WATER QUALITY

South African Standards and Guidelines for Drinking Water and Raw Water

A user manual for the assessment and analysis of water quality of a specific site based on results obtained during testing.

Water Wise

RAND WATER

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SAFETY IN THE LABORATORY

A laboratory can be a very dangerous place and it is very important that every person is aware of safety. As you will be dealing with chemicals that are dangerous you must be very careful when carrying out your experiments.

LABORATORY SAFETY RULES:

These safety rules apply to the lab and must be adhered to:-

It is the duty and responsibility of every visitor to understand and obey these rules. Every visitor must ensure that fellow visitors/students adhere to these rules for their safety.

1. It is the task of each visitor to acquaint him/herself to the whereabouts of:

(a) Fire extinguishers

(b) Eyewash station (water source e.g. tap)

(c) First aid kits

(d) Emergency exits.

2. When working with concentrated acids personal protective equipment (PPE), namely, gloves, safety glasses and laboratory coats, must be worn.

3. No reagents may be pipetted by mouth. Use a pipette filter or equivalent.

4. Beakers shall under no circumstances be used for drinking purposes. No laboratory equipment should be used in conjunction with food.

5. The consumption and/or storage of food and drink in the laboratory are forbidden.

6. Smoking in the laboratory is forbidden.

7. All reagents and chemical bottles should be labeled.

8. Closed shoes should be worn.

9. Broken glass must be carefully discarded in the bin.

10. Wash your hands immediately after contact with chemicals or any other material in the lab. This practice can prevent accidental poisoning or dermatitis.

SOME MORE HELPFUL LABORATORY TIPS:

- No chemicals should be poured down the drain or thrown into waste bins. Chemicals shall be stored in the relevant cupboard until they are taken to the Vereeniging Lab to be disposed of.
- Leave unlabeled containers alone. Benches, sinks and apparatus must be kept clean at all times.
- Don't use cracked or dirty apparatus. Handle all laboratory equipment with extra care.
- If you accidentally pour chemicals on yourself wash immediately with water.
- Wash your hands before you enter and once you leave the laboratory.
- Be sensible, neat and tidy and above all enjoy the experience.

INTERPRETATION OF TAP WATER RESULTS

The guidelines for tap water, which is used for various domestic purposes have been colour coded for each different range as well as each parameter. These colour codings have been differentiated according to 5 different colours as indicated in the guidelines and can be seen in more detail below:

- BLUE

Blue indicates that the quality of water is ideal and suitable for the purpose that it serves. Consuming water in this range will therefore have no effect on human use.

- GREEN

Green indicates that the quality of water is generally good and can also closely be compared to the blue coding. Usage of this water is generally safe and in very rare cases in this range, users of this water will have a very small chance of being affected.

- YELLOW

The risk of contamination due to exposure and contamination starts to slightly increase in the yellow colour range; however, the risk is usually very minimal. Sensitive people will usually be slightly affected.

- RED

The risk of exposure to contaminants is high and significantly increased. Sensitive people will usually be mostly affected. Normal individuals are also affected. Water in this range will therefore not be recommended and will be dangerous to human health and use.

- PURPLE

Water within this colour range is extremely dangerous and consumption and usage of this water is harmful.

INTERPRETATION OF RAW WATER RESULTS

Various colour codings have been used to assign the quality of the water of each of the ranges. Below is a key of what the specific colours indicate:

- Ideal
- Acceptable
- Tolerable
- Unacceptable
- Highly unacceptable

For each of the water quality parameters/ determinands an explanation has been given in the guidelines.

What the colours mean:

Blue- indicates that the quality of water is ideal and suitable for the purpose that it serves. Utilising water in this range will therefore have no effect on human, animal and plant life.

Green- indicates that the quality of water is generally good and can also closely be compared to the blue coding. Usage of this water is generally safe, however, in sensitive humans, plants and animals, there may be a very slight and noticeable effect.

Yellow- The risk of contamination due to exposure starts to slightly increase in the yellow colour range; however, the risk is usually very minimal. Sensitive people, animals and plants will usually be moderately affected.

Red- Water within this colour range is extremely dangerous. Utilisation of this water for various purposes indicated in the guidelines will have a great effect on humans, animals and plants. Consumption and usage of this water is harmful.

Purple- The risk of exposure to contaminants is high and significantly increased. Sensitive people will usually be mostly affected. Normal individuals are also affected. Water in this range will therefore not be recommended and will be dangerous to human health and use.

TESTING METHODS AND PROCEDURES

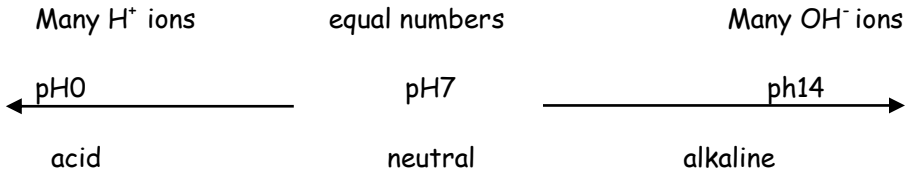
pH TEST

The pH of water reflects the acidity or alkalinity of water and is an important measure of pollution. pH has to do with hydrogen ions (abbreviated with the chemical symbol H^+). In water (H_2O), a small number of the molecules dissociate (split up). Some of the water molecules lose a hydrogen and become hydroxide ions (OH^-). The "lost" hydrogen ions join up with water molecules to form hydronium ions (H_3O^+). For simplicity, hydronium ions are referred to as hydrogen ions H^+. In pure water, there are an equal number of hydrogen ions and hydroxide ions. The solution is neither acidic or basic. (Credit: www.sciencebuddies.org)

An **acid** is a substance that donates hydrogen ions. Because of this, when an acid is dissolved in water, the balance between hydrogen ions and hydroxide ions is shifted. Now there are more hydrogen ions than hydroxide ions in the solution. This kind of solution is acidic and it has a pH of less than 7. It has a sour taste. (Adapted from www.sciencebuddies.org)

A **base** is a substance that accepts hydrogen ions. When a base is dissolved in water, the balance between hydrogen ions and hydroxide ions shifts the opposite way. Because the base "soaks up" hydrogen ions, the result is a solution with more hydroxide ions than hydrogen ions. This kind of solution is alkaline and it has a pH of greater than 7. It has a soapy taste and texture. (Adapted from www.sciencebuddies.org)

When pH is measured one is measuring the concentration of hydrogen (H^+) and hydroxide (OH^-) ions in the water. The concentration of these ions is reported using pH units. pH is measured on a pH scale from 0 to 14.



Water that is very acidic (high concentrations of H^+ ions) or very basic (high concentrations of OH^- ions) is unsafe to use around the home; can be dangerous if you swim in it; and will kill aquatic plants and animals. Water solutions that are very acidic (like battery acid) and solutions that are very basic (like drain cleaner) are very dangerous and can burn you badly. You should be very careful when you use strong acids. Pure deionised water contains equal numbers of the two ions and is regarded as neutral.

Rainwater is naturally slightly acidic but the acidity of water in a catchment is determined by the particular kinds of **rocks and minerals, biological activity and nutrient cycling**, which occurs there. Limestone is alkaline but basalt is very slightly acid. **Air pollution** (nitrates and sulphur dioxides) from vehicles and thermal power stations causes acid rain, a serious threat to aquatic ecosystems, particularly in Mpumalanga. The acid rain in Mpumalanga appears to have caused a 0.1 pH change in all its rivers. Another important place where hydronium ions come from is acid rain. Coal-fires, coal-fired power stations and motorcars release acidic gases into the air. When rain dissolves these gases it forms acids. These acids wash into the river and make the river water acidic.

Sewage and industrial effluent discharged into rivers can also affect their pH balance. The pH of healthy rivers is usually neutral (7) or ranging between 6.5 and 8.5. Many "black" rivers in the South Western Cape can have a natural pH of 4 – 5. A lot of **rotting dead leaves and plants** in a river will make the water acidic. Some rivers in the Cape flow through wild forests. These rivers collect dead leaves from the trees in the forest and become acidic. The water in these rivers looks like black tea.

Water that is very acidic or basic can usually dissolve metals (e.g. metal water pipes). The dissolved metals form ions. Water with high concentrations of metal ions can be poisonous. Strongly acidic or basic water will burn your eyes and even your skin if you swim in it. Water with high concentrations of hydronium and hydroxide ions is also *poisonous* to the animal and plant life in the water.

Factory waste can have very high concentrations of hydroxide ions or hydronium ions. Water from mines, especially coal or gold mines, can also have high concentrations of hydronium ions. Mines and factories should treat their waste to remove the hydroxide ions or hydronium ions before they pump it into a river or dam.

Very acidic or basic water is unsafe to drink. However, high concentrations of hydronium and hydroxide ions in water are not necessarily toxic by themselves. Coke has a pH of between 2 and 3, and gastric juice is also very acidic. The problem is that *acidic water tends to dissolve metals like zinc, lead and copper*. The metal ions in solution can be toxic. Also, ammonium ions (NH_4^+), which are not poisonous, can be deprotonated (removal of proton) in basic conditions, to form ammonia (NH_3), which is poisonous. Acidic water can dissolve or *damage water pipes*.

The pH for drinking water is between 7.8 and 8.4. The pH of Rand Water's water is 8.0 – 8.4.

EQUIPMENT NEEDED

- Tracer pocket tester pH/TDS/Salt electrode

MEASUREMENT PROCEDURE

1. For small samples fill a sample cup to the 20ml line with the test sample. Sample depth must be greater than or equal to 3cm.
2. Press the ON/OFF button of the pH/TDS. SELF CAL will appear in the display during the initial diagnostics.
3. Press and hold MODE/HOLD button to scroll to pH mode.
4. Immerse the TRACKER electrode in the sample. Make sure the electrode is completely submersed.
5. The reading will flash until it is stabilised. Then take the reading and rinse the electrode with distilled water and replace the cap.

WHAT DO YOUR RESULTS MEAN? pH: DOMESTIC USE

pH guideline
(pH value is a measure of acid or base quality)

INCREASING SOUR

INCREASING SOAPY

pH range	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<3	Acid burns P	Extremely sour taste P	Acid burns P	Burns skin and eyes P	Extremely corrosive P
3-3,5	Severe irritation of mucous membranes R	Extremely sour taste P	Severe irritation of mucous membranes R	Burns skin and eyes P	Very corrosive R
3,5-4	Severe irritation of mucous membranes R	Very sour taste R	Severe irritation of mucous membranes R	Burns skin and eyes R	Very corrosive R
4-4,5	Irritation of mucous membranes Y	Sour taste Y	Irritation of mucous membranes Y	Slight skin/eye sensitivity Y	Very corrosive R
4,5-5	Mild irritation of mucous membranes G	Sour taste Y	Mild irritation of mucous membranes G	MIld skin/eye sensitivity G	Corrosive in some instances Y
5-6	No health effects B	Slightly sour taste G	No effects B	Insignificant effect G	Possible corrosion G
6-9	No health effects B	No aesthetic effects B	No effects B	No effects B	No effects B
9-9,5	No health effects B	Slightly soapy G	No effects B	Insignificant effect G	No effects B
9,5-10	Mild irritation of mucous membranes G	Soapy taste Y	Mild irritation of mucous membranes G	MIld skin/eye sensitivity Y	Mild rinsing problems G
10-10,5	Irritation of mucous membranes Y	Very soapy taste R	Irritation of mucous membranes Y	Marked skin/ eye sensitivity R	Rinsing problems Y
10,5-11	Severe irritation of mucous membranes R	Extremely soapy taste P	Severe irritation of mucous membranes R	Burns skin/eyes P	Increasing rinsing problems R
>11	Alkali burns P	Extremely soapy taste P	Alkali burns P	Burns skin/eyes P	Severe rinsing problems P

Blue - Ideal Green - Good Yellow - Marginal Red* - Poor Purple* - Completely unacceptable

*Not to be used without treatment

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

WHAT DO YOUR RESULTS MEAN? pH: RAW WATER

See page 5 for colour coding interpretation

pH (Raw Water Guideline)							
DOMESTIC USE (drinking, food preparation, bathing, washing)		**RECREATIONAL USE**		**AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)**		**AQUATIC ECOSYSTEMS**	
Range (pH Units)		**Range (pH Units)**		**Range (pH Units)**		**Range (pH Units)**	**No formal guideline available**
< 4	Severe danger of health effects due to dissolved toxic metal. Water tastes sour.	0 – 5.0	Severe eye irritation. Skin, ear and mucous membrane irritation likely. Strong taste experienced if swallowed accidentally.	< 6.5	Increase in damage of leaves, especially when plants are watered. Results in decrease in crop yield and production.	< 4	Notes: - pH below 4 may be due to organic acids such as humic acids. - pH is largely determined by geological and atmospheric influences. - Some water bodies may be more acidic or alkaline than others and their respective biota's are often adapted to these conditions. - Variable pH may indicate availability of toxic substances such as aluminium and ammonia. - Resultant impacts of unsuitable pH may result in the collapse of the food chain and the loss of biodiversity.
4.0 – 6.0	Toxic effects associated with dissolved metals, including lead, are likely to occur at a pH of less than 6. Water tastes slightly sour.	5.0 – 6.5	Some eye irritation may occur, although water of this pH is generally acceptable.	6.5 – 8.4	No effect on crop yield and farming.		
6.0 – 9.0	No effects on health. No effect on taste. Very slight taste may be experienced at a pH greater than 8.5.	6.5 – 8.5	No effects on health. At a pH between 8.4- 9.0, minor eye irritation may occur.	> 8.4	Increase in damage of leaves, especially when plants are watered as alkalinity is increased greatly.	6 - 8	
9.0 – 11.0	The risks of exposure to toxins such as ammonia start to increase greatly. Water has a bitter taste. Increased rinsing problems as water appears to be very soapy.	8.5 – 9.0	Some eye irritation is expected. Skin, ear and mucous membrane irritation may occur.	**Definition of Crop Yield (also known as "agricultural output")**: measure of the yield of a crop per unit area of land cultivation, and the seed generation of the plant itself (e.g. if three grains are harvested for each grain seeded, the resulting yield is 1:3). It is expressed as kilograms per hectare.			
> 11.0	Probability of severe toxic effects on health. Water can taste bitter or even soapy. Severe rinsing problems as water appears to be extremely soapy.	> 9	Eye irritation becomes increasingly severe. Skin, ear and mucous membrane irritation occurs. Significantly strong powdery taste if accidentally swallowed.				

TURBIDITY

Most rivers and dam water are full of small grains (particles) of soil and algae. The grains of soil and algae (particulate) hang in the water. They are in suspension. These suspended grains make the water look cloudy or even muddy. This is called cloudiness, muddiness or turbidity.

Water that is very turbid carries many thousands of grains of soil and algae. Bacteria and viruses stick to these grains. This means that water, which is very turbid, may be unsafe to drink. Another problem is that plants need sunlight to grow (for photosynthesis). Water that is very turbid stops sunlight from entering the water. This means that plants will stop growing in that water. The grains in very turbid water can block the gills of aquatic animals. Animals that hunt will have difficulty finding their prey in very turbid water, which can lead to upsets in natural ecosystems. High turbidity water can lead to a loss of plant and animal diversity.

If there is a high degree of **soil erosion** in a catchment area then a lot of soil will get washed into the river making it turbid. Builders can **dump** building material and earth into a river making it more turbid. **Industrial waste** and even **sewerage** leaks can also make the river turbid. Lastly, a lot of microscopic **algae** in the water will make river and dam water turbid. Some rivers are naturally turbid. When a river is in flood the water becomes very muddy and turbid. Usually this muddiness only lasts for a few days. Some rivers are also very muddy and turbid all the time e.g. the Orange River. The plants and animals that live in the Orange River are adapted to living in very muddy water.

EQUIPMENT NEEDED

- Turbidity meter
- 2.10ml tube
- No reagent needed

MEASUREMENT PROCEDURE

1. Press and hold the ON/OFF button until meter is on.
2. Select **MEASURE**
3. Select Turbidity-With Blank
4. Rinse and clean the tube with distilled water. Fill the tube with distilled free water to the 10ml line.
5. Insert the tube into the chamber, close the lid and select **SCAN BLANK**.
6. Rinse a second clean tube with sample water. Fill to the 10ml line with sample water. Cap tube. Wipe off excess water and fingerprints. Remove all bubbles.
7. Insert the tube into the chamber, close lid and select **SCAN SAMPLE**.
8. Take readings.

WHAT DO YOUR RESULTS MEAN? TURBIDITY: DOMESTIC USE

Turbidity guideline (NTU)
(Nephelometric Turbidity Units)

TURBIDITY RANGE (NTU)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<0.1	B No effects	B Water crystal clear	B No effects	B No effects	B No aesthetic effects
0.1-1	G Slight risk of potential health effects	G Water has good transparency	G Slight risk of indirect health effects (e.g., salads)	B No effects	B No aesthetic effects
1-20*	Y Possibility of secondary health effects	Y Water slightly cloudy	Y Slight risk with e.g. salads	G Insignificant effects	G Insignificant aesthetic effects
20-50*	R Secondary health effects	R Water has a muddy appearance	R Secondary health effects	Y Slight risk of infection if ingested	Y Possibility of staining of white clothing
>50*	P Serious health effects common in all users	P Water has a increasingly muddy appearance	P Secondary health effects	R Risk of infection if ingested	R Staining of clothing

Blue - Ideal Green - Good Yellow - Marginal Red - Poor Purple - Completely unacceptable

*Note: Turbidity can have indirect health effects in association with microbiological contaminations

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

WHAT DO YOUR RESULTS MEAN? TURBIDITY: RAW WATER

See page 5 for colour coding interpretation

TURBIDITY (NTU- Nephelometric Turbidity Units) (Raw Water Guideline)					
DOMESTIC USE (drinking, food preparation, bathing, washing) **Range (NTU units)**		**RECREATIONAL USE** **Range (NTU units)**		**AGRICULTURAL USE: IRRIGATION AND FARMING**	**AQUATIC ECOSYSTEMS**
< 0.1	No effect on taste, colour or odour. No effects on health.	<10	Most users will perceive water as suitable for swimming. Risk of disease transmission is minimal. No adverse effects on aesthetics (taste, appearance and odour).	**NO GUIDELINES**	
0.1 – 1	Water relatively clear. Very slight risk of infection if micro-organisms are present.	10 – 20	Water is perceived to be suitable for swimming. Risk of disease transmission is low, but increased. No effects on aesthetics.		
1 – 20	Water becomes murky above 5 NTU. Some chance of infection by micro-organisms associated with particulate or tiny matter.	20 – 30	Minimum visibility. Not very aesthetic (taste, colour and odour). Risk of disease transmission by organisms begins to increase.		
20 – 50	Increasing risk on health. Water has a muddy appearance. Possibility of staining of white clothing.	> 30	May be unsuitable for swimming. Risk of disease transmission is present. Water is highly turbid or murky.		
> 50	Severe aesthetic effects (taste, colour and odour). Increased risk of infectious disease as presence of infectious micro-organisms may increase.				

CHLORIDE (3693-SC)

Chloride is one of the major anions found in water and sewage. The presence of chlorides in large amounts may be due to the natural process of water passing through salt formation on the earth or it may be evidence of the intrusion of seawater or pollution from industrial processes or domestic wastes. In fresh water, chloride concentrations are typically less than 10 mg/l. Higher concentrations are found wherever salt pollution or where salt water moves into freshwater aquifers, and chloride concentrations of up to 700 mg/l are common in arid areas with saline soils. Chloride is the negatively charged or anionic component of table salt. Elevated chloride imparts a salty taste to water and accelerates corrosion of metals.

EQUIPMENT NEEDED

- Colorimeter
- 020 chloride tablet
- 10ml tube
- Tablet crusher
- Water sample (tap water)

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 020 Chloride tablet.
4. Rinse the test tube and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK.
6. Remove the tube from the colorimeter.
7. Crush one 020 Chloride tablet and add it to the sample water.
8. Cap tube.
9. Invert 2 times.
10. Wait 3 minutes. DO NOT MIX.
11. Insert the tube into the chamber, close the lid and select SCAN SAMPLE.
12. Record results in ppm chloride.

WHAT DO YOUR RESULTS MEAN? CHLORIDES: RAW WATER

See page 5 for colour coding interpretation

CHLORIDES (Cl) (Raw Water Guideline)							
DOMESTIC USE (drinking, food preparation, bathing, washing)		RECREATIONAL USE		AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)		AQUATIC ECOSYSTEMS	
Range (mg/l)		No guideline		Range (mg/l)	(See page 9 for definition of Crop Yield)	No guideline	
0 – 100	No aesthetic health effects. Domestic appliances may erode from 50mg/l.			≤ 100	No effect on crop yield and quantity.		
100 – 200	No aesthetic health effects. Possible increase in corrosion rate of domestic appliances.			<140	No effects however may result in the appearance of water droplets on the leaves.		
200 – 600	Water has a distinctly salty taste, but no health effects. Likelihood of noticeable increase in corrosion rates of domestic appliances.			140 – 175	Slight injury of leaves may result in sensitive crops, as well as those that absorb the chloride through the roots. In sensitive crops, growing and produce of crops may slowly decrease.		
600 – 1200	Water has an unpleasant salty taste and will not quench thirst. Likelihood of rapid corrosion in domestic appliances.			175 - 350	Sensitive and moderately sensitive crops will display signs of leaf damage and produce of crops decrease.		
> 1200	Water unacceptably salty. Nausea and disturbance of the electrolyte balance in the body may occur, especially in infants, where fatalities due to dehydration may occur.			350 – 700	Most crops will display signs of leaf damage. Decrease in crop production is quite visible.		
				> 700	Crops display signs of increased damage in leaves and crop decrease, especially when watered with this water.		

TOTAL CHLORINE UDV (4312-J)

All water for cities and communities must be disinfected even water that comes from clean sources such as protected watersheds, reservoirs, etc. These are disinfected to assure safety. Chlorine is the most commonly used disinfectant for several reasons: it is effective against a wide range of microorganisms; the cost is low; and the methods of applying it have been well developed. If an adequate concentration of chlorine is present in the water for few minutes, disease causing bacteria will be destroyed. A number of conditions affect the disinfection action of chlorine. If chlorine is detectable in municipal drinking water it can be assumed that bacteria have been killed.

Free available (residual) chlorine is the free chlorine concentration remaining 30 minutes after breakpoint disinfection of the water with chlorine. The free available chlorine is an indication of the efficacy of the disinfection process and thus a rapid indicator of the probable microbiological safety or otherwise of the treated water. Free available chlorine does not occur in nature.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (tap water)
- Total Chlorine UDV powder

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 017 Chlorine T UDV.
4. Rinse the test tube and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK.
6. Remove the tube from the colorimeter.
7. Add total chlorine UDV powder to the tube.
8. Cap tube. Invert 3 times to mix.
10. Wait 2 minutes.
11. Insert the tube into the chamber, close the lid and select SCAN SAMPLE.
12. Record results in ppm total chlorine.

WHAT DO YOUR RESULTS MEAN? FREE AVAILABLE CHLORINE: DOMESTIC USE

Free available chlorine (Residual)

INCREASING HEALTH RISK

INCREASING HEALTH RISK

FREE AVAILABLE CHLORINE (mg/ℓ)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<0,05	P Serious risk of infection if raw water source microbiologically contaminated	B No effects	P Serious risk of infection if raw water source microbiologically contaminated	R Risk of infection if raw water source microbiologically contaminated	B No effects
0,05-0,1	R Disinfection may be compromised	B No effects	R Disinfection may be compromised	Y Slight risk of infection	B No effects
0,1-0,2	Y Slight risk of infection	B No effects	Y Slight risk of infection	G Insignificant risk of infection	B No effects
0,2-0,3	G Insignificant risk of infection, disinfection adequate	G Slight odour	G Insignificant risk of infection, disinfection adequate	B No health risks	B No effects
0,3-0,6	B Disinfection good	G Slight odour and taste	B Disinfection good	B No health risks	B No effects
0,6-0,8	G Disinfection good; insignificant risk of health effects	Y Marked odour and disinfectant taste	G Disinfection good; insignificant risk of health effects	G No health effects, marked odour	G Insignificant effects
0,8-1,0	Y Slight risk of mucous membrane irritation	R Unpleasant odour and taste	Y Slight risk of mucous membrane irritation	Y Unpleasant odour	G Insignificant effects
1,0-1,5	R May cause nausea and mucous membrane irritation	R Unpleasant odour and taste	R May cause nausea and mucous membrane irritation	R May cause skin rashes; unpleasant odour	Y Bleaching action on some dyes
>1,5	P Danger of toxic effects, nausea and vomiting	P Repulsive odour and taste	P Danger of toxic effects, nausea and vomiting at high concentrations	P Danger of toxic effects and severe skin irritation	R Bleaching action on coloured clothing at high concentrations

Blue - Ideal Green - Good Yellow - Marginal Red* - Poor Purple* - Completely unacceptable

*Not to be used without treatment

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

FLUORIDE (3647-02-SC)

Fluoride may occur naturally in some ground waters or it may be added to public drinking water supplies to maintain a 1.0 mg/l concentration to prevent dental cavities. At a higher concentration, fluoride may produce an objectionable discolouration of tooth enamel called fluorosis. The concentration of fluoride in unpolluted surface water is typically 0, 1 – 0,3 mg/l. In groundwater fluoride ranges from 0, 1 – 3 mg/l, with some groundwater containing 12 mg/l or more. Chronic intake of high fluoride levels can damage the skeleton, causing a hardening of the bones and making them brittle. Brittle bones break easily under mild stress and crippling can occur. Acute poisoning by high doses is characterised by vomiting, abdominal pain, nausea, diarrhea and convulsions.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (tap water)
- Distilled water
- Sodium Asernite Solution
- Acid-Zirconyl SPADNS Reagent

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 040 Fluoride.
4. Rinse the test tube with distilled water and fill it to the 10ml line with distilled water.
5. Use the 0.5ml pipette to add 0.5ml of Sodium Asernite Solution. Cap and mix.
6. Use the 1.0ml pipette to add 2 measures of Acid Zirconyl SPADNS. Cap and mix thoroughly. (This is the reagent blank).
7. Insert the tube into the chamber, close the lid and select SCAN BLANK.
8. Remove the tube from the chamber.
9. Rinse the test tube with sample water and fill it to the 10ml line with sample water. Repeat steps 5 & 6.
10. Insert the tube into the chamber, close the lid and select SCAN SAMPLE. Record the results.

WHAT DO YOUR RESULTS MEAN? FLOURIDE: DOMESTIC USE

Fluoride guideline

FLUORIDE RANGE (mg/ℓ)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<0,7	B No health effects	B No effects	B No effects	B No effects	B No effects
0,7-1,0	G Insignificant health effects in sensitive groups and insignificant tooth staining	B No effects	G Insignificant health effects in sensitive groups	B No effects	B No effects
1,0-1,5	Y Increasing effects in sensitive groups and tooth staining	B No effects	Y Increasing effects in sensitive groups	B No effects	B No effects
1,5-3,5	R Possible health effects in all individuals and marked tooth staining	B No effects	R Possible health effects in all individuals	B No effects	B No effects
>3,5	P Increasing risk of health effects and severe tooth staining	B No effects	P Increasing risk of health effects	B No effects	B No effects

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See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

HARDNESS, TOTAL-UDV 4309-J

Total hardness (T.H.) is the sum of calcium and magnesium concentrations expressed as mg/l calcium carbonate ($CaCO_3$) and is calculated as follows: T.H. = [2.497 x calcium (mg/l)] + [4.118 x magnesium (mg/l)].

The total hardness value indicates whether the water is soft or hard, and relates to the ease or difficulty of lathering of soap. Total hardness is low in rainwater and in fresh soft waters with little calcium and magnesium.

In some underground waters total hardness may be very high where soluble calcium and magnesium minerals are present. Some total hardness in water is beneficial to health as it contributes to human need for the essential elements calcium and magnesium. Excessive total hardness should be avoided by sensitive people.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (Acid Mine Drainage or Borehole)

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 043 Hardness UDV.
4. Rinse the test tube and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK.
6. Remove the tube from the colorimeter.
7. Add total hardness UDV powder to the tube.
8. Cap tube. Shake vigorously for 10 seconds.
9. Wait one minute. Invert the tube 3 times to mix.
10. Firmly tap the side of the tube 5-10 times to remove all bubbles.
11. Insert the tube into the chamber, close the lid and select SCAN SAMPLE. Record results.

WHAT DO YOUR RESULTS MEAN? TOTAL HARDNESS: DOMESTIC USE

(Total) hardness guideline (T.H.)

TOTAL HARDNESS AS $CaCO_3$ (mg//)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
0-25 (very soft)	B No effects	B No effects	B No effects	B Ideal lathering of soap	Y Ideal lathering, but corrosion of appliances
25-50 (soft)	B No effects	B No effects	B No effects	G Insignificant impairment of lathering	G Insignificant impairment of lathering, but some corrosion of appliances
50-100 (moderately soft)	B No effects	B No effects	B No effects	G Insignificant impairment of lathering	B Insignificant impairment of lathering. Some protection against corrosion
100-150 (slighty hard)	B No effects	B No effects	G Slight scaling of kettles	G Lathering slightly impaired	G Lathering slightly impaired
150-200 (moderately hard)	B No effects	B No effects	G Some scaling of kettles	Y Lathering impaired	Y Lathering impaired, some scaling
200-300 (hard)	G Insignificant effects	G Insignificant effects	Y Scaling of kettles	Y Increased impairment of lathering	Y Lathering impaired, increasing scaling
300-600 (very hard)	Y Possible chronic effects in sensitive groups only	Y Effect on taste	R Severe scaling of kettles	R Lathering severely impaired	R Lathering severely impaired, severe scaling
>600 (extremely hard)	R Chronic effects in sensitive groups only	R Marked effect on taste	R Very severe scaling of kettles	R Lathering severely impaired	R Lathering very severely impaired. Extreme scaling

Blue - Ideal Green - Good Yellow - Marginal Red* - Poor Purple* - Completely unacceptable

*Not to be used without treatment

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

NITRATES (3649-SC)

Nitrogen in the form of ammonia (NH_3) and Nitrates (NO_3) is a naturally occurring element which is vital for natural processes, however too much of this element can have detrimental effects on ecosystems and health. Nitrate is the name of an ion with the formula of NO_3.

Water with a high concentration of nitrates is poisonous to humans. This is because the nitrate ions are changed into nitrite ions by a person's digestive system as a result of bacterial action. Upon absorption by the body, nitrite combines with the red blood pigment, haemoglobin, to form methaemoglobin, which is not able to act as an oxygen carrier throughout the body. This condition is called methaemoglobinaemia. This reaction of nitrite with haemoglobin can be particularly hazardous in babies under 3 months of age, and is worsened when combined with an inadequate intake of Vitamin C. A baby that drinks water with a concentration of nitrate ions of about 10 mg/l might get blue baby syndrome.

The nitrogen in nitrate ions is an important nutrient (food) for aquatic plants and blue-green algae. High concentrations of nitrate ions in the water may cause large numbers of aquatic plants and blue-green algae to grow in the water. Some species of blue-green algae produce poisons and make the water green and ugly to look at. When aquatic plants die you get large numbers of bacteria decomposing them. These bacteria use up the oxygen in the water. Without oxygen many aquatic animals will die. This is called eutrophication.

Nitrate enrichment through sewage contamination and fertiliser run-off is not as critical as it is with phosphates because aquatic ecosystems are not as sensitive to increases in nitrate levels. Nitrate ions and ammonia (NH_3) are an important part of fertilisers that are used on farms to grow crops. The rain may wash the fertilisers into the rivers and dams. Nitrogen normally occurs in a form that plants cannot use (i.e. nitrogen gas), however, it may be used in the decomposition of dead water plants and by blue-green algae which can convert nitrogen in the air into ammonia and nitrates that plants can use.

Nitrate ions also come from urine. Urine can get into the rivers and dams from leaking sewerage pipes, badly built pit toilets, animal wastes, or even from people who use the bank of the river as a toilet. Urine contains urea. When the urea gets into the water it can be changed into nitrate ions. Nitrates and ammonia are used in some industrial processes and may be pumped as waste from factories into river or dam water. Industries are required by law to remove nitrates and ammonia from their waste before they pump it into rivers and dams but, unfortunately the law is often not implemented.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (surface water)

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then **064 Nitrate-NS LR.**
4. Rinse the test tube and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK.
6. Remove the tube from the colorimeter.
7. Pour off 5ml of sample water from the tube.
8. Add 5ml of Mixed Acid Reagent (V 6278) into the tube.
9. Cap tube. Wait 2-3 minutes.
10. Use the 0.1g spoon to add two measures of nitrate reducing reagent (V-6279). Cap.
11. Hold the tube by the index finger and thumb and mix by inverting approximately 60 times a minute for four minutes. Wait 10 minutes for maximum colour development.
12. At the end of the 10 minutes waiting period, mix. Insert the tube into the chamber, close the lid and select SCAN SAMPLE. Record results.

WHAT DO YOUR RESULTS MEAN? NITRATE & NITRITE: DOMESTIC USE

Nitrate + Nitrite (as N)

NITRATE + NITRITE RANGE mg/ℓ as N or (mg/ℓ as NO_3)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<6 mg/ℓ as N (< 26 mg/ℓ as NO_3)	B Negligible health effects	B No aesthetic effects	B Negligible health effects	B No effects	B No effects
6-10 mg/ℓ as N (26-44 mg/ℓ as NO_3)	G Insignificant risk	B No aesthetic effects	G Insignificant risk	B No effects	B No effects
10-20 mg/ℓ as N (44-89 mg/ℓ as NO_3)	Y Slight chronic risk to some babies	B No aesthetic effects	Y Slight chronic risk to some babies	G Insignificant risk	B No effects
20-40 mg/ℓ as N (89-177 mg/ℓ as NO_3)	R Possible chronic risk to some babies	B No aesthetic effects	R Possible chronic risk to some babies	Y Slight risk to babies only	B No effects
>40 mg/ℓ as N (> 177 mg/ℓ as NO_3)	P Increasing acute health risk to babies	B No aesthetic effects	P Increasing acute health risk to babies	R Possible health risk to babies	B No effects

Blue - Ideal Green - Good Yellow - Marginal Red - Poor Purple - Completely unacceptable

Note: Nitrite is not normally present in drinking water.

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

NITRATES (NO_3) (Raw Water Guideline) See page 5 for colour coding interpretation						
DOMESTIC USE (drinking, food preparation, bathing, washing)		RECREATIONAL USE	AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality) (See page 9 for definition of Crop Yield)		AQUATIC ECOSYSTEMS	
Range (mg/l)		Range (mg/l)	Range (mg/l)	No guidelines from DWS. These are recommendations from Rand Water.	Range (mg/l)	No guidelines from DWS. These are recommendations from Rand Water
0 – 6	No adverse health effects.	No guideline available Treat recreation guideline the same as domestic use guideline	0 – 6	Most crops, including sensitive crops are not usually affected.	0 - 6	No effects on aquatic life.
6 – 10	Rare instances of methaemoglobinaemia (blue baby syndrome) in infants as brain cells do not receive sufficient oxygen. No effects in adults. Concentrations are generally well tolerated.		6 -20	Sensitive crops are increasingly likely to be affected.	6 -20	Aquatic life may slowly become sensitive to increasing a mounts of nitrogen, however, not much impact.
10 – 20	Methaemoglobinaemia (Blue baby syndrome) may occur in infants.		> 20	Most crops are affected as crops become intolerant towards excessive nitrogen, therefore resulting in plant deaths.	>20	Excessive amounts result in eutrophication. Fish kills due to lack of oxygen in water.
> 20	Methaemoglobinaemia occurs in infants (blue baby syndrome). Occurrence of mucus membrane irritation in adults.					

PHOSPHATE LOW RANGE (3653-SC)

Phosphorus is an essential element for life, both as a nutrient for plant life and as a key element in the metabolic processes of all living things. The normal low phosphate (PO_4) level in water inhibits the growth of plants but a small increase of phosphates can result in a rapid increase in plant growth such as blue-green algae, especially in dams. If there are too many plants in the water and they die lots of bacteria will break down (decompose) the dead plants. These bacteria can use up the oxygen dissolved in the water. This process, called eutrophication, could be increased by human activities. Animals like fish and insects can't live in water where there is little or no dissolved oxygen. For example, fish will suffocate and invertebrates will die. Usually the oxygen is only used up in slow flowing rivers or in dams where the water is standing still. In fast flowing rivers new oxygen is mixed into the water all the time. Fast flowing rivers can carry orthophosphates into dams where they will cause eutrophication problems.

An increase in phosphorus can come from **domestic effluent** (especially soapy water), **farm and lawn fertilisers, industrial effluent, sewerage pipe leaks and the destruction of wetlands**. Wetlands are natural swamps where phosphate sediments are formed and used in the vigorous growth of the diverse and specially adapted vegetation of this particular ecosystem. **(NB: No Drinking Water Tests conducted for Phosphates.)**

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (surface water)

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 078 phosphate LR.
4. Rinse the test tube with sample water and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK.
6. Remove the tube from the colorimeter.
7. Use the 1.0ml pipette to add 1.0 ml of Phosphate Acid Reagent (V-6282). Cap and mix.
8. Use the 0.1g spoon to add one measure of Phosphate Reducing Reagent (V-6282). Cap and mix until powder dissolves. Wait 5 minutes for maximum colour development. Solution will turn blue if phosphate is present.
9. At the end of 5 a minute waiting period, mix, insert the tube into the chamber, close the lid and select SCAN SAMPLE. Record results.

WHAT DO YOUR RESULTS MEAN? PHOSPHATES: RAW WATER

See page 5 for colour coding interpretation

PHOSPHATES (PO_4) (Raw Water Guideline)

DOMESTIC USE (drinking, food preparation, bathing, washing)		RECREATIONAL USE	AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)	AQUATIC ECOSYSTEMS	
Range (mg/l)	**No guidelines from DWS available, however, recommendations from Rand Water have been made instead.**	**Range (mg/l) No guideline available**		**Range (mg/l)**	**No guidelines from DWS. These are recommendations from Rand Water**
< 0.03	Little or no effect on human health.			< 0.005	No effects on aquatic life.
0.03 – 0.05	Increasing risk of exposure. Slight risk of exposure to heart disease, osteoporosis and cancer.			0.005 – 0.025	Occasional growth of blue-green algae. Small chance of algal blooms being toxic.
> 0.05	Acute poisoning, skin irritation and gastrointestinal illnesses in humans. Rare cases of neurological damage and death through long term consumption. Great risk of heart disease, osteoporosis and cancer through long term exposure.			0.025 – 0.25	Frequent growth of water plants and blooms of blue-green algae. Noticeable decline in aquatic life.
				> 0.25	Overgrowth of algal blooms which results in decrease in sunlight absorption. Increase in eutrophication. Decline in aquatic life, especially bottom dwellers.

CONDUCTIVITY

The amount of material dissolved in water is a major determinant of water quality, and can be measured in three ways:

- Total dissolved solids,
- Salinity (saltiness), or
- Conductivity.

Conductivity is an electrical measure of the amount of solids dissolved in a solution, i.e. chemical salts and minerals, present in the water (e.g. calcium bicarbonate, nitrogen species, phosphates, sulphates, chlorides, iron and other metals). It is measured in milli-Siemens per metre (mS/m) using a conductivity meter. The ability of water to carry an electrical current depends on the presence of ions, their total concentration, mobility, valence (relating to or denoting electrons involved in or available for chemical bond formation), relative concentrations and temperature. The greater the concentration of ions in the water, the greater is its ability to conduct electricity. Conductivity measurements are principally used as an indication of the dissolved mineral content in water and may be related to total dissolved solids by using a factor of 6.5, i.e. electrical conductivity (mS/m) x 6.5 = total dissolved solids (mg/l).

Water in our rivers and dams usually contain low concentrations of ions. If the concentration of ions increases because of pollution, its conductivity increases, the water will begin to taste salty and can become unsafe to drink. Water with a high concentration of ions can kill plants if it is used to water them. This type of water can dissolve (corrode) water pipes or even block the pipes if the ions come out of solution. Most of the plants and animals living in the water will suffer if that water is suddenly polluted by a high concentration of ions.

Where do these dissolved ions come from that cause high conductivity? Fertilisers may be washed from a field into a river or dam. Factories and mines can also pump wastewater with a high conductivity into rivers and dams. Some natural water, like groundwater, dissolves salts from the rocks around it. This water may also have a high concentration of ions in it, even if it hasn't been polluted by humans. Rivers near the sea may also have a high conductivity because seawater has a high concentration of ions.

EQUIPMENT NEEDED

- Tracer pocket tester pH/TDS/Salt electrode

MEASUREMENT PROCEDURE

1. For small samples fill a sample cup to the 20ml line with the test sample. Sample depth must be greater than or equal to 3cm.

2. Press the ON/OFF button of the pH/TDS. SELF CAL will appear in the display during the initial diagnostics.

3. Press and hold MODE/HOLD button to scroll to TDS mode.

4. Immerse the TRACKER electrode in the sample. Make sure the electrode is completely submersed.

5. The reading will flash until it is stabilised. Then take the readings and rinse the electrode with distilled water and replace the cap.

WHAT DO YOUR RESULTS MEAN? ELECTRICAL CONDUCTIVITY: DOMESTIC USE

Electrical conductivity, (EC) total dissolved salts (TDS) guideline

ELECTRICAL CONDUCTIVITY RANGE EC:mS/m (TDS: mg/ℓ)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
EC:<70 mS/m (TDS:<450mg/ℓ)	B No effects	B Water tastes fresh	B No effects	B No effects	B No effects
EC: 70-150 (TDS:450-1000)	G Insignificant effect on sensitive groups	G Water tastes good	G Insignificant effect on sensitive groups	B No effects	B No effects
EC: 150-370 (TDS:1000-2400)	Y Slight possibility of salt overload in sensitive groups	Y Water has a distinctly salty taste	Y Slight possibility of salt overload in sensitive groups	B No effects	G Insignificant corrosion
EC: 370-520 (TDS:2400-3400)	R Possible health risk to all individuals	R Water tastes extremely salty	R Possible health risk to all individuals	G Impaired soap lathering	Y Slightly corrosive
EC: >520 (TDS>3400)	P Increasing risk of dehydration	P Tastes extremely salty and bitter	P Increasing risk of dehydration	Y Impaired soap lathering	R Corrosive

Blue - Ideal Green - Good Yellow - Marginal Red - Poor Purple - Completely unacceptable

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

WHAT DO YOUR RESULTS MEAN? CONDUCTIVITY AND TOTAL DISSOLVED SOLIDS: RAW WATER

CONDUCTIVITY (EC) and TOTAL DISSOLVED SOLIDS (TDS) (Raw Water Guideline) See page 5 for colour coding interpretation						
DOMESTIC USE (drinking, food preparation, bathing, washing)			**RECREATIONAL USE**	**AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield)**		**AQUATIC ECOSYSTEMS**
EC Range (mS/m)	**TDS Range (Mg/l)**		**No guidelines**	**EC Range (mS/m)**	**(See page 9 for definition of Crop Yield)**	**No guidelines**
0 – 70	0 – 450	Slight taste may be experienced above 45mS/m. Water with extremely low TDS may taste flat. No effects on health.		≤ 40	No effects on crop quality and production.	
70 – 150	450 – 1000	Noticeable salty taste although it is tolerable. No effects on health or domestic appliances.		40 – 90	Sensitive crops may experience damage to the leaves. No effects on moderately sensitive crops provided they obtain a low frequency irrigation system.	
150 – 300	1000 – 2000	Marked salty taste. Minimal corrosion/scaling may occur. No effects on short term use.		90 – 270	Definite damage of leaves in sensitive crops. Watering with the water should therefore be avoided. Not much effect on moderately sensitive crops.	
300 – 450	2000 – 3000	Water tastes extremely salty. Increase in corrosion/ scaling. Disturbance of body's salt tolerance and may result in diseases such as kidney failure.		270 – 540	Moderately salt-tolerant crops are able to survive, provided they obtain a low frequency irrigation system whereby watering of crops is not done often.	
> 450	> 3000	Water tastes extremely salty. High increase corrosion/scaling. Disturbance of body's salt balance. Short term health effects can be experienced.		> 540	Sound irrigation management is required for all crops. The possibility of sustainable irrigation decreases rapidly as crops are not able to grow effectively when watering is managed.	

FAECAL COLIFORM BACTERIA AND *ESCHERICHIA COLI* (*E. coli*)

River or dam water that is of good microbiological quality has few disease-causing microbes/pathogens (bacteria, viruses, parasites such as protozoa) in it. Many of these disease-causing microbes come from human faeces in the water.

It would be impossible to test the water for all the disease-causing bacteria, viruses and parasites that might be found in it. Instead we test the water for special indicator organisms. These indicator organisms tell us:

•That the water might be polluted with human and other animal faeces.

•If there are animal faeces in the water then there might be disease-causing bacteria, viruses or parasites present.

These germs or viruses can cause diseases like typhoid, dysentery and gastro-enteritis. Thousands of people die each year from these diseases. Faecal coliform bacteria (faecal coliforms - FC) are a group of bacteria, many of which are found within human beings and other warm blooded animals and aid in digestion. Total Faecal Coliforms present in the water are an indication that harmful, disease-causing organisms may be present in the water, due to faecal pollution, however, not all faecal coliforms originate from human or other mammals intestines. Therefore, we also test for *Escherichia coli* (*E. coli),* a specific indicator for faecal contamination in the water. If this is present then there are definitely pathogenic organisms in the water and it is unsafe to drink. *E. coli* is a type of total coliform bacteria but, they only live in the intestine of humans and other warm blooded animals.

These bacteria can enter the water directly because of poor sanitation; the dung and droppings of animals; runoff from streets and stormwater drains; and sewage disposal in rivers. If the faecal coliform bacteria count in a river is high due to sewage contamination it is thus probable that pathogenic organisms also occur in large numbers and can be passed on to people who drink the river water. Human diseases like typhoid, hepatitis, cholera, gastroenteritis, dysentery and ear and skin infections can be contracted from river water with a high faecal coliform bacteria count.

WHAT EQUIPMENT DO YOU NEED IN THE FIELD?

- Sterile bottles
- Gloves or materials to clean your hands e.g. Anti-bacterial soaps
- Labels
- Pen

HOW DO YOU COLLECT FAECAL COLIFORM BACTERIA?

In order to test for faecal coliform bacteria collect a water sample in a sterile bottle to ensure reliable results. Take samples both upstream and downstream of a suspected source of sewage contamination. Ensure that each sample is labeled according to where the sample was taken. These samples must be taken back to the laboratory within 4 – 6 hours in order to determine whether they contain faecal coliform bacteria and *E. coli.*

WHAT EQUIPMENT DO YOU NEED IN THE LABORATORY?

1. Bottle filled with water sample
2. A sterile container or syringe that measures 100ml and/or an automatic pipette that measures one millilitre
3. Petrifilm: Coliform Count Plate (see Appendix 1)
4. Incubator
5. Gloves
6. Pen
7. Plastic spreader

HOW DO YOU TEST FOR FAECAL COLIFORM BACTERIA?

1. In this test sterile apparatus, essential for reliable results, is used. Wash hands thoroughly before and after the test and do not touch the Petrifilm on the inside with your fingers.
2. Place the petrifilm plate on a level surface and label the back with the sample name and date.
3. Lift the top film and dispense 1 ml of sample or diluted sample onto the centre of the bottom film using the automatic pipette.
4. Roll the top film down onto the sample to prevent trapping air bubbles.
5. With the smooth side down, place the plastic spreader on the centre of the plate.
6. Press gently on the centre of the spreader to distribute the sample evenly. Spread the inoculum over the entire Petrifilm growth area before gel is formed. Do not slide the spreader across the film.
7. Remove the spreader and leave the plate undisturbed for at least one minute to permit the gel to solidify.

Incubation

1. Incubate the plates in a horizontal position with the clear side up. Not more than 20 plates should be stacked on top of each other.
2. Incubate the plates for 24 hours at $44.5^{0}C$. (Please check the temperature of the incubator.)
3. Count the pink colonies – they will represent the number of faecal coliform bacteria.
4. Count the pink or black colonies with air bubbles – they will represent the number of *E. coli* present in the sample.

NOTE: Do not touch the colonies and wash hands thoroughly after counting.

WHAT DO YOUR RESULTS MEAN? FAECAL COLIFORMS: DOMESTIC USE

Faecal coliforms guideline

FAECAL COLIFORMS RANGE (Counts/100 mℓ)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
0	B No detectable chance of infection	B No effects	B No effects	B No effects	B No effects
0-1	G Insignificant chance of infection	B No effects	G Insignificant chance of infection	G Insignificant effects	G Insignificant effects
1-10	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	B No effects	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	G Insignificant effects	G Insignificant effects
10-100	R Clinical infections common, even with once-off consumption	B No effects	R Clinical infections common, even with once-off consumption	Y Slight risk	Y Slight risk
>100	P Serious health effects common in all users	B No effects	P Serious health effects common in all users	R Possibility of infection	R Possibility of infection

Blue - Ideal Green - Good Yellow - Marginal Red* - Poor Purple* - Completely unacceptable

*Not to be used without treatment

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

WHAT DO YOUR RESULTS MEAN? FAECAL COLIFORMS: RAW WATER

See page 5 for colour coding interpretation

FAECAL COLIFORMS (Raw Water Guideline) * no specific guideline exists for *E.coli*. The faecal coliform will include *E.coli* as well and therefore these ranges will be used as generic.						
DOMESTIC USE (drinking, food preparation, bathing, washing)		**RECREATIONAL USE**		**AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)**		**AQUATIC ECOSYSTEMS**
Range (counts/100ml)		**Range (counts /100ml)**		**Range (counts/100ml)**	**(See page 9 for definition of Crop Yield)**	**No guideline**
0	No risk of infectious disease and contact.	0	No risk of infectious disease and contact.	< 1	Very little likelihood that this will lead to the spread of human pathogens.	
1 – 10	Slight risk of infectious disease with continuous exposure, and slight risk with occasional exposure. Infection may result in mild diarrhea and dehydration.	1 – 130	Risk of infectious disease. May result in mild diarrhea and gastrointestinal effects if swallowed.	1 - 1000	Likelihood of contamination of vegetables and milk from cows if crops are not cooked or pasteurised. Will result in the spread of human pathogens.	
101 – 600	Increased risk of infectious disease with continued exposure, and risk with occasional exposure. Results in diarrhea and dehydration.	130 – 600	Increased risk of exposure of infectious disease if swallowed.	> 1000	No impact on crops, however no contact is allowed to take place with humans.	
> 600	Significant risk of infectious disease. People are alerted not to consume water at levels above this. Results in stomach cramping, diarrhea and dehydration. May result in deaths, especially babies, elderly and immune compromised persons.	> 600	High risk of contracting illnesses such as giardiasis, hepatitis, cholera and other infections. Users are usually alerted to keep away from waters with high counts of coliforms.			

TOTAL COLIFORM

THE HETEROTROPHIC PLATE COUNT

The Heterotrophic Plate Count is used to assess the general bacteriological quality of treated/potable water. It determines the efficiency of the various treatment procedures within Rand Water's purification process, shows whether regrowth has occurred in the distribution system, gives an indication of the deterioration of water quality and possible cross contamination. The Heterotrophic Plate Count does not select for a specific organism but, for all types of bacteria that can grow at body temperature.

High counts on the Heterotrophic Plate Count may not necessarily indicate high levels of pathogens but, people with severely affected immune systems, such as those with HIV/AIDS, people undergoing chemotherapy, or small babies, may not be able to cope with high levels of any kind of bacteria (pathogenic or not) in the drinking water. Thus microbiological quality of water is extremely important.

WHAT EQUIPMENT DO YOU NEED IN THE LABORATORY?

1. An automatic pipette that measures one millilitre
2. Petrifilm: Aerobic Count Plate
3. Water sample
4. Incubator
5. Plastic spreader
6. Gloves
7. Pen

HOW DO YOU DO THE HETEROTROPHIC PLATE COUNT TEST?

1. In this test sterile apparatus, essential for reliable results, is used. Wash hands thoroughly before and after the test and do not touch the Petrifilm on the inside with your fingers.
2. Place the petrifilm plate on a level surface and label the back with the sample name and date.
3. Lift the top film and dispense 1 ml of sample onto the centre of bottom film using the automatic pipette.
4. Drop the film down onto the sample.
5. With the recessed side down, place the plastic spreader on the centre of the plate.
6. Press gently on the centre of the spreader to distribute the sample evenly. Spread the inoculum over the entire growth area indicated by the plastic spreader before gel is formed. Do not slide the spreader across the film.

7. Remove the spreader and leave the plate undisturbed for at least one minute to permit the gel to solidify.

8. Incubate the plates in a horizontal position with the clear side up. Not more than 20 plates should be stacked on top of each other.

9. Incubate the plates for 48 hours at $22^{0}C$. (Please check the temperature of the incubator.)

10. Count the pink colonies – they will represent the general microbiological quality of the water.

NOTE: Do not touch the colonies and wash hands thoroughly after counting.

WHAT DO YOUR RESULTS MEAN? TOTAL COLIFORMS: DOMESTIC WATER USE

Total coliforms guideline

TOTAL COLIFORMS RANGE (Counts/100 mℓ)	DRINKING (Health) 	DRINKING (Aesthetic) 	FOOD PREPARATION 	BATHING 	LAUNDRY 
0	B No detectable chance of infection	B No effects	B No detectable chance of infection	B No effects	B No effects
0-10	G Insignificant chance of infection	B No effects	G Insignificant chance of infection	G Insignificant effects	G Insignificant effects
10-100	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	B No effects	Y Clinical infections unlikely in healthy adults, but may occur in some sensitive groups	G Insignificant effects	G Insignificant effects
100-1000	R Clinical infections common, even with once-off consumption	B No effects	R Clinical infections common, even with once-off consumption	Y Slight risk	Y Slight risk
>1000	P Serious health effects common in all users	B No effects	P Serious health effects common in all users	R Possibility of infection	R Possibility of infection

Blue - Ideal
Green - Good
Yellow - Marginal
Red* - Poor
Purple* - Completely unacceptable

*Not to be used without treatment

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

TOTAL IRON UDV (4315-J)

Most natural waters contain iron. Its presence may vary from small traces to very large amounts in water which is contaminated by acid mine drainage. The metallic element iron in its pure state is silvery-white, but iron usually appears brown or black in colour because of oxidation of the surface of the metal. The reddish colour of soil is due to iron. Iron is an essential nutritional micro-nutrient needed for formation of the oxygen-carrying red blood pigment, haemoglobin.

Dissolved iron is often found in water, due to dissolution from soils or sediments under anaerobic reducing conditions. The concentration of iron in unpolluted fresh water ranges from 0,001 – 0, 5 mg/l. As the normal total dietary intake of iron by an adult is as much as 20 mg/day, health effects in adults do not occur at water concentrations below 10 mg/l.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (Acid Mine Drainage or Borehole)
- For laboratory reaction a concoction of water with red soil

MEASUREMENT PROCEDURE

1. Press and hold ON/OFF button until the colorimeter is ON.
2. Press ENTER to select TESTING MENU.
3. Select ALL TESTS, then 052 Iron-UDV.
4. Rinse the test tube and fill it to the 10ml line with sample water.
5. Close the lid, insert the tube into the chamber and select SCAN BLANK
6. Remove the tube from colorimeter.
7. Add Iron UDV powder to the tube.
8. Cap tube. Wait 2-3 minutes.
9. Invert tube for 3 times to mix.
10. Firmly tap the side of tube 5-10 times to remove all bubbles.
11. Insert the tube into the chamber, close the lid and select SCAN SAMPLE. Record results.

WHAT DO YOUR RESULTS MEAN? IRON: DOMESTIC WATER USE

Iron guideline

IRON RANGE (mg/l)	DRINKING (Health)	DRINKING (Aesthetic)	FOOD PREPARATION	BATHING	LAUNDRY
					
<0,01	No effects B	No effects B	No effects B	No effects B	No effects B
0,01-0,2	No effects B	Slight taste or colour G	No effects B	No effects B	Insignificant effects G
0,2-0,5	No effects B	Increasing taste and colour Y	No effects B	No effects B	Slight staining of white clothes Y
0,5-1,0	Insignificant effects G	Increasing taste and colour Y	Insignificant effects G	No effects B	Slight staining of white clothes Y
1,0-2,0	Increasing effects in sensitive groups Y	Increasing taste and colour Y	Increasing effects in sensitive groups Y	No effects B	Slight staining of white clothes Y
2,0-5,0	Increasing effects in sensitive groups Y	Objectionable taste & appearance R	Increasing effects in sensitive groups Y	Insignificant effects G	Staining of clothes R
5,0-10,0	Chronic health effects R	Objectionable taste & appearance R	Chronic health effects R	Increasing risk to sensitive groups where water ingested Y	Staining of clothes R
>10,0	Risk of iron-poisoning, particularly in sensitive groups P	Repulsive taste and appearance P	Risk of iron-poisoning, particularly in sensitive groups P	Increasing risk to sensitive groups where water ingested Y	Severe staining of clothes P

Blue - Ideal Green - Good Yellow - Marginal Red - Poor Purple - Completely unacceptable

See page 4 for colour coding interpretation

Credit: Water Research Commission Report No. TT101/98

WHAT DO YOUR RESULTS MEAN? IRON: RAW WATER

IRON (Fe) (Raw Water Guideline)

See page 5 for colour coding interpretation

DOMESTIC USE (drinking, food preparation, bathing, washing)		RECREATIONAL USE		AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)		AQUATIC ECOSYSTEMS	
Range (mg/l)		**Range (mg/l)**	**No guidelines from DWS. These are recommendations from Rand Water.**	**Range (mg/l)**	**(See page 9 for definition of Crop Yield)**	**Range (mg/l)**	**No guidelines from DWS. These are recommendations from Rand Water.**
0 – 0.1	No taste or effect on health.	0 – 0.1	No effect on recreation.	≤ 5.0	Natural water is usually below 0.5, however, this range is suitable for farming and irrigation. Iron deposits in the higher ranges may result in plant leaf damage when plants are watered.	≤ 5.0	Photosynthetic productivity is limited. Aquatic life may not be able to produce essential components such as haemoglobin resulting in a decline of aquatic animals.
0.1 – 0.3	No effects on health. Very slight effect on taste. Very slight problems with domestic appliances such as iron deposits.	0.1 – 0.3	No effect on health.	5.0 – 20.0	Acceptable for fine textured neutral to alkaline soils. Sensitive plants may become damaged.	0.5 – 20.0	Water is within acceptable levels for survival of aquatic life.
0.3 – 1.0	No health effects. Increase in metallic taste. Increase in problems with domestic appliances. Slight staining of white clothing.	0.3 – 1.0	Slight metal taste may be experienced. Slight staining of clothing.	> 20	May lead to extreme damage of plant leaves as normal processes such as photosynthesis, respiration and transpiration are hindered.		Results in algal blooms, and ultimately death of plant and animal life.
1 - 10	Slight health effects expected in young children, especially sensitive individuals. Pronounced metallic taste. Increase in problems with domestic appliances. Staining of clothing.	1 - 10	No effects, unless ingested or swallowed by sensitive individuals. Staining of clothes.				

10 - 100	Severe iron taste. Can result in iron overload in some individuals. Long term health effects.	10 - 100	Staining of clothing may occur. If swallowed, this may result in iron overload as excess amounts of iron enter the body, resulting in damage to tissues and organs in the body.
101 - 300	Chronic health effects Acute toxicity may begin to appear	101 - 300	May irritate eyes and throat. Will result in iron overload and ultimately damage to the tissues and organs in the body.
300 – 3 000	Chronic and acute health effects. Accidental iron poisoning from water is rare.	300 – 3 000	May irritate eyes and throat. Distinct staining of clothing. Accidental iron poisoning from swallowing is rare.
3000 – 30 000	Chronic and acute health effects. Lethal toxicity occurs.	3000 – 30 000	Severe eye, throat and respiratory infection. Fatal poisonousness occurs.

DISSOLVED OXYGEN (3688-SC)

Dissolved Oxygen is vital to the survival if aquatic organisms. Naturally present, dissolved oxygen enters the water when plants photosynthesize. Wind and wave action also cause oxygen to dissolve into water. Dissolved Oxygen is consumed by aquatic organisms and the oxidation, chemical breakdown of dead and decaying plants and animals. The concentration of Oxygen in water is affected by temperature and salinity and can range between 0-14ppm.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (raw water)
- This must be done on site to avoid contamination and change of temperature

MEASUREMENT PROCEDURE

1. Tightly cap the 10ml tube and submerge it to the depth beyond the arms reach. Remove the cap and allow the sample tube to fill.
2. Remove any air bubbles. Replace the cap the sampling tube while it is still submerged.
3. Add 2 drops of Manganese Sulphate Solution (4167) and 2 drops of Alkaline Potassium Iodine Azide (7166).
4. Cap and mix by inverting several times.
5. Add 8 drops of Sulphuric Acid (6141WT). Cap and mix gently until the precipitation has dissolved. Cap and mix by inverting several times. A clear-yellow to brown =orange colour will develop depending on the oxygen content of the sample.
6. Press and hold until colorimeter turns ON.
7. Press Enter to select TESTING MENU.
8. Select ALL TESTS then 038 Dissolved Oxygen.
9. Insert the tube and scan BLANK.
10. Fill a second tube up to the 10ml cap, and insert in the chamber and scan sample.
11. Record results.

WHAT DO YOUR RESULTS MEAN? DISSOLVED OXYGEN: RAW WATER

DISSOLVED OXYGEN (DO_2) (RAW WATER) See page 5 for colour coding interpretation							
DOMESTIC USE (drinking, food preparation, bathing, washing)		**RECREATIONAL USE**		**AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)**		**AQUATIC ECOSYSTEMS**	
Range (mg/l O_2) (VBCEC)	No guidelines available. These descriptors have been drawn up based on research	**Range (mg/l O_2)**	**No guidelines available**	**Range (mg/l O_2)**	**No guidelines available**	**Range (% of saturation)**	
> 6	Water tastes better.					80% - 120 %	No effects on aquatic ecosystems.
5.0 – 6.0	Can result in corrosion of water pipes. Impact on human consumption as humans are exposed to metals from the corrosion of pipes. these metals enter the body and become poisonous and harmful to the system.					> 60%	Acute and toxic effects on aquatic biota over a 7 day mean period. Dangerous fotr aquatic life. Bacteria and aquatic animals may overpopulate, using up the D.O in the water.
< 5	Corrosive action will result in dissolving of metals, and hence carcinogenic and other poisonous materials such as cadmium will end up in the water.					> 40%	Acute and toxic effects over a 1 day period. Results in deaths of aquatic biota. Bacteria and aquatic animals will overpopulate, using up the D.O in the water.

SULPHATES (3665-SC)

In most fresh waters the sulphate ion is the second most abundant anion. Sulphur in the form of sulphate, is considered an important nutrient element. Mineral springs are rich in sulphate and feed considerable amount of this compound to the watershed. Acid mine drainage is a form of pollution which may contribute extremely large amounts of sulphate content to the natural waters. Other sources of sulphate are waste material from pulp mills. In water bodies with low oxygen, the process of sulphate reduction causes the production of hydrogen sulphide, with its characteristic offensive odour. This must be done on site to avoid contamination and change of temperature.

EQUIPMENT NEEDED

- Colorimeter
- 10ml tube
- Water sample (raw water)

MEASUREMENT PROCEDURE

1. Press and hold until colorimeter turns ON.

2. Press Enter to select TESTING MENU.

3. Select ALL TESTS then 089 Sulphate HR.

4. Rinse a clean tube with sample water. Fill the tube with sample water to 10ml line with sample.

5. Insert the tube into the chamber and SCAN BLANK.

6. Remove tube from colorimeter. Use the 0.1g spoon (0699) to add one measure of Sulphate Reagent (V-6277). Cap and shake until powder dissolves. A white precipitate will develop if sulphates are present. Wait for 5 minutes.

7. Mix tube again. Insert tube into the chamber, close lid and select SCAN SAMPLE.

8. Record results.

WHAT DO YOUR RESULTS MEAN? SULPHATE: RAW WATER

SULPHATES (SO_4) (RAW WATER) See page 5 for colour coding interpretation				
DOMESTIC USE (drinking, food preparation, bathing, washing)		**RECREATIONAL USE**	**AGRICULTURAL USE: IRRIGATION AND FARMING (crop yield and quality)**	**AQUATIC ECOSYSTEMS**
Range (mg/l)		**Range (mg/l)**		
0 – 200	No health or aesthetic effects are experienced.	**No guidelines available**	**No guidelines available**	**No guidelines available**
200 – 400	Diarrhea may occur in sensitive individuals in the higher ranges. Slight taste may be experienced. Moderate corrosion and discolouring of clothing.			
400 – 600	Diarrhea in most individuals that are not able to adapt to increase in sulphates. Very salty or bitter taste. Increasingly corrosive.			
600 – 1000	Diarrhea in most individuals- users are not able to adapt to the taste and effects. Pronounced salty or bitter taste. Very corrosive.			
> 1000	Diarrhea in all individuals. Users are not able to adapt to taste and effects. Very strong salty and bitter taste. Highly corrosive.			

REFERENCES:

1. Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 1: Domestic Use
2. Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 2: Recreational Use
3. Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 4: Agricultural Use: Irrigation
4. Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 7: Aquatic Ecosystems
5. Department of Water Affairs and Forestry, Department of Health and Water Research Commission, 1998. Quality of Domestic Water Supplies. Volume 1: Assessment Guide. Water Research Commission Report No. TT101/98
6. Rand Water, Vaal Barrage Catchment Executive Committee Guidelines
7. Water Wise website: www.waterwise.co.za
8. www.geotechenv.com/Manuals/LaMotte_Manuals/smart3_colorimeter_operators_manual.pdf
9. www.sciencebuddies.org

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APPENDIX 1: Petrifilm™ E.coli/Coliform Count Plate Interpretation Guide

3M

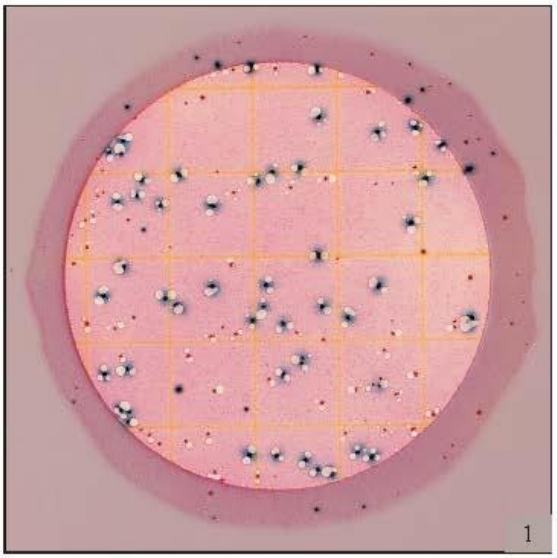
Interpretation Guide

Petrifilm™
E.coli/Coliform Count Plate

This guide familiarizes you with results on 3M™ Petrifilm™ E. coli/Coliform Count plates. For more information, contact the official 3M Microbiology Products representative nearest you.

Petrifilm E. coli/Coliform Count (EC) plates contain Violet Red Bile (VRB) nutrients, a cold-water-soluble gelling agent, an indicator of glucuronidase activity, and an indicator that facilitates colony enumeration. Most *E. coli* (about 97%) produce beta-glucuronidase which produces a blue precipitate associated with the colony. The top film traps gas produced by the lactose fermenting coliforms and *E. coli*. About 95% of *E. coli* produce gas, indicated by blue to red-blue colonies associated with entrapped gas on the Petrifilm EC plate (within approximately one colony diameter).

AOAC INTERNATIONAL and U.S. FDA Bacteriological Analytical Manual (BAM) define coliforms as gram-negative rods which produce acid and gas from lactose during metabolic fermentation. Coliform colonies growing on the Petrifilm EC plate produce acid which causes the pH indicator to make the gel color darker red. Gas trapped around red coliform colonies indicates confirmed coliforms.

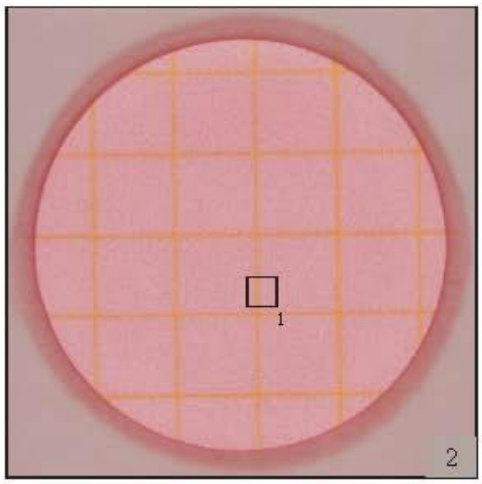


The identification of *E. coli* may vary by country (see Reminders for Use section for incubation times and temperatures):

AOAC INTERNATIONAL validated method
***E. coli* = 49** (blue colonies with gas)
Total coliform = 87 (red and blue colonies with gas)

Do not use this plate alone for the detection of *E. coli* O157. Like most other *E. coli*/coliform media, this plate will not specifically indicate whether any O157 strain is present.

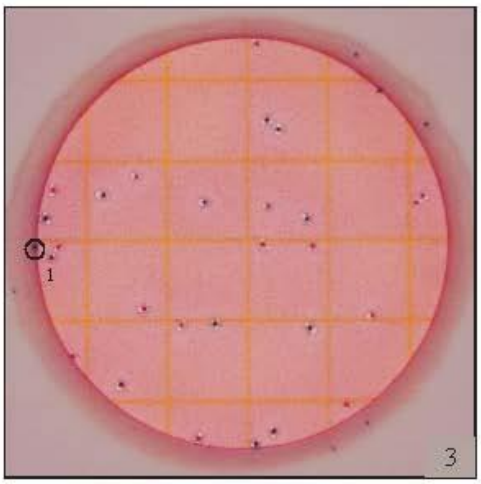
3M™ Petrifilm™ E. coli/Coliform Count Plate



No growth = 0

Notice the changes in gel color in figures 2 through 8. As the *E. coli* or coliform count increases, the color of the gel turns to dark red or purple-blue.

Background bubbles are a characteristic of the gel and are not a result of *E. coli* or coliform growth. See square 1.

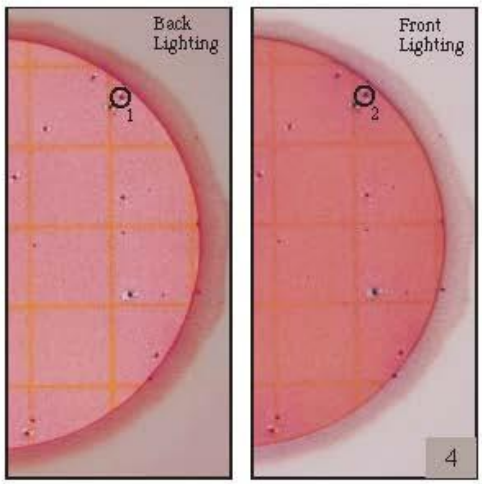


***E. coli* count = 13**

Total coliform count = 28

The counting range for the total population on Petrifilm EC plates is 15–150.

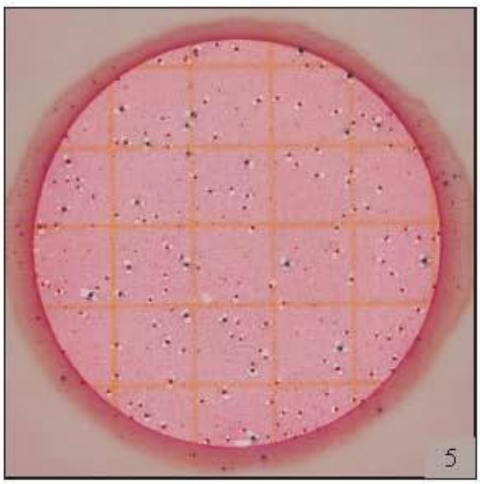
Do not count colonies that appear on the foam barrier because they are removed from the selective influence of the medium. See circle 1.



***E. coli* count = 3**

Any blue in a colony (blue to red-blue) indicates the presence of *E. coli*. Front lighting will enhance the detection of blue precipitate formed by a colony.

Circle 1 shows a red-blue colony counted using back lighting. Circle 2 shows the same colony with front lighting. The blue precipitate is more evident in circle 2.

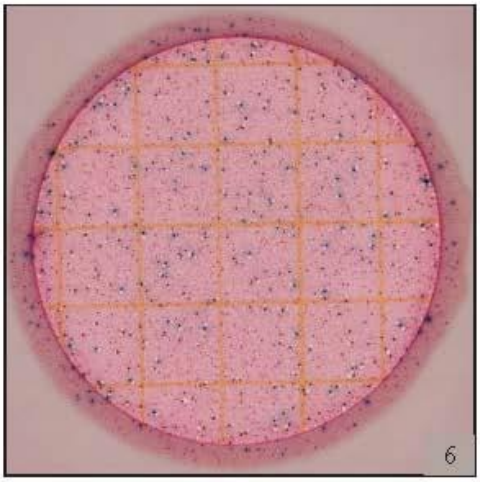


***E. coli* count = 17**

Estimated total coliform count = 150

The circular growth area is approximately 20 cm^2. Estimates can be made on plates containing greater than 150 colonies by counting the number of colonies in one or more representative squares and determining the average number per square. Multiply the average number by 20 to determine the estimated count per plate.

TNTC (Too Numerous to Count) *To obtain a more accurate count, dilute the sample further.*

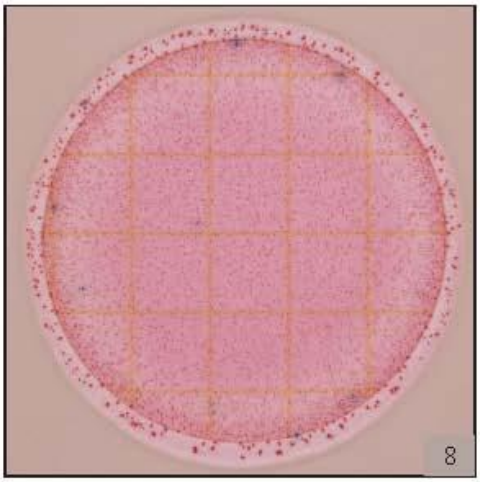


Actual count ~ 10^6

Petrifilm EC plates with colonies that are TNTC have one or more of the following characteristics: many small colonies, many gas bubbles, and a deepening of the gel color from red to purple-blue.

Actual count ~ 10^8

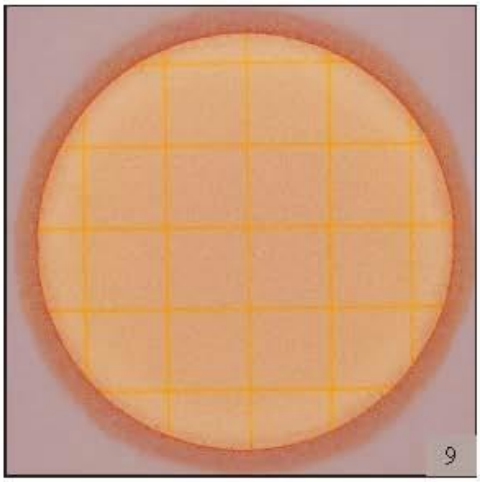
High concentrations of *E. coli* may cause the growth area to turn purple-blue.



Presumptive *E. coli* count ~ 8

Estimated total coliform count ~ 10^8

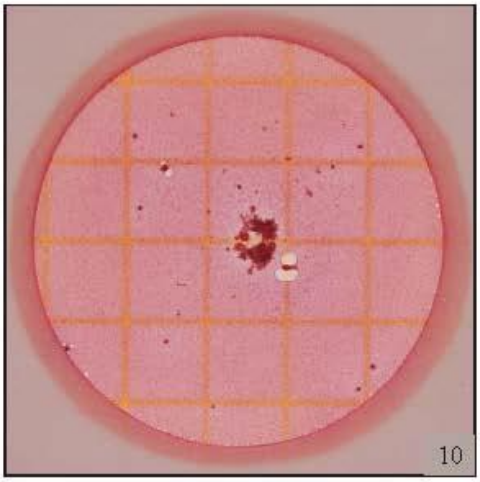
When high levels of coliforms are present (>10^8), some strains of *E. coli* may produce less gas and blue colonies may be less definitive. Count all blue colonies without gas and/or blue zones as presumptive *E. coli*. Pick blue colonies without gas and confirm if necessary.



Actual count ~ 10^8

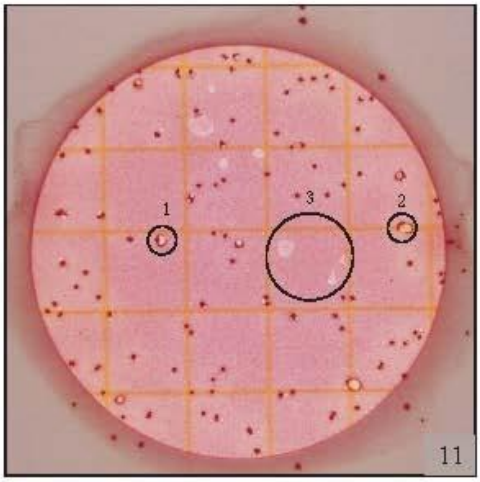
When high numbers of non-coliform organisms such as *Pseudomonas* are present on Petrifilm EC plates, the gel may turn yellow.

Bubbles



Total coliform count = 3

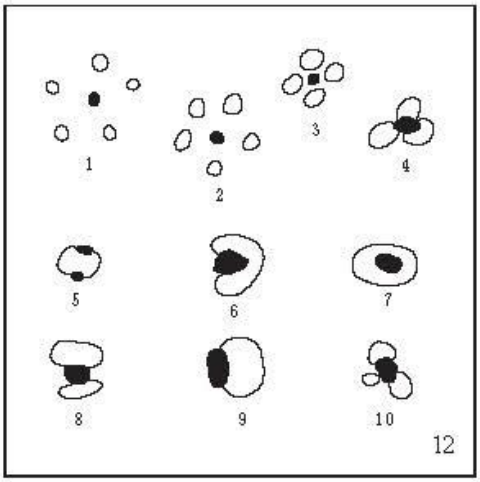
Food particles are irregularly shaped and are not associated with gas bubbles.



Total coliform count = 78

Bubble patterns may vary. Gas may disrupt the colony so that the colony "outlines" the bubble. See circles 1 and 2.

Artifact bubbles may result from improper inoculation or from trapped air within the sample. They are irregularly shaped and are not associated with a colony. See circle 3.



Examples 1–10 show various bubble patterns associated with gas producing colonies. All should be enumerated.