a second elimination process (half-life for the OB on surface water is 3.9 – 5.2 hours)<sup>78</sup>. OB acute toxicity levels are known for fish (*Brachydanio rerio*; 96 h-LC<sub>0</sub> > 1,000 mg/L), daphnia (*Daphnia magna*; 48 h-EC<sub>0</sub> ≥ 113 mg/L), and algae (*Scenedesmus subspicatus*; 96 h-EC<sub>50</sub> > 1,000 mg/L). There will be less than 68 g of OB released over the duration of all proposed tests (approximately one week). Toxicity levels for daphnia (the lowest toxicity level) would only be exceeded if the entire OB supply were deposited in a water reservoir containing 601.8 liters (~ 4 bathtubs of water).

DNATrax-OB-Silica will not impact the surrounding environment. The primary component, amorphous silica, is found naturally in marine plant fossil skeletons and is already used extensively in several products commonly found in Manhattan such as toothpaste, anti-caking agents (e.g., dried eggs) and carriers for liquid active ingredients in human and animal nutrition. DNA and OB has been discussed earlier and will present no additional risk to the environment.

Likewise, release of both SF<sub>6</sub> and PFTs in the amounts detailed earlier will have no discernable impacts on wildlife due to the low concentrations that will be observed and the absence of toxic effects from the gas tracers.

With respect to the gas alternatives, SF<sub>6</sub> is currently present at appreciable levels within the NYC environment from electric power substations. There have been no reported adverse effects. The three proposed perfluorocarbons are not known to cause adverse health effects, even at high concentrations as discussed earlier.

### ***4.3 Global Warming Potential***

SF<sub>6</sub> and PFTs are considered potent greenhouse gases in comparison to carbon dioxide. However, their contributions to global warming are small compared to the primary anthropogenic sources: carbon dioxide, methane, and nitrogen oxide due to the very low amount of SF<sub>6</sub> and PFTs in the atmosphere<sup>79</sup>. The relative contribution to global warming potential from the tracer gases described in this document is often measured in terms of Greenhouse Warming Potential (GWP). This is defined as the time-integrated radiative forcing of a tracer substance relative to the same mass of reference gas (taken here as CO<sub>2</sub>)<sup>80</sup>. The GWP of SF<sub>6</sub> is 23,600<sup>5</sup>. The GWP of the particular PFTs used in this study are not published, but can be conservatively estimated as 10,000 based on the acceptance range of GWP for PFTs as 1,000 – 10,000<sup>19</sup>. Using these GWPs for the tracers, the upper bound is estimated at 193 MTCDE (Metric Tons Carbon Dioxide Equivalent) or 424,600 lbs of CO<sub>2</sub> equivalent.

The amount of PFTs and SF<sub>6</sub> that will be released in this study (SF<sub>6</sub>: 5 kg, PFTs: 7.5 kg) is a minuscule fraction of the industrial emissions of these gases. The tracers have a GWP of only 0.0005% (1 out of 200,000) of the total PFTs and SF<sub>6</sub> released in the U.S. in 2008<sup>5</sup> and only 0.008% of the GWP from fugitive SF<sub>6</sub> emissions in NYC in 2008 alone.

### ***4.4 Environmental Compliance***

Equipment used to generate releases and collect samples will be returned to the laboratory, cleaned and evaluated for reuse. All sampling waste generated during sample collection (e.g., gloves, filters) will be disposed of properly. None of the equipment or personnel will generate loud noises that will disturb the environment. None of the materials brought to the stations will generate Resource Conservation and Recovery Act (RCRA) regulated hazardous waste. The wastes generated will not significantly differ between any of the Alternatives.

### ***4.5 Environmental Justice***

In accordance with Executive Order 12898,<sup>81</sup> federal agencies should determine whether their activities have a “disproportionately high and adverse human health or environmental effects on minority populations and low-income populations”.

All releases and the majority of sampling will take place in Manhattan. There are 1,585,873 people living in Manhattan, 48% non-Hispanic White, 25.4% Hispanic, 12.9% non-Hispanic

black, 11.2% non-Hispanic Asian, and 0.1% non-Hispanic American Indian<sup>82</sup>. Manhattan has the second highest percentage of non-Hispanic Whites of the five NYC boroughs. Approximately 21% of Manhattan households are below the federal poverty level.<sup>83</sup> However, the top 5 percent of Manhattan households earned \$864,394, which is 88 times more than the poorest 20% of residents. This is the biggest dollar income gap of any county in the U.S. Therefore, the chosen location has a diverse set of races and incomes.

With respect to health effects from particulate simulants, the small quantity of material proposed for release in the subway tests will result in upper bound concentrations (i.e., next to release site) that are over an order of magnitude lower than the established limits by OSHA and ACGIH, respectively (See Section 4.1.1 Human Health and Safety Effects from Particulate Releases). A subway passenger that is near the release site for the 15 minutes immediately after dissemination would expect a daily increase in PM<sub>10</sub> mass concentration of 3.8 µg/m<sup>3</sup>. An upper bound on the increase in the daily mass concentration (i.e., over 24 hours) directly next to the release site is expected to be 7.7 µg/m<sup>3</sup>. For comparison, the EPA has set a health-based national ambient air quality standard for daily outdoor PM<sub>10</sub> content at 150 µg/m<sup>3</sup>. EPA primary standards provide health protection for the public, including the health of “sensitive” populations (e.g., asthmatics, children and elderly). Therefore, even standing next to the release location for 24 hours, the mass concentration increase is expected to be only 5.1% of the EPA recommended outdoor guidelines.

With respect to health effects from gas simulants, the small quantity of SF<sub>6</sub> material proposed for release in the subway tests will result in upper bound concentrations (i.e., next to release site) that are over three orders of magnitude lower than the established limits by OSHA and ACGIH, respectively (See Section 4.1.2 Human Health and Safety Effects from Gas Releases). Because perfluorocarbons are not known to cause adverse health effects, even at high concentrations, no OSHA PEL, ACGIH TLV, or Acute Exposure Guideline Level (AEG) have been established. For S-SAFE, an 8-hr Acceptable Air Concentration (AAC) limit of 3 ppm was established<sup>84</sup> for the PFTs. This threshold was based on the known toxicity profile of cyclohexane, which is an industrial solvent, not an inert perfluorocarbon compound. Even at this conservative estimate, upper bound PFT concentrations (i.e., next to release site) will be approximately an order of magnitude lower than the 8-hr AAC threshold recommended.

There is no evidence that low income or minority populations would receive a higher exposure to the particulate or gas material than any other group. Furthermore, even if these groups have a higher prevalence of “sensitive” populations (e.g., asthmatics), maintaining recommended EPA outdoor PM<sub>10</sub> mass concentration levels and being well below gas thresholds (i.e., OSHA PELs, ACGIH TLVs, recommended AAC) illustrates that these alternatives would not disproportionately impact minority or low-income communities.

#### ***4.6 Historic Properties***

Pursuant to Section 106 of the National Historic Preservation Act of 1966 (NHPA) and its implementing regulations at 36 C.F.R. Part 800, consideration was given to the impact of the tests on any historic properties. The three stations where releases are planned (i.e., Times Square, Grand Central, Penn Station), as well as many stations where sampling is planned, are listed on the National Register of Historic Places. However, as discussed earlier in the document, there are no permanent changes that will occur as part of the project and temporary changes proposed are extremely minor. The project has no potential to effect historic properties as all equipment deployed is portable, has a small footprint, and requires no physical permanent changes to the deployed location. Operation and access to these stations will remain unimpeded. Furthermore, the New York State Historic Preservation Office (NYSHPO) has been contacted regarding the project and determined that review was not necessary.

## **Section 5. Conclusion and Identification of the Proposed Action**

There were three particulate (P1, P2 and P3) and three gas (G1, G2 and G3) alternatives considered for the proposed phenomenology experiments. An aerosol release of DNATrax-OB (P1) and/or DNATrax-Silica-OB (P2) would provide highly sensitive and specific measurements, allowing for the assessment of subway dispersion models. These particulates will also allow for an estimation of the amount of material reaerosolized, deposited on surfaces and passengers, as well as mechanically filtered from train HVAC systems. Therefore, the use of DNATrax-OB and/or DNATrax-OB-Silica is recommended for the current phenomenology experiments. Characterization work (e.g., limit of detection measurements, sizing capabilities, reaerosolization chamber tests) is ongoing to determine whether DNATrax-OB and/or DNATrax-OB-Silica will be released. Both alternatives may ultimately be used to create different particle size distributions; however the total amount of particulate material released will not exceed what was documented in TABLE 2. The no particulate alternative will not help to validate current particulate models and therefore does not meet the needs of the development effort and test.

The gas tracers allow the measurements from this study to be linked with previous subway studies carried out in NYC, Washington, DC, and Boston that also used these tracers. In addition, gas tracers do not deposit on surfaces and are not removed by mechanical filtration in train car HVAC systems, thereby permitting the effect of these removal processes on the particulate tracers to be more clearly identified.

The three gas tracer alternatives are SF<sub>6</sub> alone, SF<sub>6</sub> in combination with three PFTs, and no gas released, respectively. Substantial fugitive emissions of SF<sub>6</sub> may exist in NYC, which could limit the ability to detect an SF<sub>6</sub> tracer more than a few stations away from the release point. However, even in the presence of significant background levels, the real-time measurement capability afforded by SF<sub>6</sub> would be invaluable for monitoring the concentration levels in stations near the release point, for obtaining high time-resolution data needed to

determine ventilation rates in the subway stations, and to readily discern if general subway air flows are far different than anticipated.

The addition of PFTs would complement the SF<sub>6</sub> measurements by permitting measurements to be obtained at lower concentrations and at greater distances from their point of release because of their extremely low background levels. The PFTs would be released in different locations during the same test but collected with the same samplers thereby enabling multiple tests to be conducted simultaneously for identical conditions with very little additional effort. For these reasons, the combined release of SF<sub>6</sub> and PFTs is recommended.

## **Section 6. Persons and Agencies Contacted**

Dr. Charles Burrus  
MTA/NYC Transit, Department of Security  
Deputy Chief, Technology Applications Unit  
Counter-terrorism/Vulnerability Mitigation Div.  
Chief Administrator, WMD-HazMat Response Team

Mr. Michael Gemelli  
Manager, Environmental Monitoring & Emergency Response  
Ops Director, NYCT WMD Hazmat Response Team  
Department of Security

Mr. Christopher S. Higgins  
Chief, Counter Terrorism / Security Command Center  
MTA NYCT Department of Security

Dr. Michael V. Walter  
Detection Branch Chief & BioWatch Program Manager  
Dept. Homeland Security  
Office of Health Affairs

CAPT Daniel Yereb  
USPHS, Director for BioWatch Field Operations Detection Branch, Health Threats Resilience  
Division  
Department of Homeland Security

Dr. Yair Hazi  
Systems Engineering & Technical Assistance Contractor  
BioWatch Jurisdictional Coordinator, New York City  
New York City BioWatch Program Office  
Office of Health Affairs, Department of Homeland Security

Dr. Danimargot Zavasky  
Medical Director, Counterterrorism Bureau  
New York City Police Department

Dr. Joel Ackelsberg  
NYC Department of Health and Mental Hygiene  
Bureau of Communicable Diseases

Dr. Donald Bansleben  
Program Manager  
Chemical and Biological Defense Division  
Department of Homeland Security

Dr. Angela Ervin  
Program Manager  
Chemical and Biological Defense Division  
Department of Homeland Security

Dr. John Fischer  
Division Director  
Chemical and Biological Defense Division  
Department of Homeland Security

Dr. Christina Rudzinski  
Assistant Group Leader, Chemical and Biological Defense Systems  
Massachusetts Institute of Technology Lincoln Laboratory

Dr. Benjamin L. Ervin  
Technical Staff, Chemical and Biological Defense Systems  
Massachusetts Institute of Technology Lincoln Laboratory

## **Appendix A: Safety Data Sheets**



# SAFETY DATA SHEET

Issuing Date 18-Sep-2014

Revision Date 18-Sep-2014

Revision Number 0

## 1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND THE COMPANY/UNDERTAKING

### GHS product identifier

**Product Name** DNA Tagged Reagents for Aerosol Experiments

### Other means of identification

**Synonyms** DNATrax

### Recommended use of the chemical and restrictions on use

**Recommended Use** No information available

**Uses advised against** No information available

### Supplier's details

#### **Supplier Address**

Lawrence Livermore National Laboratory  
7000 East Ave.  
Livermore, CA 94550  
TEL: 925-422-1100

### Emergency telephone number

**Emergency Telephone Number** 925-422-1100

## 2. HAZARDS IDENTIFICATION

### Classification

This chemical is not considered hazardous according to the OSHA Hazard Communication Standard 2012 (29 CFR 1910.1200).

### GHS Label elements, including precautionary statements

#### Emergency Overview

The product contains no substances which at their given concentration are considered to be hazardous to health  
**Appearance** White **Physical State** Solid/Powder. **Odor** Slightly sweet

### **Precautionary Statements**

#### **Prevention**

- None

#### **General Advice**

- None

**Storage**

- None

**Disposal**

- None

**Hazard Not Otherwise Classified (HNOC)**

Not applicable

**Other information**

Dust contact with the eyes can lead to mechanical irritation.

### 3. COMPOSITION/INFORMATION ON INGREDIENTS

**Synonyms**

DNATrax

Chemical Name	CAS-No	Weight %
Maltodextrin	9050-36-6	99.9999
Non-Biological DNA	-	0.0001

### 4. FIRST AID MEASURES

**Description of necessary first-aid measures**

<b>Eye Contact</b>	Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.
<b>Skin Contact</b>	Wash skin with soap and water. If skin irritation or rash occurs: Get medical advice/attention.
<b>Inhalation</b>	IF INHALED: If breathing is difficult, remove to fresh air and keep at rest in a position comfortable for breathing. Get medical attention.
<b>Ingestion</b>	Clean mouth with water and afterwards drink plenty of water. Do NOT induce vomiting. Get medical attention.

**Most important symptoms/effects, acute and delayed**

**Most Important Symptoms/Effects** None known

**Indication of immediate medical attention and special treatment needed, if necessary**

**Notes to Physician** Treat symptomatically.

### 5. FIRE-FIGHTING MEASURES

**Suitable Extinguishing Media**

Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

**Unsuitable Extinguishing Media** No information available.

**Specific Hazards Arising from the Chemical**

No information available.

**Explosion Data**

<b>Sensitivity to Mechanical Impact</b>	None.
<b>Sensitivity to Static Discharge</b>	None.

**Protective Equipment and Precautions for Firefighters**

As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

## 6. ACCIDENTAL RELEASE MEASURES

### Personal precautions, protective equipment and emergency procedures

**Personal Precautions** Ensure adequate ventilation. Avoid contact with eyes. Refer to Section 8 for personal protective equipment.

### Environmental Precautions

**Environmental Precautions** No special environmental precautions required. See Section 12 for additional Ecological Information.

### Methods and materials for containment and cleaning up

**Methods for Containment** Take up mechanically and collect in suitable container for disposal.

**Methods for Cleaning Up** Clean contaminated surface thoroughly.

## 7. HANDLING AND STORAGE

### Precautions for safe handling

**Handling** Handle in accordance with good industrial hygiene and safety practice. Avoid contact with eyes.

### Conditions for safe storage, including any incompatibilities

**Storage** Keep containers tightly closed in a dry, cool and well-ventilated place.

**Incompatible Products** Oxidizing agents.

## 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

### Control parameters

**Exposure Guidelines** This product does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Exposure limits to follow are those for nuisance particulates:  
ACGIH TLV TWA: 10 mg/m<sup>3</sup> of total dust  
OSHA PEL TWA: 15 mg/m<sup>3</sup> of total dust

### Appropriate engineering controls

**Engineering Measures** Showers  
Eyewash stations  
Ventilation systems

### Individual protection measures, such as personal protective equipment

**Eye/Face Protection** None required under normal usage. Risk of contact, wear: Safety glasses with side-shields.

**Skin and Body Protection** None required under normal usage. Risk of contact: Protective gloves. Lightweight protective clothing.

**Respiratory Protection** None required under normal usage. If exposure limits are exceeded or irritation is experienced, NIOSH/MSHA approved respiratory protection should be worn. Respiratory protection must be provided in accordance with current local regulations

**Hygiene Measures** Handle in accordance with good industrial hygiene and safety practice.

## 9. PHYSICAL AND CHEMICAL PROPERTIES

**Information on basic physical and chemical properties**

<u>Property</u>	<u>Values</u>	<u>Remarks/ - Method</u>
Physical State	Solid/Powder	
Odor	Slightly sweet	
Appearance	White	
Odor Threshold	No information available	
pH	Not applicable	None known
Melting Point/Range	No data available	None known
Boiling Point/Boiling Range	Not applicable	None known
Flash Point	Not applicable.	None known
Evaporation rate	No data available	None known
Flammability (solid, gas)	No data available	None known
Flammability limit		
Limits in Air upper flammability	No data available	
lower flammability limit	No data available	
Vapor Pressure	No data available	None known
Vapor Density	No data available	None known
Specific Gravity	Not applicable	None known
Water Solubility	Soluble in cold and hot water	None known
Solubility in other solvents	No data available	None known
Partition coefficient: n-octanol/water	Not applicable	None known
Autoignition Temperature	No data available	None known
Decomposition Temperature	No data available	None known
Viscosity	Not applicable	None known
Flammable Properties	Not flammable	
Explosive Properties	No data available	
Oxidizing Properties	No data available	
<u>Other information</u>		
VOC Content (%)	Not applicable.	

**10. STABILITY AND REACTIVITY****Reactivity**

Not reactive under normal conditions.

**Chemical stability**

Stable under recommended storage conditions.

**Possibility of hazardous reactions**

None under normal processing.

**Hazardous Polymerization**

Hazardous polymerization does not occur.

**Conditions to avoid**

Ignitions sources - heat, sparks and open flames.

**Incompatible materials**

Oxidizing agents.

**Hazardous decomposition products**

None known.

## 11. TOXICOLOGICAL INFORMATION

### Information on likely routes of exposure

#### Product Information

<b>Inhalation</b>	Inhalation of dust in high concentration may cause irritation of respiratory system.
<b>Eye Contact</b>	Dust contact with the eyes can lead to mechanical irritation.
<b>Skin Contact</b>	No known hazard in contact with skin.
<b>Ingestion</b>	Low order of toxicity based on components. No known hazard by swallowing. May cause gastrointestinal discomfort if consumed in large amounts.

### Symptoms related to the physical, chemical and toxicological characteristics

**Symptoms** None known

### Delayed and immediate effects and also chronic effects from short and long term exposure

<b>Sensitization</b>	No information available.
<b>Mutagenic Effects</b>	No information available.
<b>Carcinogenicity</b>	Contains no ingredients above reportable quantities listed as a carcinogen.
<b>Reproductive Toxicity</b>	No information available.
<b>STOT - single exposure</b>	No information available.
<b>STOT - repeated exposure</b>	No information available.
<b>Aspiration Hazard</b>	No information available.

### Numerical measures of toxicity - Product

**LD50 Oral** >5000 mg/kg; (ATE)

## 12. ECOLOGICAL INFORMATION

### Ecotoxicity

Contains no substances known to be hazardous to the environment or not degradable in waste water treatment plants.

**Persistence and Degradability** No information available.

**Bioaccumulation** No information available.

### Other Adverse Effects

No information available.

## 13. DISPOSAL CONSIDERATIONS

**Waste Disposal Methods** This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if it is mixed with or otherwise comes in contact with a hazardous waste, if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate state, regional, or local regulations for additional requirements.

**Contaminated Packaging** Do not re-use empty containers.

## 14. TRANSPORT INFORMATION

**DOT** Not regulated

**IATA** Not regulated.

**IMDG/IMO** Not regulated.

## 15. REGULATORY INFORMATION

### International Inventories

**TSCA** Exempt  
**DSL** Exempt

### Legend

**TSCA** - United States Toxic Substances Control Act Section 8(b) Inventory

**DSL/NDL** - Canadian Domestic Substances List/Non-Domestic Substances List

### U.S. Federal Regulations

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

### SARA 311/312 Hazard Categories

<b>Acute Health Hazard</b>	No
<b>Chronic Health Hazard</b>	No
<b>Fire Hazard</b>	No
<b>Sudden Release of Pressure Hazard</b>	No
<b>Reactive Hazard</b>	No

### Clean Water Act

This product does not contain any substances regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42).

### CERCLA

This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

### U.S. State Regulations

#### California Proposition 65

This product does not contain any Proposition 65 chemicals.

### U.S. State Right-to-Know Regulations

This product does not contain any substances regulated by state right-to-know regulations.

### U.S. EPA Label Information

**EPA Pesticide Registration Number** Not applicable

## 16. OTHER INFORMATION

<b>NFPA</b>	<b>Health Hazard</b> 1	<b>Flammability</b> 0	<b>Instability</b> 0	<b>Physical and Chemical Hazards</b> -
<b>HMIS</b>	<b>Health Hazard</b> 1	<b>Flammability</b> 0	<b>Physical Hazard</b> 0	<b>Personal Protection</b> X

<b>Prepared By</b>	Product Stewardship 23 British American Blvd. Latham, NY 12110 1-800-572-6501
<b>Issuing Date</b>	18-Sep-2014
<b>Revision Date</b>	18-Sep-2014
<b>Revision Note</b>	Initial Release.

**General Disclaimer**

The information provided on this SDS is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

**End of Safety Data Sheet**



April 14, 2016  
ESH-WSH-2016-13690

Donald A. Bansleben, Ph.D.  
Program Manager  
Chemical and Biological Defense Division  
Science and Technology Directorate  
U.S. Department of Homeland Security  
Washington, DC 20528

Subject: *NYC Subway Tracer Particles for Underground Transport Restoration Project*

- Reference(s):
1. *Environmental Assessment of Proposed NYC Subway Tracer Particle and Gas Releases for the Underground Transport Restoration (UTR) Project*
  2. *NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines)*, November 2013
  3. National Ambient Air Quality Standards (40 CFR part 50), July 1987
  4. Safety Data Sheet *DNA Tagged Reagents for Aerosol Experiments*
  5. Safety Data Sheet *Non-Functionalized Silica Microparticles*
  6. Safety Data Sheet *Fluorescent Brightener 220, Technical grade*
  7. Ruth N Harding, Christine A. Hara, Sara B. Hall, Elizabeth A. Vitalis, Cynthia B. Thomas, A. Daniel Jones, James A. Day, Vicente R. Tur-Rojas, Trond Jorgensen, Edwin Herchert, Richard Yoder, Elizabeth K. Wheeler & George R. Farquar (2016): *Unique DNA barcoded aerosol test particles for studying aerosol transport*, Aerosol Science and Technology, DOI: 10.1080/02786826.2016.1162903. March 2016

Dear Mr. Bansleben,

Exposure to tracer particles designated for use in the *NYC Subway Tracer Particles for Underground Transport Restoration Project* as described in the *Environmental Assessment* report is not anticipated to pose a significant health risk to the general population due to ingestion, inhalation, or eye exposure. This is based on a review of the above referenced documents and is due to the low airborne concentrations and the benign nature of the constituents in the tracer particles. A discussion of these factors is detailed below.

The tracer particles used in this study consist of maltodextrin (i.e. food materials such as sugars, starches, etc.) that has been combined with non-biological synthetic deoxyribonucleic acid (DNA) and an optical brightener both with and without a single seed of amorphous silica. These tracer particles are very similar in composition to the *DNA Tagged Reagents for Aerosol Experiments* that consists of a particle of maltodextrin with a synthetic DNA tag. The small synthetic nucleic acid molecule tag is exempt from regulation by the *National Institutes of Health (NIH) Guidelines* for

the following reasons: (1) the synthetic nucleic acid molecule cannot replicate in any living cell, (2) does not contain an origin-of-replication (i.e., a particular sequence required to start replication) or containing elements known to interact with either DNA or ribonucleic acid (RNA) polymerase, (3) contains less than 100 nucleotides, (4) cannot integrate into the genome, and (5) cannot be translated or transcribed to produce a genetic product (e.g., protein). This material meets the specific exemption criteria in Section III C-1 of the *NIH Guidelines*.

The Food and Drug Administration (FDA) ruled in 2014 that the use of the *DNA Tagged Reagents for Aerosol Experiments* would meet the Generally Recognized as Safe (GRAS) criteria and that the DNA, its carriers, and associated substances could safely be used as a unique tracer. The FDA's determination that the ingestion of nucleic acids would not be a safety concern is based on the fact that nucleic acids are present in the cells of every living organism, including every plant and animal used for human food. Due to the small size of the synthetic DNA molecule (i.e., less than 100 nucleotides) in the *DNA Tagged Reagents for Aerosol Experiment* the FDA would not expect the DNA to remain intact or active after digestion, as cited in the *Policy for Food Derived from New Plant Varieties*, 57 FR 22984, dated May 29, 1992. Maltodextrin (i.e., the carrier component) is affirmed GRAS in Section 184.1444 Title 21 of the Code of Federal Regulations (CFR). Although starches are not specified in the regulation as a food ingredient, they have a long history of use in foods and meet the history of common use in food criteria as discussed in the 1979 report of the Select Committee on GRAS Substances on uses of starches in packaging materials.

Occupational Exposure Limits (OEL) for workers are based on airborne exposure averaged over an 8-hour workday and are referred to as an 8-hour Time Weighted Average (8-hr TWA). OELs are designed to be protective of the working population and assume that workers tend to be healthy.

There is not a comprehensive Safety Data Sheet (SDS) for the tracer particles used in this study; however, SDSs for the individual constituents were reviewed. Maltodextrin comprises the bulk of the material for *DNA Tagged Reagents for Aerosol Experiments* while the non-biological synthetic DNA represents only 0.0001%. It is anticipated that the optical brightener would also comprise a very small percentage of the finished material.

The synthetic amorphous silica seed that is at the center of some of the particles is not crystalline in nature and since it is man-made, residual crystalline silica would not be anticipated even at residual concentrations. The Federal Occupational Safety and Health Administration (OSHA) OEL for amorphous silica assumes that residual crystalline silica is present and this amount must be known or assumed to correctly identify the occupational exposure limit. For this reason, a worker exposure to nuisance dust that is insoluble or poorly soluble is compared to OSHA's Particulates Not Otherwise Regulated (PNOR) standard rather than to the amorphous silica standard. American Conference of Governmental Industrial Hygienists (ACGIH) withdrew its OEL for amorphous silica based on lack of data. Therefore exposures to amorphous silica would be compared to the Particulates Not Otherwise Specified (PNOS) guideline. The National Institute for Occupational Safety and Health (NIOSH) has an established an OEL for amorphous silica that does not rely upon an assumption of residual crystalline silica. In Table 1, NIOSH's OEL for amorphous silica is specifically identified.

Fluorescent Brightener 220 is used as a whiting agent in paper and textile industries and an OEL for the chemical has not been promulgated or recommended. A review of the SDS indicates that it is

not irritating to skin and eyes and is considered virtually nontoxic after a single short-term exposure. The exposure limits for this constituent would also be compared to PNOS/PNOR.

Maltodextrin is a polysaccharide and is produced from starch; sucrose is a monosaccharide, known as table sugar and both contain glucose in their molecular structure. In the absence of an OEL for maltodextrin, the ACGIH limits for starch and sucrose are used to evaluate potential workplace exposure. The Federal OSHA final rule on Air Contaminants published January 19, 1989, established an OEL for grain dust that specifically included starch and sucrose. These limits are incorporated in OSHA 1910-1000 Toxic and Hazardous Substances Table Z-1 limits for air contaminants.

OELs have been divided into general categories based upon where it will likely be deposited within the respiratory tract because of the particle’s aerodynamic diameter. Inhalable or total dust particles are toxic if deposited at any location within the respiratory tract and particles range from submicrometer size up to 100 µm. The respirable fraction is toxic if deposited within the gas-exchange region of the lungs and are approximately 5 µm or less.

For some chemicals, Short Term Exposure Limits (STELs) have been established. This allows workers to be exposed to higher airborne concentrations for short durations, typically 30 minutes provided that their average 8-hour TWA exposure does not exceed the established OEL. Although STELs have not been established for the constituents in the tracer particles, ACGIH has established Excursion Limits (EL) for substances with an 8-hour OEL but without a specific STEL. An EL may exceed 3 times the ACGIH OEL for no more than a total of 30 minutes during a workday, and under no circumstances should the limit exceed 5 times the ACGIH OEL. This is the basis for the 30 minute EL in Table 1.

Table 1: Occupational Exposure Limits

Substance	Occupational Exposure Limits	Federal OSHA	Cal OSHA	ACGIH	NIOSH
Maltodextrin	Starch and Sucrose	15,000 µg/m <sup>3</sup> – total dust	None established- refer to PNOR	10,000 µg/m <sup>3</sup> (8-hr TWA)	10,000 µg/m <sup>3</sup> - total dust
Non-biological synthetic DNA		5,000 µg/m <sup>3</sup> – respirable dust		30,000 µg/m <sup>3</sup> (30 minute EL)	5,000 µg/m <sup>3</sup> - respirable dust
Silicon dioxide, amorphous	Particulates not otherwise specified/regulated (PNOS/PNOR)	15,000 µg/m <sup>3</sup> – total dust	10,000 µg/m <sup>3</sup> - total dust	10,000 µg/m <sup>3</sup> inhalable	None established for PNOS
Fluorescent Brightener 220, Technical grade		5,000 µg/m <sup>3</sup> – respirable dust	5,000 µg/m <sup>3</sup> - respirable dust	3,000 µg/m <sup>3</sup> - respirable	6,000 µg/m <sup>3</sup> - amorphous silica

Notes:

- Typically OELs are expressed as mg/m<sup>3</sup> but are expressed here in units of µg/for ease of comparison to Table 2
- Exposure limits are 8-hour TWA with the exception of the ACGIH 30-minute excursion limit
- NIOSH has established an OEL for amorphous silica but not for PNOS

The mass mean aerodynamic diameter (MMAD) of the tracer particles ranges from 1 to 10 micrometers ( $\mu\text{m}$ ). If inhaled, the smallest diameter particles (less than  $5 \mu\text{m}$ ) could be deposited in the lower reaches of the lungs while the larger particles would be trapped in the thoracic or nasopharyngeal region. It would be expected that the maltodextrin coating would dissolve in the moist mucous membrane of the respiratory tract along with depositing its amorphous silica core. Various natural clearance mechanisms of the lungs and respiratory tract would aid in the removal of these particles where they could either be expelled or swallowed.

Under the National Clean Air Act, the Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. Ambient air quality standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Unlike OELs, the ambient standards for insoluble particulates and are not designated for a particle with a specific chemical composition but instead represent the collective sum of particulates present in the environment that are man-made and naturally occurring. The origins of these particles are typically from dust, sea salt, dust from construction activities, tire wear, brake wear, and organic bioaerosols such as bacteria, pollen and fungal spores. For airborne insoluble particulates, the air quality standards are based upon particle diameter. The EPA has established standards for two different particle sizes: particles with diameter below  $2.5 \mu\text{m}$  ( $\text{PM}_{2.5}$ ) and particles with diameters below  $10 \mu\text{m}$  ( $\text{PM}_{10}$ ). Since the tracer particles used for this study range in diameter from 1 to  $10 \mu\text{m}$ , it is appropriate to compare particle concentrations to the  $\text{PM}_{10}$  standard of  $150 \mu\text{g}/\text{m}^3$ . Unlike OELs that are averaged over 8-hours,  $\text{PM}_{10}$  is a 24-hour average concentration that must not be exceeded more than once per year within the 3-year average.

Based on the *Environmental Assessment* report and conversations with the researchers, 20 grams of the tracer particles will be released over a 20-minute interval. Based on their modeling, after the end of 8 hours they anticipate that no remaining tracer particles will remain airborne. They have also calculated the 8-hour and 24-hour time weighted average concentrations which are the integrated exposures averaged over an 8 or 24 hour time interval. These values are presented in Table 2.

Table 2: Average Airborne Concentrations

Location	8-Hr Time Weighted Average Concentration	24-Hr Time Weighted Average Concentration	NYC Ambient Air Quality	Combined Tracer Particle and Ambient Air	NAAQS $\text{PM}_{10}$
Next to Release	$12 \mu\text{g}/\text{m}^3$	$4 \mu\text{g}/\text{m}^3$	$60 \mu\text{g}/\text{m}^3$	$64 \mu\text{g}/\text{m}^3$	$150 \mu\text{g}/\text{m}^3$
Next Station	$3 \mu\text{g}/\text{m}^3$	$1 \mu\text{g}/\text{m}^3$		$61 \mu\text{g}/\text{m}^3$	

According to the *Environmental Assessment*, measurements of ambient outdoor  $\text{PM}_{10}$  levels in New York City from 2005 to 2011 have remained steady averaging  $60 \mu\text{g}/\text{m}^3$ . If all tracer particles from the release location moved outdoors and combined with ambient air, the computed  $\text{PM}_{10}$  24-hour average concentration of  $64 \mu\text{g}/\text{m}^3$  is well below acceptable levels for the National Ambient Air Quality Standard of  $150 \mu\text{g}/\text{m}^3$  for  $\text{PM}_{10}$ .

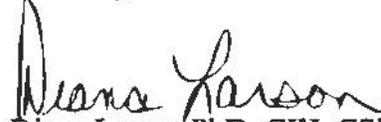
When comparing the 8-hour time weighted average concentration of  $12 \mu\text{g}/\text{m}^3$  at the release site to the inhalable (total dust) OEL of  $10,000 \mu\text{g}/\text{m}^3$  for starch, sucrose, and PNOS from ACGIH, this

concentration is 3 orders of magnitude below the concentration that a worker could be exposed to for 8 hours without experiencing adverse health effects.

Since the diameter of the tracer particles range from 1 to 10  $\mu\text{m}$ , only the fraction of tracer particles that are 5  $\mu\text{m}$  or less would be considered "respirable" and could be compared to the respirable exposure limits. The materials in the tracer particles do not pose a unique toxicity to the gas-exchange region of the lungs and since the particles from 5 to 10  $\mu\text{m}$  would be deposited in the upper airways, total dust or inhalable standards are considered the appropriate OELs for comparison since they would account for all sizes of the tracer particles used in this study. However, if all tracer particles released had a diameter of 5  $\mu\text{m}$  or less, the 8-hour time weighted average concentration of 12  $\mu\text{g}/\text{m}^3$  would be 2 orders of magnitude below the "respirable" exposure limit of 5,000  $\mu\text{g}/\text{m}^3$ . Exposing the general population to the tracer particles used in this study is not anticipated to result in adverse health effects due to the low particle concentrations and the benign nature of its constituents.

Tracer particles made from maltodextrin with non-coding synthetic DNA tracer have been considered safe for human exposure and have successfully been used in previous studies for modeling airflow in a large occupied public building. Refer to reference 7 that was published on-line in the journal Aerosol Science and Technology March 2016.

Sincerely,



Diana Larson PhD, CIH, CSP

Industrial Hygiene Section Leader  
Worker Safety & Health Functional Area  
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## Unique DNA-barcoded aerosol test particles for studying aerosol transport

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## Unique DNA-barcoded aerosol test particles for studying aerosol transport

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### ABSTRACT

Data are presented for the first use of novel DNA-barcoded aerosol test particles that have been developed to track the fate of airborne contaminants in populated environments. Until DNATrax (DNA Tagged Reagents for Aerosol eXperiments) particles were developed, there

was no way to rapidly validate air transport models with realistic particles in the respirable range of 1-10  $\mu\text{m}$  in diameter. The DNATrax particles, developed at Lawrence Livermore National Laboratory (LLNL) and tested with the assistance of the Pentagon Force Protection Agency, are the first safe and effective materials for aerosol transport studies that are identified by DNA molecules. The use of unique synthetic DNA barcodes overcomes the challenges of discerning the test material from pre-existing environmental or background contaminants (either naturally occurring or previously released). The DNATrax particle properties are demonstrated to have appropriate size-range (approximately 1-4.5  $\mu\text{m}$  in diameter) to accurately simulate bacterial spore transport. Here we describe details of the first field test of the DNATrax aerosol test particles in a large indoor facility.

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## INTRODUCTION

It is well known that poor air quality can lead to significant health consequences (American Lung Association 2015). Until DNATrax (DNA Tagged Reagents for Aerosol eXperiments) particles were developed at Lawrence Livermore National Laboratory (LLNL), there was no way to rapidly validate air transport models with realistic particles in the respirable range of 1-10  $\mu\text{m}$  in diameter. We rely on aerosol sentries to sample the air to look for contaminants and toxins in sensitive areas (Regan et al. 2008). If a toxin, environmental

contaminant, or biological threat agent were released in a public place, these sentries would be our first alarm system to isolate the area of release and enable predictions about the direction of spread. One of the challenges is knowing the best locations to place these sentries and how air will flow through a complicated system like a transportation hub or a convention center. Airflow tests typically utilize spores that are naturally found in the environment. However, there are not very many spores that are safe for release, and the costly and time-consuming decontamination process prolongs the time between tests. These new aerosol simulant particles incorporate short segments (barcodes) of DNA into sugar particles made from a U.S. Food and Drug Administration (FDA)-approved food additive, shown schematically in Figure 1. The DNA barcodes allow for nearly unlimited unique test particles by simply changing the DNA barcode sequence. As the particles are made from sugar and synthetic DNA, they are safe for human exposure and can be used in many situations, thus gaining widespread acceptance. The numerous unique barcodes allow many simultaneous releases, dramatically reducing the cost to conduct source attribution testing for contaminants. These aerosol test particles have been used to test modeling of airflow in populated buildings and have been shown to trigger conventional aerosol detectors.

Figure 1 (color for online, grayscale for print)

Aerosol transport monitoring is important for detecting the presence of airborne contaminants and tracking their fate in populated environments where they may adversely

affect human health. The challenge is to selectively detect potentially hazardous aerosols within the background aerosol matrix of the location. Typical aerosol background is in the range of 10-1000  $\mu\text{g}/\text{m}^3$  mass concentration (the mass of particulate matter in a unit volume of aerosol) and is composed of both natural and urban aerosols (Hinds 1999). Most natural background aerosol originates from direct emissions from deserts (soil dust), the oceans (sea salt), and vegetation (botanical debris) and varies by geographic location, altitude, and time of year. Urban aerosol is more complex and dominated by anthropogenic emissions with local concentrations varying greatly depending on proximity to sources and time of day (Hinds 1999). A building's heating, ventilation, and air conditioning (HVAC) air-handling system settings have substantial impacts on the aerosol transport throughout a building and also vary by season and time of day. Computational modeling studies are often used to evaluate the airflow in buildings under different HVAC system settings. Optimized evacuation routes are also determined by evaluating theoretical scenarios of fire or threat agent release at different points throughout the building. While computational models are a good starting point, there is a need for experimental feedback to inform and evaluate aerosol dispersion and transport models. The results of aerosol release tests can provide insight into some effects of building planning, design, construction, and operation on the building's airflow and airborne contaminant transport performance (Underwood et al. 2007).

Materials not generally found in a building's aerosol background are used to study aerosol transport and fate to minimize background contamination and generate more accurate

measurements. The most commonly introduced tracer material is sulfur hexafluoride (SF<sub>6</sub>) gas, which is detected and quantified at different points in the building with high sensitivity using commercial fluorescence sensors (Underwood et al. 2007). However, SF<sub>6</sub> molecules are approximately 300 pm ( $3 \times 10^{-4} \mu\text{m}$ ) in diameter, which is an order of magnitude smaller than the lower bound of the typical aerosol size range (0.002-100  $\mu\text{m}$  in diameter). As particle size is the principal characteristic governing aerosol transport dynamics, SF<sub>6</sub> does not accurately simulate the transport of aerosols in an environment because the molecules are too small. Another test material option is synthetic polymer microspheres with incorporated fluorophores. Particle transport and fate are monitored using fluorescence measurements that are tunable by incorporating different fluorophores into the plastic spheres. While these particles are the correct size for accurately simulating aerosol transport properties, they have safety concerns for human inhalation exposure and are therefore unsuitable for use in populated environments. Neither the SF<sub>6</sub> gas nor the fluorescent polymer microspheres are capable of generating accurate test data for evaluation of aerosol transport in areas where humans will be exposed, which are the areas of primary interest.

As bioaerosols are present in most environmental aerosol populations, they can be used as the release test material for aerosol transport studies and are especially advantageous when polymerase chain reaction (PCR)-based assays are used for DNA detection and quantification. Some currently used bioaerosol test particles are bacterial spores such as *Bacillus subtilis* and *Bacillus thuringiensis*, which are commonly used to simulate *Bacillus anthracis*, the causal agent

of anthrax (Madigan et al. 2000; Burton et al. 2005). These bacterial spores work well for particle counting release tests and PCR confirmation as they mimic typical aerosol size (bacterial spores are approximately 0.5-2  $\mu\text{m}$  in diameter) and contain DNA for specific detection and quantification of the number of bioaerosols in a particular location. However, there is the possibility of inherent contamination in the background aerosol matrix due to natural *B. subtilis* reservoirs in the soil and *B. thuringiensis* use as a commercial biological insecticide (Madigan et al. 2000). Also, a simulant bacterial spore may only be used for one release test in a location because after the release the environment is contaminated with that spore. In order to overcome the possibility of a naturally occurring spore indicating a false positive, spores have been genetically modified to contain unique DNA sequences for PCR detection (Buckley et al. 2012; Emanuel et al. 2012). Both naturally occurring and genetically modified spores are limited in size selection and have some safety concerns for releases in occupied settings.

Another approach involves use of synthetic, non-virulent oligonucleotides or plasmids to simulate either single or multiple virulent organisms for PCR-based detection (Carrera and Sagripanti 2009). The DNA sequences used for PCR detection of threat agents are reproduced *in vitro* to validate positive PCR results without exposing an environment or personnel to a pathogenic organism. While this approach is useful for PCR-based detection tests, it is not suitable for aerosol release tests as the physical characteristics of nucleotides and plasmids are not similar to most environmental aerosols. This limitation is resolved by incorporating the DNA

sequences into a particle material so that both aerosol transport and PCR-based detection methods are challenged during an aerosol release test.

Synthetic nucleotides were chosen as unique particle identifier molecules for these novel aerosol test particles as they are exempt from National Institutes of Health (NIH) biological material controls. Oligonucleotide DNA sequences were chosen from the thermophilic bacterium *Thermotoga maritima*. *T. maritima* exhibits optimal growth at 80 °C and is found in terrestrial hot springs and deep ocean hydrothermal vents, so the potential for natural background contamination is low (Madigan et al. 2000). The genome for *T. maritima* is sequenced due to its potential use in biotechnology applications as a hyperthermophile with heat stable enzymes (Nelson et al. 1999). Oligonucleotide DNA barcodes approximately 100 base pairs (bp) long were chosen from the *T. maritima* genome that were non-coding and dissimilar from DNA sequences of other common biological aerosol microorganisms. Corresponding oligonucleotide primers and probes were also designed for highly specific quantitative real-time (qRT)-PCR detection of the DNA barcodes in experimental samples. The incorporation of DNA barcodes into the aerosol test particles enables PCR-based detection and quantification after aerosol release tests. Multiple barcodes are available for incorporation into different batches of the test particles to alleviate background contamination problems if several release tests are desired in the same area. The customizable DNA barcodes in the aerosol test particles, along with qRT-PCR detection, facilitate aerosol release testing in most environments.

This article reports on the first aerosol transport testing of the novel DNA-barcoded aerosol test particles in a populated indoor environment.

## MATERIALS AND METHODS

### Spray Dried Microparticles

Spray drying is a common method in the pharmaceutical and food industries for producing a dry powder from a solution or slurry (BUCHI Corporation 2002; Arpagaus et al. 2010b). Commercially available systems employ a spray nozzle (nebulizer) to separate a liquid stream into a droplet spray. The droplets are quickly evaporated in a heated gas (usually air) stream parallel to the droplet spray direction, resulting in solid particles composed of the solutes in the spray dried solution. The particles are then collected from the moving gas stream using a cyclone collector. The final product is a fine, amorphous or crystalline powder (Hinds 1999; BUCHI Corporation 2002). Particle size-distribution characteristics can vary greatly, from hundreds of nanometers to tens of micrometers in diameter, depending on the droplet generation mechanism, gas and liquid flow rates, and solute concentrations in the spray dried solution (Arpagaus et al. 2010a).

A commercial spray dryer (Mini Spray Dryer B-290, BUCHI Corporation, Switzerland) was used to generate the aerosol test particles on the gram-scale. An FDA-approved, naturally occurring food additive, maltodextrin, was selected to be the bulk particle material (Organic Tapioca Maltodextrin DE 10 (Dextrose Equivalent 8-12), Ciranda, Hudson, WI). Maltodextrin is

an oligosaccharide with a  $T_g$  of 160 °C, which is sufficiently high to prevent stickiness during spray drying and caking during storage (Bhandari, undated). Several different maltodextrin concentrations in aqueous solution and several different spray gas flow rates were tested in order to optimize the resulting microparticle size. The DNA barcodes were added to the maltodextrin solution prior to being processed through the spray dryer. A schematic of the particle generation process is presented in Figure 2. The particles have also been produced in small quantities using a modified commercial inkjet printer (Udey et al. 2013).

Figure 2 (color for online, grayscale for print)

### **Microparticle Characterization**

Microparticles generated using the spray dryer were characterized using an Aerodynamic Particle Sizer (APS, TSI model 3321, Shoreview, MN) and scanning electron microscopy (SEM) for size-distribution and particle morphology information. Microparticles were collected on Teflon filter material (1.0  $\mu\text{m}$  pore size, Zeflour supported PTFE, Pall Corp., Ann Arbor, MI) using a four-stage Impactor Stack with a 9 L/min airflow rate (California Measurements, Inc., Sierra Madre, CA) for SEM analysis. Samples were sputter coated with a thin layer of gold using a Hummer 6.2 Sputter Coater (Anatech, Union City, CA) and were viewed using a Hitachi S-800 field emission scanning electron microscope (Hitachi, South San Francisco, CA) and Quartz PCI imaging software (version 6.0, Quartz Imaging Corporation, Vancouver, BC, Canada). Images from SEM analysis were further analyzed using ImageJ

software (National Institutes of Health, [ImageJ Website](#)) to measure particle sizes and count particles in the images.

## DNA Barcode Design and Detection

Non-coding DNA barcode sequences containing approximately 100 bp from the extremophile bacterium *Thermotoga maritima* were designed to be strictly unique from DNA sequences used to detect other biological aerosol microorganisms. The Lawrence Livermore Pathogen Bioinformatics team employed an in-house computational system (Slezak et al. 2003) that leveraged a comprehensive in-house microbial genomic database containing full-length genomic sequences acquired from available public and private sources. The database is continuously updated and proprietary sequence is not revealed. The genomic sequence for *T. maritima* (NCBI Reference Sequence NC\_000853.1) was the starting input sequence. Electronic subtraction was carried out using suffix trees algorithms, resulting in a uniqueness file of *T. maritima* sequence (minimum of 18 nucleotide strings) representing genomic sequence not present in any other sequenced organism. This uniqueness file was then mined for candidate TaqMan sequence triplets that included forward and reverse primers that flank amplicons of 95-130 bp and have internal binding sites for oligonucleotide probes. All candidate barcodes met optimized TaqMan PCR parameters. To further verify the specificity of each candidate barcode, a final computational screen utilizing the unpublished TaqSim PCR simulation program verified that cross-reactions were not identified when the barcodes were compared against all sequences in GenBank (including eukaryotic sequences). A set of 35 candidate barcodes was

selected for bench screening, which was further down-selected to eight barcodes containing 99-103 bp. The DNA barcodes were detected in samples using TaqMan qRT-PCR assays. The probes were synthesized with the fluorophore 6-carboxyfluorescein (6-FAM) on the 5' end and the quencher Black Hole Quencher 1 (BHQ-1) on the 3' end. Thermal cycling parameters were 10 minutes at 95 °C, followed by 40 cycles of 15 seconds at 95 °C and then 1 minute at 55 °C.

## **Aerosol Release Test**

Aerosol transport testing of the novel DNA-barcoded aerosol test particles was carried out in a large populated indoor facility after working hours. The particles were aerosolized using an eductor towards Dry Filter Unit (DFU) aerosol collectors (Lockheed Martin, Bethesda, MD). The DFUs draw 800 L/min of ambient air through two adjacent polyester felt filters (1.0  $\mu\text{m}$  pore size, Lockheed Martin) which trap aerosols for downstream analyses including qRT-PCR for DNA content. One gram of aerosol test particles was released using the eductor over approximately 10 seconds in the general direction of the DFUs. Three DFUs were positioned in the opposite direction of the release as well. There were no obstructions between the release point and the DFUs, and the building's normal ambient airflows were operational. The ambient air was sampled using the DFUs for 30 minutes post-release. At the conclusion of the test, a DFU filter from each DFU used during the test and a DFU filter from the ambient background were analyzed using qRT-PCR for the DNA barcodes incorporated into the particles. The DFU filters were eluted in phosphate buffered saline (PBS, pH 7.4, Amresco, Solon, OH) with 0.1%

Triton X-100 (Acros Organics, part of Thermo Fisher Scientific, Pittsburgh, PA). An aliquot from each DFU filter was analyzed using qRT-PCR in triplicate.

## RESULTS AND DISCUSSION

### Scanning Electron Microscopy of Generated Microparticles

Micrographs from SEM analyses of the maltodextrin microparticles are displayed in Figure 3. Figure 3A was acquired using relatively low magnification (250X) to observe the general microparticle population characteristics, and Figure 3B was obtained using higher magnification (1200X) to examine individual particle morphology. The individual particles have spherical morphology owing to the optimized droplet drying within the spray dryer. The maltodextrin microparticles in Figure 3B are approximately 1-4.5  $\mu\text{m}$  in diameter, similar to the size of bacterial spores in order to accurately simulate aerosol transport. Image analysis of several micrographs yielded the size-distribution results shown in Figure 3C. Two orders of magnitude more particles were characterized when the same maltodextrin microparticle sample was analyzed using the APS, however, the size-distribution in the SEM image generally agrees with the APS results. Microparticle characterization using SEM confirmed particle sizes from 1-5  $\mu\text{m}$  in diameter suitable for the aerosol test particles.

Figure 3

**Aerosol Release Test**

A small-scale aerosol release test was conducted using these novel aerosol test particles containing DNA barcodes to demonstrate their utility for this application (Figure 4). Prior to the release test, qRT-PCR was used to determine that the aerosol test particles contained 17.2 DNA barcodes per particle on average. As the particles were polydisperse (Figure 3C), the number of DNA barcodes per particle was proportional to the particle size. Figure 5A displays the qRT-PCR results for the DNA barcodes in the aerosol test particles collected on the DFU filters in various locations (Figure 5B) during the release test. The qRT-PCR results for the ambient background DFU filter were negative, indicating no DNA barcode was present in the testing environment prior to the release, as expected. All of the DFU filters collected after the aerosol release were positive for the DNA barcodes, meaning that particles were dispersed at least 70 m from the release point. The DFUs positioned nearest to the release point collected the most particles (on the order of  $1.5E8$  particles), and the number of collected particles decreased for the DFUs positioned farther away and around corners. The airflow generated by the eductor during the test particle release was clearly not the only airflow affecting particle transport, as some of the DFUs located behind the release point collected a relatively high number of particles as well. This result is likely due to the building's normal ambient airflows that were active throughout the release test, as well as the 800 L/min of airflow through the DFU collectors that may have affected the building's airflows.

Figure 4 (color for online, grayscale for print)

Figure 5 (color for online, grayscale for print)

The particle transport results shown in Figure 5 demonstrate that the selection of an evacuation route can have a significant impact on the concentration of material an individual is exposed to post-release. If an individual were positioned to the right of the release point in Figure 5B, they should evacuate to the right (away from the release point) and turn down a side hall as soon as possible to reduce exposure. If an individual were positioned to the left (behind) the release point, they should move to the left (away from the release point) and turn down a side hall. In this case it matters if the person turns to the left or to the right to get out of the main hallway where the release occurred. If the person turns to the right he or she will be exposed to five orders of magnitude more material than if the person turns to the left to evacuate the area. This type of evacuation route information is crucial for emergency response planning in sensitive buildings and populated areas. This critical information is quickly and safely determined for the first time using these novel DNA-barcoded aerosol test particles.

## **SUMMARY AND CONCLUSIONS**

These safe, customizable, and specifically detected aerosol test particles will provide vital experimental feedback for evaluating aerosol dispersion and transport models. The DNATrax material has size and morphology that is an appropriate simulant for bacterial spores. By using the food additive maltodextrin as the particle material and short, non-coding DNA

sequences to identify the particles, a combination of three essential properties are present: 1) the aerosol test particles are safe for human exposure, 2) the material is specifically identifiable in complex aerosol matrices using sensitive PCR analysis, and 3) the test particles can have multiple identifiers that will allow for multiple simultaneous releases. Other air contaminant simulants have some of these properties, but not all three of them in a single aerosol testing material. This new tool allows for increased sampling for aerosol transport model validation at a significant reduction in cost and time.

The aerosol release test demonstrated that the novel aerosol test particles travel in the airflows of a typical indoor environment as anticipated. Valuable aerosol transport information was obtained that could inform evacuation routes for employees inside the building in the event of an aerosol release. These DNA-barcoded aerosol test particles show great promise for large-scale aerosol release testing to evaluate airflows in buildings and study aerosol drift and dispersion in populated environments.

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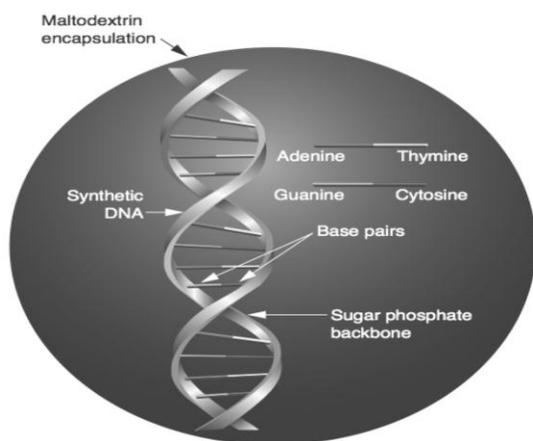
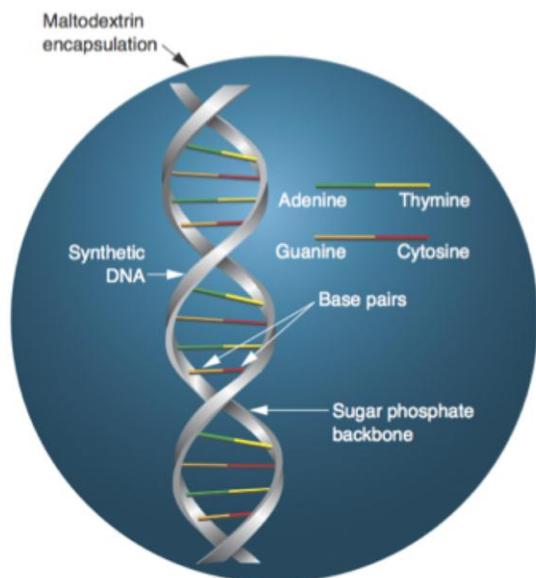


FIG. 1. Schematic representation of a DNA barcode encapsulated in a sugar particle.

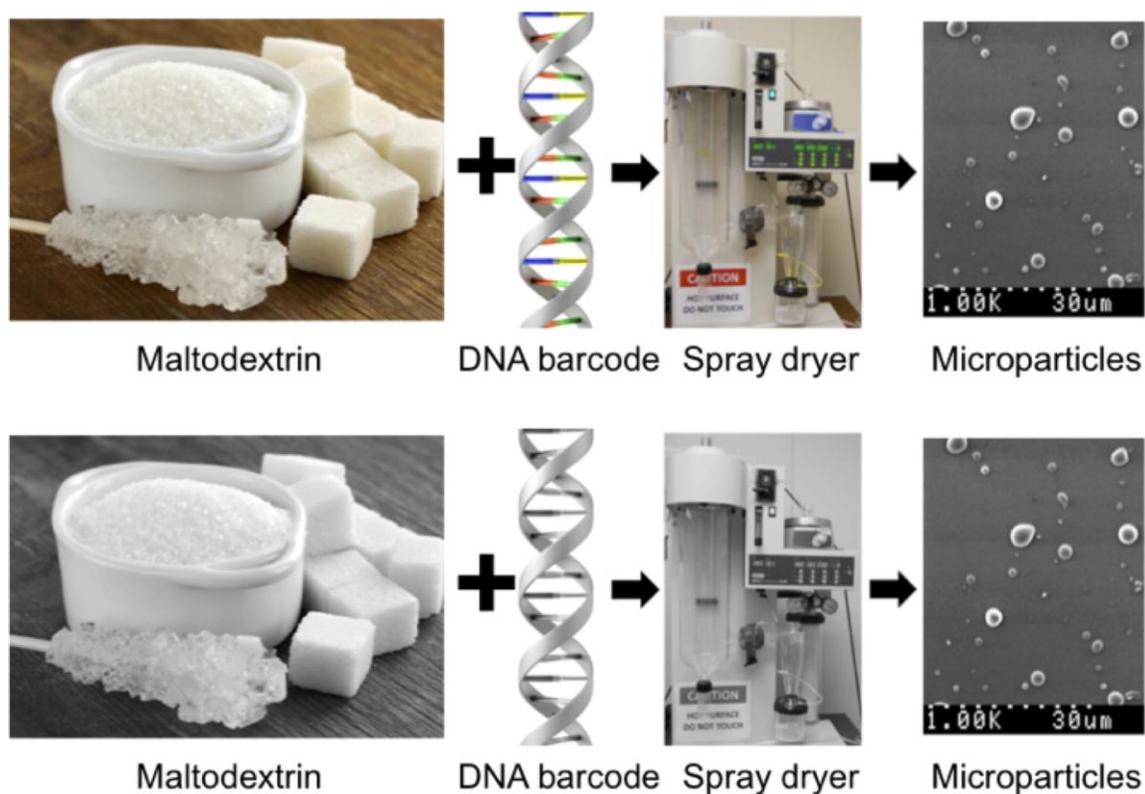


FIG. 2. Schematic of the aerosol test particle generation process.

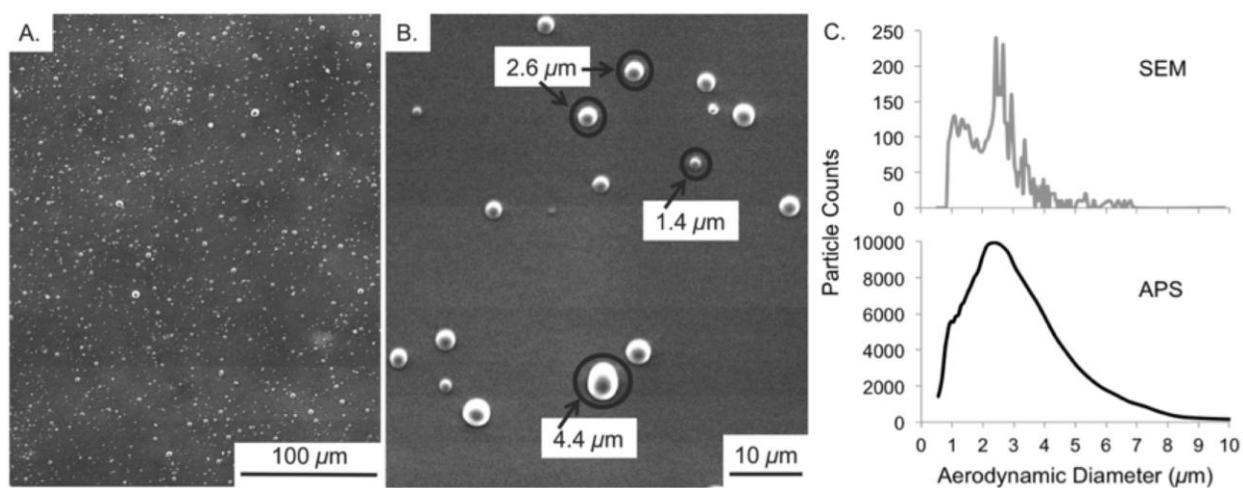


FIG. 3. Micrographs from SEM analyses of maltodextrin microparticles generated using the spray dryer. (A) Displays the general characteristics of the microparticle population at 250X and (B) shows the size and morphology of individual microparticles at 1200X. A comparison of the microparticle size-distributions measured from the SEM image (A) and the APS is shown in (C).



FIG. 4. Photograph showing release of one gram of DNA-barcoded aerosol test particles in a building hallway.

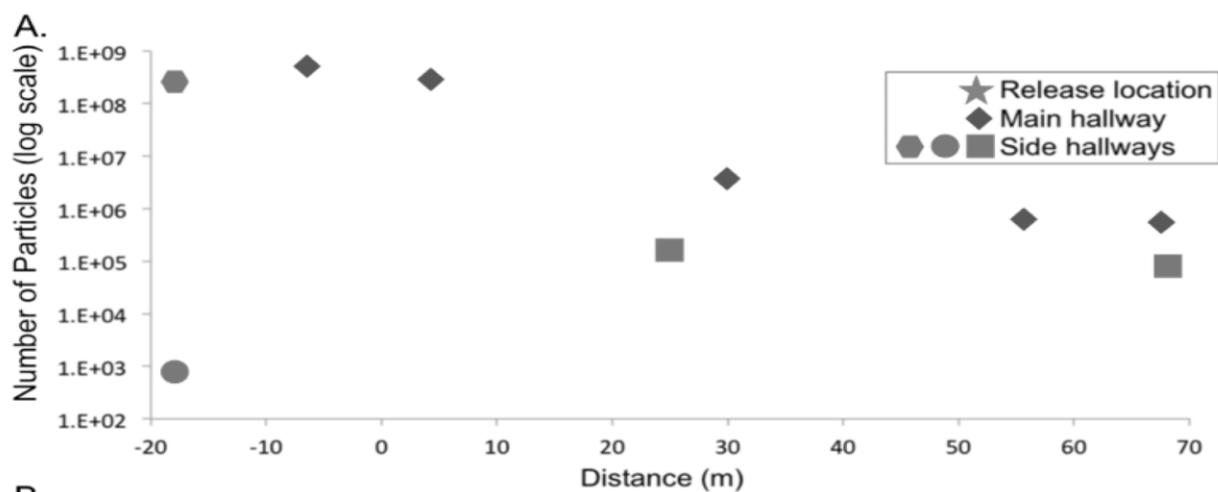
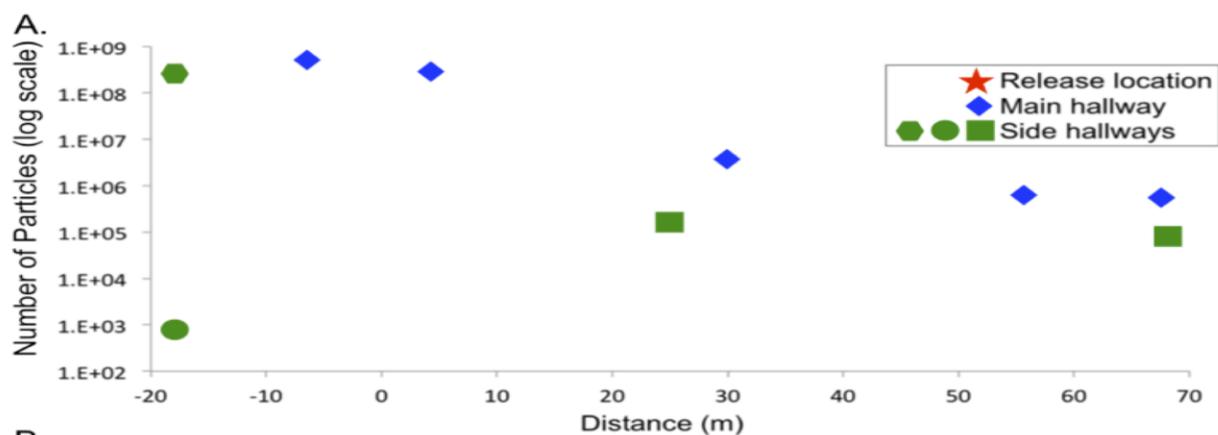


FIG. 5. (A) Number of aerosol test particles detected on DFU filters at various distances and directions from the release point. Note the y-axis is a base-10 logarithmic scale. (B) Schematic of the release hallway and cross hallways on the same distance scale as (A). Note that the release occurred at the 0 distance point with the nozzle pointing to the right of the figure.

# Maltodextrin

sc-207840

Material Safety Data Sheet



Hazard Alert Code  
Key:

EXTREME

HIGH

MODERATE

LOW

## Section 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

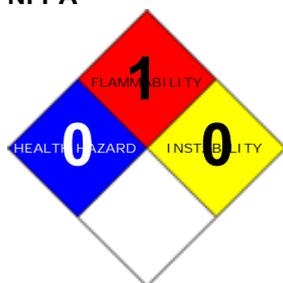
### PRODUCT NAME

Maltodextrin

### STATEMENT OF HAZARDOUS NATURE

Not considered a hazardous substance according to OSHA 29 CFR 1910.1200.

### NFPA



### SUPPLIER

Company: Santa Cruz Biotechnology, Inc.

Address:

2145 Delaware Ave

Santa Cruz, CA 95060

Telephone: 800.457.3801 or 831.457.3800

Emergency Tel: CHEMWATCH: From within the US and  
Canada: 877-715-9305

Emergency Tel: From outside the US and Canada: +800 2436  
2255 (1-800-CHEMCALL) or call +613 9573 3112

### PRODUCT USE

Food additive, bulking agent, binder, film former and carrier.

### SYNONYMS

(C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>)<sub>n</sub>, "Glucidex 12", carbohydrate

## Section 2 - HAZARDS IDENTIFICATION

### CANADIAN WHMIS SYMBOLS

None

### EMERGENCY OVERVIEW

#### RISK

### POTENTIAL HEALTH EFFECTS

### ACUTE HEALTH EFFECTS

### SWALLOWED

■ The material has NOT been classified as "harmful by ingestion". This is because of the lack of corroborating animal or human evidence. The material may still be damaging to the health of the individual, following ingestion, especially where pre-existing organ (e.g. liver, kidney) damage is evident. Present definitions of harmful or toxic substances are generally based on doses producing mortality (death) rather than those producing morbidity (disease, ill-health). Gastrointestinal tract discomfort may produce nausea and vomiting. In an occupational setting however, unintentional ingestion is not thought to be cause for concern.

### EYE

■ Although the material is not thought to be an irritant, direct contact with the eye may cause transient discomfort characterized by tearing or conjunctival redness (as with windburn). Slight abrasive damage may also result. The material may produce foreign body irritation in certain individuals.

### SKIN

■ The material is not thought to produce adverse health effects or skin irritation following contact (as classified using animal

models). Nevertheless, good hygiene practice requires that exposure be kept to a minimum and that suitable gloves be used in an occupational setting.

■ Open cuts, abraded or irritated skin should not be exposed to this material.

■ Entry into the blood-stream, through, for example, cuts, abrasions or lesions, may produce systemic injury with harmful effects. Examine the skin prior to the use of the material and ensure that any external damage is suitably protected.

#### **INHALED**

■ The material is not thought to produce adverse health effects or irritation of the respiratory tract (as classified using animal models). Nevertheless, good hygiene practice requires that exposure be kept to a minimum and that suitable control measures be used in an occupational setting.

■ Persons with impaired respiratory function, airway diseases and conditions such as emphysema or chronic bronchitis, may incur further disability if excessive concentrations of particulate are inhaled.

#### **CHRONIC HEALTH EFFECTS**

■ Long-term exposure to the product is not thought to produce chronic effects adverse to the health (as classified using animal models); nevertheless exposure by all routes should be minimized as a matter of course.

Long term exposure to high dust concentrations may cause changes in lung function i.e. pneumoconiosis; caused by particles less than 0.5 micron penetrating and remaining in the lung. Prime symptom is breathlessness; lung shadows show on X-ray.

## **Section 3 - COMPOSITION / INFORMATION ON INGREDIENTS**

### **HAZARD RATINGS**

	Min	Max	
Flammability:	1		
Toxicity:	0		
Body Contact:	0		
Reactivity:	1		Min/Nil=0 Low=1 Moderate=2 High=3 Extreme=4
Chronic:	0		

NAME	CAS RN	%
maltodextrin	9050-36-6	>99

## **Section 4 - FIRST AID MEASURES**

### **SWALLOWED**

- 
- Immediately give a glass of water.
- First aid is not generally required. If in doubt, contact a Poisons Information Center or a doctor.

### **EYE**

- If this product comes in contact with eyes:
  - Wash out immediately with water.
  - If irritation continues, seek medical attention.
  - Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.

### **SKIN**

- If skin or hair contact occurs:
  - Flush skin and hair with running water (and soap if available).
  - Seek medical attention in event of irritation.

### **INHALED**

- 
- If dust is inhaled, remove from contaminated area.
- Encourage patient to blow nose to ensure clear passage of breathing.
- If irritation or discomfort persists seek medical attention.

### **NOTES TO PHYSICIAN**

- Treat symptomatically.

## **Section 5 - FIRE FIGHTING MEASURES**

Vapour Pressure (mmHG):	Negligible
Upper Explosive Limit (%):	Not available.
Specific Gravity (water=1):	1.60 approx.
Lower Explosive Limit (%):	0.05 g/l

### **EXTINGUISHING MEDIA**

- 
- Foam.
- Dry chemical powder.
- BCF (where regulations permit).
- Carbon dioxide.
- Water spray or fog - Large fires only.

## **FIRE FIGHTING**

- 
- Alert Emergency Responders and tell them location and nature of hazard.
- Wear breathing apparatus plus protective gloves.
- Prevent, by any means available, spillage from entering drains or water course.
- Use water delivered as a fine spray to control fire and cool adjacent area.
- DO NOT approach containers suspected to be hot.
- Cool fire exposed containers with water spray from a protected location.
- If safe to do so, remove containers from path of fire.
- Equipment should be thoroughly decontaminated after use.

## **GENERAL FIRE HAZARDS/HAZARDOUS COMBUSTIBLE PRODUCTS**

- 
- Combustible solid which burns but propagates flame with difficulty.
- Avoid generating dust, particularly clouds of dust in a confined or unventilated space as dusts may form an explosive mixture with air, and any source of ignition, i.e. flame or spark, will cause fire or explosion. Dust clouds generated by the fine grinding of the solid are a particular hazard; accumulations of fine dust may burn rapidly and fiercely if ignited.
- Dry dust can be charged electrostatically by turbulence, pneumatic transport, pouring, in exhaust ducts and during transport.
- Build-up of electrostatic charge may be prevented by bonding and grounding.
- Powder handling equipment such as dust collectors, dryers and mills may require additional protection measures such as explosion venting.

Combustion products include: carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), other pyrolysis products typical of burning organic material.

## **FIRE INCOMPATIBILITY**

- 
- Avoid contamination with oxidizing agents i.e. nitrates, oxidizing acids, chlorine bleaches, pool chlorine etc. as ignition may result.

## **PERSONAL PROTECTION**

Glasses:

Chemical goggles.

Gloves:

Respirator:

Particulate

## **Section 6 - ACCIDENTAL RELEASE MEASURES**

### **MINOR SPILLS**

- 
- Clean up all spills immediately.
- Avoid contact with skin and eyes.
- Wear impervious gloves and safety glasses.
- Use dry clean up procedures and avoid generating dust.
- Sweep up or vacuum up (consider explosion-proof machines designed to be grounded during storage and use).
- Place spilled material in clean, dry, sealable, labeled container.

### **MAJOR SPILLS**

- 
- Clear area of personnel and move upwind.
- Alert Emergency Responders and tell them location and nature of hazard.
- Control personal contact by using protective equipment and dust respirator.
- Prevent spillage from entering drains, sewers or water courses.
- Avoid generating dust.
- Sweep, shovel up.
- Recover product wherever possible.
- Put residues in labeled plastic bags or other containers for disposal.
- If contamination of drains or waterways occurs, advise emergency services.

## **ACUTE EXPOSURE GUIDELINE LEVELS (AEGL) (in ppm)**

AEGL 1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL 2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL 3: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

## **Section 7 - HANDLING AND STORAGE**

### **PROCEDURE FOR HANDLING**

- 
- Limit all unnecessary personal contact.
- Wear protective clothing when risk of exposure occurs.
- Use in a well-ventilated area.

- Avoid contact with incompatible materials.
- When handling, DO NOT eat, drink or smoke.
- Keep containers securely sealed when not in use.
- Avoid physical damage to containers.
- Always wash hands with soap and water after handling.
- Work clothes should be laundered separately.
- Use good occupational work practice.
- Observe manufacturer's storing and handling recommendations.
- Atmosphere should be regularly checked against established exposure standards to ensure safe working conditions are maintained.

Empty containers may contain residual dust which has the potential to accumulate following settling. Such dusts may explode in the presence of an appropriate ignition source.

- Do NOT cut, drill, grind or weld such containers
- In addition ensure such activity is not performed near full, partially empty or empty containers without appropriate workplace safety authorisation or permit.

#### RECOMMENDED STORAGE METHODS

- Lined metal can, Lined metal pail/drum
- Plastic pail
- Polyliner drum
- Packing as recommended by manufacturer.
- Check all containers are clearly labeled and free from leaks.

#### STORAGE REQUIREMENTS

- Store in original containers.
- Keep containers securely sealed.
- Store in a cool, dry, well-ventilated area.
- Store away from incompatible materials and foodstuff containers.
- Protect containers against physical damage and check regularly for leaks.
- Observe manufacturer's storing and handling recommendations.

#### SAFE STORAGE WITH OTHER CLASSIFIED CHEMICALS



X: Must not be stored together

O: May be stored together with specific preventions

+: May be stored together

## Section 8 - EXPOSURE CONTROLS / PERSONAL PROTECTION

### EXPOSURE CONTROLS

Source	Material	TWA ppm	TWA mg/m <sup>3</sup>	STEL ppm	STEL mg/m <sup>3</sup>	Peak ppm	Peak mg/m <sup>3</sup>	TWA F/CC	Notes
US - Oregon Permissible Exposure Limits (Z3)	maltodextrin (Inert or Nuisance Dust: (d) Total dust)		10						*
US OSHA Permissible Exposure Levels (PELs) - Table Z3	maltodextrin (Inert or Nuisance Dust: (d) Respirable fraction)		5						
US OSHA Permissible Exposure Levels (PELs) - Table Z3	maltodextrin (Inert or Nuisance Dust: (d) Total dust)		15						
US - Hawaii Air Contaminant Limits	maltodextrin (Particulates not otherwise regulated - Total dust)		10						
US - Hawaii Air Contaminant Limits	maltodextrin (Particulates not otherwise regulated - Respirable fraction)		5						
US - Oregon Permissible Exposure Limits (Z3)	maltodextrin (Inert or Nuisance Dust: (d) Respirable fraction)		5						*
US - Tennessee Occupational Exposure Limits - Limits For Air Contaminants	maltodextrin (Particulates not otherwise regulated Respirable fraction)		5						
US - Wyoming Toxic and Hazardous Substances Table Z1 Limits for Air Contaminants	maltodextrin (Particulates not otherwise regulated (PNOR)(f)-Respirable fraction)		5						
US - Michigan Exposure Limits for Air Contaminants	maltodextrin (Particulates not otherwise regulated, Respirable dust)		5						

## MATERIAL DATA

### MALTODEXTRIN:

■ These "dusts" have little adverse effect on the lungs and do not produce toxic effects or organic disease. Although there is no dust which does not evoke some cellular response at sufficiently high concentrations, the cellular response caused by P.N.O.C.s has the following characteristics:

- the architecture of the air spaces remain intact,
- scar tissue (collagen) is not synthesised to any degree,
- tissue reaction is potentially reversible.

Extensive concentrations of P.N.O.C.s may:

- seriously reduce visibility,
- cause unpleasant deposits in the eyes, ears and nasal passages,
- contribute to skin or mucous membrane injury by chemical or mechanical action, per se, or by the rigorous skin cleansing procedures necessary for their removal. [ACGIH]

This limit does not apply:

- to brief exposures to higher concentrations
- nor does it apply to those substances that may cause physiological impairment at lower concentrations but for which a TLV has as yet to be determined.

This exposure standard applies to particles which

- are insoluble or poorly soluble\* in water or, preferably, in aqueous lung fluid (if data is available) and
- have a low toxicity (i.e.. are not cytotoxic, genotoxic, or otherwise chemically reactive with lung tissue, and do not emit ionizing radiation, cause immune sensitization, or cause toxic effects other than by inflammation or by a mechanism of lung overload)

## PERSONAL PROTECTION



Consult your EHS staff for recommendations

### EYE

- - Safety glasses with side shields
  - Chemical goggles.
  - Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

### HANDS/FEET

- Suitability and durability of glove type is dependent on usage. Important factors in the selection of gloves include: such as:
  - frequency and duration of contact,
  - chemical resistance of glove material,
  - glove thickness and
  - dexterity

Select gloves tested to a relevant standard (e.g. Europe EN 374, US F739).

- When prolonged or frequently repeated contact may occur, a glove with a protection class of 5 or higher (breakthrough time greater than 240 minutes according to EN 374) is recommended.
- When only brief contact is expected, a glove with a protection class of 3 or higher (breakthrough time greater than 60 minutes according to EN 374) is recommended.
- Contaminated gloves should be replaced.

Gloves must only be worn on clean hands. After using gloves, hands should be washed and dried thoroughly. Application of a non-perfumed moisturiser is recommended.

Experience indicates that the following polymers are suitable as glove materials for protection against undissolved, dry solids, where abrasive particles are not present.

- polychloroprene
- nitrile rubber
- butyl rubber
- fluorocautchouc
- polyvinyl chloride

Gloves should be examined for wear and/ or degradation constantly.

### OTHER

■ No special equipment needed when handling small quantities.

#### OTHERWISE:

- Overalls.
- Barrier cream.
- Eyewash unit.
- - Respirators may be necessary when engineering and administrative controls do not adequately prevent exposures.
  - The decision to use respiratory protection should be based on professional judgment that takes into account toxicity information, exposure measurement data, and frequency and likelihood of the worker's exposure - ensure users are not subject to high thermal loads which may result in heat stress or distress due to personal protective equipment (powered, positive flow, full face apparatus may be an option).
  - Published occupational exposure limits, where they exist, will assist in determining the adequacy of the selected respiratory. These may be government mandated or vendor recommended.
  - Certified respirators will be useful for protecting workers from inhalation of particulates when properly selected and fit tested as part of a complete respiratory protection program.
  - Use approved positive flow mask if significant quantities of dust becomes airborne.
  - Try to avoid creating dust conditions.

## RESPIRATOR

Protection Factor	Half-Face Respirator	Full-Face Respirator	Powered Air Respirator
10 x PEL	P1	-	PAPR-P1
	Air-line*	-	-
50 x PEL	Air-line**	P2	PAPR-P2
100 x PEL	-	P3	-
	-	Air-line*	-
100+ x PEL	-	Air-line**	PAPR-P3

\* - Negative pressure demand \*\* - Continuous flow

Explanation of Respirator Codes:

Class 1 low to medium absorption capacity filters.

Class 2 medium absorption capacity filters.

Class 3 high absorption capacity filters.

PAPR Powered Air Purifying Respirator (positive pressure) cartridge.

Type A for use against certain organic gases and vapors.

Type AX for use against low boiling point organic compounds (less than 65°C).

Type B for use against certain inorganic gases and other acid gases and vapors.

Type E for use against sulfur dioxide and other acid gases and vapors.

Type K for use against ammonia and organic ammonia derivatives

Class P1 intended for use against mechanically generated particulates of sizes most commonly encountered in industry, e.g. asbestos, silica.

Class P2 intended for use against both mechanically and thermally generated particulates, e.g. metal fume.

Class P3 intended for use against all particulates containing highly toxic materials, e.g. beryllium.

The local concentration of material, quantity and conditions of use determine the type of personal protective equipment required.

Use appropriate NIOSH-certified respirator based on informed professional judgement. In conditions where no reasonable estimate of exposure can be made, assume the exposure is in a concentration IDLH and use NIOSH-certified full face pressure demand SCBA with a minimum service life of 30 minutes, or a combination full facepiece pressure demand SAR with auxiliary self-contained air supply. Respirators provided only for escape from IDLH atmospheres shall be NIOSH-certified for escape from the atmosphere in which they will be used.

## ENGINEERING CONTROLS

- Local exhaust ventilation is required where solids are handled as powders or crystals; even when particulates are relatively large, a certain proportion will be powdered by mutual friction.
- Exhaust ventilation should be designed to prevent accumulation and recirculation of particulates in the workplace.
- If in spite of local exhaust an adverse concentration of the substance in air could occur, respiratory protection should be considered. Such protection might consist of:
  - particle dust respirators, if necessary, combined with an absorption cartridge;
  - filter respirators with absorption cartridge or canister of the right type;
  - fresh-air hoods or masks
- Build-up of electrostatic charge on the dust particle, may be prevented by bonding and grounding.
- Powder handling equipment such as dust collectors, dryers and mills may require additional protection measures such as explosion venting.

Air contaminants generated in the workplace possess varying "escape" velocities which, in turn, determine the "capture velocities" of fresh circulating air required to efficiently remove the contaminant.

Type of Contaminant:	Air Speed:
direct spray, spray painting in shallow booths, drum filling, conveyer loading, crusher dusts, gas discharge (active generation into zone of rapid air motion)	1-2.5 m/s (200-500 f/min.)
grinding, abrasive blasting, tumbling, high speed wheel generated dusts (released at high initial velocity into zone of very high rapid air motion).	2.5-10 m/s (500-2000 f/min.)

Within each range the appropriate value depends on:

Lower end of the range	Upper end of the range
1: Room air currents minimal or favorable to capture	1: Disturbing room air currents
2: Contaminants of low toxicity or of nuisance value only	2: Contaminants of high toxicity
3: Intermittent, low production.	3: High production, heavy use
4: Large hood or large air mass in motion	4: Small hood-local control only

Simple theory shows that air velocity falls rapidly with distance away from the opening of a simple extraction pipe. Velocity generally decreases with the square of distance from the extraction point (in simple cases). Therefore the air speed at the extraction point should be adjusted, accordingly, after reference to distance from the contaminating source. The air velocity at the extraction fan, for example, should be a minimum of 4-10 m/s (800-2000 f/min) for extraction of crusher dusts generated 2 meters distant from the extraction point. Other mechanical considerations, producing performance deficits within the extraction apparatus, make it essential that theoretical air velocities are multiplied by factors of 10 or more when extraction systems are installed or used.

## Section 9 - PHYSICAL AND CHEMICAL PROPERTIES

### PHYSICAL PROPERTIES

Solid.

Mixes with water.

State	Divided solid	Molecular Weight	Not applicable.
Melting Range (°F)	Not applicable.	Viscosity	Not Applicable
Boiling Range (°F)	Not applicable.	Solubility in water (g/L)	Soluble.

Flash Point (°F)	Not available	pH (1% solution)	Not available.
Decomposition Temp (°F)	Not available.	pH (as supplied)	Not applicable
Autoignition Temp (°F)	770	Vapour Pressure (mmHG)	Negligible
Upper Explosive Limit (%)	Not available.	Specific Gravity (water=1)	1.60 approx.
Lower Explosive Limit (%)	0.05 g/l	Relative Vapor Density (air=1)	Not Applicable
Volatile Component (%vol)	Negligible	Evaporation Rate	Not applicable

## APPEARANCE

Fine white powder with a bland odour; soluble in water.

## Section 10 - CHEMICAL STABILITY

### CONDITIONS CONTRIBUTING TO INSTABILITY

- Product is considered stable and hazardous polymerization will not occur.

### STORAGE INCOMPATIBILITY

- Avoid contamination of water, foodstuffs, feed or seed.
- Avoid reaction with oxidizing agents.

For incompatible materials - refer to Section 7 - Handling and Storage.

## Section 11 - TOXICOLOGICAL INFORMATION

maltodextrin

### TOXICITY AND IRRITATION

- Not available. Refer to individual constituents.

## Section 12 - ECOLOGICAL INFORMATION

Refer to data for ingredients, which follows:

MALTODEXTRIN:

## Section 13 - DISPOSAL CONSIDERATIONS

### Disposal Instructions

All waste must be handled in accordance with local, state and federal regulations.

! Legislation addressing waste disposal requirements may differ by country, state and/ or territory. Each user must refer to laws operating in their area. In some areas, certain wastes must be tracked.

A Hierarchy of Controls seems to be common - the user should investigate:

- Reduction
- Reuse
- Recycling
- Disposal (if all else fails)

This material may be recycled if unused, or if it has not been contaminated so as to make it unsuitable for its intended use. Shelf life considerations should also be applied in making decisions of this type. Note that properties of a material may change in use, and recycling or reuse may not always be appropriate.

DO NOT allow wash water from cleaning equipment to enter drains. Collect all wash water for treatment before disposal.

- Recycle wherever possible.
- Consult manufacturer for recycling options or consult Waste Management Authority for disposal if no suitable treatment or disposal facility can be identified.
- Dispose of by: Burial in a licensed land-fill or Incineration in a licensed apparatus (after admixture with suitable combustible material)
- Decontaminate empty containers. Observe all label safeguards until containers are cleaned and destroyed.

## Section 14 - TRANSPORTATION INFORMATION

NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS: DOT, IATA, IMDG

## Section 15 - REGULATORY INFORMATION

**maltodextrin (CAS: 9050-36-6) is found on the following regulatory lists;**

"Canada Domestic Substances List (DSL)", "OECD Representative List of High Production Volume (HPV) Chemicals", "US EPA High Production Volume Program Chemical List", "US Food Additive Database", "US Toxic Substances Control Act (TSCA) - Inventory", "US TSCA Section 8 (a) Inventory Update Rule (IUR) - Partial Exemptions"

## Section 16 - OTHER INFORMATION

*Reasonable care has been taken in the preparation of this information, but the author makes no warranty of merchantability or any other warranty, expressed or implied, with respect to this information. The author makes no representations and assumes no liability for any direct, incidental or consequential damages resulting from its use. For additional technical information please call our toxicology department on +800 CHEMCALL.*

■ Classification of the mixture and its individual components has drawn on official and authoritative sources as well as independent review by the Chemwatch Classification committee using available literature references. A list of reference resources used to assist the committee may be found at the [Chemwatch website](#).

■ The (M)SDS is a Hazard Communication tool and should be used to assist in the Risk Assessment. Many factors determine whether the reported Hazards are Risks in the workplace or other settings. Risks may be determined by reference to Exposures Scenarios. Scale of use, frequency of use and current or available engineering controls must be considered.

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Print Date:Apr-21-2010

Revision Date: 05/28/2015

## SECTION 1: CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

### 1.1 Product Identifiers

Catalog Number    Product Name

SS02N-SS06N    Non-Functionalized Silica microparticles

### 1.2 Relevant identified uses of substance or mixture and uses advised against

Identified uses: Lab use

### 1.3 Details of the supplier of the safety data sheet

Company: Bangs Laboratories / A Division of Polysciences

9025 Technology Drive

Fishers, Indiana 46038

USA

Telephone: 800-387-0672

### 1.4 Emergency telephone number

Emergency Phone: 317-348-1673

## SECTION 2: HAZARDS IDENTIFICATION

### 2.1 Classification of the substance or mixture

**GHS Classification: Non-Hazardous**

**Signal word: Non-Hazardous**

**Pictogram: NONE**

### Hazard Statement(s)

H000                      Low hazard for normal industrial use  
 P302+P352              IF ON SKIN: Wash with plenty of soap and water.  
 P305B                      IF IN EYES: Separate eyelids with fingertips.  
 P313                        Get medical advice/attention  
 P351                        Rinse cautiously with water for several minutes.

**2.2 Hazard Ratings:** These ratings are Bangs Laboratories, Inc.'s own assessments of the properties of the material using the ANSI/NFPA 704 Standard. Additional information can be found by consulting in the NFPA published ratings lists (List 325 and List 49). If no data is listed, the information is not available.

<u>Health</u>	<u>Flammability</u>	<u>Reactivity</u>
0	0	0

## SECTION 3: COMPOSITION / INFORMATION ON INGREDIENTS

<i>Item#</i>	<i>Name</i>	<i>CAS #</i>	<i>% in</i>
1	Water	007732185	90≥
2	Silicon dioxide, amorphous	007631869	≤10

## SECTION 4: FIRST AID MEASURES

**Eyes:** In case of contact, immediately flush eyes with copious amounts of water for at least 15 minutes.

**Skin:** In case of contact, immediately wash skin with copious amounts of water for at least 15 minutes.

**Ingestion:** Contact physician immediately.

**Inhalation:** Remove to fresh air if effects occur. Consult medical personnel.

**Systemic:** Human effects not established. No specific antidote. Treatment based on sound judgment of physician and the individual reactions of the patient.

## SECTION 5: FIRE FIGHTING MEASURES

- 5.1 Extinguishing Media:** Not applicable
- 5.2 Special hazards arising from the substance or mixture:** Suspended material is not flammable.
- 5.3 Advice for firefighters:** Not applicable
- 5.4 Further Information:** No data available

## SECTION 6: ACCIDENTAL RELEASE MEASURES

### 6.1 Personal precautions, protective equipment and emergency procedures

Any information given below is considered to be in addition to internal guidelines for isolation of spill, containment of spill, removal of ignition source from immediate area, and collection for disposal of spill by trained, properly protected clean up personnel. Wear vinyl gloves, soak up spill in paper toweling, and rinse area with water. Put all generated waste into an approved container and dispose of as waste. Observe all applicable federal, state, and local disposal laws.

- 6.2 Environmental Precautions:** No special measures are indicated.
- 6.3 Methods and materials for containment and cleaning up:** No special measures are indicated.
- 6.4 Reference to other sections:** For disposal see section 13.

## SECTION 7: HANDLING AND STORAGE

### 7.1 Precautions for safe handling

Respiratory Protection: None normally needed. In cases where there is a likelihood of inhalation exposure to dried particles, wear a NIOSH-approved dust respirator.

### 7.2 Conditions for safe storage, including any incompatibilities

Ventilation: Good room ventilation is adequate for most operations.

Respiratory Protection: None normally needed. In cases where there is a likelihood of inhalation exposure to dried particles, wear a NIOSH-approved dust respirator.

### 7.3 Specific end use(s)

Storage: Store at 4-8°C. Keep refrigerated. Do not freeze. Keep container closed.

## SECTION 8: EXPOSURE CONTROLS AND PERSONAL PROTECTION

### 8.1 Control parameters

Respiratory Protection: None normally needed.

Wash / Hygienic Practices: Wash with soap and water when leaving work area and before eating, smoking, and using restroom facilities.

### 8.2 Exposure Controls: None Indicated

The use of eye protection in the form of safety glasses with side shields and the use of skin protection for hands in the form of gloves are considered minimum and non-discretionary in work places and laboratories. Any recommended personal protection equipment or environmental equipment is to be considered as additional to safety glasses and gloves. Chemical-resistant gloves should be worn whenever this material is handled. The glove material has to be impermeable and resistant to the product. Gloves should be removed and replaced immediately if there is any indication of degradation or chemical breakthrough. Rinse and remove gloves immediately after use. Wash hands with soap and water. All glove recommendations presume that the risk of exposure is through splash and not internal immersion of the hands into the product. Since glove permeation data does not exist for this material, no recommendation for the glove material can be given for the product. Permeation data must be obtained from the glove manufacturer to determine if the glove is suitable for the task.

## SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

### 9.1 Information on basic physical and chemical properties

Boiling Point:	100°C / 212°F
Density (particles):	~2.0 g/cc
Solubility:	dispersible in water
Appearance:	white slurry

### 9.2 Other safety information: None

## SECTION 10: STABILITY AND REACTIVITY

- 10.1 Reactivity:** No data available
- 10.2 Chemical Stability:** Stable under recommended storage conditions
- 10.3 Possibility of hazardous reactions:** No data available
- 10.4 Conditions to avoid:** Product may irreversibly aggregate if frozen.
- 10.5 Incompatible materials:** Reacts with hydrogen fluoride, fluorine, oxygen difluoride, chlorine trifluoride, strong acids, strong bases and oxidizers.

## SECTION 11: TOXICOLOGICAL INFORMATION

- 11.1 Information on toxicological effects:** To the best of our knowledge, the chemical, physical, and toxic properties of this product have not been thoroughly investigated. This product is synthetic amorphous silica and is not crystalline in nature.

## SECTION 12: ECOLOGICAL INFORMATION

No Data

## SECTION 13: DISPOSAL CONSIDERATIONS

**13.1 Waste treatment methods:** The following chart lists the status of the chemical and its components in reference to 40 CFR Part 261.33. If the product is listed by code number, the substance may be subject to special federal and state disposal regulations. If no codes are listed, the material must be disposed of in compliance with all Federal, State, and Local Regulations.

<u>CAS #</u>	<u>Waste Code</u>	<u>Regulated Name</u>
007732185	not listed	not listed
007631869	not listed	not listed

## SECTION 14: TRANSPORT INFORMATION

Refer to bill of lading or container label for DOT or other transportation hazard classification, if any.

## SECTION 15: REGULATORY INFORMATION

All components of this product are on the TSCA public inventory.

Prop 65: Column A identifies those items which are known to the State of California to cause cancer. Column B identifies those which are known to the State of California to cause reproductive toxicity.

<u>CAS #</u>	<u>Column A</u>	<u>Column B</u>
007732185	no	no
007631869	no	no

**SARA Toxic Release Chemicals** (as defined in Section 313 of SARA Title III): This list identifies the toxic chemicals, including their de minimis concentrations for which reporting is required under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA). This list is also referred to as the Toxic Release Inventory (TRI) List.

<u>CAS #</u>	<u>Regulated Name</u>	<u>de minimis conc %</u>	<u>Rep. Thres.</u>
007732185	not listed	not listed	not listed
007631869	not listed	not listed	not listed

**SARA Extremely Hazardous Substances and TPQs:** This list identifies hazardous substances regulated under Section 302 of SARA Title III with their TPQs (in pounds), as listed in 40 CFR 355, Appendices A and B.

<u>CAS #</u>	<u>Regulated Name</u>	<u>TPQ (pounds)</u>	<u>EHS-RQ (pounds)</u>
007732185	not listed	not listed	not listed
007631869	not listed	not listed	not listed

## SECTION 16: OTHER INFORMATION

BANGS LABORATORIES, INC. provides the information contained herein in good faith, but makes no representation as to its comprehensiveness or accuracy. Individuals receiving this information must exercise their independent judgment in determining its appropriateness for a particular purpose.

BANGS LABORATORIES, INC. makes no representations or warranties, either expressed or implied, of merchantability or fitness for particular purposes with respect to the information set forth herein or to which the information refers. Accordingly, BANGS LABORATORIES, INC. will not be responsible for damages resulting from the use of or reliance upon this information.

Preparation Information:

Bangs Laboratories, Inc.

1-800-387-0672

**END OF SDS**

# Safety Data Sheet

Fluorescent Brightener 220, Technical grade

## 1. Identification

Product name	Fluorescent Brightener 220, Technical grade
Catalog#	O241
IUPAC name	tetrasodium;2-[[4-[bis(2-hydroxyethyl)amino]-6-(4-sulfonatoanilino)-1,3,5-triazin-2-yl]amino]-5-[(E)-2-[4-[[4-[bis(2-hydroxyethyl)amino]-6-(4-sulfonatoanilino)-1,3,5-triazin-2-yl]amino]-3-sulfonatophenyl]ethenyl]benzenesulfonate
Product use/Restrictions on use	For laboratory research use. Not for drug or household use.
Company	AK Scientific, Inc. 30023 Ahern Ave. Union City, CA 94587
Telephone	(510) 429-8835
Fax	(510) 429-8836
Website	AK Scientific Website
Emergency contact number:	(510) 429-8835

## 2. Hazards Identification

### GHS Classification

No data available.

### Pictogram

No data available.

### Signal word

No data available.

### Hazard statement(s)

No data available.

### Precautionary statement(s)

No data available.

### Hazards not otherwise classified (HNOC) or not covered by GHS

No data available.

## 3. Composition/Information on Ingredients

Synonyms: No data available.

CAS#: [16470-24-9]

Purity: No data available.

EC#: 240-521-2

## 4. First Aid Measures

**General information:** Immediately remove any clothing contaminated by the product. Move out of dangerous area. Consult a physician and show this safety data sheet.

**Inhalation:** Move person to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Obtain medical aid.

**Skin contact:** Immediately flush skin with running water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Obtain medical aid immediately.

**Eye contact:** Immediately flush open eyes with running water for at least 15 minutes. Obtain medical aid immediately.

**Ingestion:** Do NOT induce vomiting without medical advice. Rinse mouth with water. Never administer anything by mouth to an unconscious person. Obtain medical aid immediately.

**Most important symptoms and effects, both acute and delayed:** No further information available. Please see headings 2 and 11.

**Indication of any immediate medical attention and special treatment needed:** No further information available.

## 5. Fire Fighting Measure

**Suitable extinguishing media:** Use water spray, dry chemical, carbon dioxide, or chemical foam.

**Specific hazards arising from the chemical:** Nitrogen oxides, Sulfur oxides, Carbon oxides, Sodium oxides

## Fluorescent Brightener 220, Technical grade

**Advice for firefighters:** As in any fire, wear a MSHA/NIOSH-approved or equivalent, pressure-demand, self-contained breathing apparatus and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion

---

## 6. Accidental Release Measures

**Personal precautions, protective equipment and emergency procedures:** Wear protective equipment and keep unprotected personnel away. Ensure adequate ventilation. Remove all sources of ignition. Prevent further leak or spill if safe to do so. For personal protective equipment, please refer to heading 8.

**Environmental precautions:** Do not let product enter drains, other waterways, or soil.

**Methods and materials for containment and cleaning up:** Prevent further leak or spill if safe to do so. Vacuum, sweep up, or absorb with inert material and place into a suitable disposal container. Consult local regulations for disposal. Also, see heading 13.

---

## 7. Handling and Storage

**Precautions for safe handling:** Avoid contact with skin, eyes, and personal clothing. Wash hands thoroughly after handling. Avoid breathing fumes. Use only with adequate ventilation. Wear suitable protective clothing, gloves, and eye/face protection. Keep away from sources of ignition. Minimize dust generation and accumulation. Keep container tightly closed. Open and handle container with care. Do not eat, drink, or smoke while handling.

**Conditions for safe storage, including any incompatibilities:** Store in a tightly-closed container when not in use. Store in a cool, dry, well-ventilated area away from incompatible substances. Keep away from sources of ignition.

---

## 8. Exposure Controls/Personal Protection

### Exposure limits

OSHA PEL: No data available.

NIOSH REL: No data available.

ACGIH TLV: No data available.

**Appropriate engineering controls:** Avoid contact with skin, eyes, and clothing. Wash hands before breaks and immediately after handling the product. Facilities storing or utilizing this material should be equipped with an eyewash fountain. Use adequate ventilation to keep airborne concentrations low.

### Personal protection

Eyes: Wear chemical splash goggles.

Hand: Wear protective gloves.

Skin and body: Wear protective lab coat and boots.

Respiratory: Use NIOSH/MSHA or CEN approved respirator.

---

## 9. Physical and Chemical Properties

Physical State:	No data available.
Molecular Formula:	C40H40N12Na4O16S4
Molecular Weight:	1165.03
Odor:	No data available.
pH:	No data available.
Boiling Point Range:	No data available.
Freezing/Melting Point:	No data available.
Flash Point:	No data available.
Evaporation Rate:	No data available.
Flammability (solid, gas):	Please see section 2.
Explosive limits:	No data available.
Vapor Pressure:	No data available.
Vapor Density:	No data available.
Solubility:	No data available.
Relative Density:	No data available.
Refractive Index:	No data available.
Volatility:	No data available.

## Fluorescent Brightener 220, Technical grade

Auto-ignition temperature:	No data available.
Decomposition Temperature:	No data available.
Partition Coefficient:	No data available.

**10. Stability and Reactivity**

Reactivity	No data available.
Chemical stability	Stable under recommended temperatures and pressures.
Possibility of hazardous reactions	No data available.
Conditions to avoid	Dust generation.
Incompatible materials	Strong oxidizing agents.
Hazardous decomposition products	Nitrogen oxides, Sulfur oxides, Carbon oxides, Sodium oxides

**11. Toxicological Information**

RTECS#	No data available.
Acute toxicity	No data available.
Routes of exposure	Inhalation, eye contact, skin contact, ingestion.
Symptoms related to the physical, chemical and toxicological characteristics	Skin contact may result in inflammation characterized by itching, scaling, reddening, blistering, pain or dryness. Eye contact may result in redness, pain or severe eye damage. Inhalation may cause irritation of the lungs and respiratory system. Overexposure may result in serious illness or death.

**Carcinogenicity**

IARC	Not classified.
NTP	Not listed.
OSHA	Not listed.
Acute toxic effects	Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

**12. Ecological Information**

Ecotoxicity	No data available.
Persistence and degradability	No data available.
Bioaccumulative potential	No data available.
Mobility in soil	No data available.
Other adverse effects	No data available.

**13. Disposal Considerations**

**Disposal of waste:** Chemical waste generators must determine whether a discarded chemical is classified as hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification. Observe all federal, state and local regulations when disposing of the substance.

**Disposal of packaging:** Do not reuse containers. Dispose of as unused product.

**14. Transport Information**

<b>DOT (U.S.)</b>	
UN number	Not applicable.
UN proper shipping name	Not applicable.
Transport hazard class(es)	Not applicable.
Packing group	Not applicable.

**15. Regulatory Information**

TSCA Chemical Inventory: This product is on the EPA Toxic Substance Control Act (TSCA) inventory. The product is supplied solely for use in research and development by or under the supervision of a technically qualified individual as

Fluorescent Brightener 220, Technical grade

defined in 40 CFR 720 et seq. The health risks have not been fully determined. Any information that is or becomes available will be supplied on an SDS sheet.

California Proposition 65: Not listed.

EC#: 240-521-2

NFPA rating: **Health:**

**Flammability:**

**Instability:**

---

**16. Additional Information**

Revision Date: 12/22/2014

Printed Date: 2/11/2015

**Disclaimer:**

*The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall AK Scientific be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if AK Scientific has been advised of the possibility of such damages.*

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## SAFETY DATA SHEET

Version 3.4  
Revision Date 07/02/2014  
Print Date 11/20/2014

---

**1. PRODUCT AND COMPANY IDENTIFICATION****1.1 Product identifiers**

Product name : Sulfur hexafluoride  
Product Number : 295701  
Brand : Aldrich  
CAS-No. : 2551-62-4

**1.2 Relevant identified uses of the substance or mixture and uses advised against**

Identified uses : Laboratory chemicals, Manufacture of substances

**1.3 Details of the supplier of the safety data sheet**

Company : Sigma-Aldrich  
3050 Spruce Street  
SAINT LOUIS MO 63103  
USA

Telephone : +1 800-325-5832  
Fax : +1 800-325-5052

**1.4 Emergency telephone number**

Emergency Phone # : (314) 776-6555

---

**2. HAZARDS IDENTIFICATION****2.1 Classification of the substance or mixture****GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**

Gases under pressure (Liquefied gas), H280

For the full text of the H-Statements mentioned in this Section, see Section 16.

**2.2 GHS Label elements, including precautionary statements**

Pictogram



Signal word : Warning

Hazard statement(s)

H280 : Contains gas under pressure; may explode if heated.

Precautionary statement(s)

P410 + P403 : Protect from sunlight. Store in a well-ventilated place.

**2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none**

---

**3. COMPOSITION/INFORMATION ON INGREDIENTS****3.1 Substances**

Formula : F<sub>6</sub>S  
Molecular Weight : 146.06 g/mol  
CAS-No. : 2551-62-4  
EC-No. : 219-854-2

**Hazardous components**

Component	Classification	Concentration
<b>Sulfur hexafluoride</b>	Press. Gas ; H280	-

For the full text of the H-Statements mentioned in this Section, see Section 16.

---

#### 4. FIRST AID MEASURES

##### 4.1 Description of first aid measures

###### General advice

Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

###### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

###### In case of skin contact

Wash off with soap and plenty of water. Consult a physician.

###### In case of eye contact

Flush eyes with water as a precaution.

###### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

##### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

##### 4.3 Indication of any immediate medical attention and special treatment needed

no data available

---

#### 5. FIREFIGHTING MEASURES

##### 5.1 Extinguishing media

###### Suitable extinguishing media

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

##### 5.2 Special hazards arising from the substance or mixture

Sulphur oxides, Hydrogen fluoride

##### 5.3 Advice for firefighters

Wear self contained breathing apparatus for fire fighting if necessary.

##### 5.4 Further information

Use water spray to cool unopened containers.

---

#### 6. ACCIDENTAL RELEASE MEASURES

##### 6.1 Personal precautions, protective equipment and emergency procedures

Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.  
For personal protection see section 8.

##### 6.2 Environmental precautions

Do not let product enter drains.

##### 6.3 Methods and materials for containment and cleaning up

Clean up promptly by sweeping or vacuum.

##### 6.4 Reference to other sections

For disposal see section 13.

---

#### 7. HANDLING AND STORAGE

##### 7.1 Precautions for safe handling

Normal measures for preventive fire protection.  
For precautions see section 2.2.

##### 7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

Contents under pressure.

### 7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

### 8.1 Control parameters

#### Components with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
Sulfur hexafluoride*	2551-62-4	TWA	1,000 ppm	USA. ACGIH Threshold Limit Values (TLV)
			1,000 ppm 6,000 mg/m3**	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
			1,000 ppm 6,000 mg/m3**	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
			1,000 ppm 6,000 mg/m3**	USA. NIOSH Recommended Exposure Limits
			2.5 mg/m3***	USA. Occupational Exposure Limits (OSHA) - Table Z-2 (Z37.28-1969) (Fluoride is dust)

Remarks: \*Asphyxia

\*\*the value in mg/m3 is approximate.

\*\*\*May contain highly toxic sulfur pentafluoride as an impurity

#### Biological occupational exposure limits

Component	CAS-No.	Value	Control parameters	Specimen	Basis
Sulfur hexafluoride	2551-62-4	Fluorides	3 mg/g	In urine(sample time: Prior to shift (16 hours after	ACGIH - Biological Exposure Indices (BEI)
			10 mg/g	In urine (sample time: End of shift (As soon as possible after exposure ceases))	ACGIH - Biological Exposure Indices (BEI)

### 8.2 Exposure controls

#### Appropriate engineering controls

Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

#### Personal protective equipment

##### Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

##### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

##### Full contact

Material: butyl-rubber

Minimum layer thickness: 0.3 mm

Break through time: 480 min

Material tested: Butoject® (KCL 897 / Aldrich Z677647, Size M)

##### Splash contact

Material: butyl-rubber  
Minimum layer thickness: 0.3 mm  
Break through time: 480 min  
Material tested: Butoject® (KCL 897 / Aldrich Z677647, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail KCL sales, test method: EN374

If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

### **Body Protection**

impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### **Respiratory protection**

Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type AXBEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### **Control of environmental exposure**

Do not let product enter drains.

---

## **9. PHYSICAL AND CHEMICAL PROPERTIES**

### **9.1 Information on basic physical and chemical properties**

- |   |  |
|---|--|
| a) Appearance                                   | Form: Liquefied gas  |
| b) Odour  | no data available  |
| c) Odour Threshold                              | no data available  |
| d) pH   | no data available  |
| e) Melting point/freezing point                 | Melting point/range: -50 °C (-58 °F) - lit.  |
| f) Initial boiling point and boiling range      | -64 °C (-83 °F) at 1 hPa (1 mmHg) - lit.   |
| g) Flash point                                  | not applicable   |
| h) Evaporation rate                             | no data available  |
| i) Flammability (solid, gas)                    | no data available  |
| j) Upper/lower flammability or explosive limits | no data available  |
| k) Vapour pressure                              | 29 hPa (22 mmHg) at 21.1 °C (70.0 °F)<br>22,057 hPa (16,544 mmHg) at 20 °C (68 °F) |
| l) Vapour density                               | 5.04 - (Air = 1.0)   |
| m) Relative density                             | no data available  |
| n) Water solubility                             | no data available  |
| o) Partition coefficient: n-octanol/water       | no data available  |
| p) Auto-ignition temperature                    | no data available  |
| q) Decomposition temperature                    | no data available  |
| r) Viscosity                                    | no data available  |

- s) Explosive properties      no data available
- t) Oxidizing properties      no data available

## 9.2 Other safety information

Relative vapour density      5.04 - (Air = 1.0)

---

## 10. STABILITY AND REACTIVITY

### 10.1 Reactivity

no data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

no data available

### 10.4 Conditions to avoid

no data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - no data available

In the event of fire: see section 5

---

## 11. TOXICOLOGICAL INFORMATION

### 11.1 Information on toxicological effects

#### Acute toxicity

no data available

Inhalation: no data available

Dermal: no data available

LD50 Intravenous - rabbit - 5,790 mg/kg

#### Skin corrosion/irritation

no data available

#### Serious eye damage/eye irritation

no data available

#### Respiratory or skin sensitisation

no data available

#### Germ cell mutagenicity

no data available

#### Carcinogenicity

Organization	Classification
--------------	----------------

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
-------	---

ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
--------	--

NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
------	---

OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.
-------	---

#### Reproductive toxicity

no data available

no data available

**Specific target organ toxicity - single exposure**

no data available

**Specific target organ toxicity - repeated exposure**

no data available

**Aspiration hazard**

no data available

**Additional Information**

RTECS: WS4900000

May be harmful., Nausea, Dizziness, Headache, Central nervous system depression

---

**12. ECOLOGICAL INFORMATION****12.1 Toxicity**

no data available

**12.2 Persistence and degradability**

no data available

**12.3 Bioaccumulative potential**

no data available

**12.4 Mobility in soil**

no data available

**12.5 Results of PBT and vPvB assessment**

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

**12.6 Other adverse effects**

no data available

---

**13. DISPOSAL CONSIDERATIONS****13.1 Waste treatment methods****Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

**Contaminated packaging**

Dispose of as unused product.

---

**14. TRANSPORT INFORMATION****DOT (US)**

UN number: 1080	Class: 2.2
Proper shipping name: Sulfur hexafluoride	
Marine pollutant: No	
Poison Inhalation Hazard: No	

**IMDG**

UN number: 1080	Class: 2.2 EMS-No: F-C, S-V
Proper shipping name: SULPHUR HEXAFLUORIDE	
Marine pollutant: No	

**IATA**

UN number: 1080	Class: 2.2 EMS-No: F-C, S-V
Proper shipping name: SULPHUR HEXAFLUORIDE	

---

**15. REGULATORY INFORMATION****SARA 302 Components**

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

**SARA 313 Components**

SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

**SARA 311/312 Hazards**

Sudden Release of Pressure Hazard

**Massachusetts Right To Know Components**

	CAS-No.	Revision Date
Sulfur hexafluoride	2551-62-4	1993-04-24

**Pennsylvania Right To Know Components**

	CAS-No.	Revision Date
Sulfur hexafluoride	2551-62-4	1993-04-24

**New Jersey Right To Know Components**

	CAS-No.	Revision Date
Sulfur hexafluoride	2551-62-4	1993-04-24

**California Prop. 65 Components**

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

---

**16. OTHER INFORMATION****Full text of H-Statements referred to under sections 2 and 3.**

H280	Contains gas under pressure; may explode if heated.
Press. Gas	Gases under pressure

**HMIS Rating**

Health hazard:	0
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	0

**NFPA Rating**

Health hazard:	0
Fire Hazard:	0
Reactivity Hazard:	0

**Further information**

Copyright 2014 Sigma-Aldrich Co. LLC. License granted to make unlimited paper copies for internal use only. The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See Sigma-Aldrich Website and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

**Preparation Information**

Sigma-Aldrich Corporation  
Product Safety – Americas Region  
1-800-521-8956

Version: 3.4

Revision Date: 07/02/2014

Print Date: 11/20/2014

# Perfluoro (dimethylcyclobutane) : sc-264029

## MATERIAL SAFETY DATA SHEET

The Power to Question

### 1 Identification of substance:

**Product Name:** Perfluoro (dimethylcyclobutane)  
**Catalog Number:** sc-264029  
**Supplier:** Santa Cruz Biotechnology, Inc.  
2145 Delaware Avenue  
Santa Cruz, California 95060  
800.457.3801 or 831.457.3800

**Emergency:** ChemWatch  
Within the US & Canada: 877-715-9305  
Outside the US & Canada: +800 2436 2255  
(1-800-CHEMCALL) or call +613 9573 3112

### 2 Hazard (s) identification

#### Classification of the substance or mixture

#### Classification according to Regulation (EC) No 1272/2008

The substance is not classified as hazardous to health or the environment according to the CLP regulation.

#### Classification according to Directive 67/548/EEC or Directive 1999/45/EC Not applicable

#### Information concerning particular hazards for human and environment:

Not applicable

No information known.

**Hazards not otherwise classified** No information known.

#### Label elements

**Labelling according to Regulation (EC) No 1272/2008** Not applicable

**Hazard pictograms** Not applicable

**Signal word** Not applicable

**Hazard statements** Not applicable

**WHMIS classification** Not controlled

#### Classification system

**HMIS ratings (scale 0-4)**

(Hazardous Materials Identification System)

HEALTH
FIRE
REACTIVITY

Health (acute effects) = 1

Flammability = 1

Physical Hazard = 1

#### Other hazards

#### Results of PBT and vPvB assessment

**PBT:** Not applicable.

**vPvB:** Not applicable.

### 3 Composition/information on ingredients

#### Chemical characterization: Substances

#### CAS# Description:

28677-00-1 Perfluorodimethylcyclobutane

#### Identification number(s):

**EC number:** 249-145-3

### 4 First-aid measures

#### Description of first aid measures

##### After inhalation

Supply fresh air. If required, provide artificial respiration. Keep patient warm.

Seek immediate medical advice.

##### After skin contact

Immediately wash with water and soap and rinse thoroughly.

Seek immediate medical advice.

**After eye contact**

Rinse opened eye for several minutes under running water. Then consult a doctor.

**After swallowing** Seek medical treatment.

**Information for doctor**

**Most important symptoms and effects, both acute and delayed**

No further relevant information available.

**Indication of any immediate medical attention and special treatment needed**

No further relevant information available.

## 5 Fire- fighting measures

**Extinguishing media**

**Suitable extinguishing agents**

Carbon dioxide, extinguishing powder or water spray. Fight larger fires with water spray or alcohol resistant foam.

**Special hazards arising from the substance or mixture**

If this product is involved in a fire, the following can be released:

Carbon monoxide and carbon dioxide

Hydrogen fluoride (HF)

**Advice for firefighters**

**Protective equipment:**

Wear self-contained respirator.

Wear fully protective impervious suit.

## 6 Accidental release measures

**Personal precautions, protective equipment and emergency procedures**

Wear protective equipment. Keep unprotected persons away.

Ensure adequate ventilation

**Environmental precautions:**

Do not allow product to reach sewage system or any water course.

Do not allow to penetrate the ground/soil.

**Methods and material for containment and cleaning up :**

Absorb with liquid -binding material (sand, diatomite, acid binders, universal binders, sawdust).

**Prevention of secondary hazards:** No special measures required.

**Reference to other sections**

See Section 7 for information on safe handling

See Section 8 for information on personal protection equipment.

See Section 13 for disposal information.

## 7 Handling and storage

**Handling**

**Precautions for safe handling** Keep container tightly sealed.

**Information about protection against explosions and fires:** No information known.

**Conditions for safe storage, including any incompatibilities**

**Storage** Store at 4° C .

**Requirements to be met by storerooms and receptacles:** Refrigerate

**Information about storage in one common storage facility:**

Protect from heat.

Store away from oxidizing agents.

**Further information about storage conditions:**

Keep container tightly sealed.

Refrigerate

**Specific end use (s)** No further relevant information available.

## 8 Exposure controls/personal protection

**Additional information about design of technical systems:**

Properly operating chemical fume hood designed for hazardous chemicals and having an average face velocity of at least 100 feet per minute.

**Control parameters**

**Components with limit values that require monitoring at the workplace:**

The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.

**Additional information:** No data

**Exposure controls**

**Personal protective equipment**

**General protective and hygienic measures**

The usual precautionary measures for handling chemicals should be followed.  
Keep away from foodstuffs, beverages and feed.  
Remove all soiled and contaminated clothing immediately.  
Wash hands before breaks and at the end of work.  
Maintain an ergonomically appropriate working environment.

**Breathing equipment:**

Use suitable respirator when high concentrations are present.  
Use suitable respiratory protective device in case of insufficient ventilation.

**Protection of hands:**

Impervious gloves  
Check protective gloves prior to each use for their proper condition.  
The selection of suitable gloves not only depends on the material, but also on quality.  
Quality will vary from manufacturer to manufacturer.

**Eye protection:** Safety glasses

**Body protection:** Protective work clothing.

**9 Physical and chemical properties**

<u>Property</u>	<u>Values</u>
General Information	
Form:	Liquid
Formula:	C6F12
Weight:	300.04
pH- value:	Not determined.
Change in condition	
Melting point/Melting range:	Not determined.
Boiling point/Boiling range:	45 oc (113 op )
Sublimation temperature /start:	Not determined
Flammability (solid,gaseous)	Not determined.
Ignition temperature:	Not determined
Decomposition temperature:	Not determined.
Auto igniting:	Not determined.
Danger of explosion:	Not determined
Explosion limits:	Not determined.
Lower:	Not determined
Upper:	
Vapor pressure:	Not determined
Density at 20 °C (68 °F): Relative density	Not determined
Vapor density Evaporation rate	1.62 g/cm <sup>3</sup> (13.519lbs/gal)
Solubility in/Miscibility with Water:	Not miscible or difficult to mix Not determined.
Partition coefficient (n-octanol/water):	Not determined.
Viscosity	
dynamic:	Not determined.
kinematic:	Not determined.
Other information	No further relevant information available.

**10 Stability and reactivity**

**Reactivity** No information known.

**Chemical stability** Stable under recommended storage conditions.

**Thermal decomposition / conditions to be avoided:**

Decomposition will not occur if used and stored according to specifications.

**Possibility of hazardous reactions** Reacts with strong oxidizing agents

**Incompatible materials:**

Oxidizing agents

Heat

**Hazardous decomposition products:**

Carbon monoxide and carbon dioxide

Hydrogen fluoride

## 11 Toxicological information

Information on toxicological effects

Acute toxicity: No effects known.

LD/LC50 values that are relevant for classification: No data

Skin irritation or corrosion: May cause irritation

Eye irritation or corrosion: May cause irritation

Sensitization: No sensitizing effects known.

Germ cell mutagenicity: No effects known.

Carcinogenicity:

No classification data on carcinogenic properties of this material is available from the EPA, IARC, NTP, OSHA or ACGIH.

Reproductive toxicity: No effects known.

Specific target organ system toxicity - repeated exposure: No effects known.

Specific target organ system toxicity - single exposure: No effects known.

Aspiration hazard: No effects known.

Additional toxicological information:

To the best of our knowledge the acute and chronic toxicity of this substance is not fully known.

## 12 Ecological information

Toxicity

Aquatic toxicity: No further relevant information available.

Persistence and degradability No further relevant information available.

Behavior in environmental systems:

Bioaccumulative potential No further relevant information available.

Mobility in soil No further relevant information available.

Additional ecological information:

General notes: Avoid transfer into the environment.

Results of PBT and vPvB assessment

PBT: Not applicable.

vPvB: Not applicable.

Other adverse effects No further relevant information available.

## 13 Disposal considerations

Waste treatment methods

Recommendation Consult state, local or national regulations to ensure proper disposal.

Uncleaned packagings:

Recommendation: Disposal must be made according to official regulations.

## 14 Transport information

UN-Number DOT, ADR, ADN, IMDG, IATA	Not applicable
UN proper shipping name DOT, ADR, ADN, IMDG, IATA	Not applicable
Transport hazard class(es) DOT, ADR, ADN, IMDG, IATA Class	Not applicable
Packing group DOT, ADR, IMDG, IATA	Not applicable
Environmental hazards:	Not applicable.
Special precautions for user	Not applicable.
Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code	Not applicable.
Transport/Additional information: DOT Marine Pollutant (DOT):	No

## 15 Regulatory information

**Safety, health and environmental regulations/legislation specific for the substance or mixture**

### **National regulations**

This product is not listed in the U.S. Environmental Protection Agency Toxic Substances Control Act Chemical Substance Inventory. Use of this product is restricted to research and development only. This product must be used by or directly under the supervision of a technically qualified individual as defined by TSCA. This product must not be used for commercial purposes or in formulations for commercial purposes.

Some or all of the components of this product are not listed on the Canadian Domestic Substances List (DSL) or the Canadian Non-Domestic Substances List (NDSL).

**SARA Section 313 (specific toxic chemical listings)** Substance is not listed.

### **California Proposition 65**

**Prop 65 - Chemicals known to cause cancer** Substance is not listed.

**Prop 65 - Developmental toxicity** Substance is not listed.

**Prop 65 - Developmental toxicity, female** Substance is not listed.

**Prop 65 - Developmental toxicity, male** Substance is not listed.

**Information about limitation of use:** For use only by technically qualified individuals.

### **Other regulations, limitations and prohibitive regulations**

**Substances of very high concern (SVHC) according to REACH, Article 57**

Substance is not listed.

**REACH - Pre-registered substances** Substance is listed.

**Chemical safety assessment:** A Chemical Safety Assessment has not been carried out.

## 16 Other information:

The above information is believed to be correct but does not purport to be complete and should be used only as a guide. The burden of safe use of this material rests entirely with the user.

3/5/2014

## SAFETY DATA SHEET

Version 5.2  
Revision Date 06/25/2014  
Print Date 11/20/2014

---

### 1. PRODUCT AND COMPANY IDENTIFICATION

#### 1.1 Product identifiers

Product name : Perfluoro(methylcyclohexane)

Product Number : 302937

Brand : Aldrich

CAS-No. : 355-02-2

#### 1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

#### 1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich  
3050 Spruce Street  
SAINT LOUIS MO 63103  
USA

Telephone : +1 800-325-5832

Fax : +1 800-325-5052

#### 1.4 Emergency telephone number

Emergency Phone # : (314) 776-6555

---

### 2. HAZARDS IDENTIFICATION

#### 2.1 Classification of the substance or mixture

Not a hazardous substance or mixture.

#### 2.2 GHS Label elements, including precautionary statements

Not a hazardous substance or mixture.

#### 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

### 3. COMPOSITION/INFORMATION ON INGREDIENTS

#### 3.1 Substances

Synonyms : (Trifluoromethyl)undecafluorocyclohexane

Formula : C<sub>7</sub>F<sub>14</sub>

Molecular Weight : 350.05 g/mol

CAS-No. : 355-02-2

EC-No. : 206-573-5

No ingredients are hazardous according to OSHA criteria.

No components need to be disclosed according to the applicable regulations.

---

### 4. FIRST AID MEASURES

#### 4.1 Description of first aid measures

##### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration.

**In case of skin contact**

Wash off with soap and plenty of water.

**In case of eye contact**

Flush eyes with water as a precaution.

**If swallowed**

Never give anything by mouth to an unconscious person. Rinse mouth with water.

**4.2 Most important symptoms and effects, both acute and delayed**

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

**4.3 Indication of any immediate medical attention and special treatment needed**

no data available

---

**5. FIREFIGHTING MEASURES****5.1 Extinguishing media****Suitable extinguishing media**

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

**5.2 Special hazards arising from the substance or mixture**

Carbon oxides, Hydrogen fluoride

**5.3 Advice for firefighters**

Wear self contained breathing apparatus for fire fighting if necessary.

**5.4 Further information**

no data available

---

**6. ACCIDENTAL RELEASE MEASURES****6.1 Personal precautions, protective equipment and emergency procedures**

Avoid breathing vapours, mist or gas.  
For personal protection see section 8.

**6.2 Environmental precautions**

Do not let product enter drains.

**6.3 Methods and materials for containment and cleaning up**

Keep in suitable, closed containers for disposal.

**6.4 Reference to other sections**

For disposal see section 13.

---

**7. HANDLING AND STORAGE****7.1 Precautions for safe handling**

Normal measures for preventive fire protection.  
For precautions see section 2.2.

**7.2 Conditions for safe storage, including any incompatibilities**

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

**7.3 Specific end use(s)**

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

---

**8. EXPOSURE CONTROLS/PERSONAL PROTECTION****8.1 Control parameters****Components with workplace control parameters**

Contains no substances with occupational exposure limit values.

**8.2 Exposure controls****Appropriate engineering controls**

General industrial hygiene practice.

## Personal protective equipment

### Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

### Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

### Body Protection

impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Respiratory protection not required. For nuisance exposures use type OV/AG (US) or type ABEK (EU EN 14387) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

---

## 9. PHYSICAL AND CHEMICAL PROPERTIES

### 9.1 Information on basic physical and chemical properties

- |   |                             |
|---|-----------------------------|
| a) Appearance                                   | Form: liquid                |
| b) Odour  | no data available           |
| c) Odour Threshold                              | no data available           |
| d) pH   | no data available           |
| e) Melting point/freezing point                 | no data available           |
| f) Initial boiling point and boiling range      | 76 °C (169 °F)              |
| g) Flash point                                  | no data available           |
| h) Evaporation rate                             | no data available           |
| i) Flammability (solid, gas)                    | no data available           |
| j) Upper/lower flammability or explosive limits | no data available           |
| k) Vapour pressure                              | no data available           |
| l) Vapour density                               | no data available           |
| m) Relative density                             | 1.787 g/mL at 25 °C (77 °F) |
| n) Water solubility                             | no data available           |
| o) Partition coefficient: n-octanol/water       | no data available           |
| p) Auto-ignition temperature                    | no data available           |
| q) Decomposition temperature                    | no data available           |
| r) Viscosity                                    | no data available           |
| s) Explosive properties                         | no data available           |
| t) Oxidizing properties                         | no data available           |

## 9.2 Other safety information

no data available

---

## 10. STABILITY AND REACTIVITY

### 10.1 Reactivity

no data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

no data available

### 10.4 Conditions to avoid

no data available

### 10.5 Incompatible materials

Strong oxidizing agents

### 10.6 Hazardous decomposition products

Other decomposition products - no data available

In the event of fire: see section 5

---

## 11. TOXICOLOGICAL INFORMATION

### 11.1 Information on toxicological effects

#### Acute toxicity

no data available

Inhalation: no data available

Dermal: no data available

no data available

#### Skin corrosion/irritation

no data available

#### Serious eye damage/eye irritation

no data available

#### Respiratory or skin sensitisation

no data available

#### Germ cell mutagenicity

no data available

#### Carcinogenicity

Organization	Classification
IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

#### Reproductive toxicity

no data available

no data available

#### Specific target organ toxicity - single exposure

no data available

**Specific target organ toxicity - repeated exposure**

no data available

**Aspiration hazard**

no data available

**Additional Information**

RTECS: Not available

---

**12. ECOLOGICAL INFORMATION**

**12.1 Toxicity**

no data available

**12.2 Persistence and degradability**

no data available

**12.3 Bioaccumulative potential**

no data available

**12.4 Mobility in soil**

no data available

**12.5 Results of PBT and vPvB assessment**

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

**12.6 Other adverse effects**

no data available

---

**13. DISPOSAL CONSIDERATIONS**

**13.1 Waste treatment methods**

**Product**

Offer surplus and non-recyclable solutions to a licensed disposal company.

**Contaminated packaging**

Dispose of as unused product.

---

**14. TRANSPORT INFORMATION**

**DOT (US)**

Not dangerous goods

**IMDG**

Not dangerous goods

**IATA**

Not dangerous goods

---

**15. REGULATORY INFORMATION**

**SARA 302 Components**

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

**SARA 313 Components**

SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

**SARA 311/312 Hazards**

No SARA Hazards

**Massachusetts Right To Know Components**

No components are subject to the Massachusetts Right to Know Act.

**Pennsylvania Right To Know Components**

Perfluoro(methylcyclohexane)

CAS-No.  
355-02-2

Revision Date

## New Jersey Right To Know Components

Perfluoro(methylcyclohexane)

CAS-No.  
355-02-2

Revision Date

## California Prop. 65 Components

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

---

## 16. OTHER INFORMATION

<b>HMIS Rating</b>	<b>#</b>
Health hazard:	0
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	0

<b>NFPA Rating</b>	<b>#</b>
Health hazard:	0
Fire Hazard:	0
Reactivity Hazard:	0

### Further information

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### Preparation Information

Sigma-Aldrich Corporation  
Product Safety – Americas Region  
1-800-521-8956

Version: 5.2

Revision Date: 06/25/2014

Print Date: 11/20/2014

---

**1. PRODUCT AND COMPANY IDENTIFICATION****1.1 Product identifiers**

Product name : Perfluoro-1,3-dimethylcyclohexane

Product Number : 282316

Brand : Aldrich

CAS-No. : 335-27-3

**1.2 Relevant identified uses of the substance or mixture and uses advised against**

Identified uses : Laboratory chemicals, Manufacture of substances

**1.3 Details of the supplier of the safety data sheet**Company : Sigma-Aldrich  
3050 Spruce Street  
SAINT LOUIS MO 63103  
USA

Telephone : +1 800-325-5832

Fax : +1 800-325-5052

**1.4 Emergency telephone number**

Emergency Phone # : (314) 776-6555

---

**2. HAZARDS IDENTIFICATION****2.1 Classification of the substance or mixture****GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)**

Skin irritation (Category 2), H315

Eye irritation (Category 2A), H319

Specific target organ toxicity - single exposure (Category 3), Respiratory system, H335

For the full text of the H-Statements mentioned in this Section, see Section 16.

**2.2 GHS Label elements, including precautionary statements**

Pictogram



Signal word

Warning

Hazard statement(s)

H315

Causes skin irritation.

H319

Causes serious eye irritation.

H335

May cause respiratory irritation.

Precautionary statement(s)

P261

Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.

P264

Wash skin thoroughly after handling.

P271

Use only outdoors or in a well-ventilated area.

P280

Wear protective gloves/ eye protection/ face protection.

P302 + P352

IF ON SKIN: Wash with plenty of soap and water.

P304 + P340

IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.

P305 + P351 + P338

IF IN EYES: Rinse cautiously with water for several minutes. Remove

P312	contact lenses, if present and easy to do. Continue rinsing.
P321	Call a POISON CENTER or doctor/ physician if you feel unwell.
P332 + P313	Specific treatment (see supplemental first aid instructions on this label).
P337 + P313	If skin irritation occurs: Get medical advice/ attention.
P362	If eye irritation persists: Get medical advice/ attention.
P403 + P233	Take off contaminated clothing and wash before reuse.
P405	Store in a well-ventilated place. Keep container tightly closed.
P501	Store locked up.
	Dispose of contents/ container to an approved waste disposal plant.

## 2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

---

## 3. COMPOSITION/INFORMATION ON INGREDIENTS

### 3.1 Substances

Synonyms	Hexadecafluoro-1,3-dimethylcyclohexane (cis+trans) Hexadecafluoro-1,3-dimethylcyclohexane Decafluoro-1,3-bis(trifluoromethyl)cyclohexane
Formula	C <sub>8</sub> F <sub>16</sub>
Molecular Weight	400.06 g/mol
CAS-No.	335-27-3
EC-No.	206-386-9

### Hazardous Components

Component	Classification	Concentration
<b>1,1,2,2,3,3,4,5,5,6-Decafluoro-4,6-bis(trifluoromethyl)cyclohexane</b>	Skin Irrit. 2; Eye Irrit. 2A; STOT SE 3; H315, H319, H335	-

For the full text of the H-Statements mentioned in this Section, see Section 16.

---

## 4. FIRST AID MEASURES

### 4.1 Description of first aid measures

#### General advice

Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

#### If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

#### In case of skin contact

Wash off with soap and plenty of water. Consult a physician.

#### In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

#### If swallowed

Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

### 4.2 Most important symptoms and effects, both acute and delayed

The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

### 4.3 Indication of any immediate medical attention and special treatment needed

no data available

---

## 5. FIREFIGHTING MEASURES

### 5.1 Extinguishing media

#### Suitable extinguishing media

Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

- 5.2 Special hazards arising from the substance or mixture**  
Carbon oxides, Hydrogen fluoride
- 5.3 Advice for firefighters**  
Wear self contained breathing apparatus for fire fighting if necessary.
- 5.4 Further information**  
no data available

---

## 6. ACCIDENTAL RELEASE MEASURES

- 6.1 Personal precautions, protective equipment and emergency procedures**  
Use personal protective equipment. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.  
For personal protection see section 8.
- 6.2 Environmental precautions**  
Do not let product enter drains.
- 6.3 Methods and materials for containment and cleaning up**  
Soak up with inert absorbent material and dispose of as hazardous waste. Keep in suitable, closed containers for disposal.
- 6.4 Reference to other sections**  
For disposal see section 13.

---

## 7. HANDLING AND STORAGE

- 7.1 Precautions for safe handling**  
Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.  
Normal measures for preventive fire protection.  
For precautions see section 2.2.
- 7.2 Conditions for safe storage, including any incompatibilities**  
Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.
- 7.3 Specific end use(s)**  
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

---

## 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

- 8.1 Control parameters**
- Components with workplace control parameters**  
Contains no substances with occupational exposure limit values.
- 8.2 Exposure controls**
- Appropriate engineering controls**  
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.
- Personal protective equipment**
- Eye/face protection**  
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).
- Skin protection**  
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.
- Body Protection**  
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

### Respiratory protection

Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

### Control of environmental exposure

Do not let product enter drains.

---

## 9. PHYSICAL AND CHEMICAL PROPERTIES

### 9.1 Information on basic physical and chemical properties

- |   |   |
|---|---|
| a) Appearance                                   | Form: clear, liquid<br>Colour: light yellow |
| b) Odour  | no data available                           |
| c) Odour Threshold                              | no data available                           |
| d) pH   | no data available                           |
| e) Melting point/freezing point                 | Melting point/range: -55 °C (-67 °F) - lit. |
| f) Initial boiling point and boiling range      | 101 - 102 °C (214 - 216 °F) - lit.          |
| g) Flash point                                  | no data available                           |
| h) Evaporation rate                             | no data available                           |
| i) Flammability (solid, gas)                    | no data available                           |
| j) Upper/lower flammability or explosive limits | no data available                           |
| k) Vapour pressure                              | no data available                           |
| l) Vapour density                               | 13.81 - (Air = 1.0)                         |
| m) Relative density                             | 1.828 g/cm <sup>3</sup> at 25 °C (77 °F)    |
| n) Water solubility                             | no data available                           |
| o) Partition coefficient: n-octanol/water       | no data available                           |
| p) Auto-ignition temperature                    | no data available                           |
| q) Decomposition temperature                    | no data available                           |
| r) Viscosity                                    | no data available                           |
| s) Explosive properties                         | no data available                           |
| t) Oxidizing properties                         | no data available                           |

### 9.2 Other safety information

- |                         |                     |
|-------------------------|---------------------|
| Relative vapour density | 13.81 - (Air = 1.0) |
|-------------------------|---------------------|

---

## 10. STABILITY AND REACTIVITY

### 10.1 Reactivity

no data available

### 10.2 Chemical stability

Stable under recommended storage conditions.

### 10.3 Possibility of hazardous reactions

no data available

#### 10.4 Conditions to avoid

no data available

#### 10.5 Incompatible materials

Strong oxidizing agents

#### 10.6 Hazardous decomposition products

Other decomposition products - no data available  
In the event of fire: see section 5

---

### 11. TOXICOLOGICAL INFORMATION

#### 11.1 Information on toxicological effects

##### Acute toxicity

no data available

Dermal: no data available

no data available

##### Skin corrosion/irritation

no data available

##### Serious eye damage/eye irritation

no data available

##### Respiratory or skin sensitisation

no data available

##### Germ cell mutagenicity

no data available

##### Carcinogenicity

Organization	Classification
IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

##### Reproductive toxicity

no data available

no data available

##### Specific target organ toxicity - single exposure

Inhalation - May cause respiratory irritation.

##### Specific target organ toxicity - repeated exposure

no data available

##### Aspiration hazard

no data available

##### Additional Information

RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

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### 12. ECOLOGICAL INFORMATION

#### 12.1 Toxicity

no data available

**12.2 Persistence and degradability**

no data available

**12.3 Bioaccumulative potential**

no data available

**12.4 Mobility in soil**

no data available

**12.5 Results of PBT and vPvB assessment**

PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

**12.6 Other adverse effects**

no data available

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**13. DISPOSAL CONSIDERATIONS****13.1 Waste treatment methods****Product**

Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

**Contaminated packaging**

Dispose of as unused product.

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**14. TRANSPORT INFORMATION****DOT (US)**

Not dangerous goods

**IMDG**

Not dangerous goods

**IATA**

Not dangerous goods

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**15. REGULATORY INFORMATION****SARA 302 Components**

SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

**SARA 313 Components**

SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

**SARA 311/312 Hazards**

Acute Health Hazard

**Massachusetts Right To Know Components**

No components are subject to the Massachusetts Right to Know Act.

**Pennsylvania Right To Know Components**

	CAS-No.	Revision Date
1,1,2,2,3,3,4,5,5,6-Decafluoro-4,6 bis(trifluoromethyl)cyclohexane	335-27-3	

**New Jersey Right To Know Components**

	CAS-No.	Revision Date
1,1,2,2,3,3,4,5,5,6-Decafluoro-4,6 bis(trifluoromethyl)cyclohexane	335-27-3	

**California Prop. 65 Components**

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

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## 16. OTHER INFORMATION

### Full text of H-Statements referred to under sections 2 and 3.

Eye Irrit.	Eye irritation
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H335	May cause respiratory irritation.
Skin Irrit.	Skin irritation
STOT SE	Specific target organ toxicity - single exposure

### HMIS Rating

Health hazard:	2
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	0

### NFPA Rating

Health hazard:	2
Fire Hazard:	0
Reactivity Hazard:	0

### Further information

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### Preparation Information

Sigma-Aldrich Corporation  
Product Safety – Americas Region  
1-800-521-8956

Version: 4.3

Revision Date: 07/02/2014

Print Date: 11/20/2014

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