# Relationship between odour intensity and concentration of n-butanol

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Segura, J.C. and J.J.R. Feddes. 2010. **Relationship between odour intensity and concentration of n-butanol**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada. 52: 6.1–6.5. Odour dispersion models are validated from odour intensity data gathered by field odour assessors. These odour intensity data are compared to predicted odour concentrations. Odour intensity-concentration relationships exist for manure odours, but not for a reference odour n-butanol gas. A relationship between the intensity of air n-butanol mixtures expressed as an eight-point odour intensity reference scale (OIRS) and the corresponding n-butanol odour concentration by olfactometry was determined. A relationship was found between the n-butanol intensities in air and the odour concentration following the definition of 40 ppb = 1 OU $m^{-3}$. The training protocol used by the odour assessors with the n-butanol in jars was found to be reliable and repeatable. Livestock odour intensities measured in the field can be low by a factor of three when considering typical odour intensities. **Keywords:** odour dispersion models, reference odour, n-butanol.

Les modèles de dispersion d'odeurs sont généralement validés par des données d'intensité mesurées sur le terrain par des panélistes et ensuite ces valeurs d'intensité sont comparées aux valeurs prédites par le model. Contrairement à l'odeur de fumier, il n'y a pas présentement de barème de référence entre l'intensité de l'odeur et la concentration de mélange d'air et de gaz n-butanol. L'olfactométrie fut utilisé pour établir une échelle de huit points (OIRS) reliant l'intensité des mélanges d'air et de gaz n-butanol à leur concentration d'odeur. Les essais ont donné la relation suivante entre la concentration de gaz n-butanol dans l'air fut reliée et son intensité d'odeur: une concentration de 40 ppb de n-butanol équivaut à 1 OU $m^{-3}$. Le protocole utilisé pour former les panélistes évaluant l'odeur avec le n-butanol en bocaux a été jugée fiable et reproductible. L'intensité des odeurs produites par le fumier de bétail et mesurée par des panélistes sur le terrain avec des bocaux de gaz n-butanol peut être fiables mais doivent être multipliés par un facteur de trois pour reproduire l'intensité de l'odeur. **Mots clés:** modèles de dispersion des odeursl, référence des odeurs, n-butanol.

## INTRODUCTION

Measuring downwind odour intensity values are a major component of calibrating and validating odour dispersion models. Odour intensities are obtained by trained odour assessors who relate the odour intensity to an odour intensity referencing scale (OIRS). This scale can consist of 5, 8, 10 or 12 points of intensity. To calibrate odour dispersion models, these odour intensity values are transformed into equivalent odour concentrations and compared to model predicted values. Odour intensities are measured in a non-dilute form, while odour concentrations are determined by olfactometry and expressed as dilutions or as a concentration (OU $m^{-3}$). The OIRS is defined in ASTM (1999) and reported by McGinley and McGinley (2000). Equations to transform the observed livestock odour intensities by the trained odour assessors into concentrations have been reported (Zhang et al. 2002; Zhu et al. 2000; Guo et al. 2001; Nicolai et al. 2000). Nicolai et al. (2000) demonstrated that the Weber-Fechner and Stevens model appears to be the best fit to describe the intensity-concentration relationship for livestock odours (swine buildings) between 100 and 500 OU $m^{-3}$. Similarly, Zhang et al. (2002) reported that both the Weber-Fechner and Stevens models describe adequately the relationship between odour concentration measured by olfactometry and odour intensity assessed by odour assessors using the eight-point OIRS. Guo et al. (2001) also reported that the Weber-Fechner model provided the best fit to their experimental data for swine and cattle odours. These reported intensity-concentration equations do not present data points below 60 OU $m^{-3}$.

An important aspect in the training process of odour assessors is to determine if the relationship between the OIRS and the reference odour, water- n-butanol mixture is reliable and repeatable. During an odour assessor's training event and recalibration in the field, the air surrounding the person's nose is entrained into the jar headspace when sniffing. This dilution of the n-butanol headspace gas may change the expected original odour concentration in the jar. Also, dilution occurs as the lid of the jar is opened before the odour assessor has a chance to sniff the headspace gas. Further research is required to extend the scale to lower concentrations and identify the relationship between odour intensity and the corresponding concentration (OU $m^{-3}$) of the n-butanol gas.

The objective of the study was to determine the relationship between the intensity of the headspace n-butanol gas in the eight OIRS jars and the equivalent n-butanol concentration (OU $m^{-3}$) determined by olfactometry. The comparison between the n-butanol and the cited livestock odour intensity-concentration relationship was of particular interest.

## METHODOLOGY

This project was divided into two experimental phases as follows:

**Part A**

A group of odour assessors were trained using an adapted static scale method used by St. Croix Sensory (2000), following the standard practice ASTM (1999). Liquid n-butanol (Sigma Aldrich, Edmonton, AB) (99.4% pure) was mixed with distilled water to prepare the eight OIRS solutions (Table 1). Thirty millilitres of these solutions were placed into 60-mL jars. These jars were presented to the odour assessors for training their noses on a daily basis a minimum of 1 week prior to the odour assessing sessions. A 9$^{th}$ jar contained only distilled water was also used during the training.

A dynamic triangular forced-choice olfactometer, constructed according to BSI (2003) standards was programmed to provide diluted n-butanol concentrations to the odour assessor (Feddes et al. 2001). Certified n-butanol (40 ppm and 200 ppm) in a nitrogen carrier gas (Linde Canada, Mississauga, ON) was used as the reference gas during olfactometry (BSI 2003). The odour assessor sniffed a range of diluted n-butanol air samples from the olfactometer and recorded the intensity value from 1 to 8 for each n-butanol air sample. Before each olfactometry session, three training jars were selected at random from a set of nine jars. These jars were used to select the eight odour assessors who provided the most accurate results. Four odour panel sessions using n-butanol as an odour source were conducted to match unknown dilutions of n-butanol from the olfactometer with their corresponding eight-point scale. A minimum of two random fresh air (or blanks) were presented between each set of n-butanol dilutions during each panel session. This prevented saturation or sensory fatigue and helped to detect problem odour assessors and reduce bias.

A preliminary test was conducted to determine the approximate minimum and maximum concentrations of n-butanol required for the study. N-butanol concentrations between 0.014 and approximately 30 ppm were found to represent the range of OIRS intensities. During panel sessions 1 and 2, the first sample was the lowest concentration and subsequent samples progressed to higher concentrations. Each odour assessor assessed (matched) the presented concentration with the eight-point OIRS. The presentation of intensities at a scale of 7 and 8 were discontinued. The panelists found the concentrations offensive and their noses had to be rested for longer periods of time. Also, the olfactometer required an extensive amount of flushing with air as a result of presenting these concentrations to the panelists. During panel sessions 3 and 4, the six OIRS dilutions were presented at random. From these results, a relationship was developed between the OIRS intensities and the equivalent n-butanol gas concentrations presented to the odour assessors.

**Part B**

A group of trained olfactometer odour assessors were presented with the six concentrations of n-butanol that represented the six OIRS intensities as determined in Part A. These odour assessors met the criteria set out in BSI (2003). Initially, the six blended samples ranging from 0.06 to 4.9 ppm n-butanol in air were injected into Tedlar® bags and randomly presented following a normal olfactometer protocol, using the dynamic triangular forced-choice methodology. However, during the first panel session, the n-butanol odour concentrations corresponding to 1-5 of the OIRS scale were similar to or below the lower detection level (LDL) of a new, flushed Tedlar® sampling bag, which ranged from 7 to 70 OU $m^{-3}$. Parker et al. (2003) reported a range from 20 to 60 OU $m^{-3}$. Consequently, the panel sessions were divided into two groups. In one group, the samples were pre-mixed and presented from Tedlar® sampling bags, and in the second group, air and n-butanol gas were blended by a computer operated controller and connected directly to the olfactometer. The blended samples were the lower intensities (OIRS 1-5) and the samples presented from bags were the higher intensity (OIRS 6). During odour assessor sessions, random fresh air blanks

**Table 1. Relationship of the eight-point scale of n-butanol in headspace air and corresponding n-butanol concentrations using olfactometry.**

| Level[a] | Eight-point n-butanol scale in air[b] (ppm) | Part A Air n-butanol concentrations[c] (ppm) | Theoretical odour concentration[e] (OU $m^{-3}$) | Part B Odour concentrations (OU $m^{-3}$) |
|---|---|---|---|---|
| 1 | 12 | 0.06 | 2 | 2 |
| 2 | 24 | 0.14 | 4 | 5 |
| 3 | 48 | 0.34 | 9 | 12 |
| 4 | 96 | 0.82 | 21 | 30 |
| 5 | 194 | 2.02 | 51 | 75 |
| 6 | 388 | 4.91 | 123 | 184 |
| 7 | 775 | 11.9[d] | 304 | 452[f] |
| 8 | 1550 | 29.0[d] | 741 | 1110[f] |

[a]Eight-point n-butanol intensity referencing scale (OIRS).
[b]n-butanol concentration in air based on ASTM Standard E:544–99.
[c]Determined from Eq. 1.
[d]Predicted from Eq. 1.
[e]1 OU $m^{-3}$ = 40 ppb (BSI 2003).
[f]Predicted from Eq. 2.

were presented to check for sensory fatigue. These n-butanol concentration (OU $m^{-3}$) results were correlated with the reported OIRS jar headspace intensities.

## RESULTS

### Part A

During the four panel sessions, n-butanol concentrations ranging from 0.014 and 4.9 ppm were presented to a group of eight odour assessors trained on the eight-point OIRS (ASTM 1999). All the values from the four panel sessions are shown in Fig. 1. Figure 1 shows the n-butanol concentration OIRS relationship where the x axis represents the different n-butanol concentrations presented to the odour assessors and the y axis values corresponds to the OIRS concentration value (Table 1). The equation that relates the n-butanol intensity in the jar headspace with the equivalent n-butanol concentration is presented in Fig. 1:

$$A = 112.1\ B^{0.78} \qquad (R^2 = 0.79) \qquad (1)$$

where A is the OIRS n-butanol headspace concentration (ppm) and B is the equivalent n-butanol concentration (ppm) presented to the odour assessors.

The high correlation of the values in Fig. 1 demonstrates that training odour assessors for measuring odour intensity with jars is reliable and repeatable.

### Part B

The six n-butanol concentrations that were presented to the odour assessors during the olfactometer panel sessions in Part B were based on the predicted n-butanol concentrations by Eq. 1 in Part A. The relationship between intensity (OIRS scale value) and concentration (OU $m^{-3}$) as determined by olfactometry is shown in Eq. 2 and presented in Fig. 2:

$$C = 0.83\ e^{0.90\ I} \qquad (R^2 = 0.97) \qquad (2)$$

where C is the odour concentration in OU $m^{-3}$ and I is the odour intensity (OIRS value 1-6).

The theoretical threshold detection values based on n-butanol's detection threshold of 40 ppb = 1 OU $m^{-3}$ corresponded well with the olfactometer results (Eq. 2) (BSI 2003). The theoretical values are included in Table 1 and graphed in Fig. 2. This agreement demonstrates that the olfactometer panelists were detecting in the range 20 to 80 ppb n-butanol as required by the European standards (BSI 2003). Since the olfactometer operates at dilution steps with a factor of 2 and the percentage difference between the measured and theoretical values was less than 50%, the measured and theoretical values can be considered to be the same. Since the theoretical values for the six scales agreed with those measured, the concentration values for scale 7 and 8 were projected to be 11.9 and 29 ppm n-butanol, respectively. Their odour concentrations were predicted to be 286 and 637 OU $m^{-3}$, respectively as predicted by Eq. 2 (Table 1).

Since different OIRS scales are used by researchers, Eq. 2 was transformed into Eq. 3 that related the jar headspace n-butanol concentration and the equivalent n-butanol concentration (OU $m^{-3}$).

$$C = 0.08\ A^{1.29} \qquad (R^2 = 1.0) \qquad (3)$$

Consequently, Eq. 3 can be used to transform the headspace concentration of any OIRS scale to an equivalent odour concentration (OU $m^{-3}$). Equation 3 is in the form of a mathematical model known as the Weber-Fechner model that is commonly used to represent odour intensity-concentration relationships. Equation 3 was plotted with the equations presented by Nicolai et al. (2000), Guo et al. (2001), Zhang et al. (2002) and Zhu (2000) in Fig. 3. The comparison of the n-butanol intensity-concentration relationship with that of livestock odour was of particular interest. For a given intensity, the reported concentration (OU $m^{-3}$) of livestock odour is higher than that of n-butanol. For example, for a headspace concentration of 96 ppm (scale 4 on the eight-point scale), the concentration for n-butanol is 30 OU $m^{-3}$ and for livestock odour the predicted value is approximately 100 OU $m^{-3}$ (Fig. 3). This discrepancy is approximately a factor of 3. Furthermore, odour dispersion models can not be calibrated by the n-butanol intensity-concentration relationship. Because of this discrepancy, n-butanol does not appear to be a representative reference odour for livestock odours.

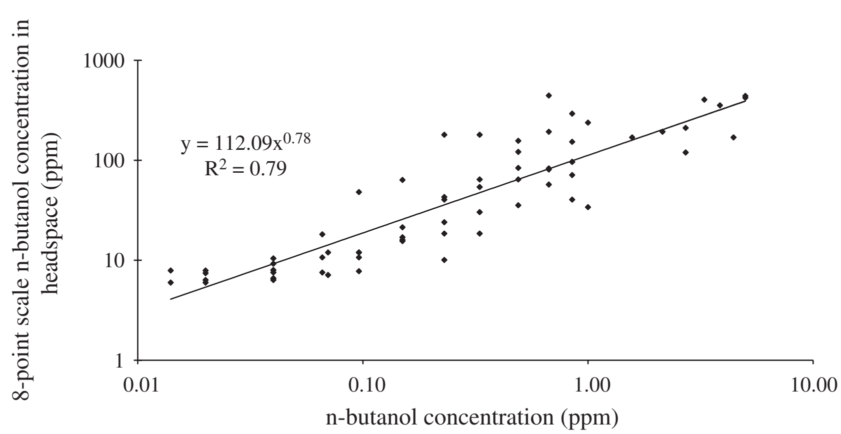


**Fig. 1. Part A: Log relationship between air-n-butanol mixture (ppm) and the OIRS jar headspace concentrations.**

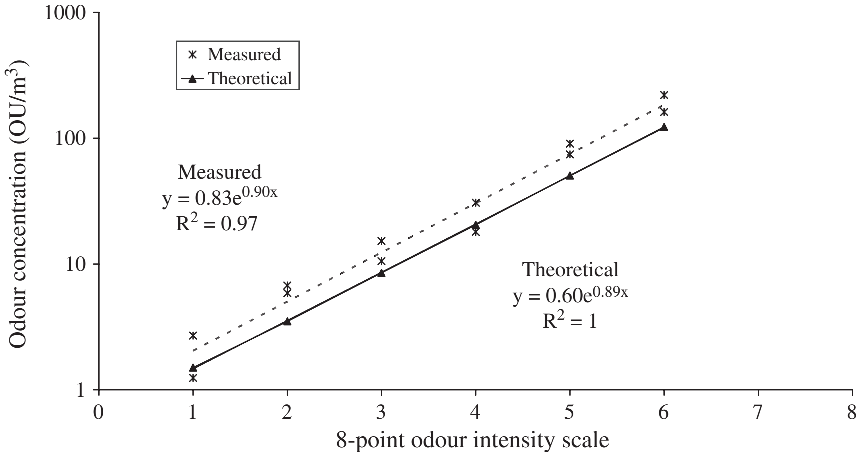


**Fig. 2. Part B: Relationship between the eight point n-butanol odour intensity scale (OIRS) and corresponding odour concentrations.**

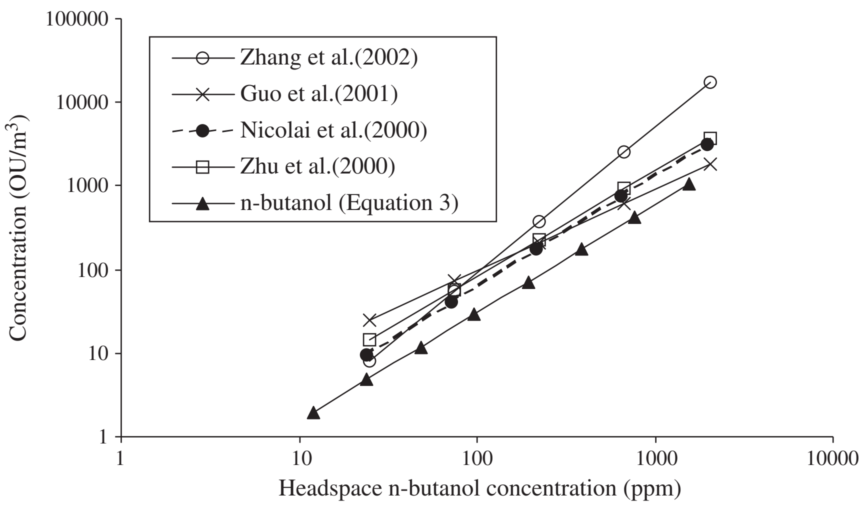


**Fig. 3. Prediction models for livestock odour and n-butanol.**

## CONCLUSIONS

(1) A relationship was found between the n-butanol intensities in air (defined by the ASTM standard E 544–99) and the odour concentration following the definition of 40 ppb = 1 OU m$^{-3}$. The technique developed a relationship to include low concentrations that have not been previously reported.
(2) The training protocol used by the odour assessors with the n-butanol in jars was found to be reliable and repeatable.
(3) For a given odour intensity, livestock odour concentrations can be higher than those for n-butanol by a factor of 3. Odour dispersion models can not be calibrated by the n-butanol intensity concentration relationship. N-butanol does not appear to be a representative reference odour for livestock odours.

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