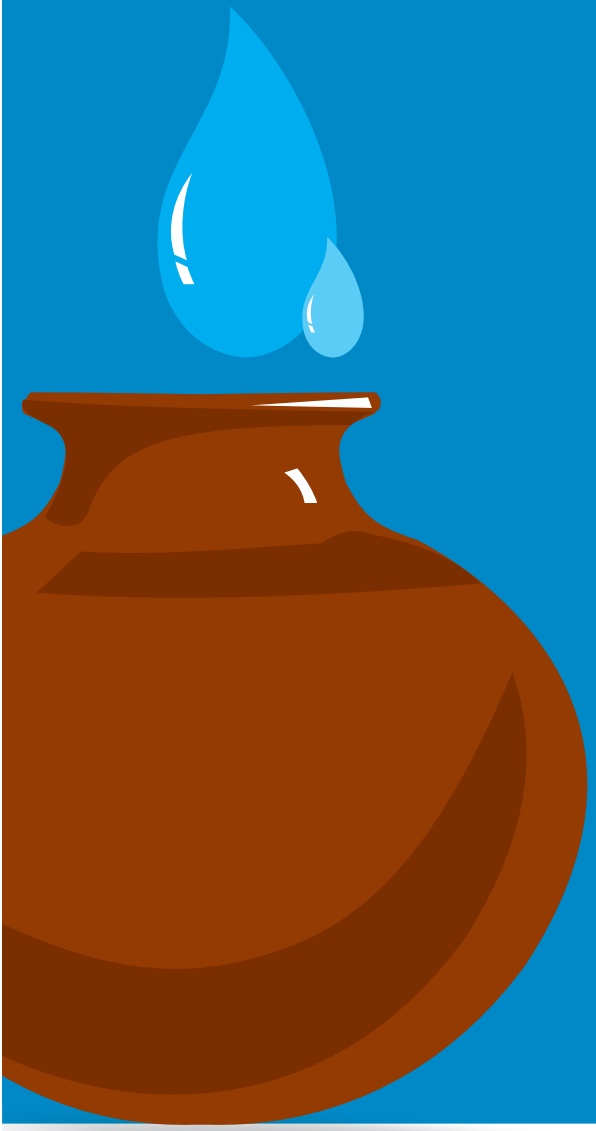
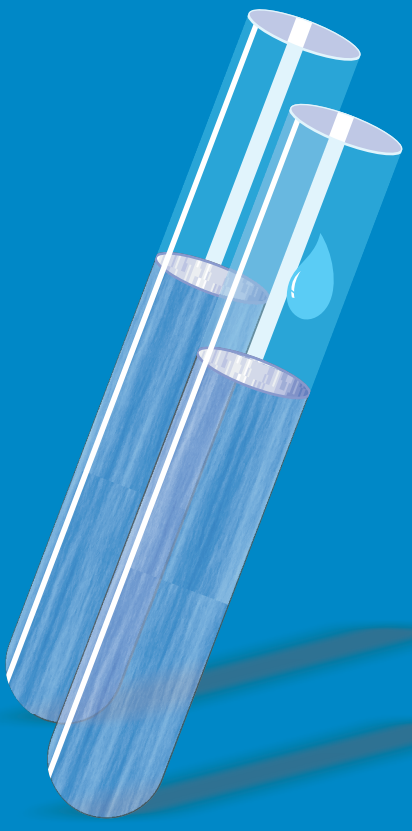
Evaluation Of Water Quality Field Test Kits





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EVALUATION OF WATER QUALITY FIELD TEST KITS

1. Background

Provision for the supply of safe drinking water in rural India, with about 1.42 million habitations and millions of water sources, is an amazing task. Due to the logistical problems and inadequate water quality testing infrastructure, generation of reliable water quality data on regular basis has been an acknowledged problem. Monitoring and surveillance of water quality on regular basis, has the objective of protecting the water sources to the greatest extent possible. When contamination occurs, effective quality testing provides early warning, which permits interventions aimed at reducing/ or eliminating undesirable constituent to the acceptable level.

Partly due to resource and time constraints to establish well-equipped water quality testing laboratories in sufficient numbers and partly due to the dynamic nature of water quality, there is a definite place for simplified Water Quality Field Test Kits (WQFTK) in an overall approach to water quality monitoring in the country. WQFTK can accomplish the initial screening and periodical monitoring of all drinking water sources. Such tests would be relatively inexpensive and can be conducted at water user level thereby improving the potential for involvement of user communities. Results of WQFTK can be supported by detailed analysis of problem sources in district level laboratories, which are in the process of being established throughout the country.

WQFTK available in Indian market in the late 1990s, were evaluated by UNICEF supported program. However, new generations of WQFTK have evolved, developed by government laboratories, NGOs and commercial organizations. UNICEF proposes to carry out a study to assess the range and reliability of Water Quality Field Test Kits available in Indian market.

2. The Assignment and Scope of Work

The UNITED NATIONS CHILDREN'S FUND (UNICEF), India Country Office, New Delhi contracted Shriram Institute for Industrial Research (SIIR), Delhi to undertake EVALUATION OF WATER TESTING FIELD KITS vide Special Service Agreement No. SSA/INDQ/2004/00001200-0; Funding GC/2002/6012-1 dated 15.05.2004.

3. Kits Procurement

SIIR has prepared the detailed inventory of Water Quality Field Test Kits in India. Based on the inventorization, kits were selected in consultation with UNICEF for procurement. Selected kits were procured in an anonymous and confidential manner. Following categories of kits were purchased from different manufacturers:

- Single parameter kits (46 Nos)
- Multiple parameter kits (4 Nos)

Table- 1: Description of kits procured for evaluation

Kit Manufacturer	Type of Kit Procured	Type of Kit
Development Alternative, New Delhi	Jal TARA Standard WTK-11 Parameter	Multiple Parameter
	Jal TARA Mini Kit-I (Fluoride)	Single Parameter
	Jal TARA Mini Kit-II (Nitrate)	Single Parameter
	Jal TARA Mini Kit-III (Iron)	Single Parameter
	Jal TARA Mini Kit-IV (R-Chlorine)	Single Parameter
	Jal TARA Mini Kit-V (Arsenic)	Single Parameter
L-TeK, Nagpur	Fluoride Test Kit (NEERI)	Single Parameter
	Fluoride Test Kit (BARC)	Single Parameter
	Fluoride Test Kit (NCL)	Single Parameter
	Nitrate Test Kit	Single Parameter
	Residual Chlorine Test Kit	Single Parameter
	Iron Test Kit	Single Parameter
	Nitrate (improved) NCL	Single Parameter
Mathbin Scientifics New Delhi	Fluoride Kit AQUA QUAL	Single Parameter
	Chloride Kit AQUA QUAL	Single Parameter
	Hardness Kit AQUA QUAL	Single Parameter
	Nitrate Kit AQUA QUAL	Single Parameter
	Iron Kit AQUA QUAL	Single Parameter
	$R\text{-}Cl_2$ Kit AQUA QUAL	Single Parameter
	Arsenic Kit AQUA QUAL	Single Parameter
	Alkalinity Kit AQUA QUAL	Single Parameter
	AQUA GAGE multi-WTK	Multiple Parameter
	CHLOROSCOPE CS-10/20	Single Parameter
MERCK, New Delhi	Merckoquant Arsenic (LR)	Single Parameter
	Merckoquant Arsenic (HS)	Single Parameter
	Merckoquant Nitrate	Single Parameter
	Aquaquant Iron	Single Parameter
	Aquamerck Chlorine	Single Parameter
	Aquaquant Aluminium	Single Parameter
Ion Exchange, New Delhi	INDION Fluoride Test Kit	Single Parameter
	INDION Iron Test Kit	Single Parameter
CPCB, Delhi	CPCB-WTK (multi kit)	Multiple Parameter
Chem-in-Corpn, Mumbai	Fluoride Test Kit	Single Parameter
	Arsenic Test Kit	Single Parameter
	Nitrate Test Kit	Single Parameter
SUMEET Instrument & Chemicals, Kolkata	Fluoride Test Kit	Single Parameter
	Arsenic Test Kit	Single Parameter
	Nitrate Test Kit	Single Parameter
	Iron Test Kit	Single Parameter
	SUMEET WTK (Multiple Parameters)	Multiple Parameter
TECHNO-AD SYSTEMS INC., Gwalior	Fluoride Test Kit (AIIH&PH)	Single Parameter
	Fluoride Test Kit (ICS)	Single Parameter
	Fluoride Test Kit (DRL)	Single Parameter
	Arsenic Test Kit (AIIH&PH)	Single Parameter
	Arsenic Test Kit (DRDO)	Single Parameter
	Nitrate Test Kit (AIIH&PH)	Single Parameter
	Iron Test Kit (AIIH&PH)	Single Parameter
	Iron Test Kit (DRL)	Single Parameter
	Iron Test Kit (ICS)	Single Parameter
IEHS-China (Supplied by UNICEF)	Arsenic Test Kit	Single Parameter

4. Testing Parameters for Evaluation

The goal of water supply programme in rural areas shall be to ensure round the year access to adequate quantities of good quality water to all the consumers. To many people the quality of water means its aesthetic characteristics like clarity, color, taste and odor. Even if water may meet such aesthetic requirement, yet it could be unsafe in terms of chemical or bacteriological quality. Though in rural areas, the majority of water quality problems are related to bacteriological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water resources. Hence, it is desired that water sources shall be subjected to regular monitoring and surveillance through sustainable water quality monitoring system such as water quality field test kits for screening of large number of sources. Significant chemical test parameters, for which, regular monitoring and surveillance shall aim, may include Arsenic, Fluoride, Iron, Nitrate, Residual Chlorine, Chloride, Alkalinity, Hardness and Aluminium.

Table- 1: Description of kits procured for evaluation

Parameter	Source of contamination; Significance and Limit	Test Method	Accuracy
Arsenic	Geological/ Chemical; High concentration can cause significant health effects based on the exposure; MPL in water is 0.01 ppb	FI-HG-AAS	±2%;MDL 5 ppb
		SDDC	±10%MDL 10 ppb
		Field Test Kit method	Qualitative to semi-quantitative method
Fluoride	Geological/ Chemical; High concentration can cause dental & skeletal fluorosis based on the exposure; MPL in water is 1.5 ppm	Specific Ion Electrode method	±2% MDL 0.01 ppm
		SPADNS (Spectrophotometric method)	±5% MDL 0.1 ppm
		Field Test Kit method	Qualitative to semi-quantitative method
Nitrate	Geological/ Chemical; High concentration can cause methaemoglobinaemia (blue baby disease); MPL in water is 45 ppm	Specific Ion Electrode method	±2% MDL 0.1 ppm
		Deverda's Alloy Reduction	±5% MDL 0.5 ppm
		Spectrophotometric method)	
		Field Test Kit method	Qualitative to semi-quantitative method
Iron	Geological/ Chemical; High concentration can cause un-aesthetic appearance and may impart bitter and metallic taste. It may also cause stains on plumbing, utensil and laundry; MPL in water is 1.0 ppm	Atomic Absorption Spectrophotometric method	±2% MDL 0.01 ppm
		Phenthroline colorimetricmethod	±5% MDL 0.05 ppm
		Field Test Kit method	Qualitative to semi-quantitative method

Parameter	Source of contamination; Significance and Limit	Test Method	Accuracy
Chlorine	Chemical; Mainly used for disinfecting the water sources. Overdose may results in the formation of organo-chloro compounds, which are very harmful; Desirable limit is 0.2 ppm (min).	Colorimetric method (o-toludine)	±5% MDL 0.05 ppm
		Colorimetric method (DPD)	±5% MDL 0.05 ppm
		Iodimetric Method	±5% MDL 0.5 ppm
		Field Test Kit method	Qualitative to semi-quantitative method
Chloride	Natural/ Runoff; High concentration can produce salty taste. Cause corrosion also; Desirable limit in water is 250 ppm & MPL is 1000 ppm	Titrimetric (Argentometric)	±5% MDL 5 ppm
		Field Test Kit method	Qualitative to semi-quantitative method
Alkalinity	Natural; It is the capability of the water to neutralize acid. It is significant for many uses and water treatment; Desirable limit in water is 200 ppm & MPL is 600 ppm	Titrimetric (Acid-neutralisation)	±5% MDL 5 ppm
		Field Test Kit method	Qualitative to semi-quantitative method
Hardness	Natural; It affects the taste of the water and cause the scales in the distribution system.Desirable limit in water is 300 ppm & MPL is 600 ppm	Titrimetric (EDTA)	±5% MDL 5 ppm
		Field Test Kit method	Qualitative to semi-quantitative method
Aluminium	Natural/ From the use of alum coagulant (chemical); Health effects are not established but high level is not desirable in drinking water.Desirable limit in water is 0.03 ppm & MPL is 0.2 ppm	AAS-Graphite Tube Atomizer	±2% MDL 10 ppb
		Eriochrome Cyanine R Method(Colorimetric)	±5% MDL 50 ppb
		Field Test Kit method	Qualitative to semi-quantitative method

5. Methodology of Evaluation

Evaluation methodology is described in following steps:

Step-1 Selection of the range of "concentration points"

Range of concentration points vis-a-vis parameter-of-interest was selected to work out maximum number of standards need to be prepared for the evaluation of WQFTK with respect to each parameter.

Step-2 Preparation of Experimental Water

Experimental water was prepared by "spiking" standards of potential components (parameters) "to be tested by WQFTK" in following manner:

(i) Millipore water from milli-Q system (Reference Water)

It represents reference water with "known spike" of standards of the parameter-of-interest covering the selected range of concentration points.

(ii) Natural water from various sources (groundwater)

It represents experimental water with "matrix effect" with "known spike" of standards of the parameter-of-interest covering the selected range of concentration points. Experimental water was prepared in different matrix.

Step-3 Accurate Analysis of Experimental Water

Purpose of conducting accurate analysis (with replicates) of experimental water using established procedures was to validate experimental water (reference as well as different matrix) at the selected level of concentration points. Key data quality indicators like %RSD and t-test were used to validate the "concentration point values" in experimental water.

Step-4 Test Performance of WQFTK

- Parameter wise test performance of WQFTK, was assessed by testing "experimental water" using the prescribed method for each test at specified concentration level.
- Opinions of different professionals were taken into account for comparison of colour with given chart/disc/ other module (if it is qualitative module).
- In order to validate the specified concentration point (s), concentration level lower/higher than the specified concentration point (s) were also taken to indicate accordingly lower/higher concentration.
- Test observations are compiled/ collated on the format given in the comprehensive report.

Step-5 Performance Measurement of WQFTK (Quantitative)

Objective of performance measurement is to assess, "how accurately WQFTK detects the presence/ or absence of the parameter-of-interest" was achieved by following modalities:

(a) Probability in testing of water by WQFTK[4]

- Probability-1 (False Positive): Test detection by WQFTK in "Blank Water" or higher detection than the specified concentration level.
- Probability-2 (True Positive): Test detection by WQFTK in "Spiked Experimental Water" approximately near to or equal to the specified concentration level.
- Probability-3 (False Negative): Non-detection or lower detection than the specified concentration of test by WQFTK in "Spiked Experimental Water".

- Probability-4 (True Negative): Non-detection of test by WQFTK in "Blank Water" or in the water containing the specified component at the below detection level.

(b) Sensitivity (SE) of WQFTK for testing water

Sensitivity of a WQFTK was estimated by the percentage of the number of true-positive test results to all positive samples tested by WQFTK with respect to each parameter.

(c) Specificity (SP) of WQFTK for testing water

Specificity of WQFTK was estimated by the percentage of the number of true-negative test results to all the blank samples tested by WQFTK with respect to each parameter.

(d) Overall Testing Efficiency (TE) of WQFTK for testing water[4]

The overall testing efficiency of WQFTK was estimated by percentage of "true finding (true-positive + true-negative) to total number of estimations with respect to each test parameter.

(e) Reliability of WQFTK

Indicators for reliability tests are taken as

(i) Actual concentration of experimental water (by accurate laboratory analysis)

(ii) Observed concentration of the parameter-of-interest by WQFTK.

Statistical tools used for reliability tests of WQFTK

The Chi-Squared (χ^2) goodness-of-fit test is used on the data obtained with WQFTK for parameter-of-interest at specified concentration range for specified DF at 95% confidence level. Lower the estimated value than the critical better the efficiency.

Step-6 Strength and Weakness Analysis

Strength and weakness analysis of each WQFTK was conducted to assess its appropriateness vis-a-vis various significant attributes. Various indicators, as specified below, have been identified for the parameters viz. Adequacy Impact, Safety Impact and Information Impact. In order to quantify the impact, statistical weight was assigned to each parameter as per the following scheme to obtain the Parameter Impact Factor (PIF):

- Formation of sub-indices ($S_1, S_2, \ldots S_n$) for the 'n' indicators, using designated weight {1-10 scale, parameter maximum weight is 10/n}, where i = 1,2, ... n.

- Sub–indices (S_i) thus, formed are aggregated together in a second mathematical form to give "aggregated index or combined index" as $\mathbf{(I_{adq})/(I_{safety})/(I_{inf})} = \sum S_i = f(S_1, S_2, \ldots S_n)$

(a) Adequacy Impact (I_{adq})

Table- 3 Adequacy Impact Indicators

Indicator	Observations	Weight (S_i)	Remarks
Ease of handling			
Adequacy of consumables			
Portability of kit			
Adequacy of main apparatus, accessories & spares			
Adequacy wrt space provided for placement of chemicals, apparatus etc.			

(b) Safety Impact (I_{safety})

Table- 4 Safety Impact Indicators

Indicator	Observations	Weight (S_i)	Remarks
Hazard involved in using kit			
Leakage of liquid chemical (s)			
Leakage of gas (if test is based on gas formation)			
Packaging of chemicals			

(c) Information Impact (I_{inf})

Table- 5 Information Impact Indicators

Indicator	Observations	Weight (S_i)	Remarks
Instructions for operations (adequate & simple)			
Precautions for handling corrosive & reactive chemicals			
Instructions for disposal of used material & wastes			
Specifications of chemicals in "public domain"			
Instructions for remedial measures in case the chemical comes in contact with skin or any other injury occurred during the use of kit.			

Step-7 Kit Performance

Overall impact with respect to the effectiveness of WQFTK was calculated by considering following modalities:

A. Technical Efficiency Impact (I_{TE})

Technical Efficiency Impact Factor — 1/10 ($OTE_{fluoride, arsenic, nitrate.....}$ for pooled matrix)

B. Adequacy Impact (I_{adq})

Adequacy Impact Factor — $I_{adq} = \Sigma S_i$

C. Safety Impact (I_{safety})

Safety Impact Factor — $I_{safety} = \Sigma S_i$

D. Information Impact (I_{inf})

Information Impact Factor — $I_{inf} = \Sigma S_i$

Step-8 Cumulative Impact Factor (CIF)

Cumulative Impact Factor was calculated to assess the quantitative performance of the kits. In order to achieve the objective each parameter was given the importance as per the following scheme:

Table- 6 Criteria for Assessment of Cumulative Impacts

Parameter	Importance	Remarks
Technical Efficiency Impact	• Parameter of most importance • 5-6 times important than adequacy or information.	Impact can not be easily reversed and requires major R&D interventions
Adequacy Impact	• Parameter of least importance.	Impact can be reversed with some interventions.
Safety Impact	• At least 2 times more important than adequacy or information.	Impact can be reversed with the appreciable R&D interventions.
Information Impact	• Parameter of least importance	Impact can be easily reversed with some interventions.

(Guidelines taken from EIA methodology by Larry W. Canter)

Hence, Cumulative Impact Factor (CIF) = $6I_{TE} + I_{adq} + 2 I_{safety} + I_{inf}$

6. Evaluation Findings

A. Arsenic Testing Kits

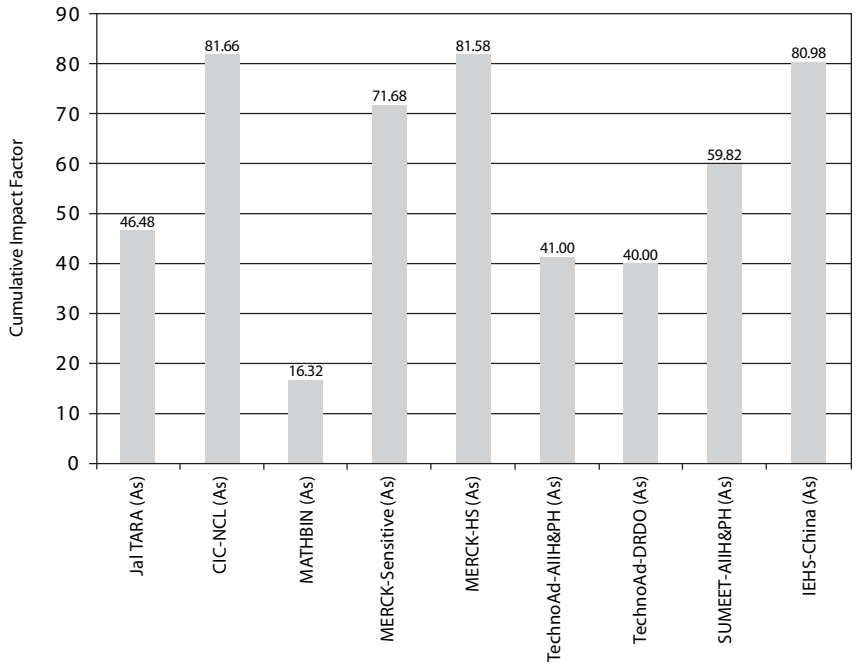
Nine kits were evaluated and their technical efficiency was estimated as under:

Table- 7 Effectiveness of Arsenic Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
Jal TARA (As)	4.58	8.0	3.0	5.0	7.72	5.99 (2DF)	46.48
CIC-NCL (As)	8.61	9.0	9.0	3.0	1.33	9.49 (4DF)	81.66
MATHBIN (As)	2.22	2.0	0	1.0	19.00	7.82 (3DF)	16.32
MERCK-Sensitive (As)	7.78	9.0	7.5	3.0	2.50	7.82 (3DF)	71.68
MERCK-HS (As)	8.18	9.5	10.0	3.0	1.11	9.49 (4DF)	81.58
TechnoAd-AIIH&PH (As)	5.00	5.0	2.0	3.0	13.50	9.49 (4DF)	41.00
TechnoAd-DRDO (As)	5.00	5.0	2.0	1.0	10.00	5.99 (2DF)	40.00
SUMEET-AIIH&PH (As)	6.97	7.0	4.0	3.0	4.94	9.49 (4DF)	59.82
IEHS-China (As)	8.33	10.0	9.5	2.0	1.44	9.49 (4DF)	80.98

Based on the CIF, three kits namely CIC-NCL (As), MERCK-HS (As) and IEHS-China (As) are observed to be the best kits as evident by their impact factors 81.66, 81.58 and 80.98 respectively.

Cumulative Impact Factor of Arsenic Test Kits



B. Fluoride Testing Kits

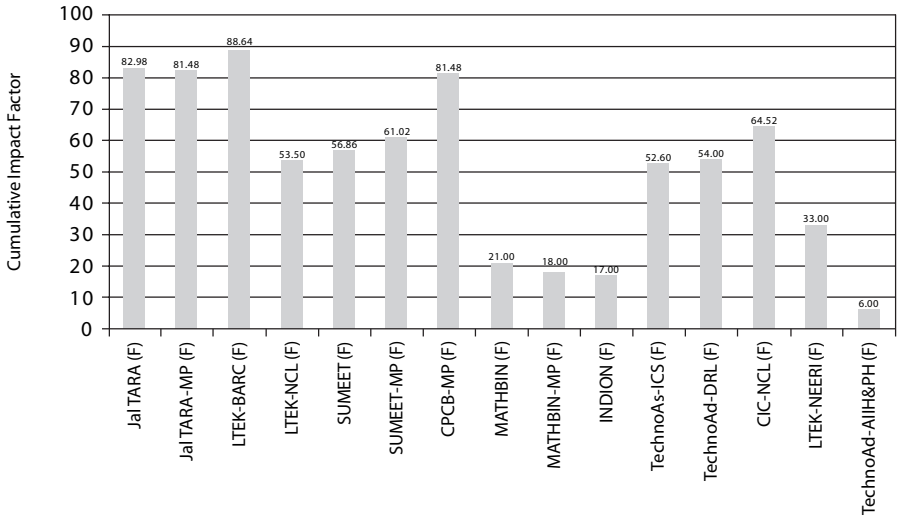
Fifteen kits were evaluated and their technical efficiency was estimated as under:

Table- 8: Effectiveness of Fluoride Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
Jal TARA (F)	8.33	10.0	7.5	8.0	3.00	5.99 (2DF)	82.98
Jal TARA-MP (F)	8.33	8.5	7.5	8.0	3.00	5.99 (2DF)	81.48
LTEK-BARC (F)	9.44	10.0	8.5	5.0	0.33	5.99 (2DF)	88.64
LTEK-NCL (F)	5.00	8.5	4.5	6.0	15.00	5.99 (2DF)	53.50
SUMEET (F)	5.56	9.5	6.5	1.0	16.00	5.99 (2DF)	56.86
SUMEET-MP (F)	6.67	8.0	4.5	4.0	6.00	5.99 (2DF)	61.02
CPCB-MP (F)	8.33	9.5	9.0	4.0	3.00	5.99 (2DF)	81.48
MATHBIN (F)	0	7.0	6.5	1.0	-	-	21.00
MATHBIN-MP (F)	0	4.0	6.5	1.0	-	-	18.00
INDION (F)	0	8.0	3.5	2.0	39	11.07 (5DF)	17.00
TechnoAs-ICS (F)	4.10	8.0	9.0	2.0	17.11	11.07 (5DF)	52.60
TechnoAd-DRL (F)	5.00	10.0	6.5	1.0	15.00	5.99 (2DF)	54.00
CIC-NCL (F)	6.67	10.0	6.5	1.5	6.00	5.99 (2DF)	64.52
LTEK-NEERI (F)	0	9.0	9.0	6.0	-	-	33.00
TechnoAd-AIIH&PH (F)	0	1.0	2.5	0	-	-	6.00

Based on the CIF, four kits namely LTEK-BARC (F), Jal TARA (F), Jal TARA-MP (F) and CPCB-MP (F) are observed to be the best kits as evident by their impact factors 88.64, 82.98, 81.48 and 81.48 respectively.

Cumulative Impact Factor of Fluoride Testing Kits



C. Iron Testing Kits

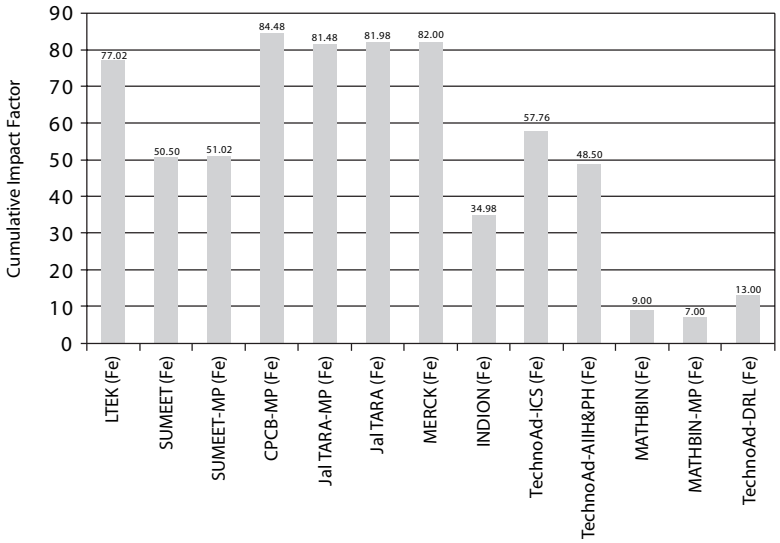
Thirteen kits were evaluated and their technical efficiency was estimated as under:

Table- 9 Effectiveness of Iron Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
LTEK (Fe)	6.67	9.0	10.0	8.0	5.00	5.99 (2DF)	77.02
SUMEET (Fe)	7.00	5.5	1.0	1.0	10.00	9.49 (4DF)	50.50
SUMEET-MP (Fe)	6.67	5.5	1.0	3.5	4.00	5.99 (2DF)	51.02
CPCB-MP (Fe)	8.33	9.5	9.0	4.0	2.00	5.99 (2DF)	84.48
Jal TARA-MP (Fe)	8.33	7.5	7.5	9.0	2.00	5.99 (2DF)	81.48
Jal TARA (Fe)	8.33	9.0	7.5	8.0	2.00	5.99 (2DF)	81.98
MERCK (Fe)	9.00	10.0	7.5	3.0	2.00	9.49 (4DF)	82.00
INDION (Fe)	3.33	7.0	3.0	2.0	12.00	5.99 (2DF)	34.98
TechnoAd-ICS (Fe)	5.71	8.5	6.5	2.0	9.33	5.99 (2DF)	57.76
TechnoAd-AIIH&PH (Fe)	6.00	5.5	3.5	0	6.00	5.99 (2DF)	48.50
MATHBIN (Fe)	0	2.0	3.5	0	-	-	9.00
MATHBIN-MP (Fe)	0	0	3.5	0	-	-	7.00
TechnoAd-DRL (Fe)	0	3.0	4.5	1.0	-	-	13.00

Based on the CIF, four kits namely CPCB-MP (Fe), MERCK (Fe), Jal TARA (Fe) and Jal TARA-MP (Fe) are observed to be the best kits as evident by their impact factors 84.48, 82.00, 81.98 and 81.48 respectively.

Cumulative Impact Factor of Iron Testing Kits



D. Nitrate Testing Kits

Twelve kits were evaluated and their technical efficiency was estimated as under:

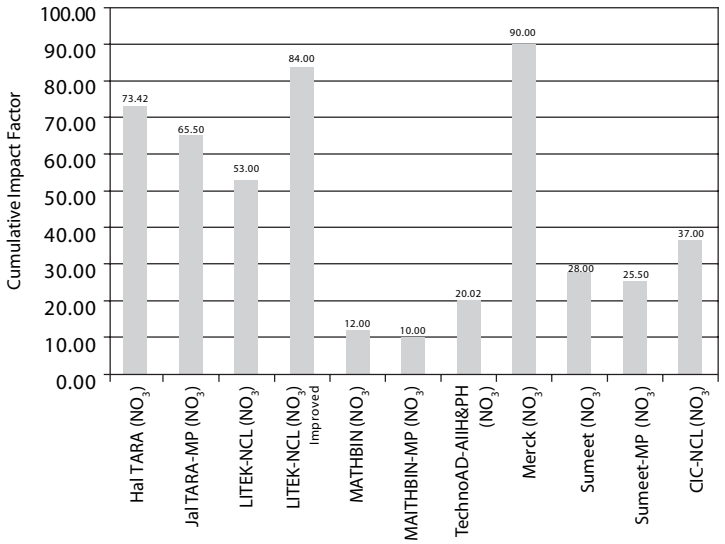
Table- 10: Effectiveness of Nitrate Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
Jal TARA (NO_3)	8.57	8.0	5.0	4.0	1.00	5.99 (2DF)	73.42
Jal TARA-MP (NO_3)	7.50	6.5	5.0	4.0	2.33	5.99 (2DF)	65.50
LTEK-NCL (NO_3)	5.00	9.0	5.0	4.0	10.00	5.99 (2DF)	53.00
LTEK-NCL (NO_3) Improved	8.75	9.5	8.0	6.0	2.00	7.82 (3DF)	84.00
MATHBIN (NO_3)	0	2.0	5.0	0	-	-	12.00
MATHBIN-MP (NO_3)	0	0	5.0	0	-	-	10.00
TechnoAd-AIIH&PH (NO_3)	1.67	5.5	2.0	0.5	14.00	5.99 (2DF)	20.02
MERCK (NO_3)	8.75	10.0	10.0	7.5	2.00	9.49 (4DF)	90.00
SUMEET (NO_3)	2.50	6.0	1.5	4.0	24.00	7.82 (3DF)	28.00
SUMEET-MP (NO_3)	2.50	5.0	1.0	3.5	12.00	7.82 (3DF)	25.50
CIC-NCL (NO_3)	2.50	8.5	6.0	1.5	12.00	7.82 (3DF)	37.00
CPCB (NO_3)*	0	0	0	0	-	-	0

*Test strips were not available in the given kit

Based on the CIF, two kits namely MERCK (NO_3) and LTEK-NCL (NO_3)-Improved are observed to be the best kits as evident by their impact factors 90.00 and 84.00 respectively.

Cumulative Impact Factor of Nitrate Testing Kits



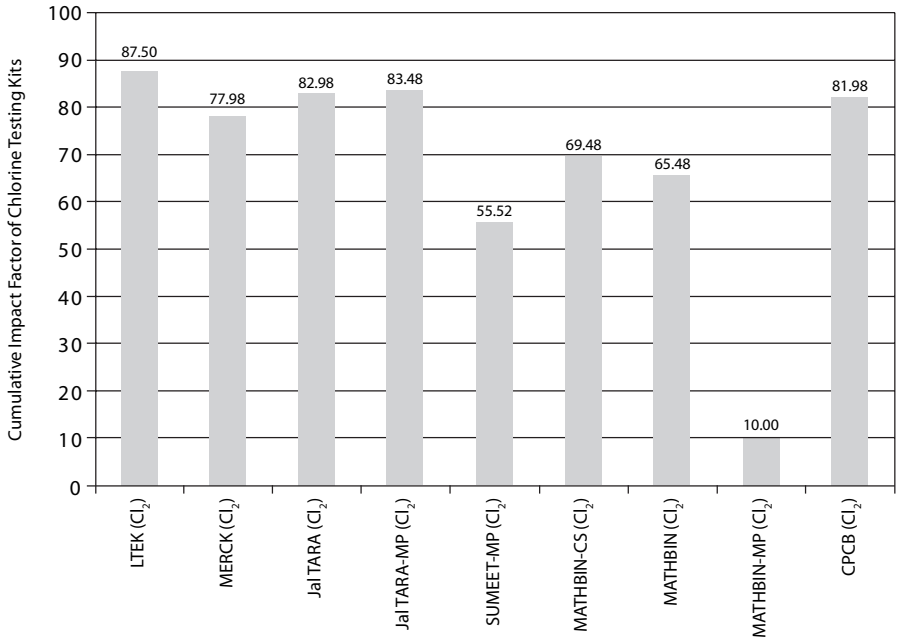
E. Chlorine Testing Kits

Nine kits were evaluated and their technical efficiency was estimated as under:

Table- 11: Effectiveness of Chlorine Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
LTEK (Cl_2)	8.75	10.0	8.5	8.0	2.00	7.82 (3DF)	87.50
MERCK (Cl_2)	8.33	10.0	8.5	1.0	2.00	5.99 (2DF)	77.98
Jal TARA (Cl_2)	8.33	10.0	7.5	8.0	2.00	5.99 (2DF)	82.98
Jal TARA-MP (Cl_2)	8.33	8.5	7.5	10.0	2.00	5.99 (2DF)	83.48
SUMEET-MP (Cl_2)	6.67	8.5	1.0	5.0	4.00	5.99 (2DF)	55.52
MATHBIN-CS (Cl_2)	8.33	8.5	3.0	5.0	2.00	5.99 (2DF)	69.48
MATHBIN (Cl_2)	8.33	8.5	3.0	1.0	2.00	5.99 (2DF)	65.48
MATHBIN-MP (Cl_2)	0	0	5.0	0	-	-	10.00
CPCB (Cl_2)	8.33	10.0	9.0	4.0	2.00	5.99 (2DF)	81.98

Cumulative Impact Factor of Chlorine Testing Kits



Based on the CIF, four kits namely LTEK (Cl_2), Jal TARA-MP (Cl_2), Jal TARA (Cl_2) and CPCB-MP (Cl_2) are observed to be the best kits as evident by their impact factors 87.50, 83.48, 82.98 and 81.98 respectively.

F. Chloride Testing Kits

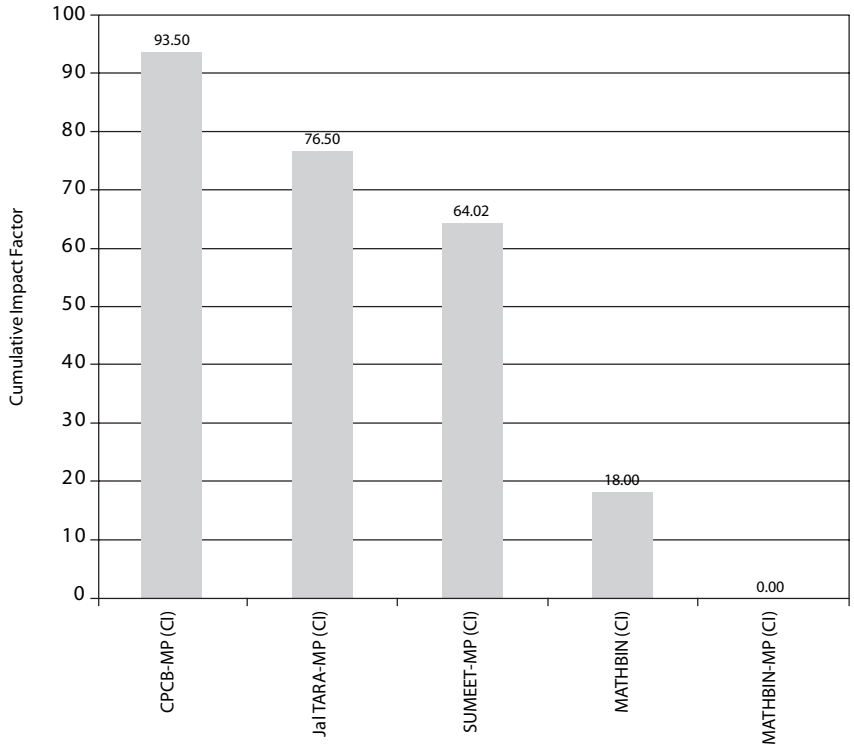
Five kits were evaluated and their technical efficiency was estimated as under:

Table- 12 Effectiveness of Chloride Testing Kits

Kit ID	PIF (I_{TE})				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
CPCB-MP (Cl)	10.00	9.5	10.0	4.0	0	5.99 (2DF)	93.50
Jal TARA-MP (Cl)	7.50	8.5	7.5	8.0	2.25	5.99 (2DF)	76.50
SUMEET-MP (Cl)	6.67	7.0	6.0	5.0	5.00	5.99 (2DF)	64.02
MATHBIN-Cl	0	6.0	5.5	1.0	12.00	5.99 (2DF)	18.00
MATHBIN-MP-Cl	0	0	5.0	0	-	-	0

Based on the CIF, only one kit namely CPCB-MP (Cl) is observed to be the best kit as evident by its impact factor 93.50.

Cumulative Impact Factor of Chloride Testing Kits



G. Alkalinity Testing Kits

Two kits were evaluated and their technical efficiency was estimated as under:

Table- 13: Effectiveness of Alkalinity Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
CPCB-MP (Alk)	10.00	9.5	10.0	4.0	0	5.99 (2DF)	93.50
MATHBIN (Alk)	0	0	0	0	-	-	0

Based on the CIF, only one kit namely CPCB-MP (Alk) is observed to be the best kit as evident by its impact factor 93.50.

H. Hardness Testing Kits

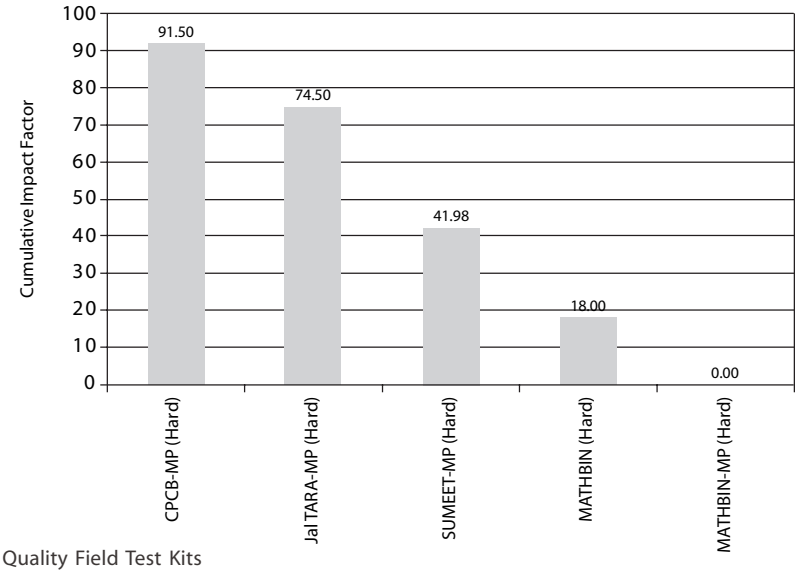
Five kits were evaluated and their technical efficiency was estimated as under:

Table- 14 : Effectiveness of Hardness Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
CPCB-MP (Hard)	10.00	9.5	9.0	4.0	0	5.99 (2DF)	91.50
Jal TARA-MP (Hard)	7.50	8.5	6.5	8.0	2.75	5.99 (2DF)	74.50
SUMEET-MP (Hard)	3.33	7.0	5.0	5.0	10.00	5.99 (2DF)	41.98
MATHBIN (Hard)	0	6.0	5.5	1.0	12.00	5.99 (2DF)	18.00
MATHBIN-MP (Hard)	0	0	0	0	-	-	0

Based on the CIF, only one kit namely CPCB-MP (Hard) is observed to be the best kit as evident by its impact factor 91.50.

Cumulative Impact Factor of Hardness Testing Kits



I. Aluminium Testing Kits

Two kits were evaluated and its technical efficiency was estimated as under:

Table- 15: Effectiveness of Aluminium Testing Kits

Kit ID	PIF				Chi-square (χ^2) Goodness-of-Fit		CIF
	I_{TE}	I_{adq}	I_{safety}	I_{inf}	Estimated	Critical	
MERCK-Al	8.89	10.0	7.5	3.0	1.33	5.99 (2DF)	81.34

CIF of MERCK (Al) kit is observed to 81.34 as evident by the analysis of data given above.

7. Effectiveness vs. Cost of the Kits

The major aim of "Water Quality Field Test Kit" is to provide a sustainable and cost-effective water quality-monitoring tool, which can test the water source effectively and periodically. Cost analysis of the kits and its comparison with the overall effectiveness, provides a useful management tool to decision-makers to decide about the sustainable and cost-effective tool for "Community based water quality monitoring programme" in India. Further, it will help in rationalizing the initial cost as well as the replenishment cost of the kits.

A. Single Parameter Kits

(a) Arsenic Testing Kits

Nine kits (single parameter "As") were evaluated during the present study. Cost analysis of these kits is summarized in the following table, which reveals the significant information as given hereunder:

Table-16 Cost analysis of arsenic test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
Jal TARA (As)	46.48	2916	50	58	2700*	54	100
CIC-NCL (As)	81.66	6918	100	69	4370	44	63
MATHBIN (As)	16.32	1998	50	40	1998*	40	100
MERCK-Sensitive (As)	71.68	4144	100	41	4144*	41	100
MERCK-HS (As)	81.58	7724	100	77	7724*	77	100
TechnoAd-AIIH&PH (As)	41.00	2079	100	21	1000	10	48
TechnoAd-DRDO (As)	40.00	2420	100	24	1750	18	72
SUMEET-AIIH&PH (As)	59.82	1980	100	20	1200	12	61
IEHS-China (As)	80.98	1200	100	12	1200*	10	100

** Replenishment cost is not available.*

(i) Out of nine kits evaluated, only three kits namely CIC-NCL (As), MERCK-HS (As) and IEHS-China (As) are observed to be the best kits as evident by their cumulative impact factor 81.66, 81.58 and 80.98 respectively. CIF of remaining kits was estimated ranging between 16.32 to 71.68.

(ii) Cost of the kits (inclusive of local taxes) varied between Rs.1200/- to Rs.7724/- based on the amount paid during the anonymous procurement of the kits for evaluation programme.

(iii) In general, these kits as per the information given in the respective kit manuals can perform 50-100 Nos. of tests. Hence, cost per test varied between Rs. 12/- to Rs.77/-. Cost per test in case of effective kits is estimated Rs.69/- for CIC-NCL (As) having CIF 81.66, Rs.77/- for MERCK-HS (As) having CIF 81.58 and Rs.12/- for IEHS-China (As) having CIF 80.98. However, in case of MERCK-Sensitive (As) having CIF 71.68, the estimated cost per test is Rs.41/-

(b) Fluoride Testing Kits

Eleven kits (single parameter "F") were evaluated during the present study. Cost analysis of these kits is summarized in the following table, which reveals the significant information as given hereunder:

Table-17 Cost analysis of fluoride test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
Jal TARA (F)	82.98	864	100	9	864*	9	100
LTEK-BARC (F)	88.64	2100	100	21	600	6	29
LTEK-NCL (F)	53.50	1500	100	15	600	6	40
SUMEET (F)	56.86	3025	100	30	500	5	17
MATHBIN (F)	21.00	324	50	6	324*	6	100
INDION (F)	17.00	1232	100	12	1232*	12	100
TechnoAs-ICS (F)	52.60	1980	300	7	1500	5	76
TechnoAd-DRL (F)	54.00	1650	100	17	1200	12	73
CIC-NCL (F)	64.52	1499	100	15	850	9	57
LTEK-NEERI (F)	29.00	2100	100	21	600	6	29
TechnoAd-AIIH&PH (F)	6.00	1386	100	14	500	5	36

** Replenishment cost is not available.*

(i) Out of eleven kits evaluated, only two kits namely LTEK-BARC and Jal TARA (F) are observed to be the best kits as evident by their cumulative impact factor 88.64 and 82.98 respectively. CIF of remaining kits was estimated ranging between 6.00 to 64.52.

(ii) Cost of the kits (inclusive of local taxes) varied between Rs.324/- to Rs.3025/- based on the amount paid during the anonymous procurement of the kits for evaluation programme.

(iii) In general, these kits as per the information given in the respective kit manuals can perform 50-300 Nos. of tests. Hence, cost per test varied between Rs. 6/- to Rs.30/-. Cost per test in case of effective kits is estimated Rs.21/- for LTEK-BARC having CIF 88.64 and Rs.9/- for Jal TARA (F) having CIF 82.98.

(c) Iron Testing Kits

Nine kits (single parameter "Fe") were evaluated during the present study. Cost analysis of these kits is summarized in the following table, which reveals the significant information as given hereunder:

Table-18 Cost analysis of iron test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
LTEK (Fe)	74.02	2100	100	21	600	6	29
SUMEET (Fe)	50.50	3025	100	30	500	5	17
Jal TARA (Fe)	81.98	1053	100	11	1053*	11	100
MERCK (Fe)	82.00	8156	300	27	8156*	27	100
INDION (Fe)	34.98	3124	100	31	3124*	31	100
TechnoAd-ICS (Fe)	57.76	2420	100	24	1710	17	71
TechnoAd-AIIH&PH (Fe)	48.50	1650	100	17	700	7	42
MATHBIN (Fe)	9.00	648	50	13	648	13	100
TechnoAd-DRL (Fe)	13.00	1320	100	13	700	7	53

** Replenishment cost is not available.*

(i) Out of nine kits evaluated, only two kits namely MERCK (Fe) and Jal TARA (Fe) are observed to be the best kits as evident by their cumulative impact factor 82.00 and 81.98 respectively. CIF of remaining kits was estimated ranging between 9.00 to 74.02.

(ii) Cost of the kits (inclusive of local taxes) varied between Rs.648/- to Rs.8156/- based on the amount paid during the anonymous procurement of the kits for evaluation programme.

(iii) In general, these kits as per the information given in the respective kit manuals can perform 50-300 Nos. of tests. Hence, cost per test varied between Rs. 11/- to Rs.31/-. Cost per test in case of effective kits is estimated Rs.27/- for MERCK-Fe having CIF 82.00 and Rs.11/- for Jal TARA (Fe) having CIF 81.98.

(d) Nitrate Testing Kits

Eight kits (single parameter "NO_3") were evaluated during the present study. Cost analysis of these kits is summarized in the following table, which reveals the significant information as given hereunder:

Table-19 Cost analysis of nitrate test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
Jal TARA (NO_3)	73.42	1188	100	12	1188*	12	100
LTEK-NCL (NO_3)	53.00	1500	100	15	600	6	40
LTEK-NCL (NO_3) Improved	84.00	2100**	100	21	600	6	29
MATHBIN (NO_3)	12.00	351	50	7	351*	7	100
TechnoAd-AIIH&PH (NO_3)	20.02	1485	100	15	950	10	64
MERCK (NO_3)	90.00	2300	100	23	2300*	23	100
SUMEET (NO_3)	28.00	3025	100	30	500	5	17
CIC-NCL (NO_3)	37.00	1499	100	15	850	9	57

** Replenishment cost is not available.*
*** Tentative cost (complimentary kit)*

(i) Out of nine kits evaluated, only two kits namely MERCK (NO_3) and LTEK-NCL (NO_3)- Improved, are observed to be the best kits as evident by their cumulative impact factor 90.00 and 84.00 respectively. CIF of remaining kits was estimated ranging between 12.00 to 73.42.

(ii) Cost of the kits (inclusive of local taxes) varied between Rs.351/- to Rs.3025/- based on the amount paid during the anonymous procurement of the kits for evaluation programme.

(iii) In general, these kits as per the information given in the respective kit manuals can perform 50-100 Nos. of tests. Hence, cost per test varied between Rs. 7/- to Rs.30/-. Cost per test in case of effective kits is estimated Rs.23/- for MERCK (NO_3) having CIF 90.00 and Rs.21/- for LTEK-NCL (NO_3)-Improved, having CIF 84.00.

(e) Chlorine Testing Kits

Five kits (single parameter "Cl_2") were evaluated during the present study. Cost analysis of these kits is summarized in following table, which reveals the significant information as given hereunder:

Table-20 Cost analysis of chlorine test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
LTEK (Cl_2)	87.50	350	100	4	28	0.3	8
MERCK (Cl_2)	77.98	1612	100	16	1612*	16	100
Jal TARA (Cl_2)	82.98	972	100	10	972*	10	100
MATHBIN-CS (Cl_2)	69.48	702	100	7	702*	7	100
MATHBIN (Cl_2)	65.48	378	50	8	378*	8	100

** Replenishment cost is not available.*

(i) Out of five kits evaluated, only two kits namely LTEK (Cl_2) and Jal TARA (Cl_2), are observed to be the best kits as evident by their cumulative impact factor 87.50 and 82.98 respectively. CIF of remaining kits was estimated ranging between 65.48 to 77.98.

(ii) Cost of the kits (inclusive of local taxes) varied between Rs.350/- to Rs.1612/- based on the amount paid during the anonymous procurement of the kits for evaluation programme.

(iii) In general, these kits as per the information given in the respective kit manuals can perform 50-100 Nos. of tests. Hence, cost per test varied between Rs. 4/- to Rs.16/-. Cost per test in case of effective kits is estimated Rs.4/- for LTEK (Cl_2), having CIF 87.50 and Rs.10/- for Jal TARA (Cl_2), having CIF 82.98.

(f) Other Single Parameter (Chloride, Alkalinity, Hardness & Alkalinity) Testing Kits

Other single parameter kits namely MATHBIN (Cl)-Chloride Test Kit, MATHBIN (Alk)-Alkalinity Test Kit, MATHBIN (Hard); Hardness Testing Kit and MERCK (Al)-Aluminium Testing Kits were evaluated during the present study. Cost analysis of these kits is summarized in following table, which reveals the significant information as given hereunder:

Table- 21 Cost analysis of other single parameter test kits

Kit Description	CIF	Basic Cost + LT (Rs)	No. of Tests	Cost (Rs)/ Test (Initial)	Replenishment of Consumables		
					Cost (Rs)	Cost (Rs)/ Test	% of initial cost
MATHBIN (Cl)*	18.00	432	50	9	432	50	100
MATHBIN (Alk)*	0	378	50	8	378	50	100
MATHBIN (Hard)*	18.00	324	50	6	324	50	100
MERCK (Al)*	81.34	8156	185	44	8156	185	100

** Replenishment cost is not available.*

(i) MATHBIN (Cl) kit is not found effective during the evaluation as evident by its CIF 18.00. As per the information provided in the kit manual, 50 tests can be done with the available reagents and cost of the kit is Rs.432/- and cost of refill is not available. Hence, cost per test is estimated at Rs.9/-.

(ii) MATHBIN (Alk) kit is not found effective at all during the evaluation as evident by its zero CIF.

(iii) MATHBIN (Hard) kit is also not found effective during the evaluation as evident by its CIF 18.00. As per the information provided in the kit manual, 50 tests can be done with the available reagents and cost of the kit is Rs.324/- and cost of refill is not available. Hence, cost per test is estimated at Rs.6/-.

(iv) MERCK (Al) kit is observed to be an effective kit during the evaluation as evident by its CIF 81.34. As per the information provided in the kit manual, 185 tests can be done with the available reagents and cost of the kit is Rs.8156/- and cost of refill is not available. Hence, cost per test is estimated at Rs.44/-.

B. Multiple Parameter Kits

Multiple Parameter Kits have the provision for testing number of parameters (Physico-chemical, Bacteriological and Biological) in one kit system. In the present evaluation programme, four multiple parameter kits, as described in the following tables, were taken for evaluation.

Table- 22 Chemical parameters evaluated in multiple-parameter kits

Kits Description	Potential Chemical Parameters taken for evaluation							No. of other parameter (not evaluated)
	F	Fe	NO_3	Cl_2	Cl	Alk	Hard	
Jal TARA-MP	✔	✔	✔	✔	✔	*	✔	9
SUMEET-MP	✔	✔	✔	✔	✔	*	✔	3
CPCB-MP	✔	✔	✔	✔	✔	✔	✔	12
MATHBIN-MP	✔	✔	✔	✔	✔	✔	✔	5

** Parameter not given in the kit*

Table- 23 Description of other parameters (not evaluated) in multiple-parameter kits

Kits Description	DO	pH	Temp	P	NH_3	Turb	SS	Colour	Odour	TDS	NO_2	Benthos	PP	Coliform Faecal
Jal TARA-MP	✔	✔	✔	✔	✔	✔	*	*	*	*	*	✔	✔	✔
SUMEET-MP	*	✔	*	*	*	✔	*	*	*	*	*	*	*	✔
CPCB-MP	✔	✔	✔	✔	✔	✔	✔	✔	✔	*	*	✔	✔	✔
MATHBIN-MP	*	✔	*	*	*	✔	*	*	*	✔	✔	*	*	✔

** Parameter not given in the kit*

Parameter- wise cumulative impact factor was estimated for the specified parameters, which have been illustrated in previous chapters. Kit-wise average CIF is compared with the cost of the kit.

Table- 24 Description of other parameters (not evaluated) in multiple-parameter kits

Kits Description	CIF								Cost
	F	Fe	NO_3	Cl_2	Cl	Alk	Hard	Average	
Jal TARA-MP	81.48	81.48	65.50	83.48	76.50	*	74.50	77.2	6048
SUMEET-MP	61.02	51.02	25.50	55.52	64.02	*	41.98	49.8	11550
CPCB-MP	81.48	84.48	0	81.98	93.50	93.50	91.50	75.2	2000
MATHBIN-MP	18.00	7.00	10.00	10.00	0	0	0	6.4	10584

** Parameter not given in the kit*

(a) Jal TARA-MP

Kit was evaluated for six parameters viz. Fluoride, Iron, Nitrate, Chlorine, Chloride and Hardness. Maximum CIF was estimated 83.48 in case of Chlorine test, followed by Fluoride and Iron tests both for which CIF was found 81.48. Minimum CIF was observed 65.50 in case of Nitrate test. However, average CIF for all the six parameters, was estimated 77.2. Cost of the kit inclusive of local taxes is Rs.6048/- and in general 100 tests for each parameter can be performed.

(b) SUMEET-MP

Kit was evaluated for six parameters viz. Fluoride, Iron, Nitrate, Chlorine, Chloride and Hardness. Maximum CIF was estimated 64.02 in case of Chloride test kit and minimum CIF was observed 25.50 in case of Nitrate test. However, average CIF for all the six parameters, was estimated 49.8. Cost of the kit inclusive of local taxes is Rs.11550/- and in general 100 tests for each parameter can be performed. Hence, kit cost per parameter is estimated at Rs.115.50.

(c) CPCB-MP

Kit was evaluated for seven parameters viz. Fluoride, Iron, Nitrate, Chlorine, Chloride, Alkalinity and Hardness. Maximum CIF was estimated 93.50 in case of Chloride and Alkalinity test kits both, which was followed by Iron (CIF 84.48), Chlorine (CIF 81.98) and Fluoride (CIF 81.48). However, for Nitrate, test strips, as mentioned in the kit manual, were not found in the kit and hence zero CIF in this case. Further, average CIF for all the seven parameters, was estimated 77.2. Cost of the kit is Rs.2000/- and in general 100 tests for each parameter can be performed. Hence, kit cost per parameter is estimated at Rs.20.00.

(d) MATHBIN-MP

Kit was evaluated for seven parameters viz. Fluoride, Iron, Nitrate, Chlorine, Chloride, Alkalinity and Hardness. Maximum CIF was estimated 18.00 in case of Fluoride. In case of Chloride, Alkalinity and Hardness, CIF is estimated zero. Cost of the kit is Rs.10584/-. Kit is of very poor quality. In case of most of the parameters, either chemical are not provided or wrong chemicals are given.

The purpose of multiple parameter kit is to test effectively the number of potential water quality parameters, using the same kit in the areas where multiple water quality problems exist. In the present study of the evaluation of water quality field test kits, only CPCB & Jal TARA kits are found effective, though degree of effectiveness varied from parameter to parameter. The cost analysis of the kits also gives significant information, which will help decision-makers to decide on the appropriate kit considering the sustainability and cost-effectiveness.

8 Decision Support System

The objective of DSS for Water Quality Field Test Kits is to provide a quantitative rating tool to decision-makers to select appropriate kit for Community based Water Quality Monitoring and Surveillance Programme. It will also help research organisations/ kit developers as well as kit manufacturers to set targets for improvement in specific area (s).

(a) Decision Tool

In order to assign appropriate rating to WQFTK based on Parameter Impact Factor (PIF) and Cumulative Impact Factor (CIF), following mechanism is devised as a "decision tool"

Table-25 Kits Rating Matrix

Parameter Impact Factor	Cumulative Impact Factor	Ranking/ Grading	Descriptor's Word	Rating
>9 to ≤10	>90 to ≤100	A1	• Kit is almost complete in all aspects	Excellent
>8 to ≤9	>80 to ≤90	A2	• Kit requires very little interventions for the up-gradation	Very Good
>7 to ≤8	>70 to ≤80	B1	• Kit needs betterment in specific area(s) with some interventions	Good
>6 to ≤7	>60 to ≤70	B2	• Kit needs betterment in specific area(s) with appreciable interventions	Moderate
>5 to ≤6	>50 to ≤60	C1	• Kit needs considerable interventions in most of the areas for improvement	Average
>4 to ≤5	>40 to ≤50	C2	• Kit needs major interventions in all areas for improvement	Below Average
>3 to ≤4	>30 to ≤40	D1	• Alarming Situation if impact is of irreversible nature.	Poor
>2 to ≤3	>20 to ≤30	D2	• Alarming Situation if impact is of irreversible nature.	Very Poor
>1 to ≤2	>10 to ≤20	E1	• Alarming Situation if impact is of irreversible nature.	Very Poor
≤1	≤10	E2	• Alarming Situation if impact is of irreversible nature.	Very Poor

(b) Ranking and Rating of WQFTK

(i) Arsenic Testing Kits

Out of nine kits evaluated, only three were found to be of A2 grade. None of the kit was found in the category of A1 grade.

Table- 26 Ranking and Rating of Arsenic Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
Jal TARA (As)	4.58	C2	8.0	B1	3.0	D2	5.0	C2	46.48	C2
CIC-NCL (As)	8.61	A2	9.0	A2	9.0	A2	3.0	D2	81.66	A2
MATHBIN (As)	2.22	D2	2.0	E1	0	E2	1.0	E2	16.32	E1
MERCK-Sensitive (As)	7.78	B1	9.0	A2	7.5	B1	3.0	D2	71.68	B1
MERCK-HS (As)	8.18	A2	9.5	A1	10.0	A1	3.0	D2	81.58	A2
TechnoAd-AIIH&PH (As)	5.00	C2	5.0	C2	2.0	E1	3.0	D2	41.00	C2
TechnoAd-DRDO (As)	5.00	C2	5.0	C2	2.0	E1	1.0	E2	40.00	D1
SUMEET-AIIH&PH (As)	6.97	B2	7.0	B2	4.0	D1	3.0	D2	59.82	C1
IEHS-China (As)	8.33	A2	10.0	A1	9.5	A1	2.0	E1	80.98	A2

(ii) Fluoride Testing Kits

Out of 15 kits evaluated, only four were found to be of A2 grade. None of the kit was found in the category of A1 grade.

Table- 27 Ranking and Rating of Fluoride Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
Jal TARA (F)	8.33	A2	10.0	A1	7.5	B1	8.0	B1	82.98	A2
Jal TARA-MP (F)	8.33	A2	8.5	A2	7.5	B1	8.0	B1	81.48	A2
LTEK-BARC (F)	9.44	A1	10.0	A1	8.5	A2	5.0	C2	88.64	A2
LTEK-NCL (F)	5.00	C2	8.5	A2	4.5	C2	6.0	C1	53.50	C1
SUMEET (F)	5.56	C1	9.5	A1	6.5	B2	1.0	E2	56.86	C1
SUMEET-MP (F)	6.67	B2	8.0	B1	4.5	C2	4.0	D1	61.02	B2
CPCB-MP (F)	8.33	A2	9.5	A1	9.0	A2	4.0	D1	81.48	A2
MATHBIN (F)	0	E2	7.0	B2	6.5	B2	1.0	E2	21.00	D2
MATHBIN-MP (F)	0	E2	4.0	D1	6.5	B2	1.0	E2	18.00	E1
INDION (F)	0	E2	8.0	B1	3.5	D1	2.0	E1	17.00	E1
TechnoAs-ICS (F)	4.10	C2	8.0	B1	9.0	A2	2.0	E1	52.60	C1
TechnoAd-DRL (F)	5.00	C2	10.0	A1	6.5	B2	1.0	E2	54.00	C1
CIC-NCL (F)	6.67	B2	10.0	A1	6.5	B2	1.5	E1	64.52	B2
LTEK-NEERI (F)	0	E2	9.0	A2	9.0	A2	6.0	C1	33.00	D1
TechnoAd-AIIH&PH (F)	0	E2	1.0	E2	2.5	D2	0	E2	6.00	E2

(iii) Iron Testing Kits

Out of 13 kits evaluated, only four were found to be of A2 grade. None of the kit was found in the category of A1 grade.

Table- 28 Ranking and Rating of Iron Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
LTEK (Fe)	6.67	B2	9.0	A2	10.0	A1	8.0	B1	77.02	B1
SUMEET (Fe)	7.00	B2	5.5	C1	1.0	E2	1.0	E2	50.50	C1
SUMEET-MP (Fe)	6.67	B2	5.5	C1	1.0	E2	3.5	D1	51.02	C1
CPCB-MP (Fe)	8.33	A2	9.5	A1	9.0	A2	4.0	D1	84.48	A2
Jal TARA-MP (Fe)	8.33	A2	7.5	B1	7.5	B1	9.0	A2	81.48	A2
Jal TARA (Fe)	8.33	A2	9.0	A2	7.5	B1	8.0	B1	81.98	A2
MERCK (Fe)	9.00	A2	10.0	A1	7.5	B1	3.0	D2	82.00	A2
INDION (Fe)	3.33	D1	7.0	B2	3.0	D2	2.0	E1	34.98	D1
TechnoAd-ICS (Fe)	5.71	C1	8.5	A2	6.5	B2	2.0	E1	57.76	C1
TechnoAd-AIIH&PH (Fe)	6.00	C1	5.5	C1	3.5	D1	0	E2	48.50	C2
MATHBIN (Fe)	0	E2	2.0	E1	3.5	D1	0	E2	9.00	E2
MATHBIN-MP (Fe)	0	E2	0	E2	3.5	D1	0	E2	7.00	E2
TechnoAd-DRL (Fe)	0	E2	3.0	D2	4.5	C2	1.0	E2	13.00	E1

(iv) Nitrate Testing Kits

Out of 11 kits evaluated, only two were found to be of A2 grade. None of the kit was found in the category of A1 grade.

Table-29 Ranking and Rating of Nitrate Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
Jal TARA (NO_3)	8.57	A2	8.0	B1	5.0	C2	4.0	D1	73.42	B1
Jal TARA-MP (NO_3)	7.50	B1	6.5	B2	5.0	C2	4.0	D1	65.50	B2
LTEK-NCL (NO_3)	5.00	C2	9.0	A2	5.0	C2	4.0	D1	53.00	C1
LTEK-NCL (NO_3) Improved	8.75	A2	9.5	A1	8.0	B1	6.0	C1	84.00	A2
MATHBIN (NO_3)	0	E2	2.0	E1	5.0	C2	0	E2	12.00	E1
MATHBIN-MP (NO_3)	0	E2	0	E2	5.0	C2	0	E2	10.00	E2
TechnoAd-AIIH&PH (NO_3)	1.67	E1	5.5	C1	2.0	E1	0.5	E2	20.02	D2
MERCK (NO_3)	8.75	A2	10.0	A1	10.0	A1	7.5	B1	90.00	A2
SUMEET (NO_3)	2.50	D2	6.0	C1	1.5	E1	4.0	D1	28.00	D2
SUMEET-MP (NO_3)	2.50	D2	5.0	C2	1.0	E2	3.5	D1	25.50	D2
CIC-NCL (NO_3)	2.50	D2	8.5	A2	6.0	C1	1.5	E1	37.00	D1

(v) Chlorine Testing Kits

Out of nine kits evaluated, only four were found to be of A2 grade. None of the kit was found in the category of A1 grade.

Table- 30 Ranking and Rating of Chlorine Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
LTEK (Cl_2)	8.75	A2	10.0	A1	8.5	A2	8.0	B1	87.50	A2
MERCK (Cl_2)	8.33	A2	10.0	A1	8.5	A2	1.0	E2	77.98	B1
Jal TARA (Cl_2)	8.33	A2	10.0	A1	7.5	B1	8.0	B1	82.98	A2
Jal TARA-MP (Cl_2)	8.33	A2	8.5	A2	7.5	B1	10.0	A1	83.48	A2
SUMEET-MP (Cl_2)	6.67	B2	8.5	A2	1.0	E2	5.0	C2	55.52	C1
MATHBIN-CS (Cl_2)	8.33	A2	8.5	A2	3.0	D2	5.0	C2	69.48	B2
MATHBIN (Cl_2)	8.33	A2	8.5	A2	3.0	D2	1.0	E2	65.48	B2
MATHBIN-MP (Cl_2)	0	E2	0	E2	5.0	C2	0	E2	10.00	E2
CPCB (Cl_2)	8.33	A2	10.0	A1	9.0	A2	4.0	D1	81.98	A2

(vi) Chloride Testing Kits

Out of five kits evaluated, only one was found to be of A1 grade. None of the remaining kit was found in the category of A2 grade.

Table- 31 Ranking and Rating of Chloride Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
CPCB-MP (Cl)	10.00	A1	9.5	A1	10.0	A1	4.0	D1	93.50	A1
Jal TARA-MP (Cl)	7.50	B1	8.5	A2	7.5	B1	8.0	B1	76.50	B1
SUMEET-MP (Cl)	6.67	B2	7.0	B2	6.0	B2	5.0	C2	64.02	B2
MATHBIN-Cl	0	E2	6.0	C1	5.5	C1	1.0	E2	18.00	E1
MATHBIN-MP-Cl	0	E2	0	E2	5.0	C2	0	E2	0	E2

(vii) Alkalinity Testing Kits

Out of two kits evaluated, one was found to be of A1 grade, while other was in E2 grade.

Table- 32 Ranking and Rating of Alkalinity Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
CPCB-MP (Alk)	10.00	A1	9.5	A1	10.0	A1	4.0	D1	93.50	A1
MATHBIN (Alk)	0	E2	0	E2	0	E2	0	E2	0	E2

(viii) Hardness Testing Kits

Out of five kits evaluated, only one was found to be of A1 grade. None of the remaining kit was found in the category of A2 grade.

Table-33 Ranking and Rating of Hardness Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
CPCB-MP (Hard)	10.00	A1	9.5	A1	9.0	A2	4.0	D1	91.50	A1
Jal TARA-MP (Hard)	7.50	B1	8.5	A2	6.5	B2	8.0	B1	74.50	B1
SUMEET-MP (Hard)	3.33	D1	7.0	B2	5.0	C2	5.0	C2	41.98	C2
MATHBIN (Hard)	0	E2	6.0	C1	5.5	C1	1.0	E2	18.00	E1
MATHBIN-MP (Hard)	0	E2	0	E2	0	E2	0	E2	0	E2

(ix) Aluminium Testing Kits

Only one kit was evaluated, which was found of A2 grade.

Table-34 Ranking and Rating of Aluminium Testing Kits

Kit Description	Parameter Impact Factor								Cumulative Impact Factor	
	Technical Efficiency		Adequacy		Safety		Information		CIF	Rank
	I_{TE}	Rank	I_{adq}	Rank	I_{safety}	Rank	I_{inf}	Rank		
MERCK-(Al)	8.89	A2	10.0	A1	7.5	B1	3.0	D2	81.34	A2

(c) Effective Water Testing Kits

The effective kits based on the evaluation studies are those, which are either complete in all aspects or require little interventions for the up-gradation in some of the areas. Based on the effectiveness in terms of parameters (Technical, safety, adequacy & information), as illustrated earlier, and ranking and rating matrix explained in this chapter, only A-1 and A-2 categories of kits can be considered as the effective kits for relevant tests.

Further, on the basis of effectiveness criteria, as mentioned above, weak parameters can be highlighted even in case of effective kits, so that these kits can be up-graded accordingly. Table-35 illustrates the overall effectiveness of A-1 and A-2 kits as well as highlights the weaknesses with ranking and the type of impact.

Table-35 Effective Kits based on the Evaluation Study

Test	Kit Description	CIF		Weakness (es)		
				Parameter	Rank	Type of Impact
Arsenic	CIC-NCL (As)	81.66	A2	Information	D2	Can be reversible
	MERCK-HS (As)	81.58	A2	Information	D2	Can be reversible
	IEHS-China (As)	80.98	A2	Information	E1	Can be reversible
Fluoride	LTEK-BARC (F)	88.64	A2	Information	C2	Can be reversible
	Jal TARA (F)	82.98	A2	Information	B1	Can be reversible
	Jal TARA-MP (F)	81.48	A2	Information	B1	Can be reversible
	CPCB-MP (F)	81.48	A2	Information	D1	Can be reversible
Iron	CPCB-MP (Fe)	84.48	A2	Information	D1	Can be reversible
	MERCK (Fe)	82.00	A2	Information	D2	Can be reversible
	Jal TARA (Fe)	81.98	A2	Information	B1	Can be reversible
				Safety	B1	–
	Jal TARA-MP (Fe)	80.48	A2	Information	B1	Can be reversible
				Safety	B1	–
Nitrate	MERCK (NO_3)	90.00	A2	Information	B1	Can be reversible
	LTEK-NCL (NO_3) Imp.	84.00	A2	Information	C1	Can be reversible
Chlorine	LTEK (Cl_2)	87.50	A2	Information	B1	Can be reversible
	Jal TARA (Cl_2)	82.98	A2	Information	B1	Can be reversible
				Safety	B1	–
	CPCB (Cl_2)	81.98	A2	Information	B1	Can be reversible
	Jal TARA-MP (Cl_2)	81.48	A2	Safety	B1	–
Chloride	CPCB-MP (Cl)	93.50	A1	Information	D1	Can be reversible
Alkalinity	CPCB-MP (Alk)	93.50	A1	Information	D1	Can be reversible
Hardness	CPCB-MP (Hard)	91.50	A1	Information	D1	Can be reversible
Aluminium	MERCK (Al)	81.34	A2	Information	D2	Can be reversible

"Decision Support System" provides

A comprehensive analytical base, which would help decision-makers to select appropriate Water Quality Field Test Kit for Community based Water Quality Monitoring and Surveillance Programme in India.It will also help in development of an effective protocol for WQFTK, which is presently not existing in India.

9 Conclusion and Recommendations

The objective of Community Based Water Quality Monitoring (CBWQM) in India can only be achieved by using effective Water Quality Field Test Kits (WQFTK). The comprehensive evaluation study conducted to assess the effectiveness of "Water Quality Field Test Kits" for potential test parameters (chemical), can be summed up into following Conclusions and Recommendations:

(a) Conclusions

The study reveals the parameter wise percentage of effective kits (A-1 and A-2 categories) as under:

Table- 36 Percentage of effective kits

S.No.	Type of Kits	No. of Kits Evaluated	Effective Kits (%)
1.	Arsenic Test Kits	09	33%
2.	Fluoride Test Kits	15	27%
3.	Iron Test Kits	13	31%
4.	Nitrate Test Kits	11	18%
5.	Chlorine Test Kits	09	44%
6.	Chloride Test Kits	05	20%
7.	Alkalinity Test Kits	02	50%
8.	Aluminium Test Kits	01	100%
9.	Single Parameter Kits	46	26%
10.	Multiple Parameter Kits	04	50%

(b) Recommendations

Study indicates very low percentage of effective water quality field test kits available in the country for community based water quality monitoring programmes. In order to strengthen CBWQM, following recommendations could be envisaged:

(i) Shelf-life study of existing water testing kits should be conducted to ascertain the useful life of the kits.

(ii) Research and development efforts should be scaled-up and shall focus primarily on:

- Reduction/elimination of the hazard involved in using the kits.
- Enhancement of the technical efficiency of the kits.
- Amelioration of the kits in terms of user-friendliness.

(iii) The cost of the kits may be rationalized.

(iv) A National level debate on the subject may help in framing the Protocol on "Water Quality Field Test Kits" in India.

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List of Abbreviations

AIIH&PH	:	All India Institute of Hygiene and Public Health
Al	:	Aluminium
As	:	Arsenic
BARC	:	Bhabha Atomic Research Centre
CIF	:	Cumulative Impact Factor
Cl	:	Chloride
Cl_2	:	Chlorine
CPCB	:	Central Pollution Control Board
CBWQM	:	Community Based Water Quality Monitoring
dF	:	Degree of Freedom
DM	:	Demineralised Water
DRDO	:	Defence Research and Development Organisation
DRL	:	Defence Research Laboratory
DPD	:	NN-diethyl-p-phenylenediamine
DSS	:	Decision Support System
EDTA	:	Ethylene diamine tetra acetic acid
FI-HG-AAS	:	Flow Injection-Hydride Generation-Atomic Absorption Spectrometry
F	:	Fluoride
Fe	:	Iron
HS	:	Highly Sensitive
LR	:	Low Range
mg/l	:	milligram per litre
MDL	:	Minimum Detection Level
MP	:	Multiple Parameter
MPL	:	Maximum Permissible Limit
NCL	:	National Chemical Laboratory
NEERI	:	National Environmental Engineering Research Institute
NGOs	:	Non-government Organisations
NO_3	:	Nitrate
OTE	:	Overall Technical Efficiency
PIF	:	Parameter Impact Factor
R&D	:	Research and Development
RSD	:	Relative Standard Deviation
SDDC	:	Silver Diethyldithio Carbamate
SPADNS		Sodium 2-(parasulfophenylazo)-1,8-dihydroxy-3,6-naphthalene disulfonate
SE	:	Sensitivity
SIIR	:	Shriram Institute for Industrial Research
SP	:	Specificity
SSA	:	Special Service Agreement
TE	:	Technical Efficiency
UNICEF	:	United Nations Children's Fund
µg/l	:	microgram per litre
µmhos/cm	:	micromhos per cm
WQFTK	:	Water Quality Field Test Kits