

## Package ‘OHcomplianceStrategies’

A. d’Errico (Toni) - [tonyderrico.github.io/blog/about.html](https://tonyderrico.github.io/blog/about.html) (a.derrico2@uu.nl)

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# Introduction

The R **OHcomplianceStrategies** package provides methods to assess the exposure compliance of similarly exposed groups (**SEGs**) of workers with European standards and tests developed by experts.

## Application

The package includes several compliance tests and calculations for overexposure and exceedance of OELs, including:

- **Phase One: Preliminary Test** from EN689 standards 1995 and 2018. Equations comparing exposure measurements with the OEL are reported in the Annex C of EN689:1995 and Section 5.5.2. of EN689:2018.
- **Phase Two: Statistical Test** from EN689 standards 1995 and 2018, and U-test of BOHS-NVvA:2011. Equations comparing exposure measurements with the OEL are reported in the Annex D of EN689:1995 and Annex F of EN689:2018. The U-test is reported in the BOHS-NvVA guidance of 2011.
- **Phase Three: Individual Compliance and Between-Worker Variance** from BOHS-NVvA guidance of 2011 (Chapter 3). Analysis of variance is used to estimate the variability of individuals' exposures within and between SEGs and consequently test compliance of an individual worker's exposure with the OEL.

## ShinyApp

The app allows you to directly apply the statistical compliance strategies of EN689:1995 and EN689:2018, and the individual compliance test of BOHS/NVvA:2011. The app is available at the following link with all needed instructions to compute your analysis.

[Visit the Shiny App](#)

# Package Dependencies

This package relies on the following R packages: - **tolerance** - **lme4** - **dplyr** - **FSA**

# Installation

To install the latest version from GitHub, use the following command:

```
install.packages("devtools")
devtools::install_github("tonyderrico/OHcomplianceStrategies")
```

## R codes and statistical tests

### Phase 1 - EN689:1995

#### testing compliance for one measurement

Compliance, uncertain compliance, or non-compliance can be evaluated for one measurement. The exposure index is calculated as worker measurement / OEL. Compliance is achieved if the index is  $\leq 0.1$ . If the index is  $> 0.1$  but  $\leq 1$ , there is no decision ("UC"), and additional measurements are necessary (at least three). Non-Compliance is reached if the measurement  $> OEL$  or if the exposure index  $> 1$ .

```
#' @param measurements One measurement under assessment
#' @param OEL Occupational Exposure Limit of the agent
#' @return Compliance ("C"), Non-Compliance ("NC"), or Uncertainty of Compliance ("UC")
#' @export
```

```
phase1EN1995_k1 <- function(measurements, OEL)
```

#### testing compliance for at least three measurements

Compliance, uncertain compliance or non-compliance can be evaluated for at least three measurements. Calculation of exposure indexes is performed (worker measurement/OEL). Compliance is achieved if all indexes are below or equal to 0.25. If at least an index is greater than 0.25 but all indices are lower/equal than 1 and the geometric mean of the measurements is lower/equal than 0.5, Compliance is accomplished. Contrarily, there is no decision ("UC"). There is Non-Compliance if at least a measurement is greater than the OEL and/or if at least an exposure index is greater than 1.

```
#' @param measurements At least 3 measurements
#' @param OEL Occupational Exposure Limit of the agent
#' @return Compliance ("C"), Non-Compliance ("NC") or Uncertainty of Compliance ("UC")
#' @export
```

```
phase1EN1995_k3 <- function(measurements, OEL)
```

### Phase 1 - EN689:2018

#### testing compliance for 3 measurements

Compliance, uncertain compliance or non-compliance of a SEG can be evaluated for three measurements. Compliance is achieved if all of the measurements are below or equal to  $0.1 \times OEL$ . There is Uncertain Compliance if at least

a measurement is greater than  $0.1 \times \text{OEL}$  but below the OEL. There is Non-Compliance if at least a measurement is greater than OEL.

```
#' @param measurements Three measurements
#' @param OEL Occupational Exposure Limit of the agent
#' @return Compliance ("C"), Non-Compliance ("NC") or Uncertainty of Compliance ("UC")
#' @export
```

```
phase1EN2018_k3 <- function(measurements, OEL)
```

#### testing compliance for 4 measurements

Compliance, uncertain compliance or non-compliance of a SEG can be evaluated for four measurements. Compliance is achieved if all of the measurements are below or equal to  $0.15 \times \text{OEL}$ . There is Uncertain Compliance if at least a measurement is greater than  $0.15 \times \text{OEL}$  but below the OEL. There is Non-Compliance if at least a measurement is greater than OEL.

```
#' @param measurements Four measurements
#' @param OEL Occupational Exposure Limit of the agent
#' @return Compliance ("C"), Non-Compliance ("NC") or Uncertainty of Compliance ("UC")
#' @export
```

```
phase1EN2018_k4 <- function(measurements, OEL)
```

#### testing compliance for 5 measurements

Compliance, uncertain compliance or non-compliance of a SEG can be evaluated for five measurements. Compliance is achieved if all of the measurements are below or equal to  $0.2 \times \text{OEL}$ . There is Uncertain Compliance if at least a measurement is greater than  $0.2 \times \text{OEL}$  but below the OEL. There is Non-Compliance if at least a measurement is greater than OEL.

```
#' @param measurements Five measurements
#' @param OEL Occupational Exposure Limit of the agent
#' @return Compliance ("C"), Non-Compliance ("NC") or Uncertainty of Compliance ("UC")
#' @export
```

```
phase1EN2018_k5 <- function(measurements, OEL)
```

## Phase 2 - EN689:1995

#### testing exposure exceedance

The normal distribution of the measurements is operated, and 99.9th percentile and 95th percentile values are observed to assess the possible exceedance of the OEL. Compliance or “Green Area” is achieved if the value of the 99.9th percentile is lower than the OEL, Uncertain Compliance or “Orange Area” is achieved if the value of the 99.9th percentile is lower than the OEL but the value of 95th percentile is greater than the OEL. Non Compliance or “Red Area” is achieved if the OEL is lower than the value of the 95th percentile.

```
#' @param measurements measurements of the SEG under assessment
#' @param OEL Occupational Exposure Limit of the agent
#' @return Green Area, Orange Area or Red Area
#' @export
```

```
phase2EN689.1995 <- function(measurements, OEL)
```

## Phase 2 - EN689:2018

### UTLv (Upper Tolerance Limit value)

This function evaluates compliance with the Occupational Exposure Limit (OEL) based on the Upper Tolerance Limit value (UTLv), calculated with a 95% Percentile Confidence Level and a 70% Confidence Level.

The test compares the UTLv with the OEL: - If **UTL > OEL**, there is exceedance → “**Not Compliant**”. - If **UTL < OEL**, the probability of exceedance is acceptable → “**Compliant**”.

```
#' @param measurements Numeric vector. At least 6 exposure measurements from the SEG under assessment.
#' @param OEL Numeric. The Occupational Exposure Limit of the agent.
#' @return A character string:
#' - `"Not Compliant"` if `UTL > OEL`
#' - `"Compliant"` if `UTL < OEL`
#'
#' @export
```

```
phase2_UTL <- function(measurements, OEL)
```

## Phase 2 - BOHS/NVvA 2011

### U test

This function applies the Mann-Whitney U test (70% Confidence) to evaluate SEG compliance based on the number of measurements performed. The test compares the calculated U value (pg. 42, EN689 2018) with the U threshold from the Mann-Whitney U table: - If **U > OEL**, there is **Compliance**. - If **U < OEL**, there is **Non-Compliance**.

The function includes U-thresholds for a maximum of 15 measurements per SEG.

```
#' @param measurements Numeric vector. Measurements of the SEG under assessment (between 6 and 15).
#' @param OEL Numeric. The Occupational Exposure Limit of the agent.
#'
#' @return A character string:
#' - "Compliant" if `U < threshold`
#' - "Not Compliant" if `U > threshold`
#'
#' @export
phase2_Uvalue <- function(measurements, OEL)
```

## Phase 3 - BOHS/NVvA 2011

### Between Worker Variance

Linear Mixed models using REML (Restricted Maximum Likelihood) is performed to calculate between workers variance and total variance. The Compliance is achieved if the between workers variance is lower than 0.2 of the total variance. Contrarily, there is Non-Compliance.

```
#' @param seg data of SEG under assessment
#' @param measurements samples concentrations of the agent
#' @param workers workers codes/names/ID
#' @return BW < 0.2totalVariance ("Compliant"), BW > 0.2totalVariance ("Not Compliant")
#' @export
```

```
phase3_BoHS.NvVA <- function(seg, workers, measurements)
```

## Individual Compliance

Individual Compliance is achieved when there is less than 20% probability that workers in a SEG have more than 5% of exposure greater than the OEL.

```
#' @param seg data of the SEG under assessment
#' @param measurements samples concentrations of the agent
#' @param workers workers code/name
#' @param OEL Occupational Exposure Limit
#' @return BW < 0.2totalVariance, Compliant or Not Compliant
#' @export
```

```
Individual_Compliance <- function(seg, workers, measurements, OEL)
```

## For possible applications, you could read:

d'Errico et al., (2022): Is the New EN689 a Better Standard to Test Compliance With Occupational Exposure Limits in the Workplace? <https://doi.org/10.1093/annweh/wxab111>

d'Errico et al., (2025): Occupational exposure to respirable and inhalable dust and its components in a Nicaraguan sugarcane plantation <https://doi.org/10.1136/oemed-2024-109604>