

SITOWISE

Correlation measurements of quartz dust, further development

Sitowise Oy April 12,
2024



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1 Summary, general information on measurements

This report is a follow-up to Matias Raiski's thesis, completed in June 2022. The thesis involved conducting correlation measurements between two different measurement systems designed to measure dust generated by construction work, and the results were reported. Dust generated by construction work was measured at construction sites where interior demolition work was underway. This is an ongoing development project aimed at verifying the suitability of a remotely readable measurement system for measuring construction site dust. The starting point was not to conduct scientific research, but to evaluate the system's reliability under practical conditions.

Currently, the only approved method for measuring respirable quartz dust is occupational hygiene measurement (cyclone collection) in accordance with international standards. In this method, dust is collected using a pump and a cyclone into collectors, from which the laboratory analyzes the average mass of respirable dust particles from the total dust generated during a workday (8 hours). The method separately determines the amount of quartz dust. In this development project, data on dust particle mass with a diameter of 4 µm collected by the remotely readable eGate equipment was compared to the total dust amounts collected by cyclone collectors (4 µm dust particle mass). The project did not seek a direct correlation with the amount of quartz dust.

The original objective of the thesis was to standardize the measurement practice and obtain approval for it. The thesis did not fully achieve this objective, as a direct comparison of the measuring devices was not entirely possible at that time. The results obtained from the two different devices were not comparable, as the devices measured dust particles of different diameters.

Based on the results of the thesis, the eGate equipment was modified so that the measuring devices were set to measure particles with a size of 4 µm in the alveolar fraction. This allowed the eGate equipment and cyclone collectors to measure the same dust fraction.

Later, the data recording interval for the eGate devices was changed from 30 minutes (default setting) to 5 minutes. In this case, the



corresponds more closely to the average obtained with the cyclone collector. In cyclone measurement, dust is collected continuously throughout the entire measurement period, and the average is determined from the accumulated dust volume. Measurements 1–22 were performed with a 30-minute recording interval. Measurements 23–50 were performed with a 5-minute recording interval.

1.1 Alveolar fraction dust to be measured

In the PUTUSA project (Kokkonen et al. 2013), a target level for dust concentration was established for respirable dust (dust particles with a diameter of less than 10 µm, median particle size 4.25 µm) was set at a level that also brings quartz dust below the limit values specified in the EU Framework Directive (effective January 1, 2020). For respirable particles, the target level was set at **0.5 mg/m³** (8-hour average). If the concentration of respirable particles is 0.5 mg/m³, quartz accounts for approximately 10% of this, or 0.05 mg/m³, which is also the limit value for quartz in Finland defined as a concentration known to be harmful, i.e., the HTP level (0.05 mg/m³) (occupational hygiene reference value).

The Government Decree on the Prevention of Occupational Cancer Risks (1267/2019) sets a binding limit value of 0.1 mg/m³ (8-hour average) for exposure to quartz.

1.2 Measuring equipment

1.2.1 eGate, DUST40

IoT measurement devices wirelessly collect data on the most important parameters at a construction site or the site being measured, such as temperature, humidity, pressure differential, CO₂ concentrations in the air, dust and fine particles, and VOC levels. The devices can also be used to measure the relative humidity and strength of concrete. In this development project, we use Dust40 devices and a support station for measurement. The devices are manufactured by Nokeval Oy. eGate has developed cloud-based software that allows the data collected by the meters to be analyzed in real time.



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Image of the DUST-40 sensor
(*google.com*)



Image of the operating system
(*google.com*)

1.2.2 Cyclone collection

In cyclonic collection, the values of respirable dust are determined quantitatively using FT-IR in accordance with the NIOSH standard method. Sample particles are collected using a constant-flow pump into a collector equipped with a GS-3 cyclone capable of separating respirable dust. The collection method follows the alveolar fraction dust calibration curve, where the collection efficiency for particles with a diameter of 4 μm is 50%. Labroc Oy was the supplier/operator of the measurement equipment and sample analyses in this development project.

1.3 Organizations involved in the development project, the so-called dust working group

- Sitowise Oy, Jouni Huura, Matias Raiski
- eGate Smart Building Innovation Oy, Jarkko Haukijärvi
- Tampereen Tilapalvelut Oy, Jani Boström, Arto Ylinen
- Cramo Finland Oy, Mika Aalto
- Fira Oy, Jari Pulkkinen, Jarmo Kärkkäinen
- North Savo Welfare Region, Anna Kokkonen



1.4 Measurement sites

Messukylä School, renovation

Messukylänkatu 35, 33700 Tampere

Construction site

General contractor: Pirkanmaan Mestari-Rakentajat Oy

Vapriikki Museum Center, Alaverstaanraitti

5, 33101 Tampere Construction site

General contractor: Consti Oy

Tampere Central Government Building,
renovation Aleksis Kiven katu 14-16 C, 33101

Tampere Construction site

General contractor: YIT

Härmälä School Renovation Site Nuolialantie 47,

33900 Tampere Construction Site

General Contractor: Aki Hyrkkönen Oy



2 Measurement results

2.1 Graphs

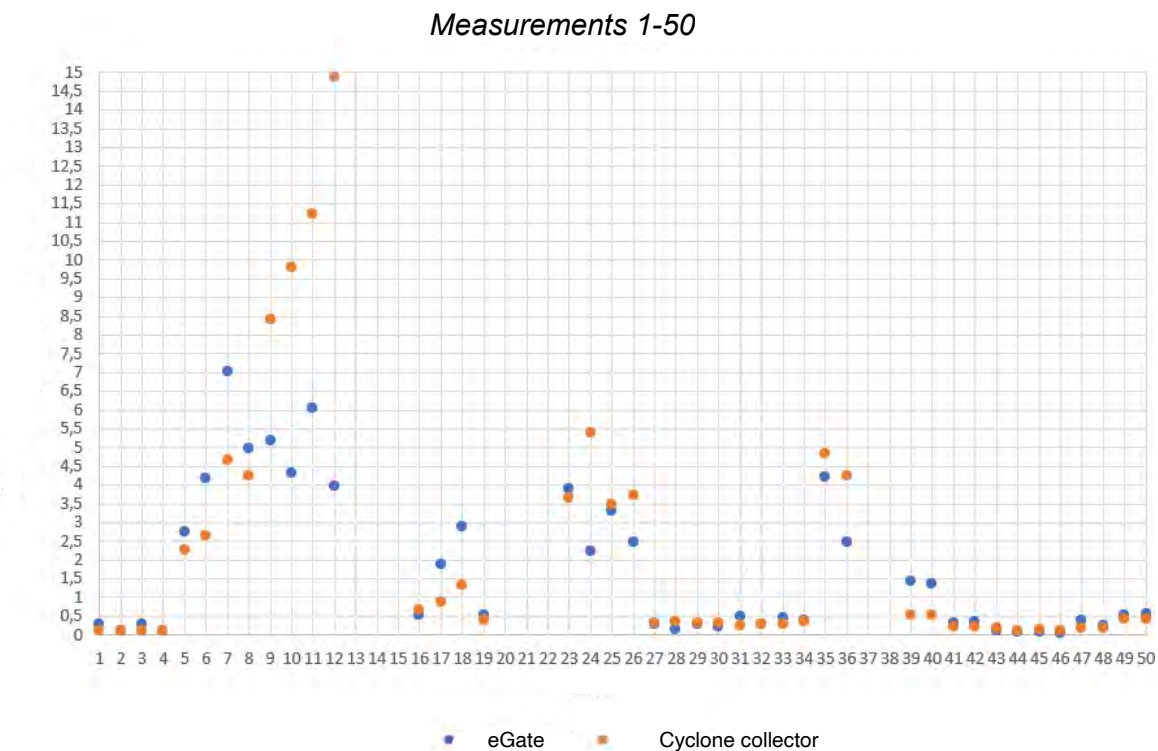


Figure 1. The graph shows all measurements (50 in total) in which both comparison devices measured PM4.



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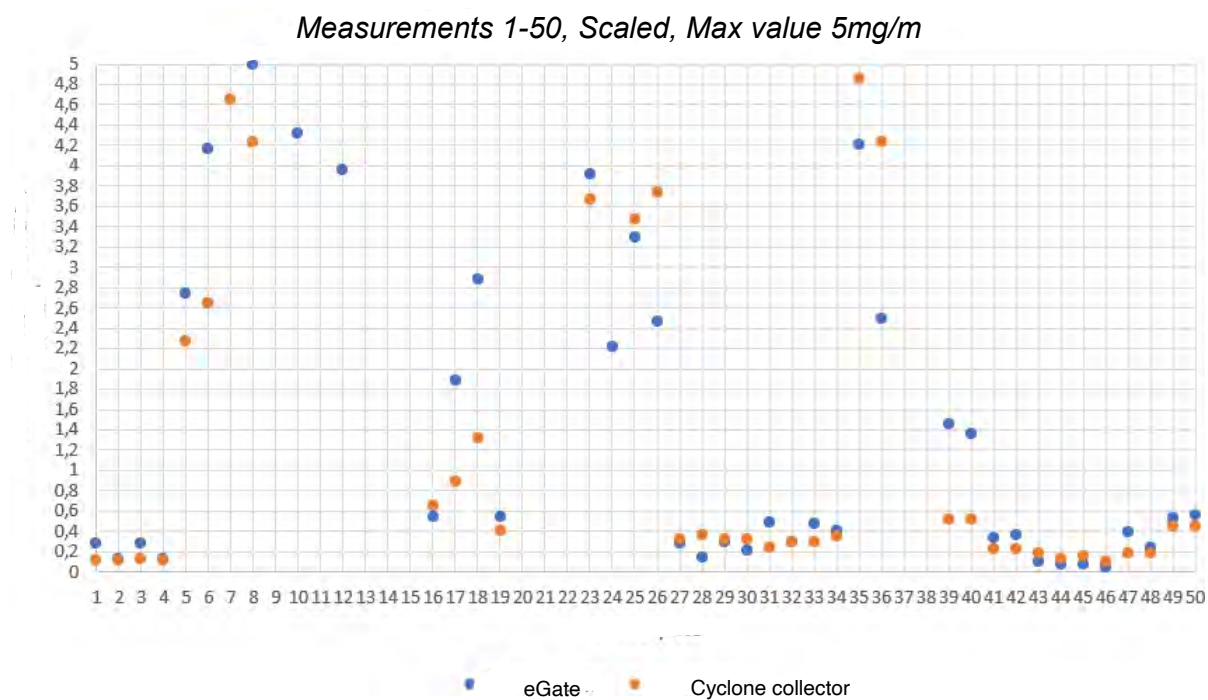


Figure 2. The graph shows all measurements (50). Measurement values exceeding 5 mg/m³ have been excluded from the graph.



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Measurements 23-50, measurement interval 5min

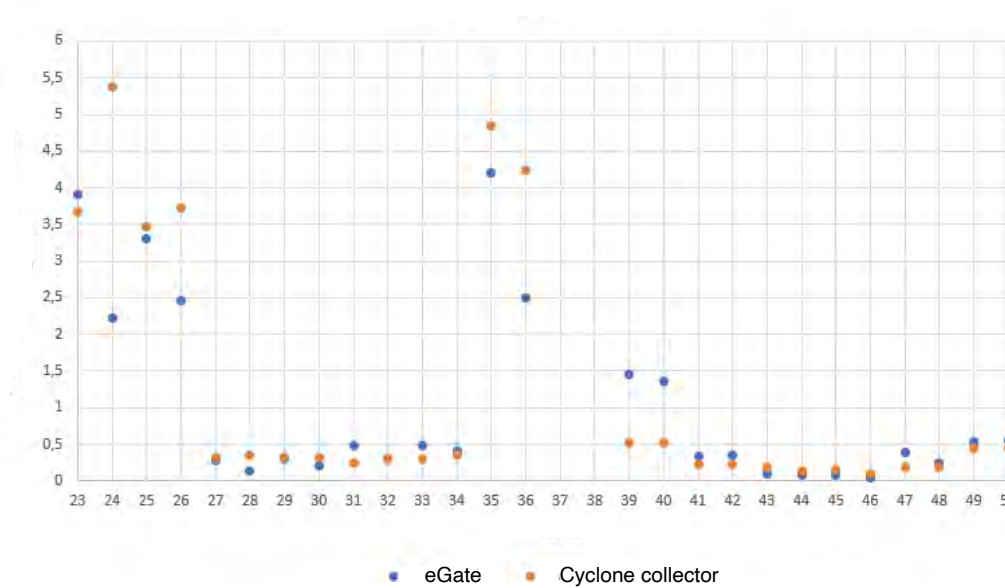


Figure 3. The graph shows measurements 1–22, in which the eGate system used a 30-minute data recording interval.

Measurements 1-22, measurement interval 30min

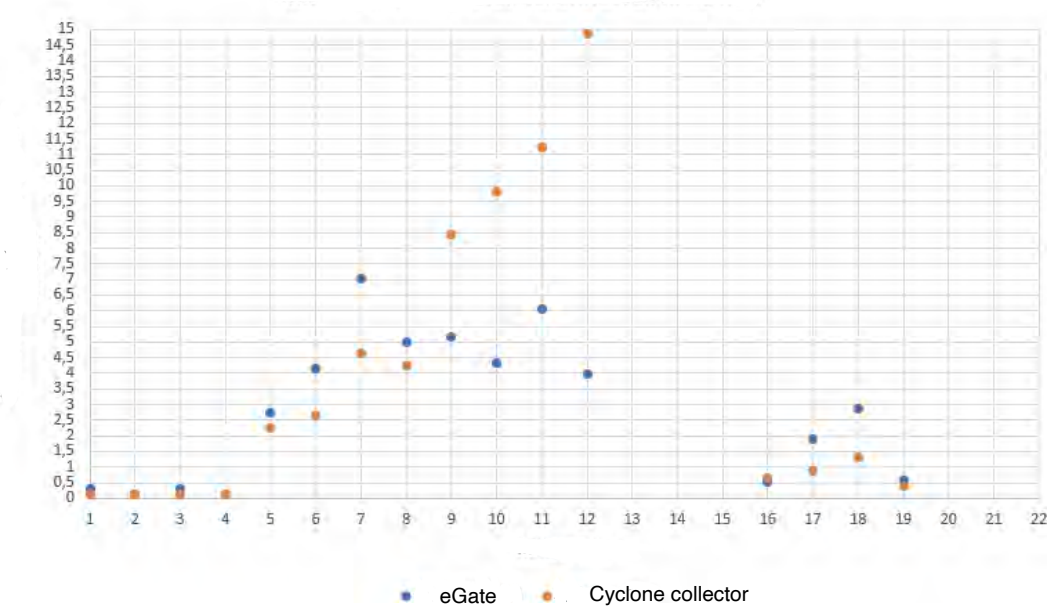


Figure 4. The graph shows measurements 23–50, in which the eGate equipment used a 5-minute data recording interval.



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Cyclone collector mg/m

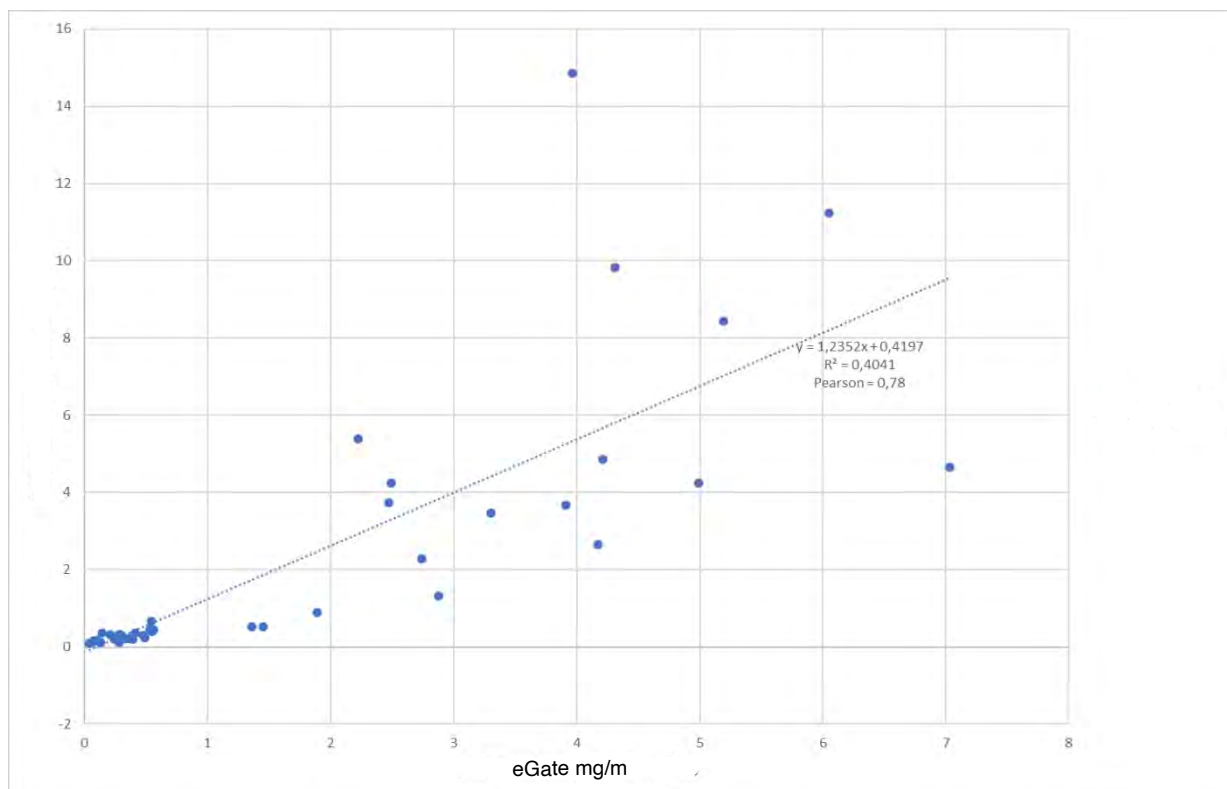


Figure 5. Table illustrating the correlation. Note how the variance increases as the dust mass increases. Prepared by Anna Kokkonen, North Savo Well-being Region.



2.2 Factors affecting the measurements and correlation

Correlation measurements were conducted at construction sites where demolition work was underway. Due to varying conditions, factors affecting the correlation occurred during the measurements, as explained below.

During the measurement periods, the amount of dust generated by construction work varied, depending on the type of work being performed and other changing factors.

eGate's measurement devices use mains power. In some measurements, the power supply was interrupted either partially or for nearly the entire duration of the measurement (plug unplugged from the outlet). The results of those measurements are not presented in the graphs above.

In cyclone measurement, dust particles are collected into a collector by a pump. Dust particles from a 360° area are drawn into the cyclone. The operating principle of eGate's DUST40 devices is based on through-flow, in which dust particles pass through the measuring device from only one direction. For example, if the measurement location is next to a wall, the cyclone collector essentially collects dust from a wider area.

When the cyclone collection is complete, the collection container is removed from the cyclone and sealed with a plastic lid. It is possible that additional dust particles may enter the collector during this process, which may contribute to an increase in the average value.



2.3 Photos of the measurement sites



Härmälä School renovation site, intermediate floor filling suction/cleaning work



Härmälä School renovation construction site, concrete beam demolition work



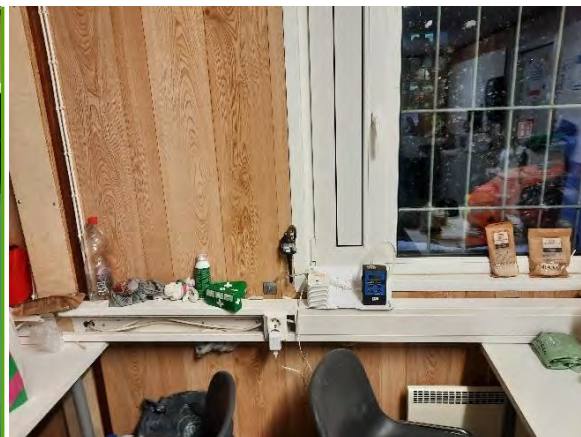
Härmälä School renovation , concrete/brick debris cleanup



Härmälä School Renovation construction site, surveyors taking measurements



Construction site shed, surveyors measuring



Construction site shed, measurement teams taking measuring

2.4 Measurement data

2.4.1 Measurements 1...4

Measurements 1–4 were conducted at the Messukylä School renovation site. The measurement locations were the lobby on the second floor of the school building and a classroom. The spaces were open. During the measurement, cleaning work was being carried out in the spaces, which included the removal of concrete debris. A vacuum cleaner was in use. The data recording interval was 30 minutes. Time:

March 23, 2023, 7:50 a.m. – 3:10 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.1	0.28	0.11
MP.2	0.13	0.11
MP.3	0.28	0.13
MP.4	0.13	0.11



2.4.3 Measurements 5...12

Measurements 5...12 were conducted at the Vapriikki Museum Center. The measuring equipment was installed in an approximately 8 m² vacuum chamber, where concrete window sills were being chiseled away. The data recording interval was 30 min.

Time: April 3, 2023, 7:50 a.m. – 3:20 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.5	0.66 (2.74*)	2.27
MP.6	1.00 (4.17*)	2.64
MP.7	1.76 (7.03*)	4.65
MP.8	1.22 (4.99*)	4.24

*For values marked with an asterisk in parentheses, the average includes data points where the dust concentration was higher (more accurately reflecting cyclonic separation).

Time: April 4, 2023, 7:11 a.m. – 3:15 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.9	2.17 (5.19*)	8.43
MP.10	1.82 (4.31*)	9.82
MP.11	2.20 (6.05*)	11.23
MP.12	1.18 (3.96*)	14.86

*For values marked with an asterisk in parentheses, the average includes data points where the dust concentration was higher (more accurately reflecting cyclonic separation).



2.4.4 Measurements 13...14

Measurements 13–14 were conducted at the renovation site of the Tampere Central Government Building. No laboratory test results were obtained for the cyclone collector from measurements 13 and 14. The measurement values are not shown in the graph. The data recording interval was 30 minutes.

Time: May 26, 2023, 8:37 a.m. – 3:15 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.13	0.18	-
MP.14	0.11	-

2.4.5 Measurements 15–18

Measurements 15–18 were conducted at the renovation site of the Tampere Central Government Building. During measurements 17 and 18, cleanup work involving concrete and brick debris was carried out. During measurements 15 and 16, Siporex partition walls were being demolished. Negative pressure systems were in use in the premises during the measurements. No DUST40 values were obtained in measurement 15. The data recording interval was 30 min.

Date and time: May 29, 2023, 8:15 a.m. – 3:13 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.15	Measurement failed	0.22
MP.16	0.54	0.66
MP.17	1.89	0.89
MP.18	2.88	1.32



Measurement points 19–50 are presented in this report and in the eGate graphs (Appendix 1) in the range 19–50. In the cyclone separator research reports (Appendix 2), the measurement points are presented in the range 1–32. For example: 19 = 1, 20 = 2, 21 = 3, etc.

2.4.6 Measurements 19...22

During measurements 19...22, cleanup work involving concrete and brick waste was carried out. In measurements MP.02...MP.04, eGate did not collect data; the measurer does not know the reason. In measurement 01, the data recording interval was approx. 30 min.

Time: October 9, 2023, 8:58–11:19

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.19	0.55	<0.4
MP.20	Measurement failed	<0.4
MP.21	Measurement failed	<0.4
MP.22	Measurement failed	<0.4

2.4.7 Measurements 23...26

During measurements 23...26, concrete and brick demolition work was carried out. The data recording interval for the measurements was approx. 5 min.

Time: October 9, 2023, 11:40 a.m.–2:11 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average average
MP.23	3.91	3.67
MP.24	2.22	5.38
MP.25	3.30	3.47
MP.26	2.47	3.73



2.4.8 Measurements 27–30

During measurements 27...30, suction work and cleaning of the lower slab were performed. The data recording interval for the measurements was approximately 5 min.

Time: October 10, 2023, 8:10–10:30 a.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.27	0.28	<0.32
MP.28	0.14	0.36
MP.29	0.29	<0.32
MP.30	0.21	<0.32

2.4.9 Measurements 31...34

During measurements 31...34, suction work and cleaning of the lower slab truss were performed. The data recording interval for the measurements was approximately 5 min.

Time: October 10, 2023, 10:26 a.m.–1:18 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.31	0.49	<0.24
MP.32	0.30	0.30
MP.33	0.48	0.30
MP.34	0.41	0.35

2.4.10 Measurements 35...38

During measurements 35...38, cleanup work involving concrete and brick debris was carried out. The data recording interval for the measurements was approximately 5 minutes.

Time: November 21, 2023, 8:29 a.m.–2:29 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.35	4.21	4.85
MP.36	2.49	4.24
MP.37	Measurement failed	5.01
MP.38	Measurement failed	5.13



2.4.11 Measurements 39...40

During measurements 39 & 40, suction work and cleaning of the lower slab were performed. The data recording interval for the measurements was approx. 5 min.

Time: November 22, 2023, 8:33–11:05

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.39	1.45	0.52
MP.40	1.36	0.52

2.4.12 Measurements 41...42

During measurements 41 & 42, suction work and cleaning of the lower slab truss were performed. The data recording interval for the measurements was approximately 5 minutes.

Time: November 22, 2023, 11:17 a.m.–2:12 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.41	0.33	< 0.22
MP.42	0.36	< 0.22

2.4.13 Measurements 43...46

Measurements 43...46 were conducted in the break rooms (changing room and coffee room) at the Härmälä School construction site. The data recording interval for the measurements was approximately 5 minutes.

Time: December 12, 2023, 8:15 a.m.–3:38 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.43	0.1	0.18
MP.44	0.07	0.13
MP.45	0.07	0.16
MP.46	0.04	0.10



2.4.15 Measurements 47...50

Cleaning was performed during measurements 47...50. The data recording interval for the measurements was approx. 5 min.

Time: December 14, 2023, 8:15 a.m.–3:48 p.m.

Measurement point	DUST40, PM4 (mg/m ³), average	Cyclone collector, PM4 (mg/m ³), average
MP.47	0.39	0.19
MP.48	0.24	0.19
MP.49	0.53	0.44
MP.50	0.56	0.44

3 Assessment of the study's reliability

3.1 General observations

The purpose of the study was to determine the reliability and suitability of the real-time measurement method for construction site conditions. For this reason, the measurements were performed under actual construction site conditions.

During the development work, the following issues relevant to the assessment of the equipment's reliability were identified:

- When evaluating the measurement accuracy of the equipment, it is appropriate to focus on the dust concentration range corresponding to the target dust concentration level of 0.5 mg/m³ for the alveolar fraction, as an eight-hour average concentration.
- The measurement interval of the equipment must be 5 minutes.

The aforementioned measurement setup achieved a reliable correlation between the measurement results of the eGate devices and the cyclone collector with sufficient certainty. The study did not investigate the effect of long-term use or calibration of the measurement equipment on the measurement results. This must be taken into account in future measurements.



The conclusions of the study pertain to the eGate equipment used in the measurements and cannot be generalized as such to other similar equipment. However, it is reasonable to utilize the observations and experiences gained in this study when evaluating the performance of other similar equipment.

3.2 Further Development of Reliability

Based on the study, the following development needs can be identified to improve the reliability of similar measurement systems:

1. Calibration and certification of equipment

The correlation of the equipment used with the results of cyclone separators must be demonstrated. System suppliers must prepare guidelines for the calibration of equipment to verify its reliable operation.

2. Qualification of personnel

Reliable use of the measurement method requires that the surveyor be proficient in operating the measurement system and understand how site conditions affect measurement results. For this reason, it is necessary to define the qualification requirements for surveyors and ensure that the necessary training is provided.

3. Measurement instructions for surveyors

Proper consideration of measurement arrangements and site conditions affects the reliability of measurements. For this reason, it is necessary to prepare general site instructions for measurers.



4 Conclusions and recommendations for further development

A total of 62 measurements were taken in the development project in connection with a previous thesis and this study. The thesis concluded that the eGate measurement system should be programmed to measure dust particles with a diameter of 4 µm, which is close to the median size of alveolar dust (4.25 µm). Through development work, the eGate sensors were made capable of measuring the 4 µm dust fraction, similar to the comparable cyclone measurement method.

As the measurements progressed, the 30-minute data recording interval (measurement interval) of the eGate sensors was changed to five minutes, making the average results between the two devices being compared more comparable. The final and largest measurement batch (30 units) was conducted using settings achieved through development work (4 µm & 5-minute recording interval), which yielded results of the highest quality currently possible.

The conclusions drawn from the measurement results in this report are presented below.

When examining the correlation between the two devices for all measurements, nearly identical results (with a difference of less than 0.2 mg/m³ in most cases) were obtained in 32 measurements. This figure is high, considering the factors that significantly affect the reliability of the measurement results, as presented above. It is worth noting in the interpretation of the measurement results that even a cyclone collector approved for the measurement of respirable dust can yield erroneous results due to user error or environmental conditions. In 29 of these 32 measurements, the results from both measurement methods either exceeded or fell below the target dust concentration level of 0.5 mg/m³ for the alveolar fraction, expressed as an eight-hour average concentration. When measuring construction site dust, exceedances of the target level provide significant information regarding the effectiveness of dust control, and based on the results, eGate equipment can be reliably used to detect exceedances of the target level.

The measurement results showed a weaker correlation in measurements where the work performed at the site was particularly dusty and the dust mass rose above 2



mg/m^3 . As the dust mass increases, so does the significance of factors affecting the reliability of the correlation, such as the difference between the 360° collection area of the cyclone collector and the one-sided collection (through-flow) of the DUST 40 devices.

eGate sensors use an external power supply. In some measurements, the power supply was interrupted either during part of the measurement period or for the entire duration of the measurement. Naturally, no correlation could be determined from these measurements. To improve the usability of the sensors, they should be converted to battery or rechargeable battery operation. Battery life must be taken into account (to enable long-term measurement). When measuring the average concentrations (8 h) of respirable dust generated at a construction site, a factor significantly affecting the reliability of the result is that the measurement is taken over the entire 8-hour period. In addition, to minimize measurement errors, attention must be paid to certain factors, such as the placement of sensors in the measurement area.

The original objective of the thesis/development project was to obtain approval for the eGate equipment to measure harmful quartz dust generated in construction site conditions. Quartz, or crystalline silica, is generated at construction sites during the mechanical processing of concrete (e.g., chipping). In cyclone measurement, the proportion of quartz in the respirable dust fraction can be determined separately in the laboratory. eGate's sensors do not distinguish the amount of quartz. In areas where work generating respirable dust is performed, the target limit for respirable dust concentration is set at $0.5 \text{ mg}/\text{m}^3$. If the work involves construction activities that generate quartz dust (e.g., concrete chipping/grinding), it has been determined that when the respirable dust concentration falls below $0.5 \text{ mg}/\text{m}^3$, the proportion of quartz remains below the HTP level (concentrations known to be harmful) of $0.05 \text{ mg}/\text{m}^3$.

Based on the above, it is possible to use eGate devices to measure exceedances of the HTP level for quartz, as well as exceedances of the limit value specified in Government Decree 1267/2019. However, this requires that the quality of the materials being processed is known. It should also be noted that even if



the material being processed is known, the quartz content of dust sources can still vary between 0–100%.

Based on the development project's report, the eGate measurement is a viable method for real-time dust measurement to monitor the effectiveness of dust control at construction sites. However, the method does not replace occupational hygiene measurements in assessing worker exposure.



5 Sources

- Anna Kokkonen et al., Dust Control in Renovation Construction, Final Report, 2013
- 1267/2019 Government Decree on the Prevention of Occupational Cancer Risks
- Ministry of Social Affairs and Health, HTP VALUES 2020
- Correlation measurement between eGate's dust measurement system and a cyclone collector, Matias Raiski, thesis 2022

6 Appendices

1. eGate, measurement data, graphs by measurement point
2. Cyclone collector, quartz and dust volume, research reports, Labroc Oy

7 Signatures

Sitowise Oy

Tampere, April 12, 2024



Matias Raiski, B.Sc. (Tech.)

Building



Jouni Huura, Architect

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050 517 5611

