Accuracy and Precision of Various Mercury Vapor Analyzers

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DESCRIPTION

Mercury exists in various states of matter, with the vapor form as the most hazardous, a neurotoxin, as it can pass through the blood brain barrier compared to the solid and liquid form (Aschner & Aschner, 1990). Various mercury vapor analyzers, including the Jerome® J505, Nippon® EMP-3, and the Picoyune which utilized the atomic fluorescence spectroscopy, atomic absorbance spectroscopy, and the localized surface plasmon resonance were tested, respectively, were tested for its accuracy and precision in a laboratory setting. This study aims to test the accuracy and precision of the devices to ensure that mercury concentrations were properly measured in the field to make proper decisions to prevent any potential adverse health effects that mercury vapor can pose on workers.

PROBLEM

There are limited amount of studies that test for accuracy and precision on various devices. Even though there is information about the accuracy and precision in the manuals of these devices, devices are mainly tested through the manufacturer. Since, different devices provide accuracy at different concentrations, it is significant to test the accuracy and precision of the devices to ensure that mercury concentrations are accurate, in order to take appropriate action when out in the field.

METHODS

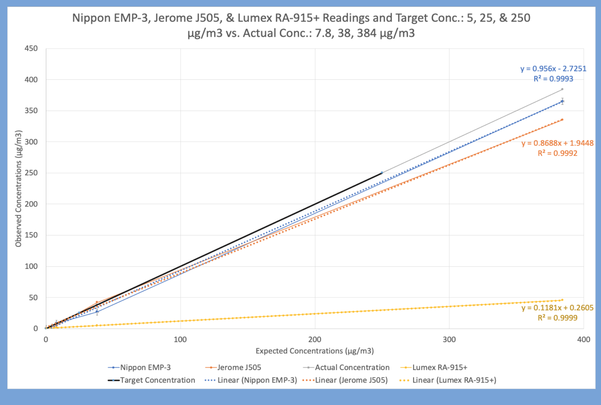
Experiment 1 *(Jerome ® J505 vs. Nippon ® EMP-3 compared to Lumex RA-915+ (benchtop device which utilized the atomic fluorescent spectroscopy) as a standard due to its versatility and precise mercury measurement in various medium:*

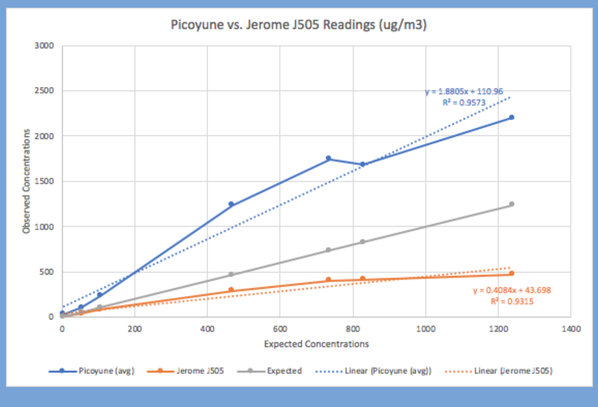
1. Prepared three 5L Tedlar bags ready to generate concentrations for 5, 25, and 250 ug/m^3 using 14,000 µg/m^3 of liquid mercury.
2. Used the Agilent flow rate meter to determine the flow rate of nitrogen.
3. The warm-up time for each device is at least 6 minutes, so it was turned on while adding nitrogen into the bag.
4. Used Teflon tubing to connect the air source to the bag and the sampling probe.
5. Added nitrogen to the bags with the calculated time needed to get a certain amount of nitrogen into the bag, using $C_1V_1 = C_2V_2$.
6. Injected concentrated mercury vapor (14,000 ug/m^3) using a 10 mL gas-tight syringe.
7. Mixed the vapor by shaking and squeezing the bag.
8. Purged the bags with nitrogen before generating new bags.
9. After the experiment, the actual concentrations had to be re-calculated as the vapor pressure was quoted from the National Institute of Standards and Technology (NIST). This led to the actual mercury concentration of 21,588 µg/m^3 , but the literature value of 21,146 µg/m^3 was used for re-calculation and analysis (Huber et al., 2006).

Experiment 2 *(Jerome® J505 vs. Picoyune)*

1. Warmed-up the direct reading instruments.
2. Set the PSA Cavkit paired with the PSA 10.534 to the desired mercury concentration. The tested concentrations were at 4.5, 54, 106, 468, 737, 828 and 1238 µg/m^3.
3. Connected Teflon tubing to the devices using a Y joint connector, so the Jerome and the Picoyune could be tested simultaneously.
4. Ran the mercury vapor concentrations for ten minutes, in order to get the concentrations to stabilize. Tried to obtain at least 3 readings.
5. Between runs of new concentrations, the Picoyune must be zeroed. This is ensured that the device is detecting mercury vapor concentrations. Jerome needed to be purged when switching to a lower concentration.

DATA





RESULTS

	Devices	Average Readings (µg/m^3)	Actual Concentrations (µg/m^3)	Accuracy (Relative Error) (µg/m^3)	Precision
Experiment 1	Jerome ® J505	4.6	7.8	-41%	±44%
		42	38	9%	±154%
		335	384	-13%	±86%
	Nippon ® EMP-3	8.3	7.8	6%	±25%
		27	38	-30%	±12%
		365	384	-5%	±8%
	Lumex RA-915+	1.4	7.8	-82%	±19%
		4.8	38	-87%	±0%
		46	384	-88%	±0%
Experiment 2	Jerome ® J505		4.5	-20%	±15%
			54	-25%	±1%
			106	-23%	±1%
			468	-38%	±4%
			737	-45%	±7%
			828	-50%	±7%
			1238	-62%	±8%
	Picoyune		4.5	582%	±2%
			54	93%	±4%
			106	122%	±4%
			468	165%	±4%
			737	137%	±20%
			828	103%	±2%
			1238	78%	±7%

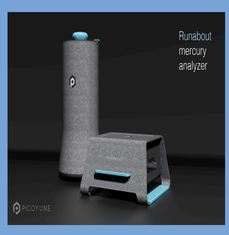
- According to the manuals of the Jerome® J505, Nippon® EMP-3, and Picoyune, the accuracy was ±10% at 1.0 µg/m^3 and above, ±10% of range, and ± 3% of reading, respectively.
- The precision of the devices vary among these devices, but it was at least 3-15% depending on the concentration.
- Accuracy was measured through relative error, in which if the value is closer to zero, the more accurate the reading was, this also applies to precision.
- The highest accuracy and precision values obtained in Experiment 1 was the Nippon EMP-3, with the lowest values of -30% & ±25% , respectively. The Jerome ® J505 had an accuracy within 13% at concentrations at or above 42 µg/m^3. The Lumex RA-915+ was precise at a few of the concentrations, but not accurate.
- Experiment 2 trials tended to have better precision for the Jerome ® J505 due to continuous flow of mercury vapor with higher precision above 54 µg/m^3 with better accuracy at lower concentrations. While the Picoyune had high accuracy at almost all the concentrations, on the contrary to accuracy.

CONCLUSION

This study determined the accuracy and precision of portable direct reading devices. In Experiment 1, the Nippon® EMP-3 had a better accuracy and precision overall compared to the Jerome ® J505. In Experiment 2, the Jerome ® J505 had high precision at almost all concentrations, with higher accuracy at lower concentrations. The Nippon® EMP-3 was recommended due to its overall accuracy and precision but needs further testing with a reliable source of mercury vapor generator, in addition the cost was relatively lower than the other devices listed and had a larger range.

Jerome® J505
https://www.azic.com/jerome/j505/

Nippon ® EMP-3
https://www.hg-nic.biz/product/emp/emp3/index.html



Picoyune
https://www.picoyune.com/

FUTURE STUDIES

- Test for interferences for each device
  - Jerome® J505 – acetone vapor; negligible response to chlorine, ammonia, humidity/water vapor, and gasoline vapors
  - Nippon® EMP-3 – hydrocarbons (resolve with gold filter), chlorine, sulfides, copper, tellurium, dust and smoke
  - Picoyune – N/A
- Duplication of the studies with all devices present

REFERENCES

Aschner, M., & Aschner, J. L. (1990). Mercury neurotoxicity: mechanisms of blood-brain barrier transport. *Neuroscience & Biobehavioral Reviews, 14*(2), 169-176.

Huber, M. L., Laesecke, A., & Friend, D. G. (2006). The vapor pressure of mercury. *National Institute of Standards and Technology*. doi: 10.6028/nist.ir.6643.

James, J., & Crosby, J. (n.d.). Innovative mercury analysis, more places, less effort. Retrieved from https://www.picoyune.com/#products

Jerome® J505 Mercury Vapor Analyzer. (2015). *Jerome® J505 Mercury Vapor Analyzer*. Chandler, AZ.

"Products." *Portable Mercury Survey Meter: EMP-3 - Nippon Instruments Corporation*, www.hg-nic.biz/product/emp/emp3/index.html.

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