Technical report

Volcano DIGIT Vaporization System
- Investigation of the aluminium content in the exhaust air stream -
Storz & Bickel GmbH & Co. KG

Customer:

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1 Type of problem and general information

Storz & Bickel GmbH & Co. KG produces vaporization systems like e.g. the product *Volcano DIGIT* to solve aroma and active ingredients of plant material or to manufacture essences (aroma oils) through vaporization of the resulting solutions with heated air.

Through the contract of October 10 / 2009 UTM GmbH was asked from Storz & Bickel GmbH & Co. KG (the customer) to investigate the aluminium content in the exhaust air stream of the test device *Volcano DIGIT* which was delivered by the customer.

2 Technical data of the *Volcano DIGIT Vaporization System* - operating principles

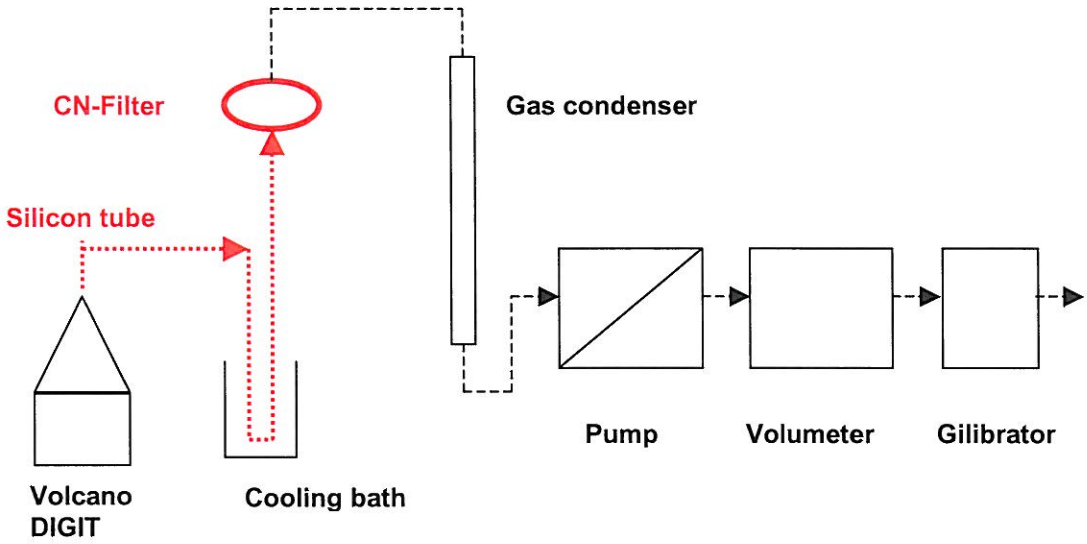
The used *Volcano DIGIT* model has the following characteristics:

Model	Volcano DIGIT
Power (electrical appliance)	120 W
Voltage	220 - 240 V
Frequency	50 - 60 Hz
Serial number	D 004198

The test device (system) *Volcano DIGIT* suck the ambient air with a membrane pump into the device and passes this air into a heating block which is produced of aluminium (all data from customer). After heating the air to an adjusted temperature the air passes a subsequent small chamber in which – depending of the application - the respective plant material or the manufactured essence is located. The active ingredients will then be extracted by the heated air to reach a subsequent balloon.
All active ingredients extracted and transported by the heated air will be breathed by the user of the system *Volcano DIGIT.*

3 Experimental setup and conditions

The investigation of the aluminium content in the exhaust air stream of the *Volcano DIGIT* device was done according the following outlined experimental setup:



The here presented experimental setup is also documented in picture 1 of the photo documentation.

To execute the experiment the following materials and devices were used (besides the *Volcano DIGIT)*:

Filter:	Cellulose nitrate - filter (CN); Producer: Sartorius Stedim Biotech GmbH, 37070 Göttingen, Pore size: 8 µm, Diameter: 37 mm, Lot: 1108 11301 0603143.
Suction pump:	Flite 2A, High Volume Sampling Pump; Type: 901-2011, S/N 09522813.
Flow meter:	Gilibrator 2 with "High Flow Cell". Producer: Gilian, U.S.A., P/N 800 285-1, S/N 050 8014-H.
Tubing:	Rotilabo – Silicon tube; Producer: Carl Roth GmbH + Co., 76185 Karlsruhe, Type: 9575.1, Inner diameter: 7 mm, Outer diameter: 11 mm, Wall Thickness: 2 mm, Lot - No. 200047506/1.

Volumeter (volume gauge): Model - GMZ 6 made available by UTM GmbH.

Test procedure:

To the air exhaust of the *Volcano DIGIT* a silicon tube was connected which ended in a filtrierstativ of polystyrene. A cellulose nitrate - filter (CN - Filter) was put into the filtrierstativ to separate possible aluminium particles. An additional gas condenser (glass manufactured) and a suction pump were joined subsequently. The sucked off air was passed into the volumeter and the flow meter (Gilibrator) and finally exhausted to the surrounding air. The volumeter was used to evaluate the volume of the air sample and the flow meter was used for the permanent control of the air flow rate.

The heating block of the *Volcano DIGIT* device was operated at a temperature of 230 °C (446 °F). Therefore the exhausted air has nearly the same temperature. While CN - filters cannot used above temperatures of 121 °C (249.8 °F) the air has to be cooled before. For this reason a silicon tube (length: 70 cm) was used and additionally cooled in a water bath. After passing the CN - filter the air precautionary was further cooled with a gas condenser to avoid overheating of the suction pump (Gilian Flite 2A).

The suction pump was used to balance the loss of pressure caused by the CN - filter. Within the normal operation the membrane pump in the *Volcano DIGIT* operates with an air flow rate of about 15 l/min. The used CN - filter reduce this air flow rate down to about 8.9 l/min. The subsequent joined suction pump guarantees an air flow rate of about 15 l/min.

Within the framework of some pretests different filter types were tested to precipitate the aluminium. Thermoresistent Teflon®- and quartz glass- filter were proved as unsuitable because their porosity is to low. Glass fiber - filters were eliminated because their metal blanks were too high. This filter type can only be used for gravimetric dust measurements.

That is the reason why cellulose nitrate - filter (CN - filter) with a diameter of 37 mm and a pore size of 8 µm were used. The detection of the aluminium content in the exhaust air stream and the usage of this filter type were described in the procedure "BGIA - procedure 6060".

CN - filter are only suitable to a maximum temperature of 121 °C ((249,8 °F), data from manufacturer). At higher temperatures it is taken into account that obliteration (filter sealing) can happen by sintering or deformation / decomposition of the filter material. An appropriate dimensioned thermoresistent silicon tube connected to a water bath (in function as a cooling section) was used to avoid overheating of the CN - filter. The used silicon tube was also part of the investigation of the aluminum content, because it could not be excluded that before the emitted aluminium reach the CN – filter a precipitation at the inner side of the silicon tube takes place.

The investigation of the CN – filter in the laboratory took place after decomposition with nitric acid and hydrogen peroxide. The inner side of the silicon tube was repeatedly rinsed with hot nitric acid. The aluminium content in the decomposition solutions were analyzed with ICP/OES.

Two test trials (attempt V1 and V2) to evaluate the aluminium emissions were performed with the *Volcano DIGIT*. Having a worst-case-consideration in mind, both test trials were performed within a 4 hours time period (each) and a maximum temperature of 230 °C (446 °C).

While using the device in practice the operating period time is only in the range of some few minutes mostly at significantly reduced temperatures.

An attempt (method) blank (V3) was performed in the same way - however without the *Volcano DIGIT*. For that reason the ambient air also passed through a silicon tube and a CN – filter within a 4 hours time period.

Furthermore a pure CN – filter (V4) was investigated as blank.

The following experimental parameters were chosen:

Attempt (V)		V1	V2	V3*	V4**
Date		Nov. 04 / 2009	Nov. 04 / 2009	Nov. 05 / 2009	Nov. 04 / 2009
Time		09:02 - 13:02	13:10 - 17:10	07:02 - 11:02	14:30
Temperature	°C	230	230	-	-
*Volcano****	(°F)	(446)	(446)		
Adsorbent		CN-Filter Silicon tube	CN-Filter Silicon tube	CN-Filter Silicon tube	CN-Filter Silicon tube
Volume flow	l/min	13.91	13.61	13.84	0.00
Sample volume	m^3	3.339	3.267	3.322	0.00
Sampling time	min	240	240	240	0

* V3 = Blank of the method
** V4 = Material blank (the CN – filter was investigated, a sample of the silicon tube was stored as retained sample)

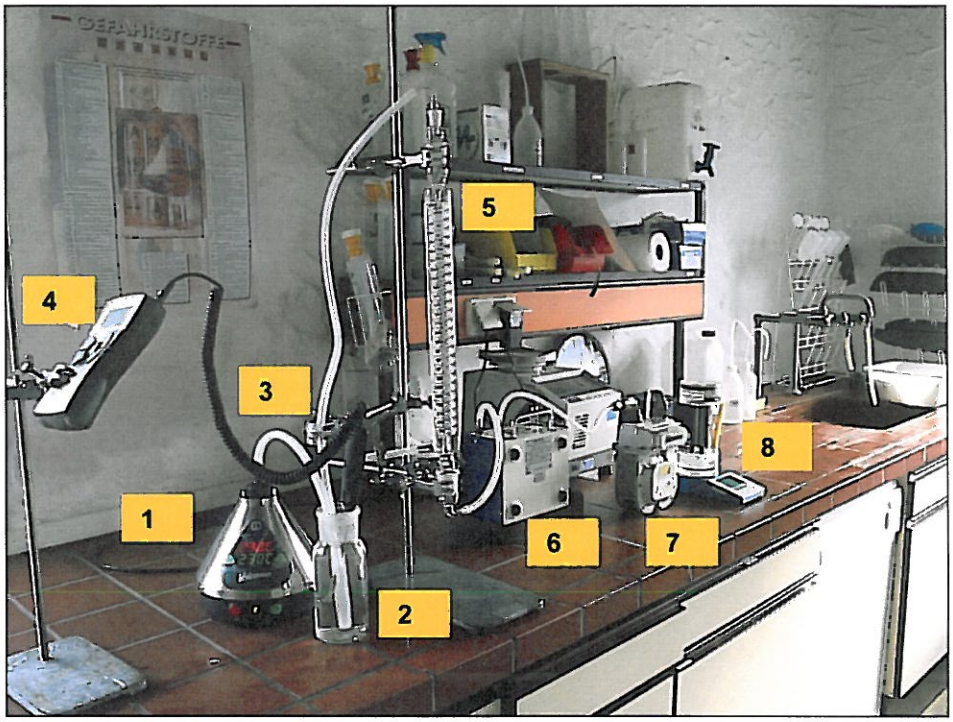
The silicon tube of trial 2 (V2) was also stored as retained sample.

*** The temperature of 230 °C (446 °F) is related to the chamber in which the herbs or essences will be given. At the inner parts of the heating block temperatures up to 250 °C (482 °F) will be reached.

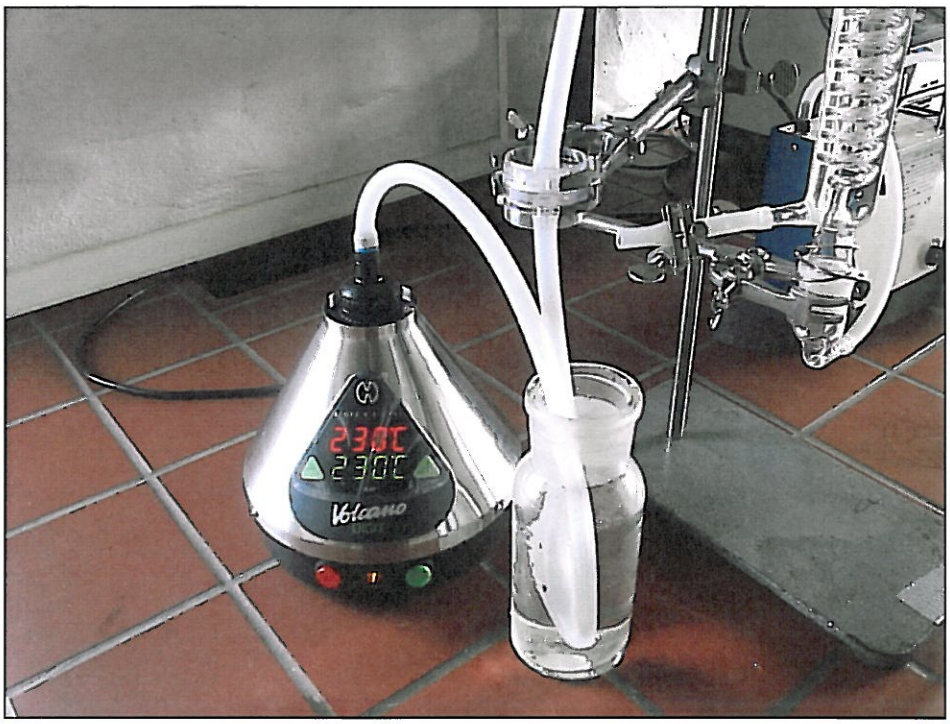
The following climate conditions were used in the test room (averaged values):

Place		Test room Nov. 04 / 2009	Test room Nov. 05 / 2009
Temperature	°C (°F)	15.6 (60.1)	16.1 (61.0)
Rel. Humidity	%	37	41
Atmospheric pressure	hPa	976	998

4 Photo documentation



Pict. 1: Experimental setup to sample the air emissions of the Volcano DIGIT:
1 = Volcano DIGIT, 2 = Cooling bath, 3 = Table filter with filtrierstativ, 4 = Thermometer with sensor to monitor the bath temperature, 5 = Gas condenser, 6 = Pump, 7 = Volumeter, 8 = Gilibrator.



Pict. 2: Photo in detail of the Volcano with subsequent cooling bath and table filter.

5 Results

The investigation of CN - Filters and silicon tubes led to the following results for the aluminium content (Al) in the exhaust air stream:

Attempt (Trial)	V1 Volcano DIGIT	V2 Volcano DIGIT	V3 Method blank
CN-Filter	< 5 µg Al/m³	< 5 µg Al/m³	< 5 µg Al/m³
Silicon tube	< 5 µg Al/m³	n. u.	< 5 µg Al/m³

n. u. = not investigated (retained sample).

In the blank filter (CN-Filter, V4) an aluminium concentration of 7 µg absolute was detected. All above mentioned results were corrected with this blank.

In the supplied CN - Filters and silicon tubes (resulting from the *Volcano* attempts V1 and V2) no aluminium (in particular or ionogenic) was detectable. The V3 blank showed also no detectable aluminium. The detection limit of the procedure is 5 µg/m³.

The results verify, that on the basis of the chosen experimental setup (worst case conditions) the usage of the test device (type *Volcano DIGIT*) no aluminium components or aluminium ions were released in provable concentrations.

Note: The author know no reference values of the possible aluminium contents in the exhaust air from devices comparable to the *Volcano DIGIT* or other medical devices or of air from interior rooms.

6 Physical properties of aluminium and check of plausibility

Caused by its high oxygen affinity aluminium (Al) exist in nature not pure but only as oxide compounds. It is the most spread metal on earth and the lithosphere (earth's crust). It exists as clay, mica, feldspar and gneiss. Of high technical importance is aluminium oxide (Al_2O_3, "Alumina"), which is the main component in bauxite.

Aluminium is a silver white metal with the density 2.699 and crystallizes in a cubic closest packed form. The melting point of Aluminium is 660.2 °C (1220.4 °F), its boiling point 2330 °C (4226 °F).

In spite of its high oxygen affinity pure aluminium is – opposite to the easy corrosive iron - resistant in contact with air because it is covered with a strong, adhered thin oxide layer, which protect deeper layers of the metal (resistant against "rust" attacks). Also the persistence of aluminium against oxidizing acids is based on its behavior to build an oxide layer ("Passivation" of aluminium). α – aluminium oxide ("Corundum", "alum clay") has a melting point of 2045 °C (3713 °F) and a boiling point of 3300 °C (6026 °F).

The heating block of the *Volcano DIGIT* consists of an aluminium alloy according the type AlMgSi (data from manufacturer). While using the heating block there is no mechanical stress. The thermal stress is restricted to a temperature range between room temperature and a maximum temperature of 230 °C (446 °F).

On the basis of the above described properties of aluminium (hard, strong, temperature- and corrosive resistant) and analogous aluminium alloy it is not to calculate with any aluminium emission during the usage of the thermal block.

The results of the done attempts with the *Volcano DIGIT* correspond to theoretical aspects and therefore these results are plausible.

7 Summary

The exhaust air stream of the test device (type) *Volcano DIGIT* (delivered by the customer) was investigated (within 2 trials / attempts) to the compound aluminium.

The trials were performed under worst case - conditions (long test intervals, high temperature).

In both test trials no emission of aluminium or its compounds especially no aluminium ions were detected while using the *Volcano DIGIT* device.

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