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# Odour Dispersion Modelling for a Proposed Beef Slaughter Facility

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***Abstract.*** Dispersion modelling was conducted to assess the odour impact of a proposed beef processing facility on neighboring community. Odour samples were collected from two existing facilities that are similar to the proposed facility to determine the odour emission rate. The odour concentrations of these samples was measured by using a dynamic dilution olfactometer and the odour emission was then determined from the measured odour concentrations and the proposed ventilation rate of the facility. ISCST3 was used in conducting dispersion modelling. Results from dispersion modelling were analyzed for odour concentration and occurrence frequency surrounding the proposed facility. High odour concentration occurs in the northeastern and southwestern directions due to local weather conditions. The area within 2000 m away from the facility has most potential to be affected by odour.

**Keyword:** beef processing facility, odour, dispersion modelling.

## INTRODUCTION

In the USA, about 70% of all complaints on air quality are related to odour (Watts and Sweeten, 1995). In Western Australia, odour has been recorded as the cause of about one-third of all public complaints received by local eenvironmental protection authorities and most odour complaints against industry have centred on animal products processing activities (Western Australia EPA, 2002). In many jurisdictions in North America, the environmental protection authorities require odour assessment for new facilities and for expansion of existing facilities with potentially odourous emissions.

Odour dispersion modelling provides a cost-effective approach to achieve the assessment goal. Odour dispersion models are computerized mathematical tools used to predict the occurrence and concentration of odours at any distance from the facility (Godfrey et al, 2000; Zhang et al., 2002). The commonly used dispersion models are either based on the Gaussian plume or Lagrangian particle trajectory theory. Gaussian plume models consist of the steady–state models and the puff models. These models have simple and a small number of input requirements and are relatively easy to use (Zhang et al., 2005). These features make them widely used and well understood in terms of their applications and limitations. Carney and Dodd (1989), Zhu et al. (2000) and Guo et al. (2003) have studied the applicability of Gaussian plume dispersion models to ground level odour emission from agricultural sources. Improved odour dispersion modelling results have been tested by other researchers using Lagrangian particle models (Godfrey and Scire, 2000; Ormerod, 2001). The disadvantage of Lagrangian particle models is that this model type has very high computational requirements.

In the United States, the model recommended by the State Air Pollution Regulatory Agencies (SAPRAS) is the Industrial Source Complex Short Term (ISCST3) model. ISCST3 is a steady-state Gaussian plume dispersion model developed by the US EPA. It can be used to assess pollutant concentrations from wide variety of sources associated with industrial complex. This model is specially designed to support the US EPA regulatory modelling programs, and is widely used for odour dispersion modelling in North America (Zhang et al., 2005).

The input to ISCST3 includes locations of odour sources and receptors, odour source emission information (emission rate, source height, source area, etc.), and weather information (stability class, temperature, wind direction, wind speed, and mixing height). For the model output, the model permits ground-level concentrations to be calculated for a range of averaging times, from at least one hour and to days, months, or over the full meteorological data period.

The objective of this project was to use ISCST3 to predict the downwind odour concentrations from a proposed beef slaughter facility. The predicted odour concentrations were further analyzed to estimate the odour impact of the proposed facility on the surrounding area.

## MATERIALS AND METHODS

### Facility Description

The proposed beef processing facility includes a holding barn of 44.1 × 44.1 m, and meat processing building (kill/dressing plus fabrication building) of 52.3 × 52.3 m (fig.1). The design ventilation rates are 13.21 $m^3/s$ (28,000$ft^3/min$) for the kill/dressing room, 9.44 $m^3/s$ (20,000$ft^3/min$) for the fabrication room, and 33.04 $m^3/s$ (70,000 $ft^3/min$) for the holding barn. Air will be exhausted from roof mounted vents at a height of 10.6m (35 ft) above the ground for all three rooms.

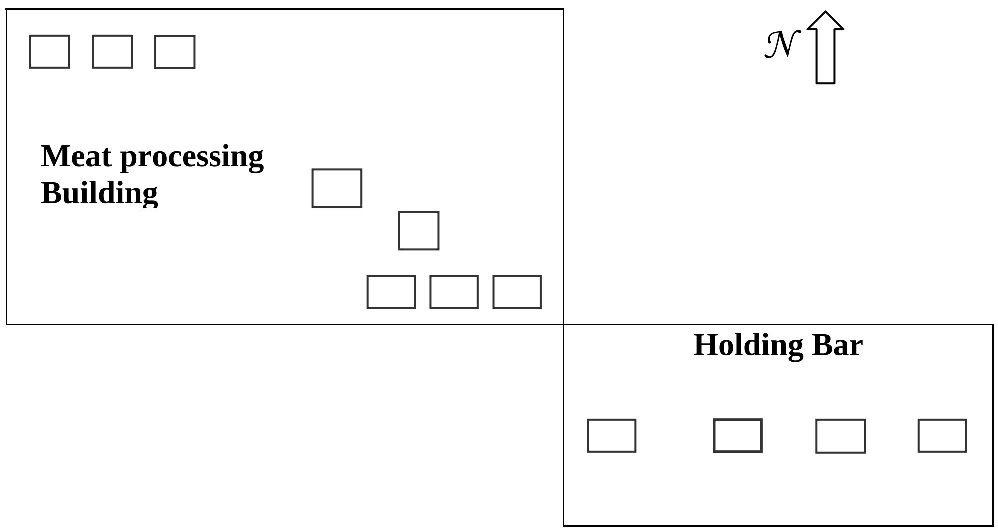


**Figure 1.** Sketch of floor layout of the proposed facility (squares represent air exhaust vents)

### Odour Emission Rates

To estimate odour emission rates for the proposed facility, odour concentrations were measured from two similar, existing facilities, and the emission rates were then determined from the measured odour concentrations and the design ventilation rates.

Twenty-eight (28) samples were taken by an engineering consulting company and shipped to University of Manitoba for analysis. The samples contained in Tedlar bags were evaluated for odour concentrations within 24 hours of sampling.  A single-port olfactometer (AC'SCENT, St. Croix Sensory Inc., Stillwater, MN) with six trained assessors was used for odour concentration measurement. The triangular forced-choice method was used to present samples to the assessors, with 3-s sniff time. Assessors were selected and re-evaluated periodically following the procedure of CEN (1999). For each olfactometry session, data were retrospectively screened by comparing assessors' individual threshold estimates with the panel average (CEN, 1999). Odour concentration was expressed as odour units per unit volume ($OU/m^3$).

The odour emission rates from buildings were calculated from the measured odour concentration and proposed (design) ventilation rates (airflow rate of exhaust fans) as follows:

$$Q = C \times V \tag{1}$$

where: Q = odour emission rate from building exhaust (OU/s)
C = odour concentration of the sample ($OU/m^3$)
V = ventilation rate ($m^3/s$)

The total ventilation rate of each room (holding barn, meat processing building) was used in calculating the odour emission rate for the vents in each building. The emission rate for each exhaust vent in a room was determined by dividing the room ventilation rate by the number of vents.

### Odour Dispersion Model - ISCST3

ISCST3 (US EPA) was used in this project. We used the RURAL condition to calculate 1-hour average concentration values. We assumed receptors on a FLAT Terrain in a Cartesian grid receptor network extended to 3000 m away from the site. Dispersion simulations were conducted for summer months (from June to August). Five-year (2000 to 2004) historical weather data of Environment Canada were used in simulations.

## RESULTS AND DISCUSSION

### Odour Concentration and Emission from Building Exhaust

A total of 28 air samples assessed were collected from two existing facilities similar to the proposed facility. The first facility originally processed lamb and veal and they have recently added an expansion to process beef and bison. At this facility, air samples inside the holding barn, and the exhaust air from the kill floor were taken. The second facility was a meat cutting and packaging operation after animals had been killed at other places. Air samples were taken from the cutting floor exhaust fans. Table 1 summarizes the average odour concentration of different sections in these two facilities.

**Table 1.** Summary of average odour concentration

| Area | Average odour concentration ($OU/m^3$) |
|---|---|
| Kill floor | 226 |
| Holding barn | 296 |
| Cutting and packing section | 70 |

The animal holding bar has the highest odour concentration (296 $OU/m^3$) compared to killing floor (226 $OU/m^3$) and cutting packing section (70 $OU/m^3$). The high odour concentrations from the holding barn and the killing floor were attributable to the manure from animals while cutting and packing floor was relatively clean.

In modelling odour emission, the killing floor, and the cutting and packing floor were recognized as one section, the meat processing building because they are in the same building (fig. 1). For the conservative purpose, 226 OU/m$^3$ from the killing floor was chosen as the odour concentration for the meat processing building. The estimated emission rates for the proposed facility were determined as follows (table 2).

**Table 2.** Estimated odour concentration and emission rates from buildings in the proposed beef slaughter facility.

| Room | Concentration (OU/m$^3$) | Ventilation Rate (m$^3$/s) | Stack Diameter (m) | Temperature (°C) | Number of Stacks | Gas velocity per stack (m/s) | Emission Rate per stack (OU/s) |
|---|---|---|---|---|---|---|---|
| Meat processing Building | 226 | 13.21 | 0.61 | 18 | 8 | 5.7 | 373 |
| Holding Barn | 296 | 33.04 | 0.91 | 20 | 4 | 12.7 | 2442 |

If the odour emission rate is expressed on per unit (m$^2$) of floor area, the rate is 0.14 and 1.26 OU/s-m$^2$ for the meat processing building and the holding barn, respectively. These emission rates are lower than the reported odour emission rates for mechanically ventilated swine finishing barns (3 - 21 OU/s-m$^2$, Zhang et al., 2002).

**Dispersion Modelling**

Figure 2 shows predicted odour concentrations for an area of 3-km surrounding the proposed facility. The contour lines designate odour concentrations in OU/m$^3$.

Different standards are used in different jurisdictions for defining acceptable odour levels, typically ranging from 1 to 8 OU/m$^3$. According to the odour concentration plot (fig. 2), the area up to 2000 m away from the proposed facility may be considered to be affected by the potential odour. The average odour concentration is 1.7 OU/m$^3$ within 1000 m, 1.2 OU/m$^3$ between 1000 and 2000 m, and less than 1 OU/m$^3$ beyond 2000 m.

The areas in northeast and southwest directions have higher possibilities for odour nuisance compared to northwestern and southeastern directions, and the southeast direction has the least possibility to be affected by odour nuisance. This situation is ascribed to the predominant local weather condition (wind).

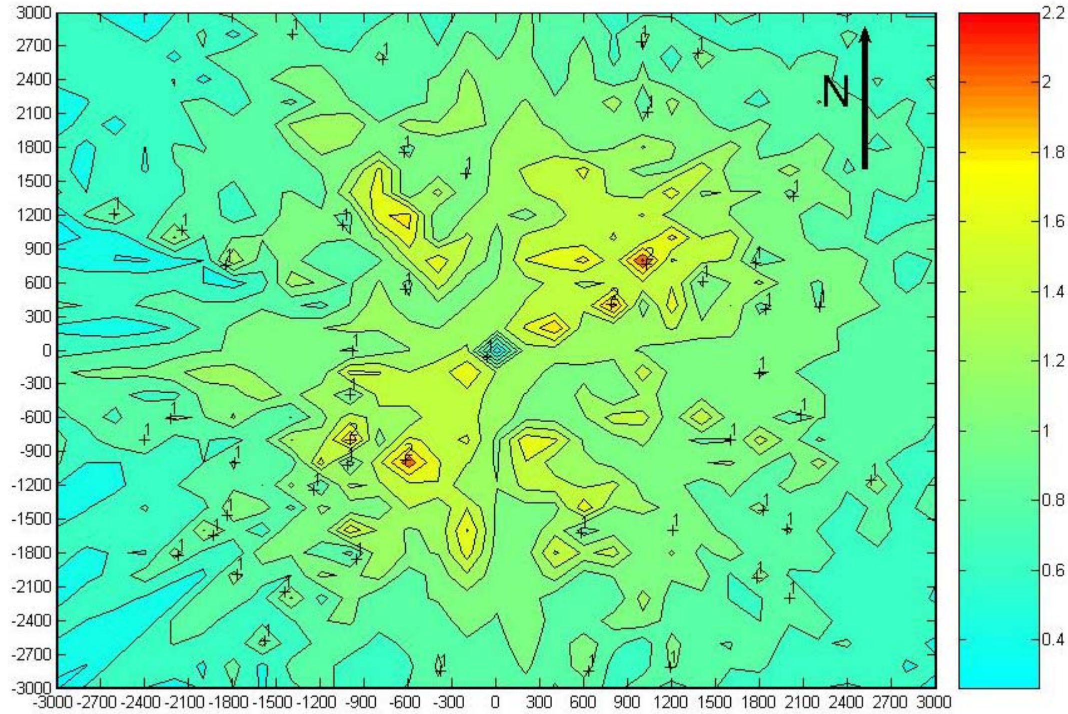


**Figure 1.** One-hour average odour concentration (OU/m$^3$) predicted by ISCST3 based on the weather data from 2000 to 2004 (x- and y-axes represent the distance in meters from the proposed facility).

The occurrence frequency of odour events was calculated as the number of hours when odour exceeded a predefined level divided by the total number of hours for the simulation period. In this study we examined the occurrence frequencies for 1 and 8 OU/m$^3$. Table 3 shows the results for 1 OU/m$^3$. The occurrence frequency for 8 OU/m$^3$ is zero (0) for distances greater than 1000 m.

Odour occurs 5% of the time at 1000 and 1200m away from the proposed facility. The occurrence frequency decreases as the distance increases after 1200 m. It goes down to 2% and 1% at 2000 and 2500m, respectively.

**Table 3.** Occurrence frequency exceeding 1 OU/m$^3$ at different distances
(1-hour average odour concentration)

| Distance (m) | Frequency (%) |
|---|---|
| 1000 | 5 |
| 1200 | 5 |
| 1500 | 4 |
| 1800 | 3 |
| 2000 | 2 |
| 2200 | 2 |
| 2500 | 1 |

## CLOSING REMARKS

Odour dispersion modelling could provide a clear picture of potential odour impact by a proposed beef slaughter facility on surrounding neighbors. The model predicts both odour distribution and occurrence frequency.

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