Inmetro's participation in the second run of SIM kilogram dissemination project (SKDP)

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Abstract. Inmetro's metrology mass laboratory (Lamas) participated in SIM Kilogram Dissemination Project (SKDP). The assessment of mass stability of the SIM21 1 kg stainless steel mass standard was carried out between 2018 and 2021 and a second run of measurements is in progress. The new results show a typical variability for a weighing system but not clear trend in measurements. Therefore one can say no mass drift for SIM21 mass standard was observed along the period between 2018 and 2023.

1. Introduction

In the SIM meeting in Montevideo Uruguay (2018), the SIM kilogram dissemination project (SKDP) was introduced to the participant, National Metrology Institutes (NMIs), and the Brazil's participation was agreed. The (SKDP) is a research project involving a set of highly correlated stainless steel mass artifacts standards provided to the participating NMIs across the SIM region aiming to assess their stability in use. Each mass standard is made of the same material and has similar surface, magnetic and density properties. The cylindrical mass standards were manufactured from one of two stainless steel rods with each artifact numbered based on the position within the rod from which it was cut.

The S21 standard was assigned to Inmetro and the mass measurements were performed between 2018 and 2021 [1] when it was returned to NIST (USA) for new mass measurements. In 2022 a 2nd run of mass measurements for the S21 standard was agreed and the results of this study are shown here.

2. Framework for mass measurements

The setup for mass measurements is the same shown in [2]. Data of S21 characterization with new mass measurement from NIST are shown in tables 1 – 3 [3]. Figure 1 shows the receipt of the SIM21 mass standard.

Table 1. Volume, Density and Coefficient of Volumetric Expansion.

Mass Identification	Volume [cm^3] at 20 °C	Volume Uncertainty [cm^3] (k = 1)	Density [g/cm^3] at 20 °C	Density Uncertainty [g/cm^3] (k = 1)	Volumetric Coef. of Exp. [$°C^{-1}$]
SIM21	124.4236	0.0037	803.706	0.00024	0.000045

Table 2. Mass Corrections and Uncertainties.

Date	Nominal [g]	True Mass Correction [mg]	True Mass Uncertainty mg (k = 1)	Conventional Mass Correction [mg]	Conventional Mass Uncertainty [mg] (k = 1)
20 May 2019	1000	0.4675	0.0158	1.1592	0.0152
17 Jan 2022	1000	0.4549	0.0277	1.1467	0.0273

A 13 µg mass variation in the mass correction can be a result of the standard transport between NIST – Inmetro – NIST. Thus, the increased uncertainty for 2022 measurements [4] should be due to the addition of an uncertainty component for transport which was not accounted for in the 1st run of measurements.

Table 3. Measurement Environmental Conditions.

	Temperature [°C]	Humidity [%RH]	Pressure [kPa]	Computed Air Density [mg/cm^3]
Average	20.270	45.5	100.425	1.1879

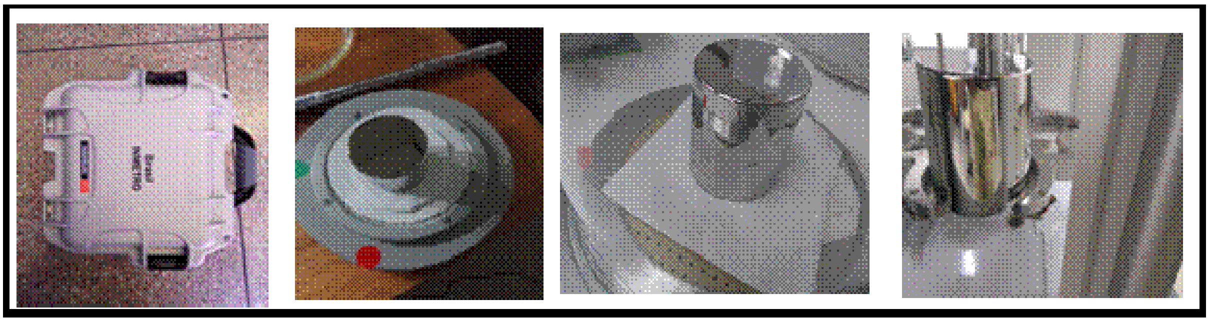

Figure 1. Receipt, storage and placing upon the weight handler of AT1006 mass comparator of S21 standard.

Weighings performed in a 1 kg automatic mass comparator Mettler Toledo AT1006 with the aid of a climate station Klimet A30 were corrected for buoyancy effect where air density were determined by CIPM equation [5]. The 1 kg mass standards used to check the stability of SIM/NIST S21 standard in mass and conventional mass are shown in Inmetro’s traceability chain in figure 2 [6].

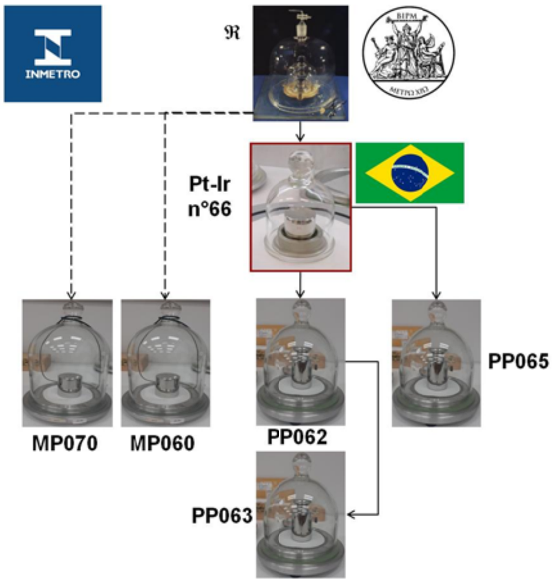

Figure 2. Inmetro's traceability chain

The typical environmental conditions in a period of a week (May 26th to June 4th 2021) in Module 1 of Lamas are shown in figures 3, 4 and 5.

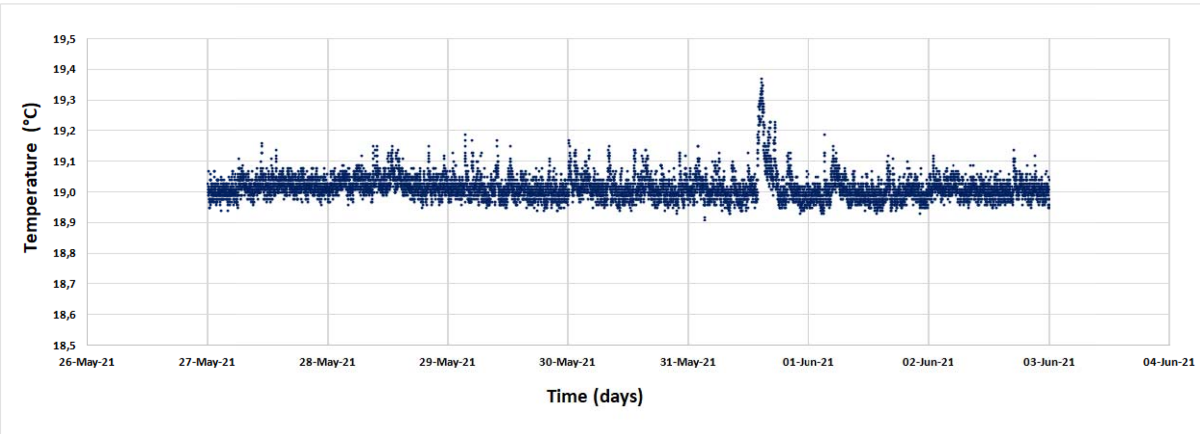

Figure 3. Air temperature.

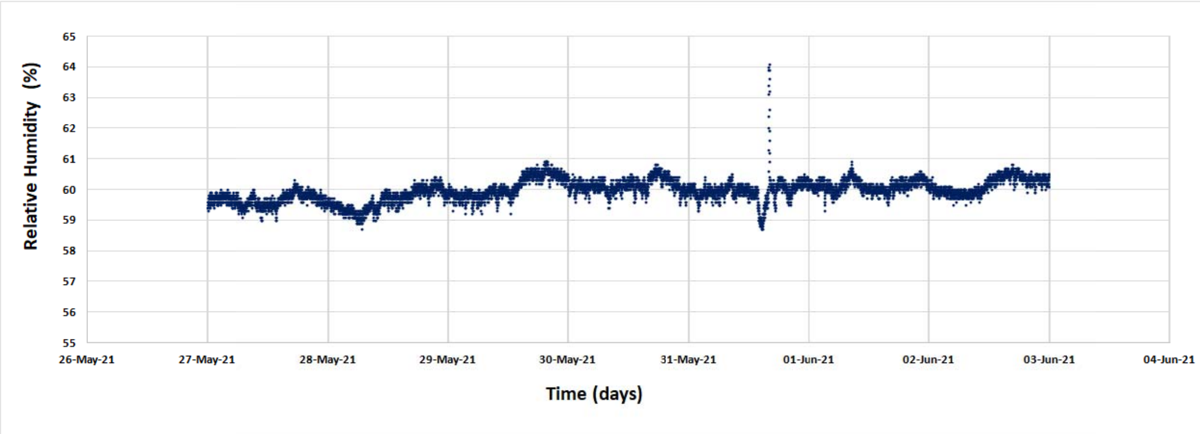

Figure 4. Air relative humidity.

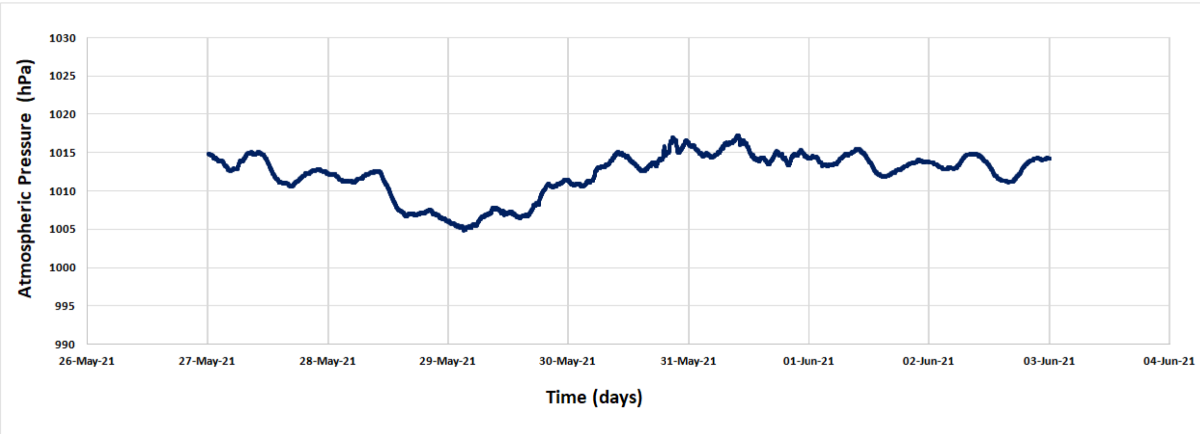

Figure 5. Atmospheric pressure.

3. Results

The mass measurements for the S21 standard performed between 2018 and 2023 are shown in table

Table 4. Measurement results from 2018 up to 2023.

Date	(Mass - 1 kg)/mg	$u(k=1)$/mg	Ref Std
29/10/2018	0.477	0.018	MP060
03/12/2018	0.480	0.033	PP062
09/12/2018	0.492	0.033	PP062
14/06/2019	0.477	0.020	MP060
29/11/2019	0.480	0.020	PP062
03/12/2019	0.478	0.020	PP062
14/01/2020	0.475	0.020	PP065
29/05/2021	0.474	0.016	MP060
04/03/2022	0.476	0.020	MP060
08/03/2022	0.477	0.020	MP060

10/03/2022	0.472	0.017	MP070
12/03/2022	0.471	0.016	MP070
12/03/2022	0.472	0.017	MP070
14/03/2022	0.481	0.020	MP060
26/01/2023	0.479	0.020	MP060
31/01/2023	0.480	0.020	MP060
03/02/2023	0.480	0.020	MP060
03/05/2023	0.477	0.020	MP060

The measurements performed in conventional mass are shown in table 5.

Table 5. Measurement results in conventional mass.

Date	(Conv. Mass - 1 kg)/mg	$u(k=1)$/mg	Ref Std
29/10/2018	1.168	0.018	MP060
02/12/2018	1.167	0.034	PP063
03/12/2018	1.171	0.033	PP062
09/12/2018	1.184	0.033	PP062
09/12/2018	1.176	0.034	PP063
14/06/2019	1.169	0.020	MP060
29/11/2019	1.172	0.020	PP062
03/12/2019	1.170	0.020	PP062
14/01/2020	1.167	0.020	PP065
24/07/2020	1.186	0.023	PP063
28/07/2020	1.194	0.023	PP063
05/08/2020	1.189	0.024	PP063
12/08/2020	1.190	0.023	PP063
29/05/2021	1.166	0.016	MP060
08/03/2022	1.168	0.020	MP060
08/03/2022	1.169	0.020	MP060
10/03/2022	1.164	0.014	MP070
12/03/2022	1.163	0.015	MP070
12/03/2022	1.164	0.014	MP070
14/03/2022	1.172	0.020	MP060
26/01/2023	1.171	0.020	MP060
31/01/2023	1.172	0.020	MP060
03/02/2023	1.172	0.020	MP060
03/05/2023	1.169	0.020	MP060

The deviations $d_i = M_{Inmetro} - M_{NIST}$ between Inmetro's mass or conventional mass measurements and those provided by NIST allow to evaluate the progress of measurements over time. The deviation in mass and conventional mass are shown, respectively, on figures 6 and 7. Since Inmetro and NIST measurements can be considered uncorrelated, uncertainty bars u (d_i) means the root of the sum of the variances associated to the respective u (k=1).

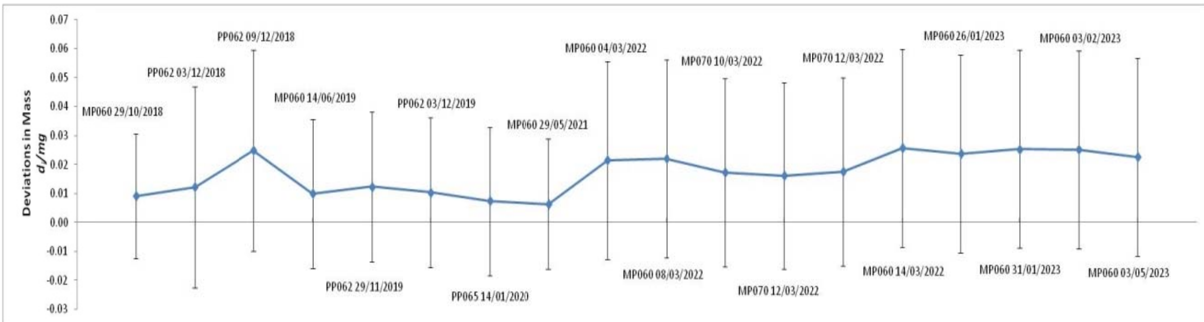

Figure 6. Deviations in mass between Inmetro and NIST measurements over time.

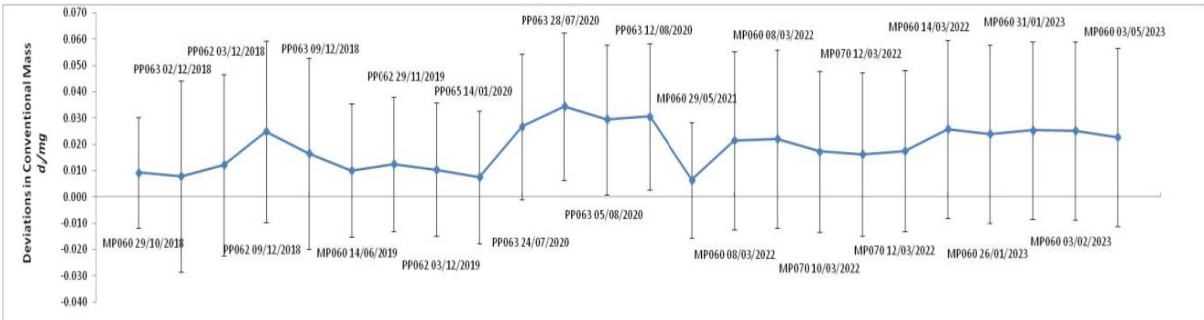

Figure 7. Deviations in conventional mass between Inmetro and NIST measurements over time.

Since Inmetro's mass measurements are correlated with correlation coefficient 1 due to systematic effects as buoyancy or traceability, mass variations are affected just for random effects. Thus, at consecutive times i and j ($j > i$) the mass variation $M_{\text{inmetro}\ j}$ - $M_{\text{inmetro}\ i}$ can be evaluated with reduced uncertainties. Inmetro's typical repeatability for 1 kg comparisons at 10 ABBA weighing cycles is about 0.002 mg yielding a 95 % confidence interval from Student-t of 0.007 mg for mass variations. Mass and conventional mass variations between consecutive measurements are shown on figures 8 and 9.

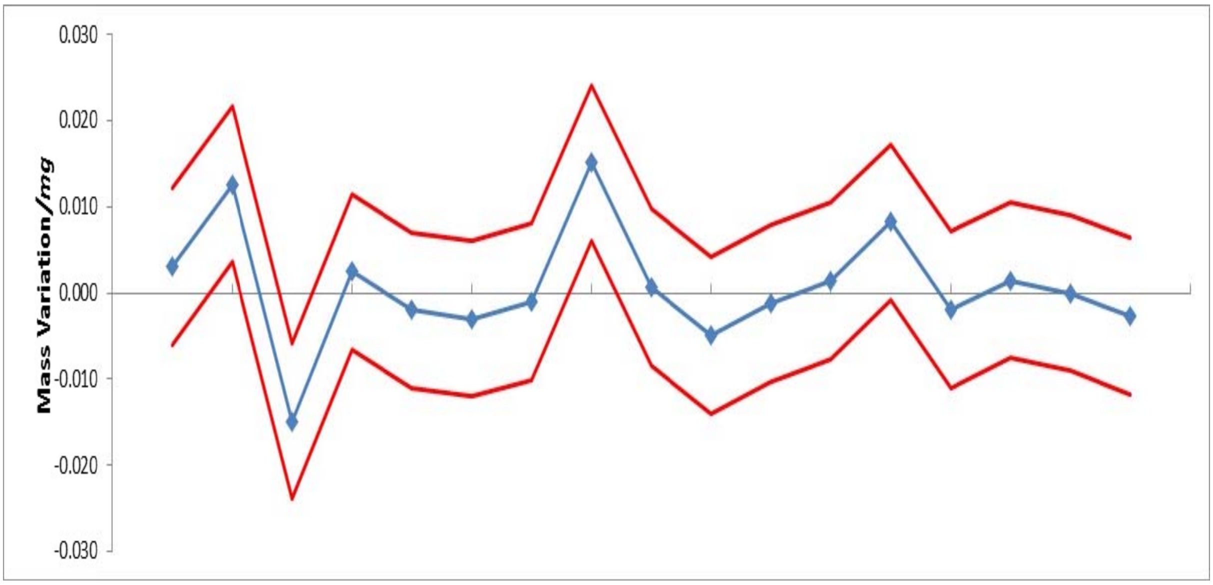

Figure 8. Mass variations (blue line) and confidence interval limits (red line).

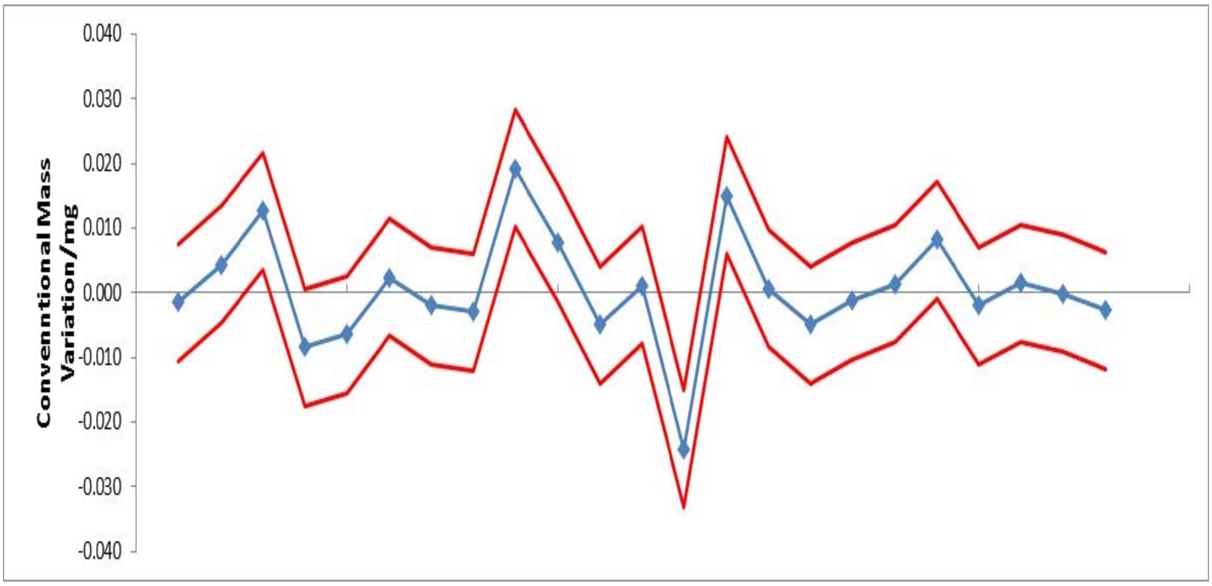

Figure 9. Conventional mass variations (blue line) and confidence interval limits (red line).

4. Conclusion

Inmetro is one NMI participating in SIM Kilogram Dissemination Project (SKDP). The mass measurements for the SIM21 standard were carried out at Inmetro between 2018 and 2023.

In the first run of measurements (2018 – 2021) most mass and conventional mass measurements were compatible with the measurement value provided by NIST, but some are not. In the second run, compatibility was obtained as a result of the added uncertainty transport in 2022 NIST's mass measurement value. The observed mass variations demonstrate typical random fluctuations compatible with the variability of our measurement system. Therefore, it can be considered that within 30 µg no mass variation of the SIM21 standard was observed in both runs of measurements.

Acknowledgments
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