



Title: The Standard Drink

Author: J. Semenov

Counterpoint Volume 1, Free Introductory Issue; Summer 2015; Pages 10-18

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It is published quarterly and is available for a subscription of \$99 USD annually.
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Industrial Training & Design Ltd.

Counterpoint is a Registered International Serial Educational Journal: **ISSN 2369-2774**



The Standard Drink

J. Semenov

ABSTRACT

This article introduces the concept of the “Standard Drink” as a means of quantifying ethanol dosage. The mechanisms of absorption, distribution, metabolism and elimination of ethanol are also introduced. We discuss the different volumes, types, and concentrations of ethanol in alcoholic beverages. This article is important as it sets the ground work for future articles: Investigations into the mechanics of absorption; Issues in calculating ethanol concentrations at a specific point in time; Specificity towards ethanol; and the effects of body mass and gender.

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Keywords: Ethanol; Alcohol; Methanol; Isopropanol; Alcohol Dehydrogenase Enzyme; Acetaldehyde; Absorption; Distribution; Metabolism; Elimination; Drink size; Alcohol concentration; Alcohol by volume; Alcohol by weight; Elimination rate; Widmark’s formula; Gender; Body mass.

INTRODUCTION

To a toxicologist – it’s all about the dosage. Dosage refers to the measurable quantity of a substance that a subject receives. The Swiss Renaissance physician, Paracelsus, is widely regarded as the founder of the field of toxicology. He famously wrote, “*The dose makes the poison.*”

In other words, a glass of wine or two enjoyed in a lingering fashion over dinner presents a very different toxicological profile to the consumption of 18 Boilermakers over a six-hour period at a frat party. One profile should present no toxicological issues, while the other is likely fatal.



Figure 1 - Paracelsus (1493-1541) A wild character who drank with students, ran after women and fundamentally changed the practice of medicine. He was the first to discover what we now refer to as Industrial Disease. His work on chemical contact established the first studies of Toxicology.

Ethanol versus Alcohol

Let's start off with an important distinction. The "alcohol" we drink should be properly referred to as *ethanol*. The generic term *alcohol* refers to the group of compounds in the "alcohol" family – methanol, ethanol, isopropanol, butanol, etc. The alcohols are organic hydrocarbon molecules with an Oxygen-Hydrogen (O-H), or *hydroxyl functional group*. *Upcoming articles will focus on the chemical properties of ethanol, as we need to understand these characteristics in order to understand how breath test devices work, and how the ethanol moves through the human body. We will also look at the interferent effect of these other alcohols, but for now, we will concentrate on ethanol.*

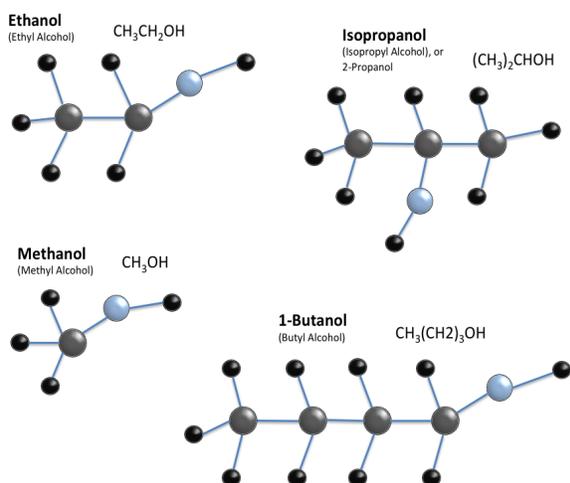


Figure 2 - The Alcohols - Ethanol, Isopropanol, Methanol and Butanol

At the outset, you also need to know that ethanol is a metabolic poison, and your body goes to great lengths to remove this toxin. If ingested in high doses, it takes less than 500 millilitres of pure ethanol to kill an average size human. Even under normal conditions, the process of ridding the body of ethanol produces toxic byproducts itself. As your body eliminates the poison, it suffers the side effects

of the toxin. You don't need to suffer an hangover to experience these negative side effects.

First, your body metabolizes the ethanol into *acetaldehyde*, the chemical responsible for hangover symptoms, among other things. Your body will eventually convert the acetaldehyde into *acetic acid*, the key ingredient in common household vinegar. *When people say they are getting pickled, it's not far from the truth.* Eventually, the acetic acid is metabolized into carbon dioxide and water. *More on this process in three upcoming articles discussing the Absorption, Distribution, and Metabolism of ethanol.*

Biologists have come to believe that consumption of ethanol may be an adaptive process among humans, occurring over the millennia. The ability to metabolize the alcohols found in fermented fruit shows up in our enzymes about 10 million years ago. The earliest known discovery of ancient pottery jars in northern China shows the residue of a fermented grape, berry, honey, and rice beverage. This dates back to about 7000 BC, about the time when fermented beer and grape wine were being produced in the Middle East. In the European Middle Ages, low-yield wines and beers were common beverages for all classes and ages of people.

In fact, during that period of time, consuming these low-yield ales and wines was perhaps beneficial. Drinking local stream or well water, often contaminated with bacteria due to poor sanitation, gave rise to such diseases as Cholera, Listeria and Botulism. Keep in mind that the production of low-grade alcoholic beverages involves both *boiling* the water, and *fermenting* the grains or fruit into ethanol. The resulting ales and wines were, in effect, pasteurized and laden with disinfectant.

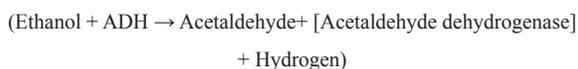
Humans and Ethanol

The main enzyme responsible for eliminating ethanol is called the *Alcohol Dehydrogenase Enzyme*, or ADH. In humans, ADH production does not begin until after birth, and only matures after years before reaching adult levels.¹ The ADH enzymes are unique to humans and the great apes, and are found in the linings of the stomach and the liver. Our bodies create 6-9 different forms of alcohol dehydrogenase, each with slightly different properties. Their sole function is to rid the body of ethanol.

The following chemical reaction occurs:



or



The *acetaldehyde* (chemically, also referred to as *ethanal*) is *more* toxic than ethanol, and is responsible for your hangover symptoms. In fact, acetaldehyde is a highly reactive and flammable liquid that is also volatile. Volatile, in the chemical sense, means that it can evaporate at room temperature.

The acetaldehyde is then broken down by *Acetaldehyde Dehydrogenase* into acetic acid. Finally, the acetic acid is broken down, giving off water and carbon dioxide as the final metabolites of the process.

ADH & Elimination of Ethanol

For most people, the levels of ADH remain constant throughout their lives. Chronic alcoholics, however, have been studied to show that their ADH levels *increase* as their bodies' respond to incessant metabolic poisoning. This may account for their faster degree of metabolism of alcohol. While the typical person has an alcohol elimination rate varying between 0.013 – 0.018 grams BAC per hour², British researchers found that chronic alcoholics may eliminate alcohol by *0.020 – 0.040 grams BAC per hour*. Once the metabolic stress of alcohol consumption is reduced, the ADH levels of these persons may return to normal values over time.

Studies also indicate that the ADH enzyme levels vary between individuals based upon racial or hereditary factors. A person may be less able to metabolize alcohol due to lowered levels of one or more of the ADH enzymes. This trait may be passed down from generation to generation. Persons of Pacific Rim heritage, North and South America's Indigenous peoples, and Australian Aborigines have been shown by some researchers to have lower overall levels of ADH in their bodies (*beginning with Fenna et al, 1971*). This finding is in dispute (*Bennion & Li, 1976, Lee et al, 1999*). Some researchers believe that the levels of ADH are an adaptive process, as few of these cultures had any comparable history of alcohol production or consumption prior to its introduction by European settlers.

1 Faassen, E and Niemelä, O., *Biochemistry of prenatal alcohol exposure*, NOVA Science Publishers, New York 2011.

2 The total amount of ethanol broken down per hour is estimated in the range of 0.1-0.3 grams per kilogram body weight per hour. This is usually translated into 6 – 9 grams of ethanol per hour for a healthy subject. This is usually estimated at .013 - .018 grams/100 mL per hour subtracted from the BAC.

The Standard Drink

What constitutes a “*standard drink*” varies from country to country, with no agreed upon definition. The volumes served vary in different government regulations. As an example:

Australia	10 grams (ethanol total dosage)
Canada / US	14 grams
Hungary	17 grams
Japan	20 grams

In general, the standard measure for how much ethanol is contained in a beverage alcohol drink is defined as the number of millilitres of pure ethanol present in 100 millilitres of the

beverage, at standard room temperature, or 20 °C (68 °F)³. This determines the Alcohol by *Volume* (ABV, abv, or alc/vol). There is a formula to do this...

However, in North America, it is common to express alcohol percentage as Alcohol by *Weight*, or ABW. There is also a conversion formula for this calculation, but you don’t need to worry about it....

³ In order to have a standard reference condition in chemical equations, NIST (The National Institute of Standards and Technology) created a condition known as STP. This is an acronym for Standard Temperature and Pressure. The standard temperature is comfortable room, or laboratory, temperature of 20 °C (68 °F) and a standard ambient air pressure equal to sea level – 1 Atmosphere or 14.7 psi (pounds per square inch).

North American Drink Types

Drink Type	Ethanol Concentration weight/ volume %	Drink Size to Produce a Dosage of 0.6 ounces (14 grams) ethanol	
		Ounces	Millilitres
Beer – Regular	≈ 5.0%	12.0 oz.	355 mL
Beer – Light	≈ 4.2%	14.0 oz.	415 mL
Beer – Ice	≈ 5.5%	11.0 oz.	325 mL
Beer – Malt Liquor	≈ 6.5%	9.0 oz.	265 mL
Beer – Fortified	≈ 9.5%	6.0 oz.	180 mL
Wine – Regular	≈ 12.0%	5.0 oz.	150 mL
Wine – Sparkling	≈ 12.0%	5.0 oz.	150 mL
Wine – Fortified	≈ 18.0%	3.5 oz.	100 mL
Distilled Spirit – 80 Proof	≈ 40.0%	1.5 oz.	45 mL
Distilled Spirits – 100 Proof	≈ 50.0%	1.0 oz.	30 mL
Liqueurs and Cordials	≈ 7.0%	2.0 oz.	60 mL
Coolers	≈ 5.0%	12.0 oz.	355 mL
Prepackaged Cocktails	Vary	???	???

Table 1 - Standard North American drink types
 The symbol ≈ Means, “approximately equal to.”

Source: International Center for Alcohol Policies (ICAP). *What Is a Standard Drink?* ICAP Reports No. 5. Washington, DC: ICAP, 1998.

Why are we concerned about “Standard Drinks”? We need to be able to quantify the ethanol consumption in order to make meaningful comparisons and dosage calculations. Each North American Standard Drink (SD) will deliver about 0.6 ounces (or 14 grams) of ethanol in total dosage of ethanol. This, in turn, produces the equivalent Blood Alcohol Concentration (BAC) of about 0.02 grams (20 mg)/100 mL of blood for a 190-lb male, on average.

Common alcoholic beverages run at the following average ethanol concentrations:

Beer	4-6%	(some are between 2-15%)
Wine	12-14%	(some are between 9-16%)
Port	15-20%	(some are between 9-30%)
Whiskeys	40%	(some are between 35-70%)

These beverages are typically served in different volumes:

Beer	12 ounces	(341 ml)
Wine	5 ounces	(142 ml)
Port	3 ounces	(85 ml)
Whiskeys	1-½ ounces	(43 ml)

So, North American “Standard Drinks” deliver the following ethanol levels:

Beer	12 oz @ 5% = 14 g of 100% ethanol
Wine	5 oz @ 12% = 14 g of 100% ethanol
Port	3 oz @ 20% = 14 g of 100% ethanol
Whiskeys	1.5 oz @ 40% = 14 g of 100% ethanol

Elimination of Ethanol

We know that average *elimination*, on the other hand, is for the most part, between 0.008 – 0.025 grams per hour. This gives us the rough guide of about “a drink per hour” for most people (*well, actually 1.25 hours*). Many toxicologists use an average of 0.015 – 0.017 grams per hour for computations. However, the elimination rate value has been reported from 0.008 – 0.045 grams per hour. It is important to remember that without testing an individual subject, we just don’t know what their specific elimination rate will be.

More problematically, a person’s elimination rate can vary from time to time; determining an absolute elimination rate value for a person is probably not possible. Some toxicologists will perform calculations using both the high and low elimination value, often resulting in a situation where the calculation results in a series of readings that straddles the legal limit. Many researchers suggest that these retrograde extrapolation calculations are little more than an educated guess. Again, we will delve into this area in greater detail in the future.

The problem is keeping track of consumption. Most people don’t count their drinks. Some will refresh their beer from the pitcher, and totally lose track of their actual consumption. Alcoholic beverages can vary in proof⁴, or concentration among brands. We also have the issue of consumption patterns. Some people discount the beers they had earlier in the day as not affecting them; some people will forget the shooters that finish the night just prior to driving home.

⁴ The term proof is derived from the early frontier practice of testing the whiskey sold to make sure it wasn’t watered down. A sample of the whiskey was mixed with gunpowder and ignited. If the whiskey burned with a steady blue flame, it was “proof” that the whiskey was good. In general, proof equals twice the alcohol concentration in w/v%. For example, 80 proof whiskeys contain 40% ethanol by weight per volume.

If a 190 lb. male goes to a bar, as an example, and quickly downs a couple of standard drinks, and then slows down his consumption to a drink every 45 minutes or so, his initial BAC will be rather high, based on the first few drinks. Even slow consumption after that will maintain the initial high BAC, due to the combined efforts of slow consumption, and elimination.

An estimated BAC at the *end* of the first hour would be:

$$\begin{array}{r} 2 \text{ Standard Drinks @ } 0.020 \text{ g per drink} \approx 0.040 \text{ g} \\ \text{Subtract 1-hour worth of elimination} \quad - 0.015 \text{ g} \\ \text{BAC} \approx 0.025 \text{ g} \end{array}$$

The Effect of Drink Sizes

In some licensed establishments, a Standard Drink is served⁵. Consumption at home, on the other hand, probably does not produce a Standard Drink. Few people measure the rum in their cola at home, and pour substantially stronger drinks than standard. If the subject has honestly consumed only “a couple” – meaning two drinks, but they contained 3 ounces of whiskey each, then each drink has delivered about 0.04 grams instead of the expected 0.02 grams. In short, they haven’t had two drinks.... *They’ve had the equivalent to four Standard Drinks.*

If the first two heavy drinks deliver 0.04 grams each, and are consumed in an hour, we would have a corresponding BAC at the end of that hour as follows:

$$\begin{array}{r} 2 \text{ NON standard drinks @ } \approx 0.040 \text{ g / drink} \approx 0.080 \text{ g} \\ \text{Subtract 1-hour worth of elimination} \quad - 0.015 \text{ g} \\ \text{BAC} \approx 0.065 \text{ g} \end{array}$$

If the subject slows their consumption to just one truly standard drink per hour, then after three more hours, they are approaching the legal limit. Real world consumption patterns dictate actual BACs, unlike the controlled experiments conducted with test subjects in the lab.

The Effect of Ethanol Concentration

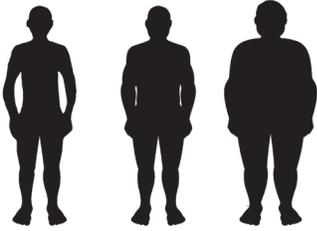
Of course, this assumes a standard ethanol concentration. If the subject consumes three standard SIZE beers, but the beers contain a 9.5% concentration of ethanol (as opposed the standard 5%), then the person has consumed the equivalent of almost 6 Standard Drinks. More and more, the ethanol concentration of some fortified beers on the market are increasing beyond the typical 5% beverage. Similarly, a single shot of 80% rum (160 proof) is equivalent to two standard drinks.

The Effect of Body Mass

What happens to persons of different body weights? Let’s pretend three men are having a beer at a BBQ, and the beers are the same – 12 ounces at 5% ethanol concentration. But, one guy weighs 150 lbs., the second weighs 190 lbs., and the third weighs 240 lbs.:

⁵ Some establishments offer the “club size”, doubling the alcohol content for a dollar or so more. Some bars pour martinis that are the equivalent to 3-4 standard sized drinks. I’m concerned that this double, triple, or quadruple drink is not taken into account when a person self-assesses the amount they’ve consumed in an evening. *Two generous martinis could be equivalent to 8 Standard Drinks...*

BAC Equivalent from 1 Standard Drink based on Body Weight:



Weight	150 lb.	190 lb.	240 Lb.
BAC	0.025 g	0.020 g	0.015 g

Final Thoughts:

As Paracelsus taught us 500 years ago, it's all about the dosage. Understanding the concept of the Standard Drink is important because it gives us a common language to use to describe and quantify effective dosages of ethanol among different subjects. When we explore issues in absorption and distribution of ethanol, this concept will become important. During the articles focusing on *Retrograde Extrapolation*, *Anterograde Extrapolation*, and the *Pharmacokinetics of Ethanol*, the concept of *dosage* will be critical. ▲

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Glossary of Terms

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