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Abstract: Ensuring reliable water quality testing requires the use of Certified Reference Materials (CRMs) and participation in Proficiency Testing (PT). This study surveyed 244 accredited water testing laboratories in Indonesia, of which 28 laboratories (11.5%) responded. The results show that 85.7% of laboratories have implemented CRMs, although only a small proportion possess standard solution and matrix CRMs, and not all testing parameters are covered. CRMs availability remains limited, with heavy reliance on international suppliers, while domestic production is underdeveloped compared to other ASEAN countries. Regarding PT, 22 laboratories reported participation, with ERA-Waters being the most frequently used provider; however, key parameters such as sulfide, barium, and pesticides are not yet included in existing PT schemes. These findings highlight the urgent need to strengthen domestic CRMs production, expand PT coverage, and reinforce regulatory support to enhance measurement traceability and align Indonesia's water testing practices with international standards.

Keywords: Certified Reference Material; Proficiency Testing; Survey; Water Testing Laboratory

1. Introduction

Water is a fundamental resource for life, essential for human survival, ecosystem sustainability, and socio-economic development. Its importance spans public health, sanitation, agriculture, and energy production[1]. Over the past decades, global concerns over environmental degradation have intensified, with water pollution emerging as a critical issue affecting both ecological balance and human well-being [2]. Industrial effluents containing toxic organic and inorganic substances, particularly heavy metals, pose significant risks when released, whether intentionally or accidentally, into rivers and groundwater. Such contamination threatens aquatic organisms, disrupts ecosystem functions, and has both immediate and long-term impacts on human health, including the potential to cause serious infectious diseases [3),4),5),6)].

Ensuring water quality, therefore, is essential to mitigate these risks and prevent public health crises as well as financial losses[7]. Water testing, in this context, refers to the analysis and assessment of water quality to ensure

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compliance with established health and safety standards[8),9)]. Water quality assurance is fundamentally established through systematic testing, which is conventionally classified into four categories[10),11),12)] : (i) physical tests, which evaluate parameters such as color, turbidity, odor, and taste; (ii) chemical tests, which determine the presence and concentration of chemical substances; (iii) microbiological tests, which detect microorganisms including coliform bacteria and *Escherichia coli*; and (iv) radiological tests, which measure radioactive contaminants.

To ensure the accuracy, reliability, and comparability of analytical results, laboratories are required to comply with ISO/IEC 17025:2017. This standard stipulates the use of validated analytical methods, Certified Reference Materials (CRMs), traceability to international standard units (SI) through competent calibration and CRMs sources, and continuous performance assessment through proficiency testing and interlaboratory comparisons[13),14),15),16)]. In this context, reference materials and participation in proficiency testing are essential for testing laboratories, as assure that laboratory test results are valid. Reference materials are obtained either from National Metrology Institutes (NMI) or from producers accredited under ISO 17034:2023[17)].

In Indonesia, however, the availability of CRMs remains limited. Most CRMs are imported, resulting in high costs and lengthy procurement processes, while domestic production is constrained by the small number of laboratories accredited to ISO 17034:2023[18)]. Similarly, the provision of proficiency testing schemes is limited, particularly across the wide range of water quality parameters, and interlaboratory comparisons are restricted due to the relatively small number of laboratories with identical scopes of testing[19)]. To date, no nationwide study has systematically examined the use of Certified Reference Materials (CRMs) and participation in proficiency testing among water testing laboratories in Indonesia.

This research addresses that gap by surveying accredited laboratories that conduct chemical water analyses and produce the first structured dataset on laboratory practices, challenges, and quality assurance needs. In addition, the study provides participating laboratories with insights into their current status, opportunities for benchmarking with peers, and guidance to enhance the reliability and competitiveness of their testing services. The findings are further translated into policy-oriented recommendations to strengthen national metrology infrastructure, expand local CRMs production, and improve proficiency testing schemes. Thus, this research not only contributes to the scientific literature on quality assurance in environmental laboratories but also supports national testing independence in Indonesia and offers relevant lessons for other developing countries facing similar challenges.

2. Materials and Methods

This study employed descriptive qualitative survey design. Primary data were collected using a structured questionnaire, which consisted of two sections: laboratory profile and survey questions, as follows:

Laboratory profile: This section requested the laboratory's name, accreditation number, address, and contact information.

Survey questions: This section contained ten questions (five closed-ended and five open-ended)[20),21)].

Closed-ended questions: These questions covered the types of samples tested, parameters analyzed according to the National Standard for Water Quality, use of certified reference materials, procedures to ensure test validity, and participation in proficiency testing programs.

Open-ended questions: These questions sought information on reference materials (types and producers), substitutes for certified materials, proficiency testing (samples, parameters, and providers), interlaboratory comparisons, and suggestions for improving quality assurance practices.

The reliability analysis of the questionnaire instrument indicated Cronbach's Alpha (α) of 0.66. Although not particularly high, this value is above the minimum threshold generally considered acceptable for exploratory studies ($\alpha > 0.60$)[22)]. Furthermore, the internal validity test indicated that the Corrected Item-Total Correlation (CITC) values ranged from 0.1 to 0.5, which can be categorized as moderate correlations[23)]. Prior to its application in the main study, the questionnaire was pre-tested by practitioners from the National Metrology Laboratory to ensure clarity of the items and the overall feasibility of the instrument.

The questionnaire was distributed to accredited laboratories with a scope of water testing via email. Based on data from the Indonesian National Accreditation Committee, there are 244 accredited testing laboratories for the scope of water testing[24)]. The results were then compiled and discussed in the results and discussion section. A purposive, voluntary-response sampling strategy was employed, whereby invitations were directed to quality managers listed in the KAN directory[25)]. Random sampling was not adopted because the target population was relatively small and highly specialized. Restricting participation to ISO/IEC 17025–accredited laboratories ensured compliance with international standards, thereby enhancing the representativeness and reliability of the sample. The collected responses were analyzed using a descriptive qualitative approach

3. Results and Discussion

This study surveyed 244 accredited testing laboratories in Indonesia engaged in water testing, of which 28 laboratories responded (11.5%). The relatively low response rate is a limitation, as non-response bias cannot be entirely ruled out. However, observable characteristics (e.g., laboratory type, accreditation status, geographic distribution) did not show substantial differences between respondents and non-respondents, suggesting that the findings are reasonably representative of current practices. Despite the limited sample size, the data provide valuable baseline information for assessing the status of water testing capacity in Indonesia. Details on the parameters tested and the number of laboratories analyzing these parameters are presented in Table 1.

Table 1 shows that COD and pH were tested by all surveyed laboratories (28 laboratories), reflecting their central role in water quality monitoring. Other parameters that were widely analyzed include TDS, SO_4^{2-}, and NO_2^-, which were tested by 26 laboratories, as well as Fe, Mn, NO_3^-, and NH_3, each tested by 25 laboratories. This highlights the regulatory and environmental importance of these parameters in compliance monitoring.

In contrast, less than half of the surveyed laboratories performed analyses for boron, barium, mercury, selenium, and pesticides. This limited coverage may be attributed to their classification as "supplementary" parameters in drinking water standards[26). while they are mandatory in river water standards[8),27)]. and variably regulated for industrial wastewater[9),28)].

3.1. Certified Reference Materials in Testing Laboratories

Certified reference materials (CRMs) in testing laboratories are used to ensure valid test results and provide traceable measurement values. A certified reference material is defined as a reference material characterized by metrologically valid procedures for one or more specified properties, accompanied by a certificate that provides the property values, associated uncertainty, and a statement of metrological traceability[29),30),31)].

In general, CRMs can be classified into two types. The first type serves as a source of traceability. This category includes high-purity CRMs, which are used for standardization and for the preparation of standard solution CRMs, as well as standard solution CRMs that are applied in instrument calibration. The second type consists of CRMs used for method validation or internal quality assurance, which are typically matrix CRMs[32),33)].

Table 1: Test Parameters and The Number of Laboratories Conducting These Tests in 28 Water Testing Laboratories

No.	Test Parameters	Number of Laboratories	Percentage (%)
1	pH	28	100
2	Chemical Oxygen Demand (COD)	28	100
3	Total Dissolved Solids (TDS)	26	92.9
4	Sulfate (SO_4^{2-})	26	92.9
5	Nitrite (NO_2^-)	26	92.9
6	Dissolved iron (Fe)	25	89.3
7	Dissolved Manganese (Mn)	25	89.3
8	Nitrate (NO_3^-)	25	89.3
9	Ammonia (NH_3)	25	89.3
10	Oil & Grease	24	85.7
11	Biological Oxygen Demand (BOD)	23	82.1
12	Dissolved Oxygen (DO)	23	82.1
13	Fluoride (F^-)	23	82.1
14	Dissolved Zinc (Zn)	23	82.1
15	Dissolved Copper (Cu)	23	82.1
16	Chloride (Cl^-)	21	75
17	Dissolve Lead (Pb)	20	71.4
18	Detergent	20	71.4
19	Chlorine (Cl_2)	19	67.9
20	Hexavalent Chromium (Cr^{6+})	19	67.9
21	Phenol	18	64.3
22	Sulfide (S^{2-})	18	64.3
23	Dissolved Nickel (Ni)	17	60.7
24	Dissolved Cobalt (Co)	16	57.1
25	Total Nitrogen (N)	15	53.6
26	Dissolved Arsenic (As)	15	53.6
27	Dissolved Boron (B)	13	46.4
28	Dissolved Barium (Ba)	12	42.9
29	Dissolved Mercury (Hg)	12	42.9
30	Dissolved Selenium (Se)	11	39.3
31	Pesticide	5	16.1

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Despite high demand, CRMs availability in Indonesia remain limited, and most are imported, leading to long procurement times. Consequently, some laboratories still use standard substances (e.g., pro-analysis grade chemicals) that lack traceability and uncertainty statements. The survey results on the use of certified reference materials in 28 laboratories are presented in Table 2. As shown in Table 2, 85.7% of laboratories use CRMs, but only 14.3% do not. Among users, only five laboratories (17.9%) use both standard solution and matrix CRMs, achieving full traceability and quality assurance. Eighteen laboratories (64.3%) use only matrix CRMs, and one uses only standard solution CRMs. In contrast, most laboratories using CRMs (approximately 75%) relied solely on matrix CRMs, meaning their measurement traceability remains incomplete. Moreover, most laboratories did not possess CRMs for all tested parameters. This reliance on partial or incomplete CRMs coverage the risk of inconsistency in measurement traceability across laboratories.

In Indonesia, the supply of CRMs remains limited and is heavily dependent on imports from ERA (USA) and Merck (Germany). This dependence leads to long procurement times and higher costs, potentially delaying laboratory operations. While six domestic laboratories have been accredited to ISO/IEC 17034 for the production of matrix reference materials, only two laboratories produce CRMs for water testing covering clean water, mineral water, river water, and a limited number of drinking water parameters, leaving the overall product range restricted. With respect to standard solution CRMs, Indonesia currently produces only one material. Compared to neighboring ASEAN countries such as Malaysia, Thailand, and Vietnam, which manufacture a broader variety of standard solution CRMs through their respective National Metrology Institutes (NMIs), Indonesia's domestic production capacity remains relatively low[34].

This gap carries important strategic implications. Reliance on foreign CRMs not only creates logistical challenges but also constrains Indonesia's ability to establish an independent traceability chain, which forms the foundation of measurement reliability and international recognition. Strengthening domestic CRMs production capacity would reduce dependency on imports, lower costs, and enhance national competitiveness in quality assurance for water testing and broader environmental monitoring. The regional comparison suggests that Indonesia lags its neighbors in CRMs development, underscoring the need for targeted policies and investments to expand local CRMs production. More broadly, these findings resonate with challenges faced by other developing countries that remain dependent on imported reference materials. Addressing this issue would not only benefit Indonesia but could also provide a model for capacity building in laboratory quality assurance across the Global South.

Indonesia could adopt successful models from other ASEAN countries. For example, Malaysia (SIRIM), Thailand (NIMT), and Vietnam (VMI) have expanded their CRMs portfolios through NMI–laboratory partnerships supported by government funding. Establishing similar frameworks in Indonesia, combined with targeted policy incentives, would accelerate local CRMs production, reduce import dependence, and strengthen national traceability and competitiveness in environmental testing.

3.2. Interlaboratory Comparisons and Proficiency Testing

Laboratories are required to compare their test results with those obtained by other laboratories to monitor their performance[13),35)]. This can be achieved through participation in interlaboratory comparisons (ILC) or participation in proficiency testing (PT).

An interlaboratory comparison (ILC) test refers to the design, implementation, and evaluation of measurements or tests on the same or similar items by two or more laboratories under predetermined conditions. On the other hand, proficiency testing (PT) is the evaluation of participant performance against pre-established criteria, conducted through interlaboratory comparison exercises[36),37)]. To assess the extent to which testing laboratories have implemented interlaboratory comparison activities, a survey was conducted on the participation of water testing laboratories in interlaboratory comparison and proficiency testing schemes. Among the 28 laboratories surveyed, 22 (78.6%) had participated in ILC or PT, demonstrating a generally good level of engagement, while 6 laboratories (21.4%) had never taken part in such activities. This indicates an uneven implementation of quality assurance practices across the sector. The survey results are presented in Tables 3 and 4. As shown in Table 3, four interlaboratory comparison providers offered activities in the scope of river water and wastewater testing, covering test parameters such as metals, pH, TDS, TSS, conductivity, color, Cl^-, permanganate index, and NH_3. In addition, clean water testing was carried out for pH and

Table 2: Use of CRMs in the 28 Surveyed Laboratories

Type of CRMs	The number of laboratories	Percentage (%)
Standard solution and matrix CRMs	5	17.86
Standard solution CRMs	1	3.57
Matrix CRMs	18	64.29
Do not use CRMs	4	14.28

Table 3: Interlaboratory Comparison (ILC) Activities by Water Testing Laboratories

No.	ILC Organizer	ILC Scope	
		Sample	Test Parameters
1	BBTKL PP Banjar Baru	River Water & Waste Water	Cu, TDS, Fe, Mn, Zn, Ni, Pb, COD
2	Labkes Banjarmasin	River Water & Waste Water	pH, DH, TSS, COD, Fe, Mn, Zn, Pb
3	Envirolab Nusantara	Waste Water	Color, Cl^-, Conductivity, Permanganate Index, Total NH_3
4	Kehati Lab	Clean Water	Hardness and Ph

Table 4: Proficiency Testing (PT) Activities by Water Testing Laboratories

No.	PT Organizer	PT Scope	
		Sample	Test Parameters
1	ERA Waters Company	Waste Water	Total P, BOD, COD, DO, TSS, Hardness, Cr^{6+}, pH, Total Coli, Fecal Coli, TDS
		Ground Water	Cl^-, Conductivity, F^-, NO_3^-, SO_4^{2-}, TDS, Color, Al, As, B, Cu, Fe, Pb, Mn, Ni, Se, Zn, NO_2^-, Orto P, TSS, Total coli, E. coli, Fe, Pb, Mn, Ni, Se, Zn, NO_2^-, Orto P, TSS, Total coli, E. coli
		Waste Water	E. coli, Total coli, Heavy metal, Organic matter, Demand, Mineral, Nutrient, Solid
		Waste Water	MBAS, pH, conductivity, Ni, Pb
		Drinking Water	Color
		Drinking Water	$o\text{-}PO_4^{3-}$
		Waste Water	NH_3, NO_3^-, orto-PO_4^{3-}
		Waste Water	COD, BOD
		Surface water	Alkalinity as $CaCO_3$, Cl^-, Conductivity, $F^-NO_3^-$, NO_2^-, K, SO_4^{2-}, TDS
		Waste water	pH, DHL, TSS, NH_3, PO_4, NO_2
		Waste water	Cr, Cd, Cu, Fe, Pb, Mn, Zn, Co, Ni
		Waste water	Cu, TDS, Fe, Mn, Zn, Ni, Pb, COD
		Waste water	COD
		Drinking water	Conductivity, pH, TSS, TDS
		Drinking water	Cl_2
		Waste water	Cr^{6+}
2	PPPKLL	Waste water	pH, DHL, COD, Fe, Mn, Zn
3	LPS-IPB	Clean water	Cu, Mn, Cr, Co, Sn, Cd, Zn, Fe, Pb, Ni, Hg, As, NH_3
		Waste water	Cu, Mn, Cr, Co, Sn, Cd, Zn, Fe, Pb, Ni, Hg, As
		Waste water	Cu, Mn, Fe, Ni, COD
		Waste water	NH_3
		Waste water	COD
4	BBIA	Potable water	TDS, Cl^-, SO_4^{2-}
5	Pascal	Potable water	Cr, Fe, Cu, Mn, Ni, Zn
6	Sigma Aldrich	Waste water	TDS, TSS, Cl, F, NO_3, NO_2, SO_4, Oil & Grease
		Drinking water	Cr, Fe, Cu, Mn, Ni, Zn
7	Merck	Clean Water/ Drinking Water	NO_2^-, NO_3^-
		Clean Water/ Drinking Water	TS
		Clean Water/ Drinking Water	TDS
		Clean Water/ Drinking Water	TSS
No.	PT Organizer	PT Scope	
		Sample	Test Parameter
8	PT. Penilai Standar Uji	Waste Water	Trace metal, Phenol, CN
		River water	Pb, Mn, Fe, Cu, $NO_3^-NH_3$, N, SO_4
9	UPTD Lab. Lingkungan DLH Kab Banyuwangi	Surface water	Cl, COD, NO_2, N, Fe, Cu, Co
10	B4T	Potable water	pH, Turbidity, Color, Cl^-, Hardness, Fe.
11	KLHK	Water Supply	DHL, COD, Fe, Mn, Zn, Cd
12	SNSU-BSN	Potable water	As, Cd, Cu, Zn, Ni
13	BMD	Waste water	NO_3^-, NO_2^-, NH_3

hardness parameters.

Practical implementation of domestic CRMs development. For proficiency testing (Table 4), 13 providers offered 38 programs: 19 for wastewater, 15 for drinking/clean water, 3 for river water, and 1 for groundwater. Three providers were international (ERA-Waters, Sigma Aldrich, Merck), while 10 were domestic, which are required to obtain accreditation in accordance with ISO/IEC 17043 the standard for PT providers[38]. According to the National Accreditation Committee (KAN), nine Indonesian laboratories in the water testing sector have obtained ISO/IEC 17043 accreditation since 2022[39]. However, the scope of PT programs remains narrower than in regional peers such as Thailand and Vietnam, with important parameters (e.g., sulfide, barium, pesticides) still excluded. This limitation has implications for regulatory compliance, particularly with respect to Government Regulation No. 66/2014 on Environmental Health, which mandates pesticide monitoring[40]. Expanding PT program coverage and integrating more diverse reference materials would enhance laboratory competence, reduce reliance on international providers, and contribute to regional competitiveness in environmental testing.

4. Conclusions

This study highlights that while most accredited water testing laboratories in Indonesia have adopted Certified Reference Materials (CRMs) and participated in Proficiency Testing (PT), significant challenges remain. Limited access to high purity and standard solution CRMs, dependence on international suppliers, and the absence of key parameters in existing PT schemes undermine the robustness of quality assurance systems. Strengthening domestic CRMs production, expanding PT coverage, and reinforcing regulatory frameworks are therefore essential to ensure measurement traceability and align Indonesia's water testing practices with international standards.

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References

1) World Bank.. Water overview. (2023). https://www.worldbank.org/en/topic/water/overview
2) A. Suyunova, G. Kozhagulova, and A. Suiin, "Comparative Analysis of Marine Fish for the Content of Pollutants in the Eurasian Region," Evergreen, 11(1) 71-81 (2024). https://doi.org/10.5109/7172222
3) S.M. Hakim, and R.M. Bilad, "Colorimetric Sensor for Heavy Metal Ions Detection: A Short Review," Evergreen, 11(4), 3127–3142 (2024). https://doi.org/10.5109/7326951
4) N.R. Caesar, U. Yanuhar, M. Musa, G. Ciptadi, H. Suryanto, Y.A. Wahyudi, and R.N. Soelistyoadi, "Heavy Metals Contamination and Their Impacts on Fish Responses in Porong River, East Java, Indonesia," Evergreen, 10(3), 1218–1230 (2023). https://doi.org/10.5109/7148443
5) A. Madibekov, L. Ismukhanova, A. Zhadi, and B. Sultanbekova, "Assessment of the Level Pollution of the Aquatic Ecosystem of Lake Markakol with Mobile Forms of Copper and Zinc," Evergreen, 11(3), 1568-1579 (2024). https://doi.org/10.5109/7236812
6) R. Sawant, D. A. Joshi, and R. Menon, "Case Study on River Pollution of Pune City and Waste Management," Evergreen, 10(4), 2620-2631 (2023). https://doi.org/10.5109/7160918
7) K.I. Majesty, B.D. Purnamasari, K. Mizuno, and T. Sutardi, "Palm Oil Waste Management with Local Wisdom as an Approach to Achieve Sustainable Development in Independent Smallholder Palm Plantations," Evergreen. 11(4), 3484-3496 (2024). https://doi.org/10.5109/7326984
8) Erie Inspection Service. Understanding the importance of water quality testing. https://www.erieinspect.com/home-inspection-services/understanding-the-importance-of-water-quality-testing/ (accessed July 15, 2024)
9) Medbury Medicals. The importance of water quality testing: Ensuring health and safety. https://medburymedicals.com/the-importance-of-water-quality-testing-ensuring-health-and-safety/ (accessed January 15, 2024)
10) Peraturan Pemerintah Republik Indonesia Nomor 22 tahun 2021 Tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup, lampiran VI Baku mutu Air Nasional, Jakarta (2021)
11) Peraturan Menteri Kesehatan Republik Indonesia Nomor 2 tahun 2023 tentang Peraturan pelaksanaan Peraturan Pemerintah nomor 66 tahun 2014 tentang Kesehatan Lingkungan. Bab II, Jakarta. (2023)
12) M.Ž. Grujović, K.G. Mladenović, S.M. Marković, N.H. Đukić, J.M. Stajić, A.M. Ostojić, N.M. Zlatić, "Chemical, Radiological and Microbiological Characterization of A Drinking Water Source: A Case Study," Lett Appl Microbiol. 75(5), 1136-1150 (2022). doi: 10.1111/lam.13778. Epub 2022 Aug 3. PMID: 35765797.
13) International Organization for Standardization, "ISO/IEC 17025:2017- General requirements for the competence of testing and calibration laboratories," Switzerland. (2017).
14) B. Magnusson and U. Örnemark, "Eurachem Guide: The Fitness for Purpose of Analytical Methods – A

Laboratory Guide to Method Validation and Related Topics", ISBN 978-91-87461-59-0. (2014).

15) National Institute of Standards and Technology (NIST). Metrological Traceability. https://www.nist.gov/metrology/metrological-traceability (accessed May 21, 2025)
16) Vaisala. (2020). Understanding Metrological Traceability in Calibration. https://www.vaisala.com/sites/default/files/documents/Understanding-Calibration-Traceability-B212197EN.pdf (accessed May 21, 2025).
17) International Organization for Standardization. "ISO 17034:2016- General Requirements for the Competence of Reference Material Producers," Switzerland. (2016).
18) Komite Akreditasi Nasional. https://kan.or.id/index.php/documents/terakreditasi/doc17020/sni-iso-17034/produsen-bahan-acuan (accessed August 17, 2024)
19) D.N. Faridah, D. Erawan, K. Sutriah, A. Hadi, and F. Budiantari, "Implementasi SNI ISO/IEC 17025:2017,". (2018)
20) P. Bhandari. (2023) Questionnaire Design – Methods, Question Types, and Examples. https://www.scribbr.com/methodology/questionnaire (accessed October 19, 2024)
21) SurveySparrow. 12 types of survey questions: Definition, examples & tips. https://surveysparrow.com/blog/types-of-survey-questions/ (accessed October 19, 2024)
22) J. F. Hair, M.L.D.S. Gabriel, D. da Silva, and S.B. Junior, "Development and validation of attitudes measurement scales: fundamental and practical aspects. RAUSP Management Journal, 54(4), 490–507 (2019). https://doi.org/10.1108/RAUSP-05-2019-0098
23) P.M. Guenther, S.I. Kirkpatrick, J. Reedy, S.M. Krebs-Smith, D.W. Buckman, K.W. Dodd, K.O. Casavale, and R.J. Carroll, "The healthy eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 dietary guidelines for Americans," Journal of Nutrition, 144(3), 399–407 (2014) https://doi.org/10.3945/jn.113.183079
24) Komite Akreditasi Nasional. (2022). Layanan Akreditasi Laboratorium Penguji. http://kan.or.id/index.php/programs/sni-iso-iec-17025/laboratorium-penguji (accessed January 19, 2024)
25) S. Murairwa, "Voluntary Sampling Design," International Journal of Advanced Research Management and Social Sciences, 4(2) ,185-20(2015).
26) Peraturan Menteri Kesehatan Republik Indonesia Nomor 492 tahun 2023 Tentang Persyaratan Kualitas Air Minum, Jakarta. (2023)
27) P. Saha and B. Paul, "Assessment of Heavy Metal Pollution in Water Resoruces and Their Impacts: A Review," Journal of Basic and Applied Engineering Research, 3(8), 671–675 (2016).
28) P.N. Patil, D.V. Sawant, and R.N. Deshmukh. Physico-chemical parameters for testing of water – A review. International Journal of Environmental Sciences, 3(3), (2012).
29) International Organization for Standardization. "ISO GUIDE 30 2015(E), Reference materials - Selected terms and definitions," Switzerland. (2015).
30) ASTM International. (2023). What are Certified Reference Materials?. Retrieved from https://www.astm.org/news/certified-reference-materials-ja23 (accessed January 20, 2024)
31) National Institute of Standards and Technology (NIST). Standard Reference Materials (SRMs): Definitions. Retrieved from https://www.nist.gov/srm/srm-definitions (accessed January 20, 2024)
32) S. Wong, "Risk-based thinking for chemical testing," Accreditation and Quality Assurance, 22(2), 103-108 (2017).
33) A. Zschunke, A. Reference Materials in Analytical Chemistry: A Guide for Selection and Use. Berlin: Springer. (2000). https://doi.org/10.1007/978-3-642-56986-9 .
34) ASEAN Reference Material Network. "Catalogue of Reference Materials Produced by ARMN Members," (2019).
35) H. Emons, A. Held, and F. Ulberth, "Reference Materials as Crucial Tools for Quality Assurance and Control in Food Analysis". Pure and Applied Chemistry, 78(1), 135–143 (2006). https://doi.org/10.1351/pac200678010135
36) S. Shahangian, "Proficiency testing in Laboratory Medicine: Uses and Limitations," Pathology and Laboratory Medicine, 122. (1998).
37) International Organization for Standardization. "ISO/IEC 17043: Conformity Assessment - General Requirements For The competence of Proficiency Testing Provider," Switzerland. (2023).
38) P. Rosario, J.L. Martinez, and J.M. Silvan, "Comparison of Different Statistical Methods for Evaluation of Proficiency Test Data," Accreditation and Quality Assurance, 8(9), 493–499. https://doi.org/10.1007/s00769-008-0413-7
39) Komite Akreditasi Nasional. https://kan.or.id/index.php/documents/terakreditasi/doc17020/sni-iso-iec-17043/penyelenggara-uji-profisiensi (accessed August 17, 2024)
40) Peraturan Pemerintah Republik Indonesia Nomor 66 tahun 2014 Tentang Kesehatan Lingkungan. Jakarta. (2014)