SNV

Guidelines for Water Quality Testing and Monitoring

A Practical Guide to the Design and Implementation of Drinking Water Quality Studies and Monitoring Programme

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Introduction

Access to clean water and proper sanitation facilities is important in safeguarding the health of people and communities. Poor sanitation and unsafe drinking water are known to cause illness and death through diarrhoeal diseases.

In Kenya, an estimated 19,500 people, including 17,100 children, die every year because of diarrhoea (WSP 2012). Communities and families can prevent these deaths by having improved sanitation and drinking water sources, which are designed and constructed to promote hygiene and reduce contamination. For instance, in Homa Bay county, less than a quarter of the population (22%) have access to improved sanitation, and over a third (39%) do not have any latrines at all but use open spaces. In Kericho county, only 36% of the population have improved sanitation coverage and 8% practice open defecation. The situation in Elgeyo Marakwet is similar, with only about a quarter of the population (26 %) having access to improved sanitation and 19% still practicing open defecation (WSP 2014). The impact of this inadequate sanitation on the well-being of the population in these counties and their ability to contribute to the counties' economic activities is expected to be profound and far-reaching.

SNV Netherlands Development Organisation (SNV) in Kenya, through the Voice for Change Partnership (V4CP) programme and the Institute of Economic Affairs Kenya (IEA) commissioned a study entitled *Understanding the Effects of Poor Sanitation on Public Health, the Environment and Well-being.* This study was undertaken in three counties: Kericho, Elgeyo Marakwet and Homa Bay. To conduct this study, SNV in Kenya contracted a local research company, the Centre for Population Health Research and Management (CPHRM).


Household water storage

Key Study Water Quality Findings

A case-control design was adopted in which children who had diarrhoea (cases) and children who had no diarrhoea but reported other illnesses (controls) were selected at sampled public health facilities in each county between February and March 2018. The research study used a mixed methods design that comprised a case-control quantitative study, qualitative interviews in the community (key informant interviews and focus group discussions), observation, review of health facility data on under-five morbidity and mortality and water sampling and testing.

The study tested the quality of household water at the household level and ten main sources of water in the three counties. The study classified common water sources into improved and unimproved in each of the counties. Improved sources were piped water, public tap and tube well, borehole with pump, protected wells and springs. Among unimproved water sources were unprotected wells and springs, water provided by small vendors and all surface water (rivers and ponds). The results show that slightly more households in the case group (household with an child under five with diarrhoea) used unimproved water sources (37.7%) compared to the control group (35.7%). (OR=0.92, 95%CI: 0.72-1.16)

The study also analysed water quality at point of consumption to determine the proportion of household water samples passing the designated water safety quality threshold. The research team analysed all water samples for free chlorine levels and presence and absence of coliform. This involved two tests: the rapid water test kit compares the strength of colour against standard colours on a chart to determine the chlorine and pH concentration and the Colilert test involves introducing an enzyme powder to 100 ml of water. After an incubation period of 24 hours, a positive result is indicated by a change in colour to yellow to magenta.
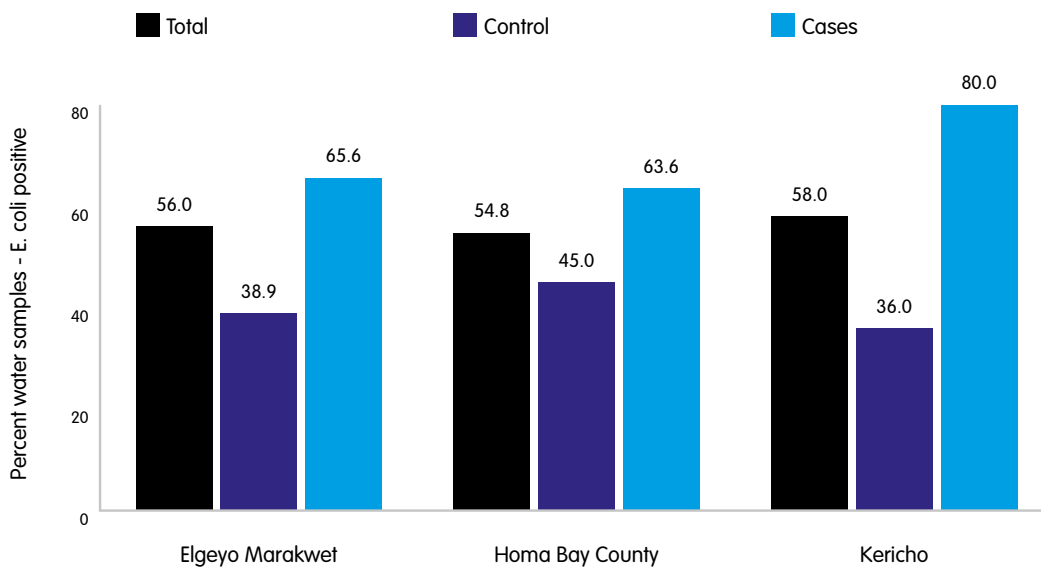
In Homa Bay, Elgeyo Marakwet and Kericho respectively, the Colilert test indicated that in 63.6%, 65.6 % and 80% of the households with children with diarrhoea, the water tested positive, indicating possible presence of faecal contamination. Further observation of the water indicated that 58.2% of the children with diarrhoea used water which was either turbid, had a smell or was coloured.

Purpose of the Guideline

The study adopted a standard procedure for water testing. This guideline provides the step-by-step procedures that were followed to successfully implement water testing at community and household level. The guidelines can be used for water testing in the county by a range of implementers such as public health officers and community health workers. The guidelines further discuss the resources required to support the implementation process and provides useful resources such as testing tools.

The main objectives of this guideline are to:

- support the operationalisation of the implementation of the water testing and monitoring services
- provide guidance to county and sub-county health management teams, facility and departmental in-charges, health workers and other relevant stakeholders on how to strengthen water monitoring to ensure quality water for the population.

Water Quality Testing Methods

A. Physicochemical water analysis

The presence of free residual chlorine in drinking water indicates a sufficient amount of chlorine was initially added to the water to inactivate the bacteria and some viruses that cause diarrhoeal disease. The presence of free residual chlorine in drinking water is correlated with the absence of disease-causing organisms and thus is a measure of the potability of water.

pH is a measure of hydrogen in a concentration. It is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Low pH values help in effective chlorination. Values below 4 generally do not support living organisms. Drinking water should have a pH between 6.5 and 8.5.

Procedure using rapid water test kits

Testing free chlorine and chlorine residual

- Fill the small vial to the fill line with a sample of water.
- Add five drops of solution No. 1, which in this kit (Ortho-Tolidin) is a chlorine indicator.
- Place caps on vials and slowly turn upside down several times.
- Colour Comparison: Wait a few seconds to compare the colour in the vial with the colour standards indicated on the plastic tester to determine the free chlorine level. After that, wait a couple minutes and compare again to determine the chlorine residual level. Check the instructions or test kit website if you are not sure what to do.

Testing the pH levels

- Fill the small vial to the "fill" line with a sample of water.
- Add five drops of Solution 2, a phenol red indicator, and mix by gently turning upside down several times.
- Compare the colour with the pH colour standards on the plastic tester.

Rinse and dry

After testing, rinse your plastic tester with running water, dry, pack up the kit and put it in a cool, dry place.

Parameter	Guide value	Common sources	Health considerations	Applying the guideline
Chlorine free residue	0.6-1.5 mg/l	Used as drinking water disinfectant	Free residual chlorine available in drinking water to inactivate disease-causing organisms	Presence of free residual chlorine in drinking water indicates the likely absence of disease-causing organisms, it is used as one measure of the potability of drinking water
Colour	None	Naturally occurring organic substances, metals, industrial waste	None	May interfere with disinfection; removal is important to ensure effective treatment
pH	6.5 -8.5	None	pH of the water entering the distribution system must be controlled to minimise the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking-water and in adverse effects on its taste, odour and appearance	The control of pH is important to maximise treatment effectiveness, control corrosion and reduce leaching from distribution system and plumbing components
Taste	Inoffensive	Biological or industrial sources	None	Important to provide drinking water with no offensive taste, as consumers may seek alternative sources that are less safe
Odour	Inoffensive	Biological or industrial sources	None	Important to provide drinking water with no offensive odour, as consumers may seek alternative sources that are less safe

B. Microbial water testing

Microbiological water testing is based on the detection of indicators of faecal contamination. The great majority of waterborne infections are the result of human faecal contamination. The parameter *Escherichia coli* (*E. coli*) is of paramount importance for the assessment of the microbiological quality of drinking water.

When *E. coli* is detected in water it usually indicates faecal contamination, either from human, agricultural or wildlife sources. Any count of *E. coli* bacteria would make the water unfit to drink. Total coliform counts give a general indication of the sanitary condition of a water supply. Total coliform and *E. coli* testing is performed simultaneous on the same water sample with Colilert.

Parameter	Guide value	Common sources	Health considerations	Applying the guideline
Escherichia coli (E. coli)	None detectable per 100 ml	Human faeces	The presence of *E coli* indicates recent faecal contamination and the potential presence of microorganisms capable of causing gastrointestinal illnesses; pathogens in human faeces pose the most immediate danger to public health	*E. coli* is used as an indicator of the microbiological safety of drinking water; if detected, enteric pathogens may also be present
Total coliforms	None detectable per 100 ml	Human faeces; naturally occurring in water, soil and vegetation	Total coliforms are used as a tool to determine how well the drinking water treatment system is operating and to indicate water quality changes in the distribution system	In water leaving a treatment plant, the presence of total coliforms indicates a serious breach in treatment In a distribution and storage system, detection of total coliforms can indicate regrowth of the bacteria in biofilms or intrusion of untreated water In non-disinfected groundwater, the presence of total coliforms may indicate that the system is vulnerable to contamination, or it may be a sign of bacterial regrowth

Colilert

Colilert is a direct test of water samples that offers simultaneous determination of both total coliforms and *E. coli* within 24-48 hours. Colilert Reagent is used for the simultaneous detection and confirmation of total coliforms and *E. coli* in water. It is based on IDEXX's patented Defined Substrate Technology® (DST™). This product utilises nutrient indicators that produce colour and/or fluorescence when metabolised by total coliforms and *E. coli*. When the reagent is added to the sample and incubated, it can detect these bacteria at 1CFU/100 ml within 24 hours with as many as two million heterotrophic bacteria/100 ml present.

Testing the presence and absence using Colilert

- Carefully separate one snap pack from the strip taking care not to accidentally open adjacent pack.
- Tap the snap pack to ensure that all of the Colilert powder is in the bottom part of the pack. Open one pack by snapping back the top at the score line.
- Add the reagent to the water sample in a sterile, transparent, non-fluorescent vessel as per the instruction provided by the manufacture.
- Aseptically cap and seal the vessel.
- Shake until dissolved. Incubate for 24 hours at 35°± 0, 5°C.
- Read the results at 24 hours. Compare each result against the comparator dispensed into an identical vessel. If no yellow colour is observed, the test is negative.
- If the sample has a yellow colour equal to or greater than the comparator, the presence of total coliforms is confirmed. If colour is not uniform, mix by inversion then recheck.
- If the sample is yellow, but lighter than the comparator, it may be incubated an additional 4 hours (but no more than 28 hours total). If the sample is coliform positive, the colour will intensify. If it does not intensify, the sample is negative.
- If yellow is observed, check vessel for fluorescence by placing a 6 watt 365 nm UV light within five inches of the sample in a dark environment. Be sure the light is facing away from your eyes and towards the vessel. If fluorescence is greater or equal to the fluorescence of the comparator, the presence of *E. coli* is confirmed.

Procedural Notes

- If an inoculated Colilert sample is inadvertently incubated over 28 hours, the following guidelines apply: Lack of yellow colour is a VALID NEGATIVE TEST. A yellow colour after 28 hours is not valid and should be repeated or verified.
- Some water samples containing humic material may have an innate colour. If a water sample has some background colour, compare inoculated Colilert sample to a control blank of the same water sample.
- Use sterile water, not buffered water for making dilutions. Colilert is already buffered. Always add Colilert to the proper volume of diluted sample after making dilutions.
- Colilert is a primary water test. Colilert performance characteristics do not apply to samples altered by any pre-enrichment or concentration.

** Storage of Colilert: Store at 4°- 30°C away from light.

Preparing a coliform monitoring plan

All public water systems with more than 14 connections or that serve 25 or more individuals for 60 or more days per year must collect samples for coliform bacteria analysis. If distribution system sampling is coliform-positive, you must determine whether *E. coli* is in the groundwater by sampling all groundwater sources that were in use when you collected the coliform-positive distribution system sample. You must include this sampling in your coliform monitoring plan.

Coliform samples should be collected from the distribution system and the source(s) of supply. The focus should be:

- distribution system
- groundwater source
- surface water source.

Your coliform monitoring plan (CMP)

You must base your coliform bacteria sample collection on a written monitoring plan that identifies sampling sites throughout the distribution system. Systems served by multiple groundwater sources should also include information on triggered source sampling in their plan.

The primary purpose includes:

- ensuring representative routine distribution sampling
- identifying repeat and triggered sample sites in case routine samples indicate a possible water quality problem
- providing a written guide so that more than one person associated with a water system - or a temporary or new operator - knows where and how to collect coliform samples
- enhancing water quality surveillance.

A person with knowledge of the system's distribution facilities and the way the system operates should prepare and maintain the CMP. That person will also need a fundamental knowledge of coliform bacterial monitoring. When the CMP is complete, it must be kept in the water system's files and be available to all system operators.

Coliform monitoring programme

Your coliform monitoring programme should enable the user to use economical tests to evaluate the microbial water quality of your water system. These tests help to ensure the water you provide to consumers is free of disease-causing organisms.

Routine coliform samples

The total coliform rule requires routine coliform samples be collected from representative points in the distribution system at regular time intervals. Routine coliform samples must never be collected from one source. A properly developed and implemented coliform monitoring programme will ensure that you monitor each area of the distribution system adequately on a regular basis.

> Coliform bacteria tend to cluster and do not evenly disperse within a distribution system. It is possible for two samples taken a few minutes apart from the same tap to have different results, one indicating the presence and the other indicating the absence of coliform. This happens because a cluster of bacteria can break up, mix up and move to other parts of the distribution system.

The minimum number of required routine samples depends on the population the water system serves each month.

Repeat coliform samples and triggered source samples

The total coliform rule requires the collection of repeat samples within 24 hours when a routine distribution system sample is unsatisfactory.

Repeat sampling requirements

You **must** take a total of **THREE REPEAT** samples for each unsatisfactory routine sample. The samples must come from the following locations:

- The same tap as the original unsatisfactory routine sample
- An active service within five active connections upstream from the original routine sample location
- An active service within five active connections downstream from the original unsatisfactory sample location.

Or you may use alternative sampling locations in lieu of the requirement to collect at least one repeat sample upstream and one downstream of the original sampling site. You may propose repeat monitoring locations that you believe to be representative of a pathway for contamination into the distribution system. With this approach in your CMP, you can choose to specify alternative fixed locations or present a standard operating procedure (SOP) that defines criteria for selecting repeat sampling sites on a situational basis.

C. Bacteriological water analysis

Bacteriological analysis aims to establish contamination or bacteria as an indicative of faecal pollution as demonstrated in a given sample of water using specified culture methods. Water bacteriological analysis turnaround time is 5-7 days. The microbiological examination of drinking-water emphasises assessment of the hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of faecal contamination.

The National Microbiology Reference Laboratory (NMRL)

The National Microbiology Reference Laboratory (NMRL) is a public health laboratory in the division of national public health laboratory services. The laboratory's mandate is to offer reference microbiology services and oversee all quality assurance programmes for microbiology. The water should be submitted to the NMRL within 24 hours of collection.

a) Microbiological samples:

Microbiological samples should be collected in sterile plastic or glass bottles which NMRL supplies. NMRL supplies 100 ml sterile glass bottles. A sample volume of 200 ml should be sufficient for faecal coliform and *E. coli* count.

b) Chemical analysis:

The process of chemical analysis is as follows:

- Keep sample bottles closed until they are to be filled
- Collect a sample that will be representative of the water being tested
- Remove the cap of bottle and ensure no contamination of cap or the neck of the bottle when filling occurs.

Test	Turnaround time (days)	Charges
Water bacteriological analysis	7	No charges for public health officers (PHOs) working with the national or county government and KSh 2000/= for others

Note:The NMRL does not charge water analysis submitted by registered PHOs. The NMRL in Kenya are in:

1. Nairobi: Located at Kenyatta National Hospital grounds (Next to KEMRI)
    P.O Box 20750-00200
    Nairobi, Kenya.
    Email: info@nphls.or.ke
    Website: www.nphls.or.ke
    T: +254 20286

2. Kisumu: Located Next to Jaramogia Odinga Referral Hospital (JOORH)
    Kisumu, Kenya

A water analysis request as shown in Annex 1 should be attached while submitting the water for analysis. Sample water testing results for the three counties can be found in Annexes 2 to 4.

Potable water testing guidelines

Potable water: Apply the procedures as described above. Never sample leaking taps where water runs down on the outside of the tap. When collecting water from wells and boreholes, pump water for five minutes when a pump is fitted. When sample locations for a distribution system are identified, include dead-end sections and all the different lines in the sample programme.

Waste or effluent water: Sampling frequency may be seasonal for recreational waters, daily for water supply intakes and even hourly for waste water where the quality may vary tremendously. Hold the sample bottle near its base in one hand and plunge it mouth downwards below the surface of the water. This is especially important when sampling from a dam; never sample water from the surface.

Sample size: Sample volume should be sufficient to carry out all tests required. A sample volume of 750 ml should be sufficient.

Sample identification: Samples must be sufficiently identified. Important information that could be included for identification are: a) sampling date, b) sampling time, c) origin of sample and d) type of sample.

Sample preservation and storage: Although recommendations vary, the time between sample collection and analysis should, in general, not exceed 6 hours, and 24 hours is considered the absolute maximum. It is assumed that the samples are immediately placed in a lightproof insulated box containing melting ice-packs with water to ensure rapid cooling. Sample temperature should be kept below 100°C for a maximum transportation time of 6 hours. If ice is not available, the transportation time must not exceed two hours. It is imperative that samples are kept in the dark and that cooling is rapid.

See Figure 1 for steps for water testing and monitoring.

Figure 1: Steps in water testing and monitoring

Develop a water monitoring plan
(why, how, when, where and who)

↓

Prepare for sampling
(Logistics and equipment)

↓

Record site conditions
(e.g. borehole, river and treatment plan)

↓

Decontaminate sampling equipment

↓

Collect samples for analysis

↓   ↓

Transport samples to
national labs   Conduct rapid test
                                     e.g. Colilert

↓   ↓

Laboratory analysis

↓

Review results and reports
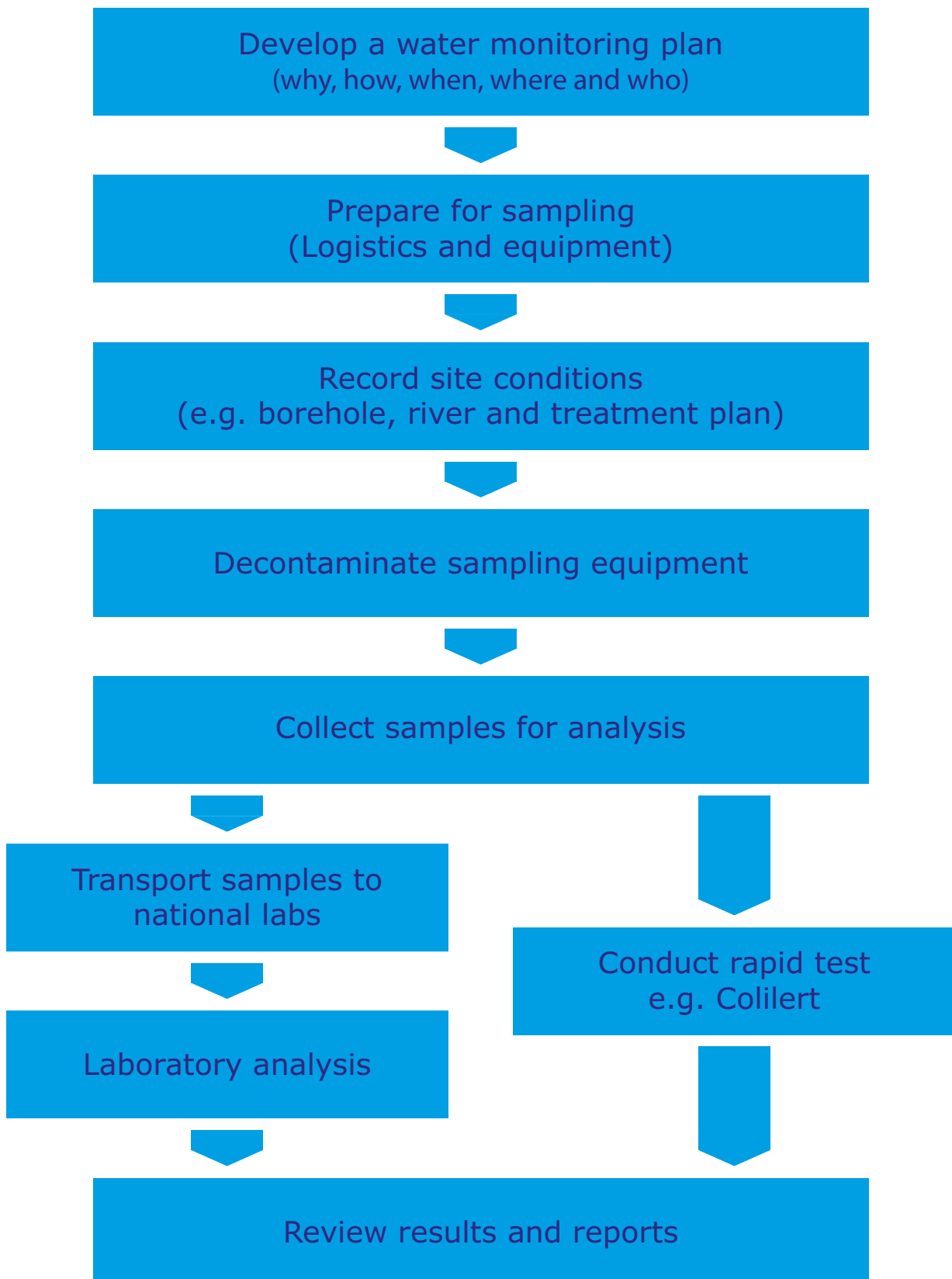
ANNEXES

Annex 1: Bacteriological analysis of water form

Telegrams: "BACTERIA",
Nairobi
Telephone: Nairobi 725601/4
When replying please quote
Lab REF.   No NMRL//13

NATIONAL PUBLIC HEALTH
LABORATORIES
P.O Box 20750
NAIROBI, KENYA

BACTERIOLOGICAL ANALYSIS OF WATER QUESTIONNAIRE
FOR SUBMITTING AUTHORITY ONLY

CONTACT INFORMATION

Contact Person………………………………………………………………………………...
Authority/Address...
Telephone number………………………………………………………………………………
Email……………………………………………………………………………………………

COLLECTED SAMPLE INFORMATION

Sample Number…………….....…………………………………………………………………
Collection Pick-Up Site……………………………………………….........................
Collection Date and Time…………………………………………………………………………
Sample Collected by…………………………………………………………………………
Reason for Sampling…………………………………………………………………………
Is the water sampling suspected of causing illness...
Is the water for public health surveillance...
If yes, what are the legal implications………………………………………………………...
Sample source (well, spring, stream or public supply) ……………………………………....
Is it protected..
If so, how…………………………………………………………………………….................
Is there a pump...
If so, how long has it been in use...
Has it been overhauled recently..
Is this a repeat sample………………………………………………………………….......
If yes, indicate whether the sample was suspicious or rejected………………………………..
If rejected, indicate the tracking Number...
Exact site sample was taken from……………………………………………………………
Are there any latrines or other sources of pollution………………………………………….
If so, where..
Is it a treated supply…………………………………………………………………………
If so, by which method………………………………………………………………………

FOR NMRL USE ONLY

Date Received………………………………………………………………………………....
Date Examined………………………………………………………………………………
Presumptive coliform test……………………………………………………………………….
Coliform count:………………………………………………………………………….......
Escherichia coli:……………………………………………………………………............
Others:………………………………………………………………………………………..
Comments:…………………………………………………………………………...........
Specialist Bacteriologist……………………………………………………………………...
Copies to …………………………………….…… Date…………………………………….
Compiled by………………………………………..Date…………………………………….
Reviewed by………………………………………..Date…………...

Annex 2: Sample water testing results for Elgeyo Marakwet County

Telegrams:"BACTERIA"
Nairobi
Telephone:Nairobi 725601/4
When replying please qoute
Lab REF CMRL/136/18
Sample Number:760466

MINISTRY OF HEALTH

NATIONAL PUBLIC HEALTH
LABORATORY SERVICES
P.O Box 20750
NAIROBI, KENYA
Date:2/14/2018 2:22:35PM

ELGEYO MARAKWET

BACTERIOLOGICAL ANALYSIS OF WATER

Sample Ref No: 01

Time and Date sample taken. .2/8/2018

Time and Date sample Examined. 2/9/2018

Taken By: **ALICE KARANI**

Authority: **Public Health Officer**

Authority Description: ELGEYO MARAKWET

REASON FOR SAMPLING:. QUALITY

(If water is suspected of causing ill health please say so)

SOURCE OF SAMPLE: Stream Water

(State if well, spring, stream or public supply)

Is it protected? **No**

If so, how

Is there a pump? **No**

If so, how long has it been in use?

Has it been overhauled recently? No

EXACT SITE SAMPLE TAKEN: CHESOI

ARE THERE ANY LATRINES OR OTHER SOURCES OF POLLUTION

If so, where? **BUSH AROUND & ALONG THE STREAM**

IS IT A TREATED SUPPLY? No

REPORT

PRESUMPTIVE COLIFORM

Most Probable Number of Coliforms   >1800 in 100 ml of untreated water
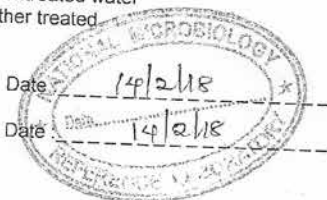Most Probable Number of E. coli   425 in 100 ml of untreated water
nments: Unsatisfactory for Human Consumption unless further treated

piled by :_____ Gikonyo _____   Date ____ 14/2/18

ewed by :_____ Muchiri _____   Date ____ 14/2/18

Annex 3: Sample water testing results for Homa Bay County

Telegrams:"BACTERIA"
Nairobi
Telephone:Nairobi 725601/4
When replying please qoute
Lab REF CMRL/123/18
Sample Number:760149

MINISTRY OF HEALTH

NATIONAL PUBLIC HEALTH
LABORATORY SERVICES
P.O Box 20750
NAIROBI, KENYA
Date:2/12/2018 4:14:28PM

HOMABAY

BACTERIOLOGICAL ANALYSIS RESULTS

Sample Ref No: 01

Time and Date sample taken. .2/6/2018

Time and Date sample Examined. 2/7/2018

Taken By: **MICHAEL OTIENO**

Authority: **Public Health Officer**

Authority Description: HOMA BAY COUNTY

REASON FOR SAMPLING:. BACTERIAL

    (If water is suspected of causing ill health please say so)

SOURCE OF SAMPLE: Tap Water

    (State if well, spring, stream or public supply)

Is it protected? **Yes**

    If so, how

Is there a pump? **No**

    If so, how long has it been in use?

Has it been overhauled recently? **No**

EXACT SITE SAMPLE TAKEN: HOMABAY TOWN CENTER TAP

ARE THERE ANY LATRINES OR OTHER SOURCES OF POLLUTION

    If so, where?

IS IT A TREATED SUPPLY? Yes

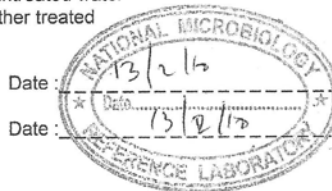
REPORT

PRESUMPTIVE COLIFORM
    Most Probable Number of Coliforms   >180 in 100 ml of treated water
    Most Probable Number of E. coli   0 in 100 ml of treated water
Comments: Class IV - Unsatisfactory for Human Consumption unless further treated

Compiled by :_____   Date :_____

Reviewed by :_____   Date :_____

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Telegrams:"BACTERIA"
Nairobi
Telephone:Nairobi 725601/4
When replying please qoute
Lab REF CMRL/117/18
Sample Number:759924

MINISTRY OF HEALTH

NATIONAL PUBLIC HEALTH
LABORATORY SERVICES
P.O Box 20750
NAIROBI, KENYA
Date:2/12/2018 3:57:15PM

KERICHO

BACTERIOLOGICAL ANALYSIS OF WATER

Sample Ref No: **01**

Time and Date sample taken. **.2/6/2018**

Time and Date sample Examined. **2/6/2018**

Taken By: **JEMES WANJAU**

Authority: **Public Health Officer**

Authority Description: KERICHO COUNTY

REASON FOR SAMPLING:. ROUTINE

(If water is suspected of causing ill health please say so)

SOURCE OF SAMPLE: Storage Tank

(State if well, spring, stream or public supply)

Is it protected? **Yes**

If so, how

Is there a pump? **No**

If so, how long has it been in use?

Has it been overhauled recently? **No**

EXACT SITE SAMPLE TAKEN: SIGOWET COMMUNITY WATER TANK

ARE THERE ANY LATRINES OR OTHER SOURCES OF POLLUTION

If so, where?

IS IT A TREATED SUPPLY? No

REPORT		
PRESUMPTIVE COLIFORM		
Most Probable Number of Coliforms	>1800 in 100 ml of untreated water	
Most Probable Number of E. coli	12 in 100 ml of untreated water	
Comments:	Unsatisfactory for Human Consumption unless further treated	

Compiled by :_____ Date :_____
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Reviewed by :_____ Date :_____

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For more information on these findings, see research report: *Understanding the Effects of Poor Sanitation on Public Health, the Environment and Well-being. Report of a study conducted in Homa Bay, Elgeyo Marakwet and Kericho counties in Kenya. 2018*. Published by the V4CP programme.

Further information

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Tel.: +254 724 463355

Email: kenya@snv.org

SNV