The empirical effects of alcohol and glycols on insects and other animals. The lethality formula based on body mass.

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1 Introduction

It is essentially trivial to see that any amount of alcohol is harmful for any creature as it has a denaturating and poisonous effect which can disrupt the digestive and circulatory systems. My goal with this research is to introduce an universal measurement which can determine that given an alcohol source or ingestion or air pollution, how much alcohol is still non-lethal for an animal given its body mass.

2 Acknowledgements

I would like to thank Roga Szegedi for supplying the all kinds of insects which were needed for the research.

I hereby declare that I took the uttermost care to prevent unnecessary animal cruelty and suffering while the research took place. Endangered species were not harmed during the research and mostly only invasive species were used for physical research.

3 Deriving the general formula

To be able to derive the general characteristic of the formula, we need some data first.

These are the metric and data inputs I will use at maximum:

1. **Concentration (p)**: [1] (Dimensionless fraction, ratio of alcohol mass to total mixture mass)
2. **Ingested Volume ($A_{\textbf{ingestion}}$)**: $[L]$ or $[m^3]$ (Amount of alcohol ingested by the animal)
3. **Atmospheric Concentration ($C_{\textbf{air}}$)**: $[kg/m^3]$ (Mass of alcohol vapor per unit volume of the container)
4. **Container Volume ($V_{\textbf{container}}$)**: $[m^3]$ (Total volume of the static chamber)
5. **Contacted Surface Volume ($V_{\textbf{contact}}$)**: $[m^3]$ (Volume of alcohol directly covering the surface area contacted by the animal)
6. **Exposure Duration ($t_{\textbf{exp}}$)**: $[s]$ (Time elapsed from the start of exposure)
7. **Subject Body Mass ($m_{\textbf{animal}}$)**: $[kg]$
8. **Toxicity Coefficient (c_0)**: $[kg_{\text{substance}} * m^2/kg_{\text{body\_mass}}]$ (Normalized lethality constant)
9. **Transfer Coefficient (k)**: $[s^{-1}]$ (The rate constant representing the fractional probability per unit time that the substance crosses the biological barrier, respiratory or dermal to enter the animal's internal systems)

3.1 Conceptual Model

The total effective dose D_{total} received by the animal can be modeled as a composite function that represents both ingestion and environmental exposure.

The amount of dose based on ingestion will be modeled by this equation:

$D_{\text{ingestion}} = p \cdot A_{\text{ingestion}} \cdot c_0/m$

The amount of dose based on contact with the material will be modeled by this equation:

$D_{\text{contact}} = (p \cdot V_{\text{contact}}) \cdot k \cdot t_{\text{exp}} \cdot c_0$

The amount of dose based on atmospheric respiratory ingestion the material will be modeled by this equation:

$D_{\text{atmospheric}} = (C_{\text{air}} \cdot V_{\text{container}}) \cdot k \cdot t_{\text{exp}} \cdot c_0$

The amount of dose total based on the subformulas will be modeled by this equation:

$D_{\text{total}} = D_{ingestion} + D_{contact} + D_{atmospheric}$

Which when expanded, looks like this:

$D_{\text{total}} = p \cdot A_{\text{ingestion}} \cdot c_0/m + (C_{\text{air}} \cdot V_{\text{container}} + p \cdot V_{\text{contact}}) \cdot k \cdot t_{\text{exp}} \cdot c_0$

My goal in this research is to derive $c0$ for denaturated alcohol and other elements where $c0$ will suffice this rule:

$Dtotal > 1.0$ and $Dtotal = 1.0$ means lethal amount for animals based on bodymass, while smaller values indicate that the dose was not lethal.

Note: The product of the $Vcontact$ could've also been produced using the ρ value of the volume, however in later this will save me big hurdles.

4 The nature of the experiments

I did my best to make large, lively terrariums for larger insects and both smaller ones. I provided automatic ventillation systems, lights and dark places. Smaller terrariums used manual water feeding wrapped in cotton while larger terrariums used automatic water sprinklers. I also made sure no parasites got in to the experiments.

Figure 1: An example larger terrarium featuring the watering system.

Figure 2: The smaller terrarium, featuring cotton based water feeding.

5 Measurements

The following table provides the average body mass for selected insect species, including their scientific nomenclature. Note that these values are approximations based on typical adult specimens.

Common Name	**Latin Name**	**Avg. Body Mass (kg)**
Wasp	*Vespula vulgaris*	1.5×10^{-5}
Common harvestman	*Phalangium opilio*	1.2×10^{-5}
Ladybug	*Coccinella septempunctata*	2.0×10^{-5}
Great Green Bush-cricket	*Tettigonia viridissima*	1.5×10^{-3}

Table 1: Average body mass of selected insect species.

5.1 Experimental Solution Application

To standardize the experimental conditions, the following chemical applications were performed:

- **Denatured Alcohol (60%):** 0.03 measured sprinkles applied.
- **1,2-Hexanediol (5%):** 0.05 measured sprinkles applied.

I will also count with a $k = 10^{-4} s^{-1}$ transfer coefficient which was derived from measurements and the uptake half-time: $t_{1/2} = ln(2)/k$

5.2 Getting the c0 values

Based on the measured scenario, the model will need to suffice the dose criterias for these values. I will use $C_{air} = 0$ because of the constant ventillation and to simplify the equation.

5.3 Governing Differential Equation

Assuming the container is well-mixed and the ventilation process acts as a first-order removal mechanism, the rate of change of the substance's concentration is proportional to the concentration itself:

$$\frac{dC_{\text{air}}(t)}{dt} = -k \cdot C_{\text{air}}(t) \tag{1}$$

where:

- $C_{\text{air}}(t)$ is the concentration of the substance at time t [kg/m^3].
- k is the air exchange rate or ventilation rate constant [s^{-1}], which depends on the flow rate of the ventilation and the volume of the container.
- The exact value of k is not needed for the correct formula.

5.4 Solution for C$_{air}$

This is a separable first-order ordinary differential equation.It can be solved by separating the variables:

$$\frac{dC_{\text{air}}}{C_{\text{air}}} = -k\,dt \tag{2}$$

Integrating both sides:

$$\int \frac{1}{C_{\text{air}}}\,dC_{\text{air}} = \int -k\,dt \tag{3}$$

$$\ln(C_{\text{air}}(t)) = -kt + C \tag{4}$$

By exponentiating both sides, we find the general solution:

$$C_{\text{air}}(t) = C_0 e^{-kt} \tag{5}$$

where C_0 is the initial concentration at time $t = 0$.

5.5 Asymptotic Behavior

As time $t \to \infty$, the concentration approaches zero:

$$\lim_{t\to\infty} C_{\text{air}}(t) = \lim_{t\to\infty} C_0 e^{-kt} = 0 \tag{6}$$

This confirms that with sufficient ventilation, the substance is effectively purged from the container volume over time.

5.6 Necessary solutions

All of these models should need to show correct behaviour of the specified function. With the measured avg. values substituted in for each species, each must hold.

(> 1.0) For denaturated alcohol:

$$1.0 = 0.6 \cdot 0.0001L \cdot c_0 / 1.5 \times 10^{-5} + \big(0 + 0.6 \cdot 10^{-7} m^3\big) \cdot 10^{-4} s^{-1} \cdot 9000 s \cdot c_0$$

$$1.0 = 0.6 \cdot 0.0001L \cdot c_0 / 2.0 \times 10^{-5} + \big(0 + 0.6 \cdot 10^{-7} m^3\big) \cdot 10^{-4} s^{-1} \cdot 9000 s \cdot c_0$$

(< 1.0) And for 1,2-Hexanediol:

$$0.2 = 0.05 \cdot 0.0001L \cdot c_0 / 1.5 \times 10^{-5} + \big(0 + 0.05 \cdot 10^{-7} m^3\big) \cdot 10^{-4} s^{-1} \cdot 61200 s \cdot c_0$$

$$0.2 = 0.05 \cdot 0.0001L \cdot c_0 / 2.0 \times 10^{-5} + \big(0 + 0.05 \cdot 10^{-7} m^3\big) \cdot 10^{-4} s^{-1} \cdot 61200 s \cdot c_0$$

$$0.1 = 0.05 \cdot 0.0001L \cdot c_0 / 1.5 \times 10^{-3} + \big(0 + 0.05 \cdot 10^{-7} m^3\big) \cdot 10^{-4} s^{-1} \cdot 61200 s \cdot c_0$$

A good, average c_0 for 60% denaturated alcohol would be the value of $c_0 = 0.291665$ $[kg_{\text{substance}} * m^2 / kg_{\text{body\_mass}}]$

A good, average c_0 for 5% 1,2-Hexanediol would be the value of $c_0 = 10.466$ $[kg_{\text{substance}} * m^2 / kg_{\text{body\_mass}}]$

6 Some explanation for $\mathbf{c}_0$

As seen, the c_0 value for more potent and poisonous elements are actually smaller gradually. A good explanation for c_0 would be: "How much can you interact with an element without dying with an X bodymass in a Y container with Z characteristics over T time?"

It is also important to notice that in reality it is very hard to judge based on this value and I need so much more measurements to be able to pinpoint the exact value of c_0 but still, this can be an useful indicator about the poison potency of an element.

References

[1] Tettigonia viridissima,
https://en.wikipedia.org/wiki/Tettigonia_viridissima

[2] Harmonia axyridis,
https://en.wikipedia.org/wiki/Harmonia_axyridis

[3] Vespula vulgaris,
https://en.wikipedia.org/wiki/Vespula_vulgaris

[4] Phalangium opilio,
https://en.wikipedia.org/wiki/Phalangium_opilio