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Exposure Implications of Electronic Cigarette Surface Contamination

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Presenters

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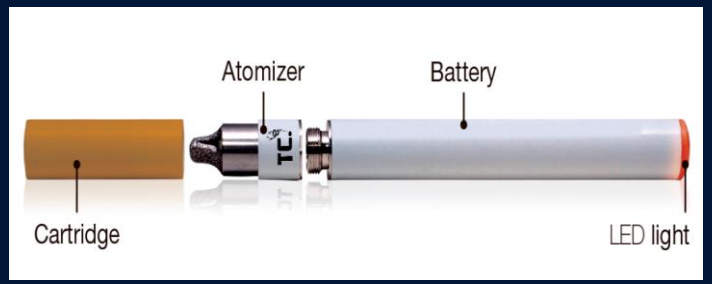
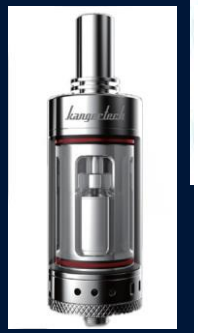
What are e-Cigs?
1st, 2nd, 3rd Generation???

- A picture is worth a thousand words s





As With Politics and Prison Tatoos – The Lines Start to Blur

Ingredients

"There are four basic e liquid ingredients: water, nicotine, flavorings and a propylene glycol or vegetable glycerine base (or sometimes a mixture of PG and VG)"

http://www.licensetovape.com/e-liquid-ingredients/

Propylene Glycol (PG)

Glycerol (Vegetable Glycerin, VG)

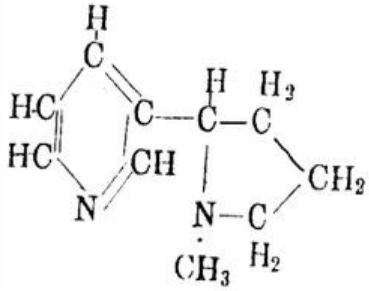
Flavorings:

- Sweeteners, fruit flavorings, butter flavor, vanilla, chocolate, tobacco, herbs…

Water (0-6%)

Nicotine (0-24 mg/mL)

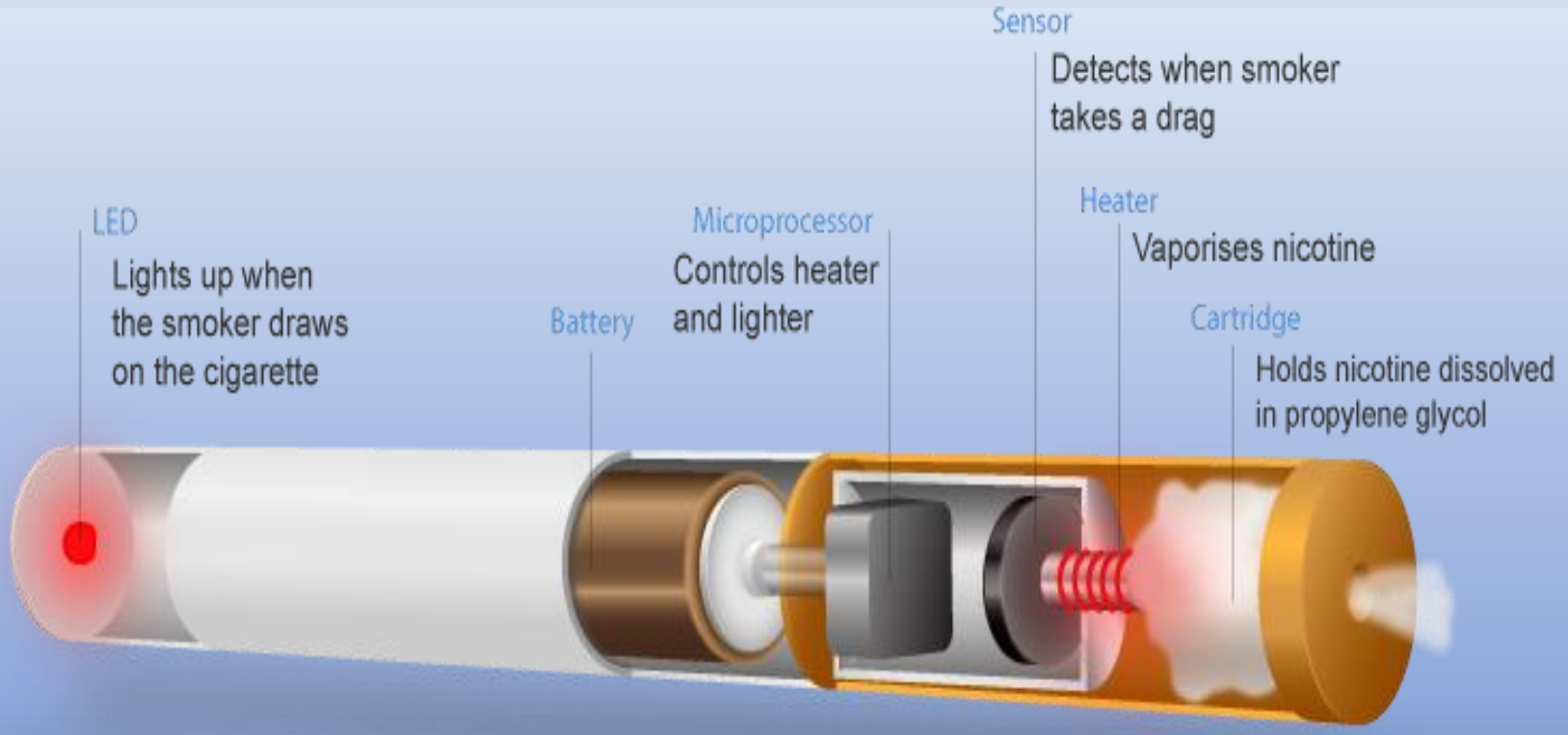
You're thinking of making the switch from regular cigarettes to e-cigs but need to know the **e liquid ingredients.** And more importantly, is e liquid bad for you? Don't worry, we had a ton of questions before we started vaping as well. We put together this e liquid ingredients guide that hopefully helps to answer your e-liquid questions. And it might help you wean off of tobacco and other harmful carcinogens! It's time to learn more, so let's break down e liquid ingredients:



What Are E Liquid Ingredients?

So we know e-cigs don't have actual tobacco or the other harmful ingredients (tar, carcinogens, etc.) that you find in regular cigarettes. Instead, e-cigs use a liquid nicotine solution known as e liquid or e juice. But what exactly is e liquid? There are four basic e liquid ingredients; water, nicotine, flavorings and a propylene glycol or vegetable glycerine base (or sometimes a mixture of PG and VG). Let's break down the e liquid ingredients in detail.

How an e-Cig Works



http://elektrousa.com/flavor-refills/

Cloud Chasing

- High powered e-Cigs
  - 50-250 Watts
- Low Nicotine Conc.
  - 2-8 mg/mL
- High VG%, Low PG%
  - 70:30 is common
  - 95:5 is for cloud chasers
- Customizable Devices
- Large visible plume
- Users inhale large amounts of e-juice
  - 1-20 mL/dy

Stealth Vaping

- Low powered devices
  - 4-7 Watts
- Low VG%, high PG%
- High nicotine conc.
  - 24 - 56 mg/mL
- Non-customizable
- Does not make a noticeable plume
- Small volume of e-juice inhaled
  - 0.05-0.5 mL/dy

Vaping in Public Places

- More and more banned
- Must be carried onboard aircraft rather than in luggage
- Vaping in hotel rooms likely
- Lavatory and hotel smoke / fire alarms may (or may not) detect vaping
- Vaping aerosol can travel through ventilation systems (Floyd, 2017)

Third-hand Exposure?

- Nicotine from traditional cigarettes can remain on surfaces for several months (contributes to potential third-hand exposure)
- Nicotine on surfaces also reacts with ambient ozone and nitrous acid to form carcinogenic tobacco-specific nitrosamines (TSNAs)
- Will nicotine from electronic cigarettes (ECs) persist and do the same?
  - This could impact the health and safety of cleaning personnel/subsequent occupants of the rooms/lavatories where vaping has occurred

Previous Studies

- Goniewicz and Lee reported that in a chamber study, only three of the four EC tested showed elevated concentrations of surface nicotine immediately after a puff test.
- Bush and Goniewicz found that of EC user's homes studied, only half had measurable levels of surface nicotine.

Other Impacts

- For tobacco cigarettes, in mainstream (user) and sidestream (from the end of the cigarette) smoke, nicotine is primarily found in the particle phase
- 95% of nicotine in environmental tobacco smoke is found in the gas phase
  - When nicotine concentration is very high (mainstream smoke) it condenses and partitions to the particle phase; when nicotine concentration is dilute (ETS, secondhand smoke) it begins to evaporate and partition into the gas phase
- In an inhaled dose of EC vapor, 76-100% of the nicotine is found in droplets

Other Impacts

- Is it possible that nicotine deposited from EC aerosol dissipates faster than nicotine from second-hand tobacco smoke, since there is no persistent (smoke) particle providing a sorption surface for the nicotine like there is with traditional tobacco smoke?

Objective

- Determine whether indoor use of e-cigarettes presents a risk of third-hand exposure to subsequent occupants or cleaning personnel

Scope

- Determine the persistence (decay rate) of nicotine deposited from e-cig aerosol on a porous material and a non-porous surface

Methods

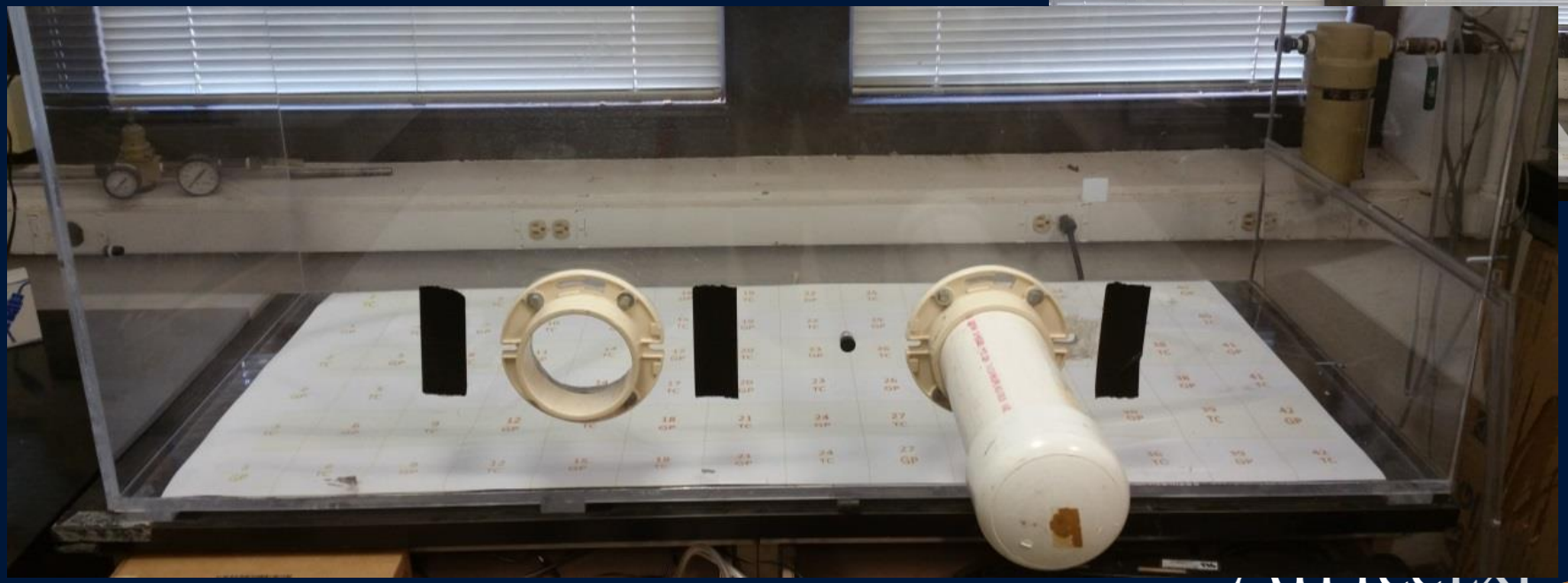
- Many methods in the literature describe extraction of nicotine from surface wipes and material swatches, but some are complex due to the cigarette smoke matrix and use equipment uncommon to the IH analytical lab
- We sought to adapt and simplify these methods so that we could perform sample analyses at-scale and have confidence in our ability to address the primary question of nicotine persistence from e-cig aerosol

Study Design

- Short term aging study conducted in an environmental test chamber
- 42 pairs of porous (terry cloth) and non-porous (glass plate) samples were exposed to e-cig aerosol and allowed to age from 0-72 hrs under controlled ventilation conditions
- Triplicate randomized samples analyzed for nicotine content at each time point with 1 hr and 36 hr double sampled
- Nicotine persistence assessed via regression

Test Chamber

- 0.92 m^3 acrylic test chamber (1.5m x 0.6m x 1.0m) equipped with removable side door, access ports / glove holes in front, exhaust ventilation on top, and test grid on floor



Sample Loading

- Clean samples were placed inside the test chamber and sealed. Three random baseline samples were removed via access ports before any e-cig aerosol exposure occurred
- Ventilation to chamber was shut off and 49 puffs were manually administered over 15 min using a 500 mL Hamilton syringe
  - 40 Watts, ~3 sec, 500 mL; 50:50,12 mg/mL nicotine e-juice
  - 2.57 g puffed --> 2.20 mL
- Puffs were injected upward and alternated between right and left access ports every 5 puffs to avoid loading biases
- After puffing was completed an additional 45 min was allowed for deposition without mixing for a total of 60 min from the first puff
- Applied a high ventilation rate (~45 air changes per hour) for 15 min to clear the chamber then adjusted to ~10 air changes per hour for the duration of the experiment.
- Alternated between L and R port each sampling

Sample Loading - Assumptions

- 50% of aerosols deposit on chamber floor and 50% of chamber floor covered by samples
- No collection efficiency bias between TC and GP and no differences in nominal surface areas
- Nicotine in e-cig aerosol proportional to e-juice conc.

Expected loading based on assumptions

- 2.57 g e-juice vaporized --> 2.20 mL
- 12 mg nicotine/ mL e-juice = 26.4 mg nicotine aerosolized
- 26.4 mg x 50% x 50% / 42 pairs of samples = 78.6 ug / sample
- 78.6 ug / 58.1 cm^2 = 1.35 ug/cm^2

Sample Loading - Assumptions

- Puff injections (upward and alternating between right and left ports) did not increase loading at locations nearer the ports
- Deposition during the 15 min clear-out doesn’t matter since we are interested in decay after deposition
- Triplicate randomized samples will distribute potential systematic biases normally

Sample Collection

- Triplicate randomized samples removed from the chamber at 0,1,2,4,8,18,24,36,48 and 72 hours after e-cig aerosol exposure.
- Double samples collected at 1 hr and 36 hr time points
- Each sample location numbered and assigned a random order for time point collection
- All samples extracted immediately after removal from the test chamber

Time	Sample Location
Pre	31
	17
	21
T=0	33
	19
	6
T=1	40
	37
	11
T=1	9
	12
	8
T=2	23
	18
	16
T=4	42
	36
	2
T=8	27
	29
	34
T=12	10
	14
	26
T=18	7
	4
	38
T=24	28
	41
	35
T=36	22
	1
	39
T=36	20
	25
	13
T=48	15
	24
	5
T=72	30
	32
	3

Sample Extraction - Terry Cloth

Simple extraction with 20 mL DCM in VOA vial

- Pre-weigh VOA vial
- Place TC sample in VOA vial with forceps
- Spike with ISTD, add DCM and tumble for ≥20 min
- Remove sample and cram into 10 mL syringe
  - Squeeze as much DCM out as possible (~15 mL)
  - Post weight VOA vial to determine exact volume
- Evaporate to ~1 mL
  - Post weigh VOA vial to determine exact final volume

Sample Extraction - Glass Plate

Simple extraction with 16 mL DCM

- Pre-weigh a VOA vial
- Place GP sample on a warm hot plate (~40C) and spike with ISTD
- Wash GP sample with 4 mL DCM, transfer 1st wash to VOA vial, repeat for a total of 4 washes
- Evaporate to ~1 mL
  - Post weigh VOA vial to determine exact final volume

Analysis - Overview

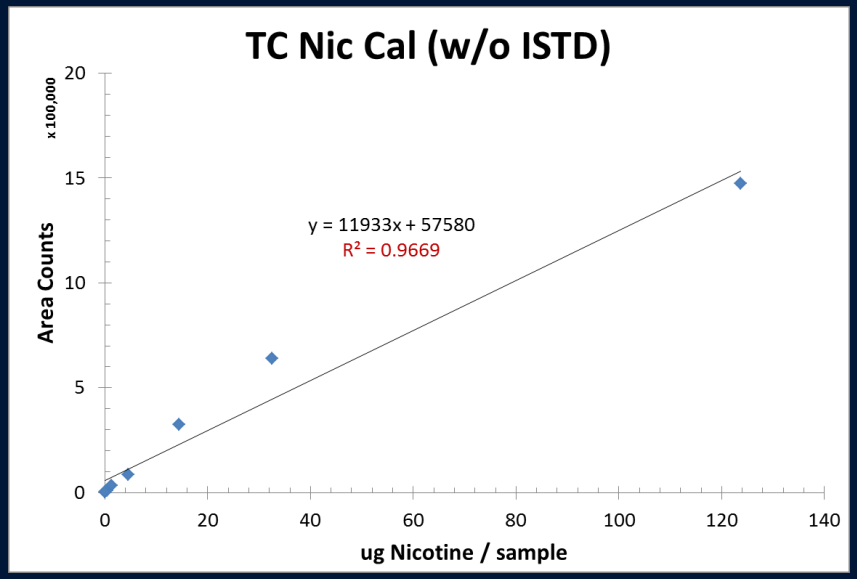
Prepare calibrations from matrix spikes of TC and GP, trying our best to mimic real samples

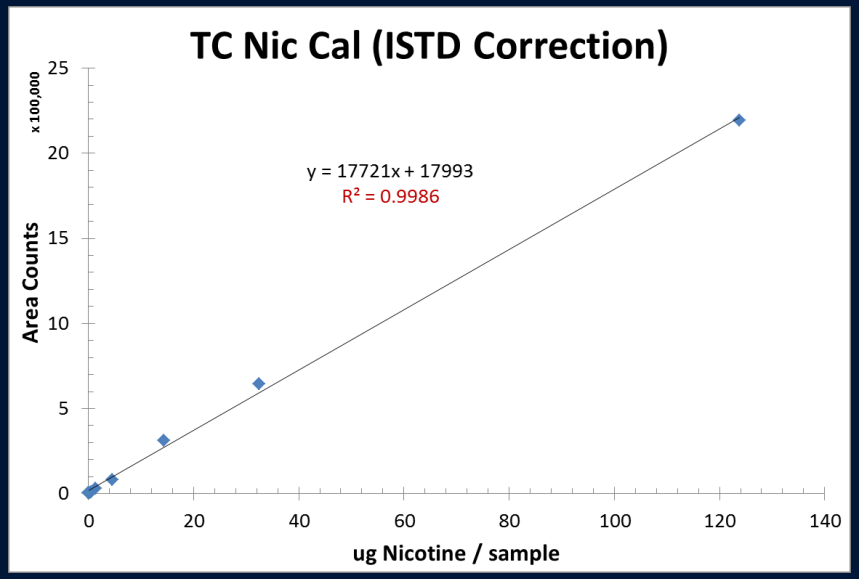
- Independent calibrations for TC and GP
- Independent MDL determinations
- Dose samples with quinoline ISTD same as samples

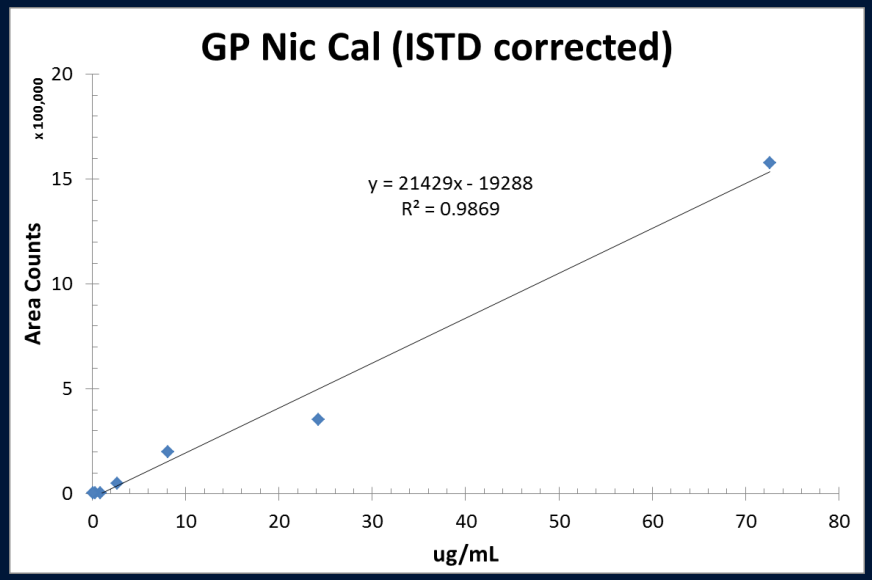
Prepare QC samples from matrix spikes of TC and GP samples from independent Nicotine solution

- Verify calibration with QC standards
- Analyze samples with QC standards every 20 samples
- Adjust sample mass based on solvent extract recovery (TC) and final volume after evaporation

Calibration Curves







Analytical Methodology - Lessons Learned

Simplified extraction in DCM was equally as effective as an acidic water extraction followed by basification and DCM extraction

Double 10 mL extractions of TC (instead of single 20 mL) is <10% more efficient, but double the work, double the supplies and more prone to error. 1.35 vs 1.46 ug/cm^2

Pre/post weighing VOA vials compensated for initial extraction losses, was simple and effective, and tedious

Analytical Methodology - Lessons Learned

Making a representative GP matrix spike was challenging

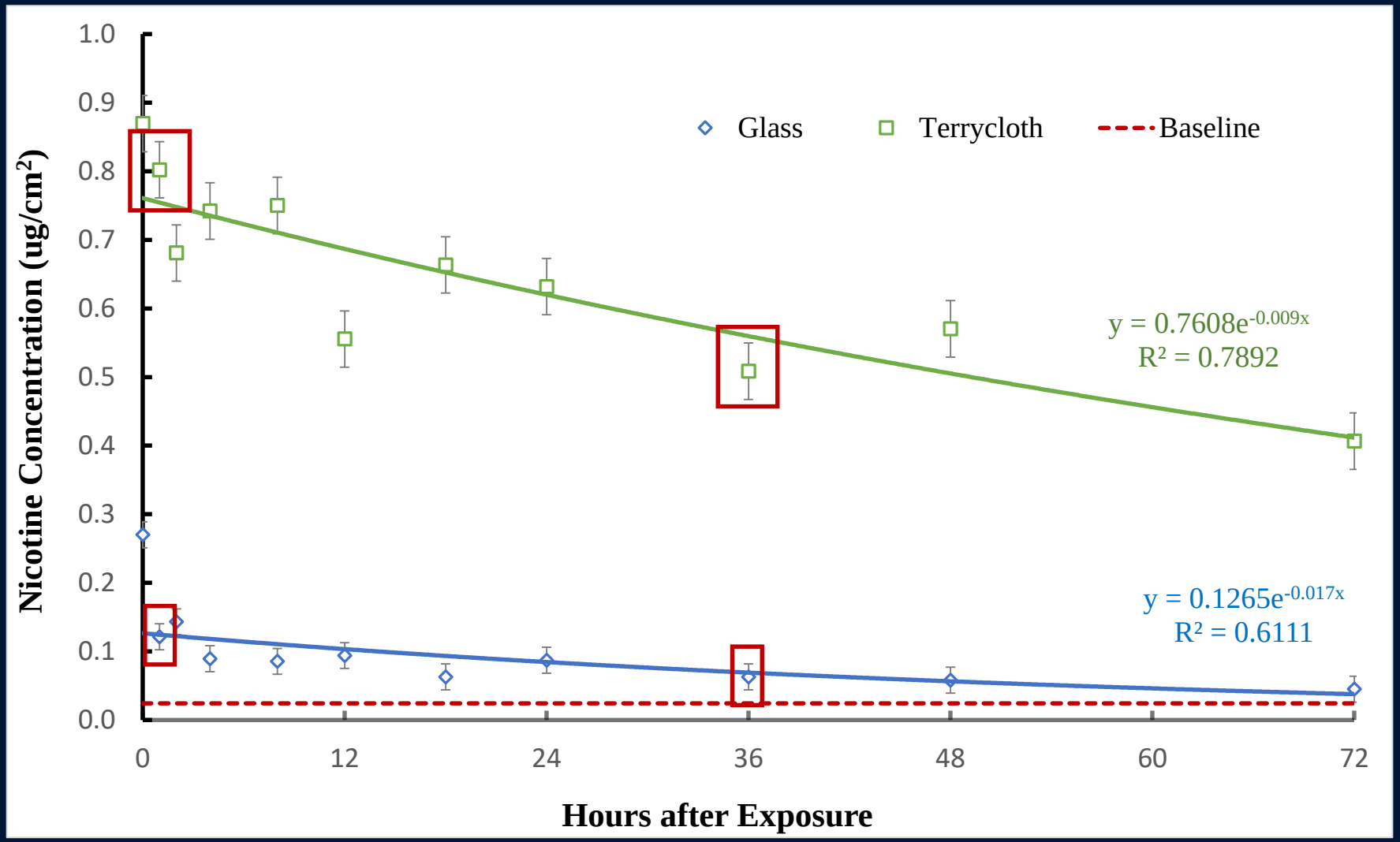
- Diluting nicotinized e-juice in DCM was more reliable than pure nicotine in DCM
- Preventing water condensation from forming (warm hot plate) during repeated extraction washes reduced variability and increased yield

Don’t try to use Eppendorf type pipettes with high vapor pressure solvents

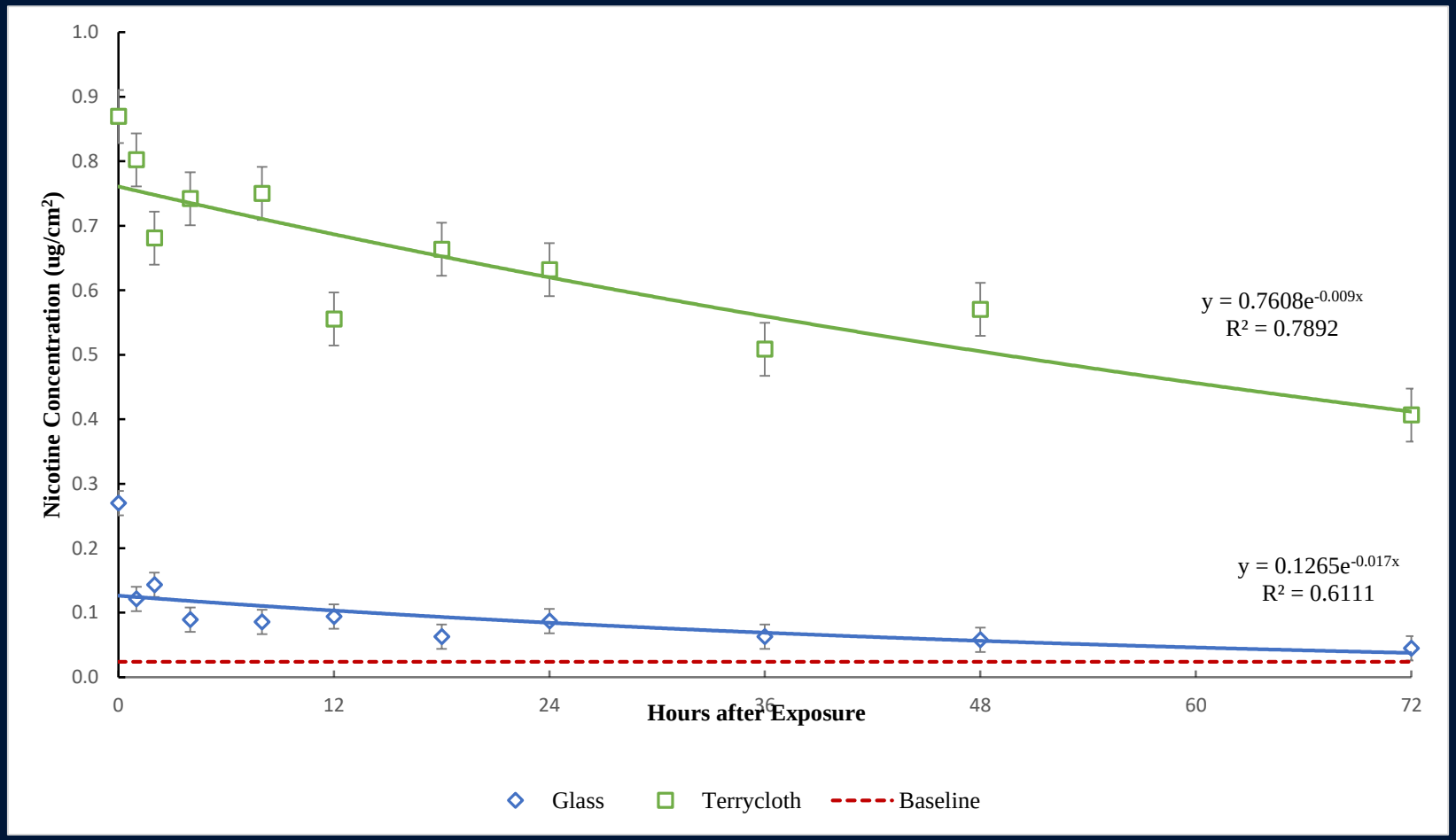
Results

- Calibrations were successful, simplified method was scalable and simple
- MDL for both techniques were very similar
  - TC = 0.52 ug/sample
  - GP = 0.47 ug/sample
- LOQ for both techniques were very similar
  - TC = 1.56 ug/sample --> 0.027 ug/cm^2
  - GP = 1.41 ug/sample --> 0.024 ug/cm^2
- Deposition on GP was ~1/10 TC samples
- Nicotine dissipated faster from GP than TC

Nicotine Concentration over Time



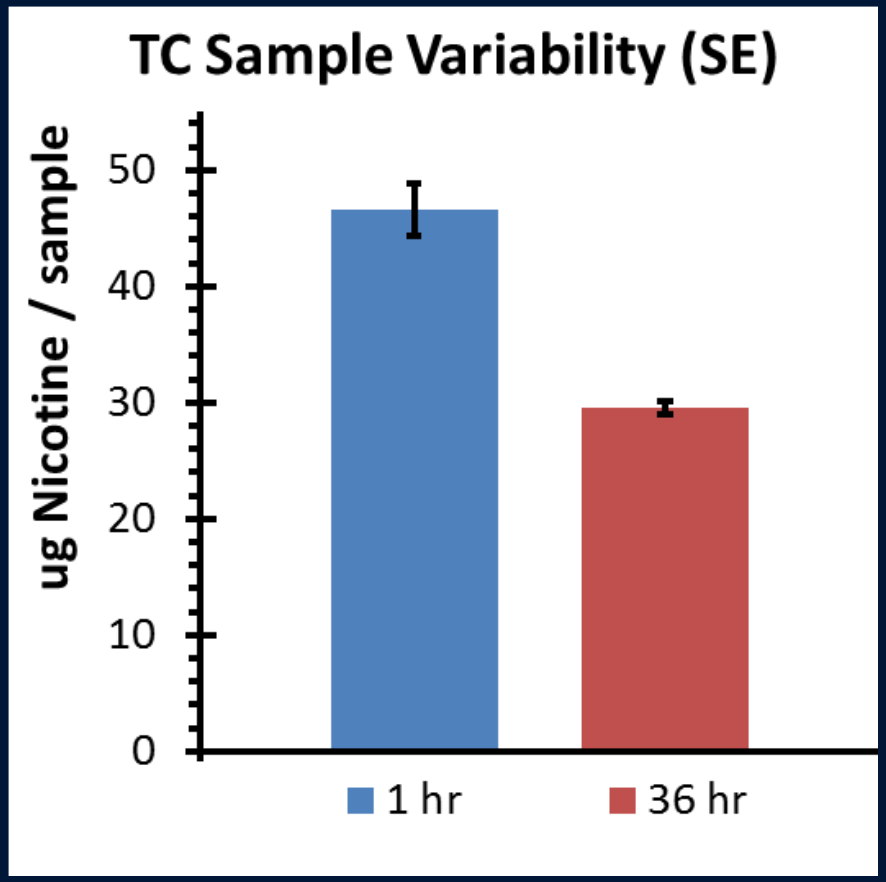
Regression to Reach Background Levels

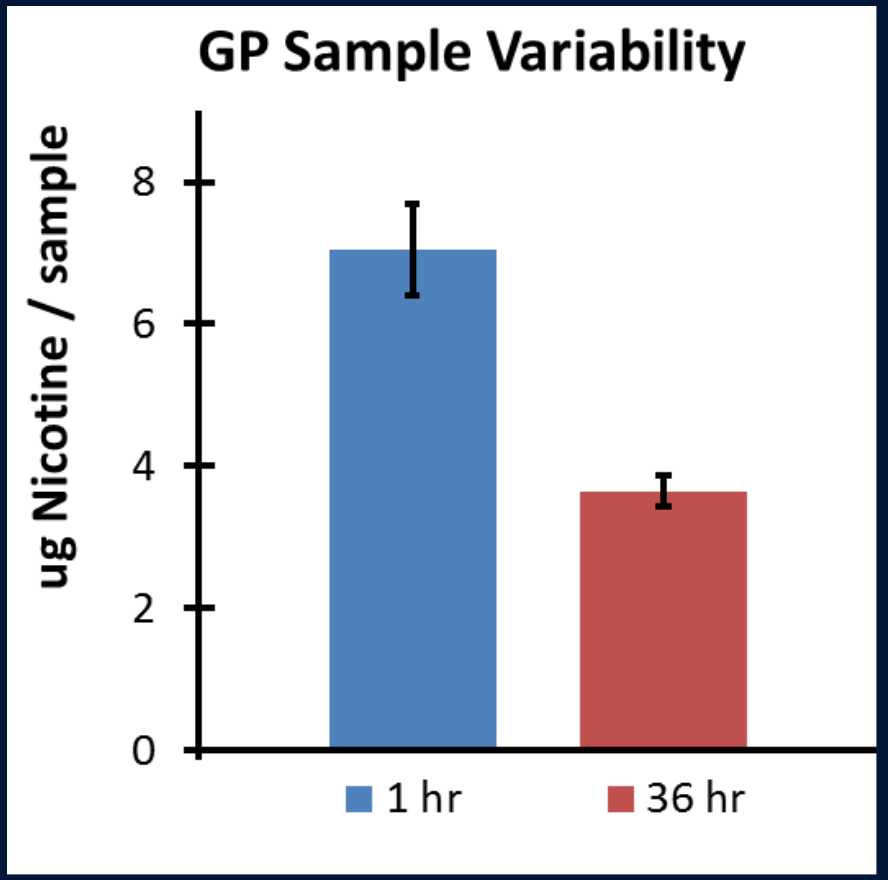


- Glass – 6.2 days
- Terry Cloth – 107 days

AIHce 2018 EXP

Sample Variability





- Means with Std Error Bars (n=6)

Discussion

- Deposition was quite similar to our ball park estimates
- Overall deposition was much greater in TC samples than GP samples
  - Possible boundary layer effects on smooth GPs
  - Possible sorption/sink effect with hydrophillic TC
  - Much greater surface area on TC due to loops may have collected small particles by diffusion
- Sample variability decreased with time, possibly redistribution of nicotine through vapor phase partitioning homogenized concentrations across samples

Discussion

- Time to baseline is much shorter for GP than TC.
  - Higher initial level means longer to decay to LOQ
  - Decay rate ~2x higher in GP than TC
- Deposition on non-porous surfaces seems to be slower than on porous-hydrophyllic materials such as TC.
  - Indicates minimal environmental risk of long term persistence on non-porous surfaces and transformation into tobacco specific nitrosamines (TSNAs)
  - Faster (more efficient collection) on porous materials indicates clothing, upholstery and carpeting may attract e-cig aerosol and retain it compared to non-porous surfaces

Limitations

- Duration of trial was only 72 hrs; longer trials to verify decay rate and time to baseline are recommended
- Initial loading was from a very high concentration e-cig aerosol environment not typical of stealth vaping or even vapor lounges. Deposition dynamics may be affected by initial concentration
- Only one blend of e-juice was used in this study, it is suspected PG:VG blend will affect nicotine persistence
- The extraction methods used were based off of well established techniques, but is not fully validated and inter-lab reliability is unknown

Conclusions

- Retention of nicotine on ***porous***, hydrophilic surfaces can be long enough to allow reaction with ambient gases to form TSNAs
- Potential risk for third-hand exposure over time appears to be low, but should be verified by longer term studies
- Use of ECs should be consistent with traditional cigarette smoking policies