THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

TECHNOLOGY TYPE:	**OZONE INDICATOR CARDS**	
APPLICATION:	**PERSONAL MONITORING OF EXPOSURE TO OZONE IN AIR**	
TECHNOLOGY NAME:	**Ozone Detector Card**	
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ETV Joint Verification Statement

The U.S. Environmental Protection Agency (EPA) has established the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies. Information and ETV documents are available at www.epa.gov/etv.

ETV works in partnership with recognized standards and testing organizations, with stakeholder groups (consisting of buyers, vendor organizations, and permitters), and with individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field and laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Advanced Monitoring Systems (AMS) Center, one of six verification centers under ETV, is operated by Battelle in cooperation with EPA's National Risk Management Research Laboratory. The AMS Center evaluated the performance of a colorimetric indicator card for estimating the concentration of ozone in the air. This verification statement provides a summary of the test results for the EnviroScan, Inc. Ozone Detector Card.

VERIFICATION TEST DESCRIPTION

This verification test evaluated the ability of the EnviroScan, Inc. Ozone Detector Card to provide reliable qualitative indications of ozone in air. Laboratory testing was conducted by delivering ozone at known concentrations in a flowing air stream to Ozone Detector Cards placed in a test apparatus. The delivered ozone concentrations ranged from zero to approximately 200 parts per billion by volume (ppbv), and were confirmed by measurements with a continuous monitor designated by EPA as a Federal Equivalent Method (FEM) for ozone. Visual readings of Ozone Detector Cards exposed in the laboratory testing were made by two non-technical Battelle staff members who had no knowledge of the ozone test concentrations. Laboratory testing also included exposure of Ozone Detector Cards to a fixed ozone concentration under lighting conditions ranging from darkness, to normal laboratory lighting, to simulated full overhead solar spectrum and intensity.

Field testing was conducted by providing Ozone Detector Cards to personnel of the California South Coast Air Quality Management District (SCAQMD) and to volunteers associated with Breathe California of Los Angeles (BCLA). SCAQMD personnel exposed and visually read Ozone Detector Cards at field sites where ozone was being routinely monitored by FEM instruments for compliance purposes. Ambient temperature, relative humidity (RH), and wind speed were also recorded at the SCAQMD sites. BCLA volunteers exposed and visually read Ozone Detector Cards at local sites such as schools and parks. Both SCAQMD personnel and BCLA volunteers provided comments on the use of the cards under field conditions.

The EnviroScan Inc. Ozone Detector Card was verified by evaluating the following performance parameters:

- ***Accuracy*** – User readings taken with Ozone Detector Cards in laboratory and field testing were compared to simultaneous ozone measurements made with an EPA FEM ozone monitor. Each comparison in which the FEM ozone reading fell within the Ozone Detector Card range reported by the card user was deemed an accurate response.
- ***Variability –*** Ozone Detector Card readings obtained with constant ozone concentrations in laboratory testing were used to assess the variability of the card response. Variability was quantified in terms of the number of different Ozone Detector Card ranges reported by card users when sampling a constant concentration of ozone.
- ***Duplication*** – The degree of duplication or consistency of Ozone Detector Card readings was assessed in three ways, using data from both the laboratory and field testing. *Intra-card duplication* was assessed using all readings in which multiple reagent spots on the same card were exposed simultaneously and then read by a single card user. *Inter-card duplication* was assessed using all readings in which multiple reagent spots on different cards were exposed simultaneously and then read by a single card user. *User agreement* was assessed using all data in which visual reading of the same exposed reagent spot was made by more than one user.
- ***Effect of Light Intensity*** – The effect of light intensity on reagent color development during exposure to ozone was assessed by laboratory testing at a constant ozone concentration, under three lighting conditions ranging from darkness to full sun intensity. The impact of light intensity on the accuracy, variability, and duplication of Ozone Detector Card readings was evaluated.
- ***Effect of Ambient Conditions*** – Ozone Detector Card readings obtained in field testing were segregated into accurate and inaccurate readings (i.e., agreeing/disagreeing with coincident FEM measurements). Ambient temperature, RH, and wind speed data for these two data sets were then statistically compared to investigate whether field conditions of accurate card readings differed significantly from those of inaccurate readings.
- ***Operational Factors*** – This performance parameter included factors such as the ease of use of the Ozone Detector Cards, the readability of the reagent color change in different lighting conditions, and the stability of the reagent spots during storage before use. Such factors were evaluated based on comments provided by the users of the cards in field and laboratory testing. Cost was also evaluated based on vendor pricing.

QA oversight of verification testing was provided by Battelle and EPA. Battelle QA staff conducted a technical systems audit of the laboratory testing, and SCAQMD QA staff conducted a technical systems audit of the field

testing, under direction of Battelle QA staff. Battelle QA staff also conducted a data quality audit of the test data. This verification statement, the full report on which it is based, and the test/QA plan for this verification test are available at www.epa.gov/etv/centers/center1.html.

TECHNOLOGY DESCRIPTION

The following is a description of the EnviroScan Inc. Ozone Detector Card, based on information provided by the vendor.

The Ozone Detector Card is approximately 8 cm x 11 cm (3.25 x 4.25 in) in size. Each card has a row of five spots of solid reagent, with each spot covered by a protective strip of foil. When a foil strip is removed to expose a reagent spot to air, the reagent reacts with ozone in the air to produce a color change in the spot proportional to the ozone concentration. An ozone measurement is conducted by removing the foil from a spot and placing the card in the atmosphere to be tested for 10 minutes. At the end of the 10 minute exposure, the card is folded onto itself and the user visually compares the color of the exposed reagent spot to a reference color wheel printed on the front of the Ozone Detector Card. The color wheel has four gradations corresponding to four different ranges of ozone concentrations:

- Range 1 (10 to 45 parts per billion by volume (ppbv) ozone) corresponds to conditions of little to no ozone pollution,
- Range 2 (45 to 75 ppbv ozone) corresponds to normal ozone pollution on sunny days,
- Range 3 (75 to 105 ppbv ozone) corresponds to potentially unhealthy conditions,
- Range 4 (>105 ppbv ozone) corresponds to unhealthy conditions.

With a 10-minute exposure period, the degree of reagent color change increases progressively from little to no change for Range 1 to significant darkening of the reagent spot for Range 4.

VERIFICATION RESULTS

Table VS-1 summarizes the performance results found for the EnviroScan Inc. Ozone Detector Card. Where data permit, Table VS-1 shows the Ozone Detector Card performance broken down according to the card range reading that would have been expected based on the actual ozone concentration present.

The table shows that in both laboratory and field testing the Ozone Detector Cards exhibited lower accuracy and duplication of readings at ozone concentrations corresponding to the highest range reading of the cards (i.e., range 4). In laboratory testing the accuracy, variability, and duplication of the Ozone Detector Cards were sometimes worse when exposed to an ozone concentration near the boundary of a detection range than when exposed to a concentration near the middle of a range, but this effect was not consistently observed. The Ozone Detector Cards are relatively inexpensive (approximately $1.60 or less per card, when purchased in lots of 100 or more). Users reported the cards were easy to use, but users had difficulty in matching the color developed in the reagent spots with the color index printed on the cards. This difficulty may have contributed to the observed variability of card readings (e.g., in laboratory testing the reported card readings fell into three different card ranges regardless of the expected range reading). Bright simulated sunlight during laboratory ozone exposure, and temperature, RH, and wind speed during field use had little effect on Ozone Detector Card accuracy, but users reported that the lighting conditions under which exposed reagent spots were read could affect their reported readings.

Table VS-1. Performance Summary for EnviroScan Ozone Detector Cards

Performance Parameter	Testing Effort		
	Laboratory	**SCAQMD Field**	**BCLA Field**
Accuracy (%)[a]	Range[b] 1: 96 2: 64 3: 7.8 4: 3.1	Range 1: 17 2: 98 3: 65 4: 10	NA[c]
Variability (number of card ranges)[a]	Range 1: 3 2: 3 3: 3 4: 3	NA	NA
Intra-Card Duplication (%)[a]	Range 1: 94 2: 84 3: 94 4: 77	Range 1: 100 2: 100 3: 97 4: 60	NA
Inter-Card Duplication (%)[a]	Range 1: 92 2: 59 3: 85 4: 47	100[d]	NA
User Agreement (%)[a]	Range 1: 91 2: 53 3: 81 4: 55	NA	100[e]
Effect of Light Intensity on Color Development during Ozone Exposure	No effect on accuracy, variability, or user agreement; reduced intra-and inter-card duplication with full sun condition	NA	NA
Effect of Ambient Conditions on Accuracy	NA	Full data set suggests higher accuracy with higher temperature and lower RH; breakdown by expected range shows no conclusive effects.	NA
Operational Factors	Easy to use; Difficult to match reagent spot color to color wheel; Presence of cards reduces ozone in test chamber; Development of color in reagent spots during storage of cards	Easy to use; Difficult to match reagent spot color to color wheel; Visual reading depends on ambient lighting conditions; Develop-ment of color in reagent spots during storage of cards	Easy to use; Difficult to match reagent spot color to color wheel; Development of color in one reagent spot during storage of cards

a: Performance shown for expected ranges of card readings, when information is available.
b: Range 1 = 10 to 45 ppbv; Range 2 = 45 to 75 ppbv; Range 3 = 75 to 105 ppbv; Range 4 = >105 ppbv.
c: NA = not applicable, no data on this parameter collected from this effort.
d: Based on 23 total cases (insufficient data for breakdown by expected range).
e: Based on 10 total cases.

Signed by Tracy Stenner May 16, 2011	Signed by Sally Gutierrez May 20, 2011
Tracy Stenner Date	Sally Gutierrez Date
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