Laboratory Ventilation Inspection & Failure Data

Literature Review & Data Compilation Report

1. Literature Sources

1.1 Chinese Literature

#	Title	Source / Journal	Year	Sample Size
1	2025 National Laboratory Safety Hazard Special Inspection Bulletin	Joint bulletin by Ministry of Emergency Management & Ministry of Education	2025	Nationwide R&D, educational & testing laboratories
2	Survey of Local Exhaust Ventilation Facilities in 27 Manufacturing Enterprises, Shanghai	Journal of Occupational Health and Emergency Rescue	2024	27 enterprises, 52 fans, 49 exhaust hoods
3	Investigation and Analysis of Air Pollution in a University Laboratory	Experiment Science and Technology (UESTC)	2022	University lab questionnaire + field testing
4	Study on Basic Metrological Characteristics of Biological Safety Cabinets	Metrology Science and Technology (NIM)	2023	Multi-brand BSC comparative testing
5	T/NAHIEM 64—2022 Technical Standard for Workbench Front Suction-Type Fume Hoods	National Association of Health Industry Enterprises — Hospital Building Engineering Equipment Branch	2022	Industry standard
6	JG/T 222—2007 Variable Air Volume Fume Hoods	Ministry of Construction Industry Standard	2007	Industry standard

1.2 International Literature

#	Title	Source / Journal	Year	Sample Size
7	Performance evaluation of biological safety cabinets: a real-world analysis	Frontiers in Bioengineering and	2026	360 Class II BSCs in Beijing, 1,803 test

		Biotechnology		records (2018–2023)
8	Testing the performance of microbiological safety cabinets used in microbiology laboratories in South Korea	Letters in Applied Microbiology (Oxford)	2011	31 MSCs across 14 facilities in South Korea
9	Quantitative evaluation of chemical fume hoods performance by CO_2 tracer gas	American Journal of Infection Control / Medscape	2022	Multi-laboratory chemical fume hoods
10	Evaluation and control of formaldehyde exposures in a modern university anatomy laboratory	Journal of Occupational and Environmental Hygiene	2026	University anatomy laboratory
11	A review of published quantitative experimental studies on factors affecting laboratory fume hood performance	Seoul National University (Elsevier)	2008	Review of 43 studies (1966–2006)

2. Core Failure Data Summary

2.1 Fume Hood Failure Data

(1) National-Level Inspection Data (Source 1)

Based on the 2025 National Laboratory Safety Hazard Special Inspection Bulletin:

Indicator	Value
Overall fume hood non-compliance rate	**18.7%**
Face velocity out of standard	42% of non-conforming items
Air tightness failure	28% of non-conforming items
Exhaust filtration system failure	22% of non-conforming items
Control system malfunction	8% of non-conforming items
Annual incidents caused by fume hood defects	127 incidents
Direct economic loss	RMB 190 million

> Source: 2025 National Laboratory Safety Hazard Special Inspection Bulletin, as cited in the 2026 Non-conforming Fume Hood Rectification Plan.

(2) SAMR Sampling Data

- National sampling of 100+ universities: **over 60% of fume hoods are non-compliant**
- Typical case — a southwestern university: out of 28 fume hoods, **19 (67.9%)** had face velocity persistently below 0.3 m/s (national safety threshold: 0.35 m/s)

> Source: State Administration for Market Regulation (SAMR) product quality supervision sampling bulletin.

(3) CO_2 Tracer Gas Quantitative Evaluation (Source 9)

Test Condition	Pass Rate	Leakage Rate
Sash fully open	**0%**	—
Sash half open	Only 16.3%	—
Sash at 25% opening	34.9%	—
Visible leakage (overall)	—	**50.2%**

(4) International Expert Estimate

Dr. Mark Tan (laboratory safety consultant): an estimated **50% of all chemistry fume hoods do not operate at peak efficiency**.

2.2 Biological Safety Cabinet (BSC/MSC) Failure Data

(1) Large-Scale Cross-Sectional Survey in Beijing (Source 7)

Sample: 360 Class II BSCs, 1,803 test records (2018–2023), 52 general hospitals in Beijing

Indicator	Value
Overall pass rate	**70.4%**
Domestic BSC pass rate	71.3%
Imported BSC pass rate	69.2%
Median service life	7 years (IQR 5–10 years)

Indicators with relatively lower pass rates:

- Inflow velocity — among the lowest pass-rate indicators
- Downflow velocity — among the lowest pass-rate indicators
- Illumination — among the lowest pass-rate indicators

Service life vs. pass rate relationship:

- Service life <5 years: FQP (Fully Qualified Performance) rate extremely high (aOR = 32.44)
- Service life 5–10 years: medium FQP rate (aOR = 6.37)
- Service life >10 years: significant performance degradation

> Cited NIFDC (National Institutes for Food and Drug Control) data: among 187 Class II BSCs, the **non-conformance rate reached 63%** for units in service for approximately 7 years.

(2) Korean MSC Performance Test (Source 8)

Sample: 31 Class II MSCs across 14 facilities (Type A1: 8, Type A2: 19, unknown type: 4)

Indicator	Value
Overall pass rate	**Only 23%**

Failure cause distribution (multi-factor overlap):

Failure Cause	Proportion
Inappropriate intake velocity	**65%**
HEPA filter sealing leakage	**50%**
Unbalanced airflow smoke pattern inside cabinet	39%
Inappropriate downflow velocity	27%

> Source: Hwang SH, Yi TW, Cho KH, Lee IM, Yoon CS. Letters in Applied Microbiology, 2011, 53(3): 371–373.

2.3 Local Exhaust Ventilation System Failure Data

Shanghai 27-Enterprise Survey (Source 2)

Sample: 27 enterprises, 52 ventilators, 49 local exhaust hoods

Exhaust hood problem distribution:

Failure Type	Non-conformance Rate	Standard Reference
Expansion angle >90° (should be ≤60°, not exceed 90°)	**46.9% (23/49)**	GB/T 16758—2008
Control distance > hood equivalent diameter (should be ≤D)	42.9% (21/49)	Industrial ventilation theory

Control velocity <0.25 m/s (minimum requirement)	38.8% (19/49)	GBZ/T 194—2007

Ventilator problem distribution:

Failure Type	Non-conformance Rate
Connected hood outlets >10 (recommended ≤10)	**51.9% (27/52)**
Actual airflow / rated airflow ≤0.7 (severe efficiency decay)	**51.9% (27/52)**
No inspection port on duct upstream of fan	32.7% (17/52)

Airflow uniformity across hoods on the same fan (farthest / nearest ratio):

Ratio Range	Proportion
≤0.5 (severe non-uniformity)	9.6%
0.5–0.7 (non-uniform)	15.4%
0.7–0.9 (basically uniform)	46.2%
>0.9 (uniform)	28.8%

> Source: Journal of Occupational Health and Emergency Rescue, 2024, Issue 5. DOI: 10.16369/j.oher.issn.1007-1326.2024.05.009

2.4 HVAC / Ventilation System Common Failure Causes

Lab Cleanroom HVAC Insufficient Airflow Failure Causes (Engineering Statistics)

Failure Cause	Proportion Range	Troubleshooting Method
Filter clogging	**40%–50%**	Measure initial resistance
Fan belt slack / wear	20%–30%	Visual inspection + RPM measurement
Duct air leakage	15%–20%	Light leakage test
Others (fan performance decay, damper drift, etc.)	Remainder	—

Fan Performance Decay Data (Tsinghua University School of Environment, 2023)

Service Life	Airflow Retention Rate	Power Loss

3 years	92 ± 3%	5%
8 years	**76 ± 5%**	18%

3. Failure Type Classification — Cross-Equipment Comparison

Failure Category	Specific Symptoms	Affected Equipment	Frequency
Velocity non-compliance	Face velocity too low/high, inflow velocity improper, control velocity insufficient	Fume hood, BSC, exhaust hood	★★★★★ Highest
Filtration system failure	HEPA filter leakage, filter clogging, initial resistance exceedance	BSC, fume hood exhaust filter section, cleanroom HVAC	★★★★☆
Air tightness issues	Cabinet seal leakage, duct leakage, sash seal failure	Fume hood, BSC, ductwork	★★★★☆
Airflow pattern abnormality	Unbalanced smoke flow pattern, vortex, dead zones, airflow disturbance	BSC, fume hood	★★★☆☆
Control system failure	VAV response delay, sensor drift, alarm failure, damper drift	VAV fume hood, BSC control unit	★★★☆☆
Fan / power transmission failure	Belt wear, fan efficiency decay, motor failure	Ventilator, exhaust fan	★★★☆☆
Design deficiency	Excessive expansion angle, too long control distance, too many hood branches, excessive system resistance	Exhaust hood system, pipe network	★★★☆☆

4. Key Standard Limits Reference

Test Item	Standard Limit	Standard No.
Fume hood face velocity	0.3–0.5 m/s (VAV type)	JG/T 222—2007
Face velocity deviation	≤30% (max/min deviation from average)	T/NAHIEM 64—2022
BSC inflow velocity	≥0.50 m/s	YY 0569—2011
BSC downflow velocity	0.25–0.50 m/s	YY 0569—2011
BSC noise	≤67 dB(A)	JG 170—2005

BSC illumination	≥650 lx	JG 170—2005
HEPA filter leakage rate	Type A ≤0.01%; Type B supply ≤0.01%, exhaust ≤0.005%	SN/T 3901—2014
Exhaust hood expansion angle	Preferably <60°, must not exceed 90°	GB/T 16758—2008
Workplace control velocity	0.25–3 m/s (minimum ≥0.25 m/s)	GBZ/T 194—2007

5. Key Conclusions and Findings

1. **Non-compliance rates are universally high:** Overall fume hood non-compliance is ~18.7% (national level), BSC non-compliance is ~30% (Beijing survey), and Korean MSC survey showed as high as 77% failure rate — reflecting a generally unsatisfactory operational status of laboratory ventilation equipment.
2. **Velocity non-compliance is the #1 failure mode:** Cross-equipment, cross-study evidence consistently shows that face velocity / inflow velocity / downflow velocity / control velocity issues rank first among all failures (42% for fume hoods, 65% for BSCs in Korea) — these are the core inspection indicators.
3. **Service life is a critical factor:** BSCs in service for 7 years can reach 63% non-compliance; after 8 years, fan airflow retention drops to only 76% — indicating that aging decay is a systemic problem.
4. **HEPA filter issues are prominent:** 50% of Korean MSCs had sealing leakage; filter clogging accounts for 40–50% of cleanroom HVAC failures — filtration systems are the second largest failure source.
5. **Design-stage deficiencies cannot be ignored:** The Shanghai survey showed 46.9% of exhaust hoods had excessive expansion angles and 51.9% of fans had too many connected hood branches — many failures originate at the design phase rather than the maintenance phase.

This report is compiled from publicly available literature for technical reference purposes only.