University of Applied Sciences and Arts of Southern Switzerland
Water, Sanitation and Hygiene Competence Centre

SUPSI

SWISS WATER PARTNERSHIP

Schweizerische Eidgenossenschaft
Confédération suisse
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Swiss Agency for Development and Cooperation SDC

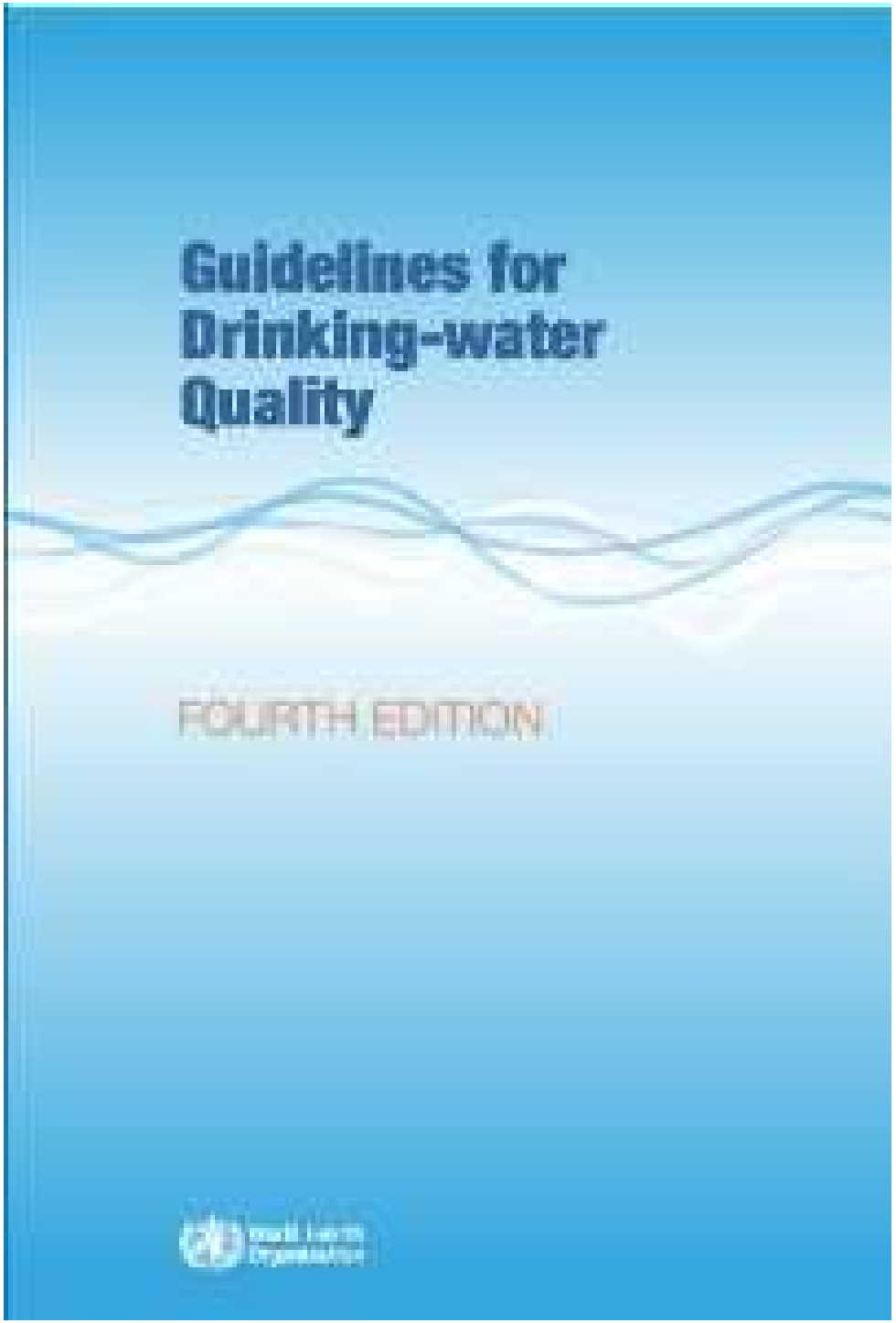
Basics of water quality

SWP Learning event 2018

Claudio Valsangiacomo (www.supsi.ch/go/wash)

World Health Organization

1. Introduction
2. A conceptual framework for implementing the Guidelines
3. Health-based targets
4. Water safety plans
5. Surveillance
6. Application of the Guidelines in specific circumstances
7. Microbial aspects
8. Chemical aspects
9. Radiological aspects
10. Acceptability aspects: Taste, odour and appearance
11. Microbial fact sheets
12. Chemical fact sheets
13. Annexes



Types of portable laboratories and sampling

Del agua and WAGTECH kits for water testing

- Only turbidity, free residual chlorine and coliforms.
- More difficult to use than SHA water lab (preparation of sterile artificial media.

Oxfam

Schweizerische Eidgenossenschaft
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Swiss Agency for Development and Cooperation SDC

SHA kit for water testing

Intruments and equipment for **sampligns** and **oganoleptic, physical** analyses

Intruments and equipment for the **bacteriological** analyses

Instruments and equipment for the **chemical** analyses

Sampling of water for bacteriological analysis

Principles

Wash hands and use sterile bottles / receptacles

→ Sterilization (15' @ 121° C) or by boiling

Pump and purge the system (borehole, network, tap,…) during **10 minutes**

→ Temperature, pH, conductivity stabilisation

Rinse (with the sample) the bottles and recipients **3 x**

→ Guarantees that the sample is well the one of the collection

2 sterile bottles / receptacles of <u>100 ml</u> per sample

→ Avoid unpleasant surprise (bottle which breaks,…)

In-situ measures or for a quick use (max. 24 h.)

→ Temperature ° C, pH, conductivity, color, smell, turbidity, residual free chlorine

⇨ Keep it cool

2 sterile 100 ml receptacles

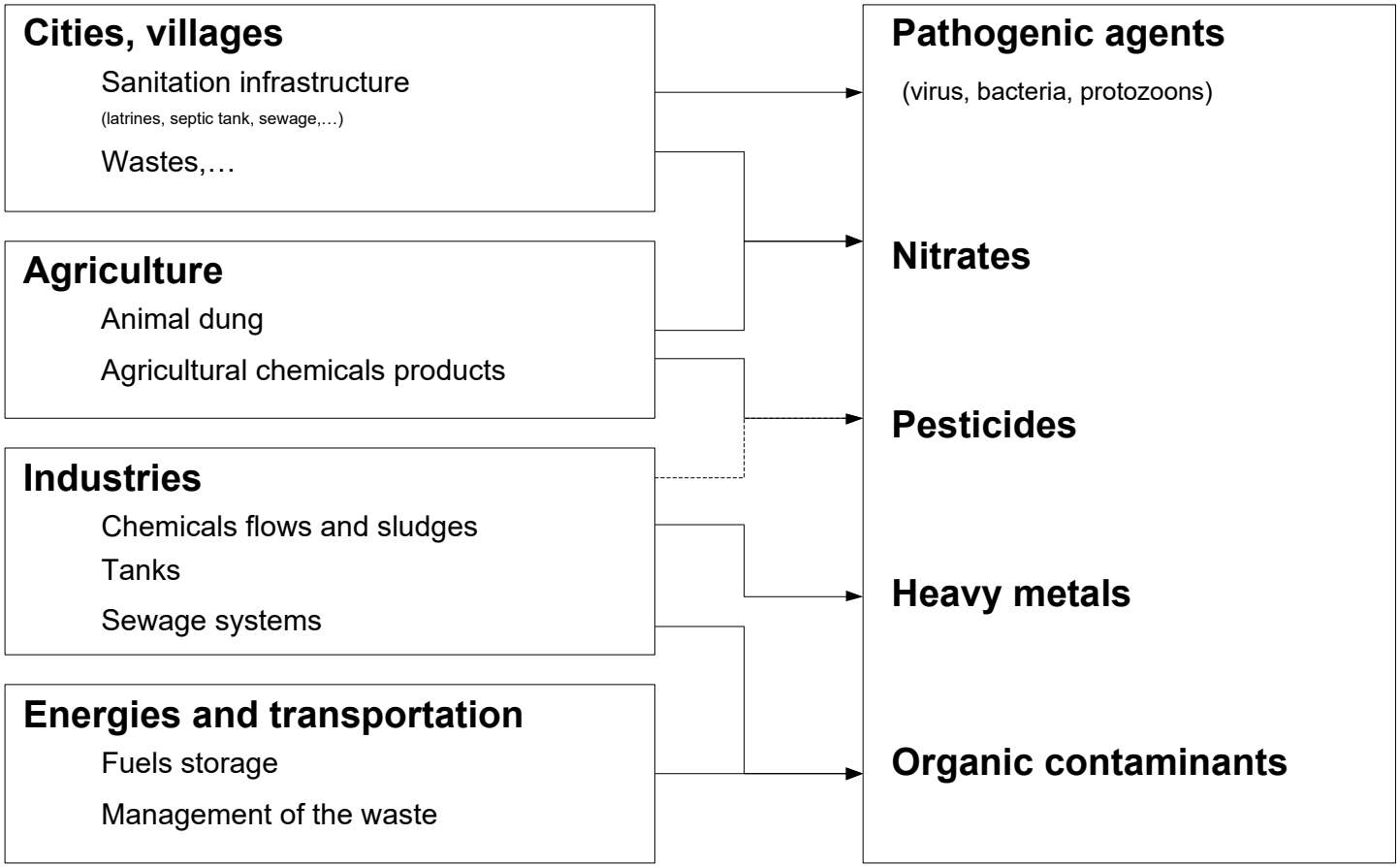
Analytical Parameters and sources of contamination

Sources of contamination

Sources and impacts of contamination

→ Human origin sources or after a natural disaster

→ Non-exhaustive list

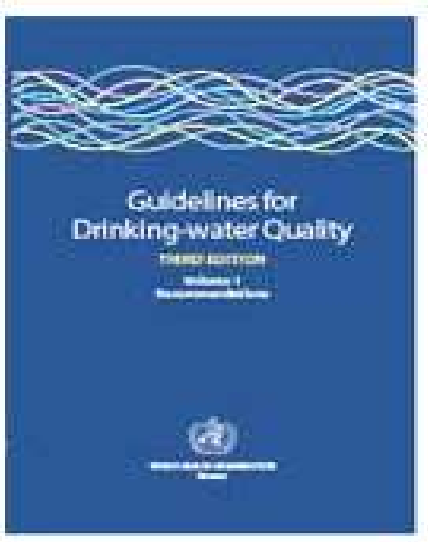


Drinking water and intense pesticide uses : risks of pollution

Drinking water quality control

Microbioliogical aspects	Disinfection	Chemical aspects
Pathogenic agents from faecal origin (excreta : sources of bacteria, virus, protozoons and helminthes)	Destruction of microbial pathogenic agents (chemical reagent: chlorine)	Provoke harmful effects due to prolonged exposure (apart for some exceptions presenting short-term risks)

Radiological aspects	Aspects of acceptability
Presence of radionucleids in the water (rare)	Organoleptic parameters (According to the senses of the consumers) taste, smell and appearance



Main analysis parameters during emergency

Analysis	Analyte	Sample	Result	Requirements (WHO)
Bacteriological analysis with Compact Dry EC	*E. coli* as indicator of fecal contamination	100 ml water (sterile sample collection, analyze within 24 h, no thermal shocks, use thiosulfate soln. if chlorine treated).	CFU/100 ml (Colony Forming Units in 100 ml)	0 CFU/100 ml
Free residual chlorine	Free residual chlorine (FRC)	Just fill the vial as required (analyse on the spot, no sterile conditions required)	ppm (parts per million) or mg/L	> 0.5 ppm (for humanitarian situations > 0.2 ppm (BUT: Turbidity requirements satisfied)
Turbidity	Turbidity	Just fill the turbidimeter (analyse on the spot, no sterile conditions required)	NTU (Nephelometric Turbidity Units)	< 5 NTU (for humanitarian situations < 10 NTU)

Chemical versus Bacteriological contamination

1. Presence of *E. coli* means presence of fecal contamination, during Cholera or other diarrheal epidemics the risk to get sick is high
2. Presence of total coliforms indicates bad disinfection practice of water (**only *Escherichia coli* accurately indicates fecal contamination!**).
3. Presence of chemical contamination has a variety of different meanings. Usually risk to get sick is very low (if consumption only for short period)

FRC and turbidity during emergency

If

A. Free Residual Chlorine > 0.5 ppm (> 0.2 ppm for humanitarian situations)

and

B. Turbidity < 5 NTU (< 10 NTU for humanitarian situations)

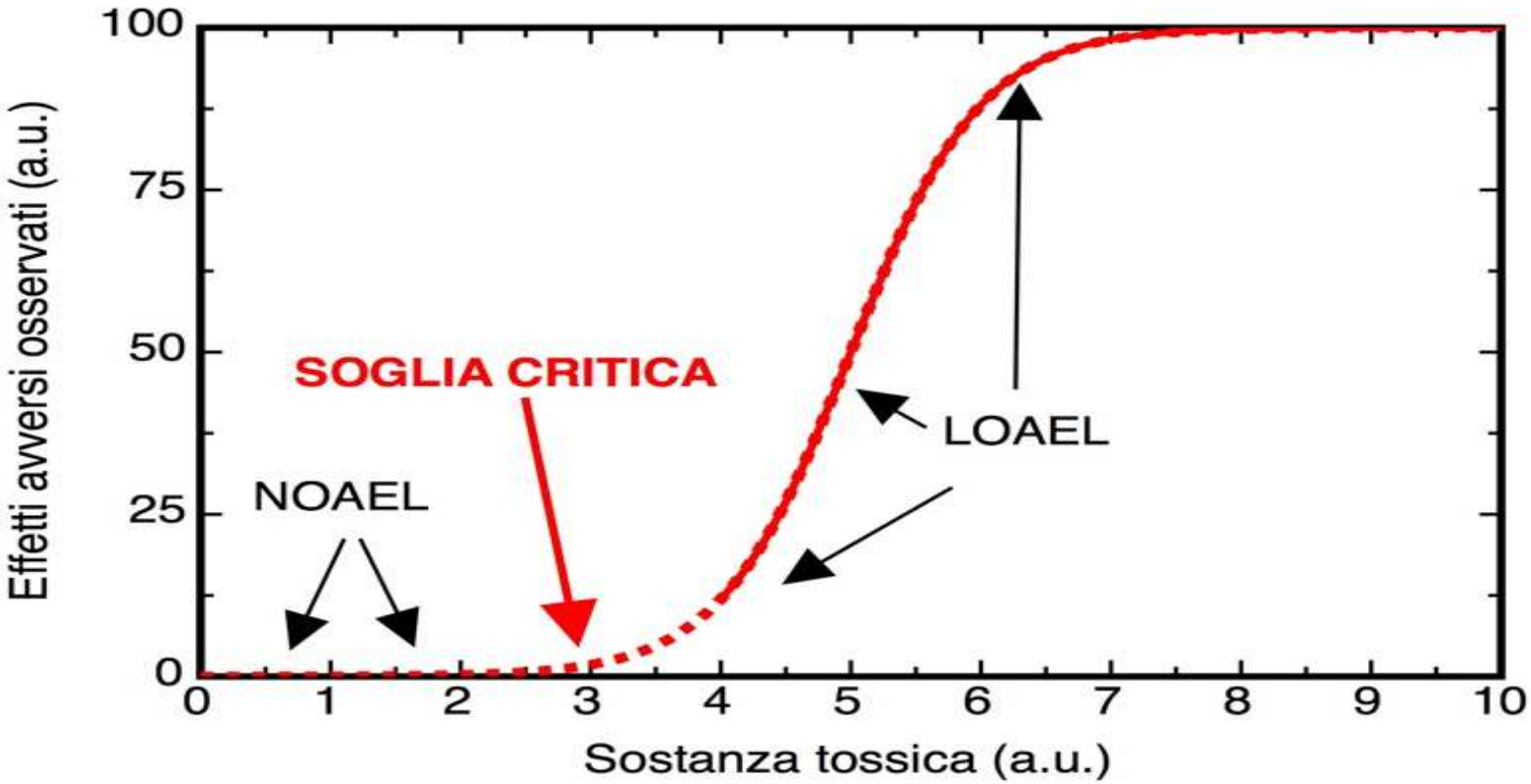
Then: No need for bacteriological water testing

P.S. Be sure the pH is within the ideal range 6.5 – 8.5

Selected chemical parameters and interpretation of results and its meaning for health

Reference values for chemical contamination: basics of toxicology

With experiments on animals LOAEL (Lowest observed adverse effect level) and NOAEL (No observed adverse effect level) are determined. The animals are fed for the whole life with a specific concentration of the substance.



Extrapolation of reference value from experimental toxicology – Example for Hg residues in water

10 mg/kg

- Critical treshold for animals NOAEL

1 mg/kg

- Critical treshold for human beings

0.1 mg/kg

- Critical treshold for particularly susceptible human beings (intraspecific susceptibility)

0.01 mg/kg

- Legal reference value

→ O : origin → H : health → NH : not linked to the health

Parameters	WHO guideline values	Interpretation (see following section)
Arsenic (As)	0.01 mg/l	O: rocks, industrial waste (iron and steel, precious-metal processing industry) H: proven carcinogenic effect (skin cancer)
Chlorine (Cl_2)	5 mg/l	O: water disinfection products
Copper (Cu^{++})	2 mg/l	O: corrosion of copper pipes, agricultural NH: colour and bitter taste if > 5mg/l
Fluorides (F^-)	1.5 mg/l	O: rocks, fertiliser, food (fish), industrial pollution (aluminium manufacture) H: dental and bone fluorosis
Lead (Pb)	0.01 mg/l	O: natural (galena), chemical industry, lead pipes corrosion, surface treatment H: cumulative neurological toxicity
Manganese (Mn)	0.4 mg/l	O: iron-bearing rocks H: toxic effect on nervous system when > 20 mg/l NH: turbidity and taste when > 0.3 mg/l
Nitrates (NO_3^-)	50 mg/l	O: faecal contamination, organic matter, soil leaching, fertiliser, wastewater H: child methaemoglobinaemia
Nitrites (NO_2^-)	3 mg/l	O: organic matter H: child methaemoglobinaemia

→ essential elements: Na, Mg, K, Ca, Si, P, S, Cl, H, C, O ;

→ toxic elements: As, Pb, Cd, Al, Ag, Sb, Hg, U, Rn ;

→ toxic essential elements only if high concentration : N, F, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Mo, Ba, Be.

pH	The acceptable range for drinking water is between 6.5 to 8.5. pH measures water acidity or alkalinity. Levels below 6.5 may be corrosive, while levels above 8.5 may create scaling problems and a bitter taste.
CONDUCTIVITY	Most drinking waters have conductivity measurements below 2000 uS/cm. Conductivity is used to determine the total amount of dissolved solids in the water.
SODIUM	There is no apparent hazard to people in good health. Over 200 mg/L is considered high and may cause corrosion of the water supply system particularly if the water is warm and alkaline. For people on salt-restricted diets or those suffering from hypertension, congestive heart failure or heart disease, the recommended limit is 20 mg/L. If in doubt, consult your physician. **Note:** Water softening devices usually increase sodium concentration, while reverse osmosis and distillation units will reduce it.
POTASSIUM	The recommended limit is 20 mg/L. Levels above 100 mg/L may cause a laxative effect, while levels above 340 mg/L may affect taste.

CALCIUM	The recommended limit is 200 mg/L. Excessive calcium may contribute to the formation of kidney or bladder stones. Calcium also contributes to the hardness of water and may cause problems with laundering, washing and bathing.
MAGNESIUM	The recommended limit is 150 mg/L. Magnesium is a salt that contributes to the hardness and taste of water. Excessive magnesium may give water a bitter taste, but is normally not a health hazard. Water softeners will reduce the level of magnesium in the water.
TOTAL HARDNESS	The most desirable range of hardness is between 80 and 100 mg/L. Water hardness results from the water accumulating calcium, magnesium, and other minerals as it moves through the earth. Total hardness less than 80 mg/L may result in corrosive water, while hardness above 100 mg/L may result in the need for more soap during bathing and laundering. Excessive hardness may also lead to scale deposits in pipes, heaters, and boilers.

IRON	The recommended limit is 0.3 mg/L. Excessive iron may result in staining (reddish brown) of laundry, plumbing fixtures, and even hair. It may also cause undesirable taste in beverages. High iron levels also encourage the growth of iron bacteria. Iron in drinking water is not a health concern unless at extreme levels. Iron removal units will reduce iron concentrations.
TOTAL ALKALINITY	The acceptable limit is 500 mg/L. Excessive alkalinity may cause stomach upset and encrustation of utensils, pipes, and water heaters. High levels can also give a 'flat' taste to the water and cause "itchy" skin when bathing.
CARBONATE	The recommended limit is 350 mg/L. Carbonates are associated with the level of alkalinity. Water may have a "flat" taste.
BICARBONATE	The recommended limit is 1000 mg/L. In high levels, it is often observed as "white bubbles" (sodium bicarbonate.) Excessive bicarbonates contribute to the production of scale in water heaters and kettles.

CHLORIDE The recommended limit is 250 mg/L. Excessive chlorides give the water a "salty" taste, usually noticeable over 500 mg/L.

FLUORIDE The recommended limit is 1.5 mg/L. Values over 1.5 mg/L may cause dental fluorosis or mottling of permanent teeth in children between the ages of birth to 13 years. Steps may be taken to reduce the risk of dental fluorosis. For more information, contact the Dental Program through your Community Health Centre.

NITRITE The recommended limit is 1 mg/L.

NITRATE The recommended limit is 10 mg/L.

If these limits are exceeded, human and/or animal waste contamination should be suspected and an investigation carried out to determine the source.

Nitrite and Nitrate concentrations above the recommended limits are dangerous to pregnant women and pose a serious health threat to infants under 3 months of age because of their ability to cause Methaemoglobinaemia or "Blue Baby Syndrome" in which the blood loses its ability to carry sufficient oxygen. Distillation and reverse osmosis units can remove nitrates and nitrites. Water softeners do not remove nitrates and nitrites. Boiling the water will not remove nitrates/nitrites. To reduce the levels, it is best to eliminate the source of high nitrates/nitrites.

WU3 Put in alphabetical order
Chloride as pollution indicator
Windows User; 26/01/2016

SULPHATE	The recommended maximum concentration is 500 mg/L. Excess sulphate levels may have a laxative effect on new users and produce an objectionable taste. Regular users tend to become accustomed to high sulphate levels. Consult your physician if sulphate levels exceed 500 mg/L.
TOTAL DISSOLVED SOLIDS	Levels less than 500 mg/L are considered good. Total dissolved solids indicate the amount of chemical substances dissolved in the water. At increasing levels, palatability decreases. Levels in excess of 1000 mg/L may produce a bad taste.
CATION/ANION BALANCE	These numbers are laboratory quality control accuracy checks for instrumentation and process.

FRC and turbidity

FRC and turbidity

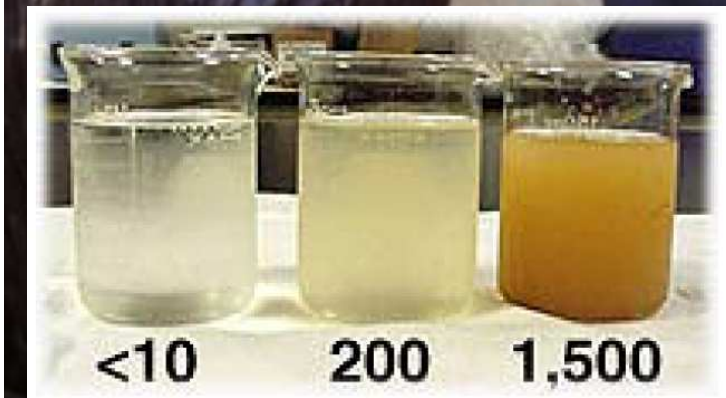
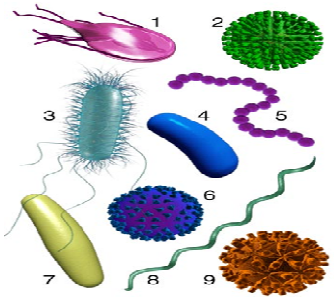


Figure 1: Sample Turbidities (Howard, 2001)

Bacteriological analysis, fecal indicators

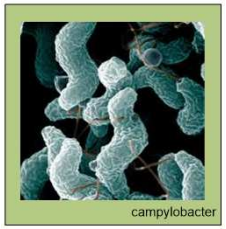


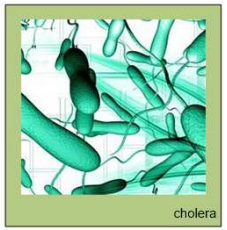
Why we do not measure pathogens

- Numerous water borne pathogens
- Individual pathogen numbers may be too low to detect in a reasonable sized water sample
- Isolation and detection of some pathogens can take several days, weeks, or months
- Absence of one particular pathogen does not rule out the presence of another

Infections

Infection		Pathogenic agent
Diarrhoeas and Dysenteries	*Campylobacter enteritis*	Bacterium
	Cholera	Bacterium
	E. coli diarrhoea	Bacterium
	Salmonellosis	Bacterium
	Shigellosis (bacillary dysentery)	Bacterium
	Yersiniosis	Bacterium
	Rotavirus diarrhoea	Virus
	Giardiasis	Protozoon
	Amoebic dysentery	Protozoon
	Balantidiasis	Protozoon
Enteric fevers	Typhoid	Bacterium
	Paratyphoid	Bacterium
Poliomyelitis		Virus
Hepatitis A		Virus
Leptospirosis		Spirochaete
Ascariasis		Helminth
Trichuriasis		Helminth


campylobacter

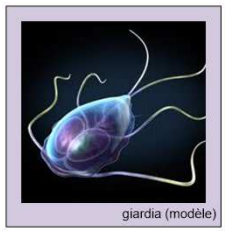

cholera


salmonella

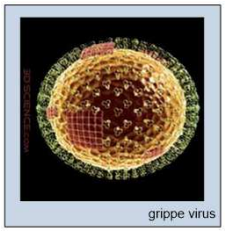

protozoaire

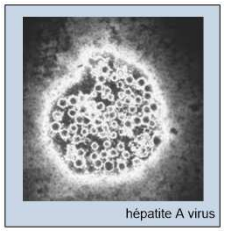

amoeba


crysporodium


giardia (modèle)

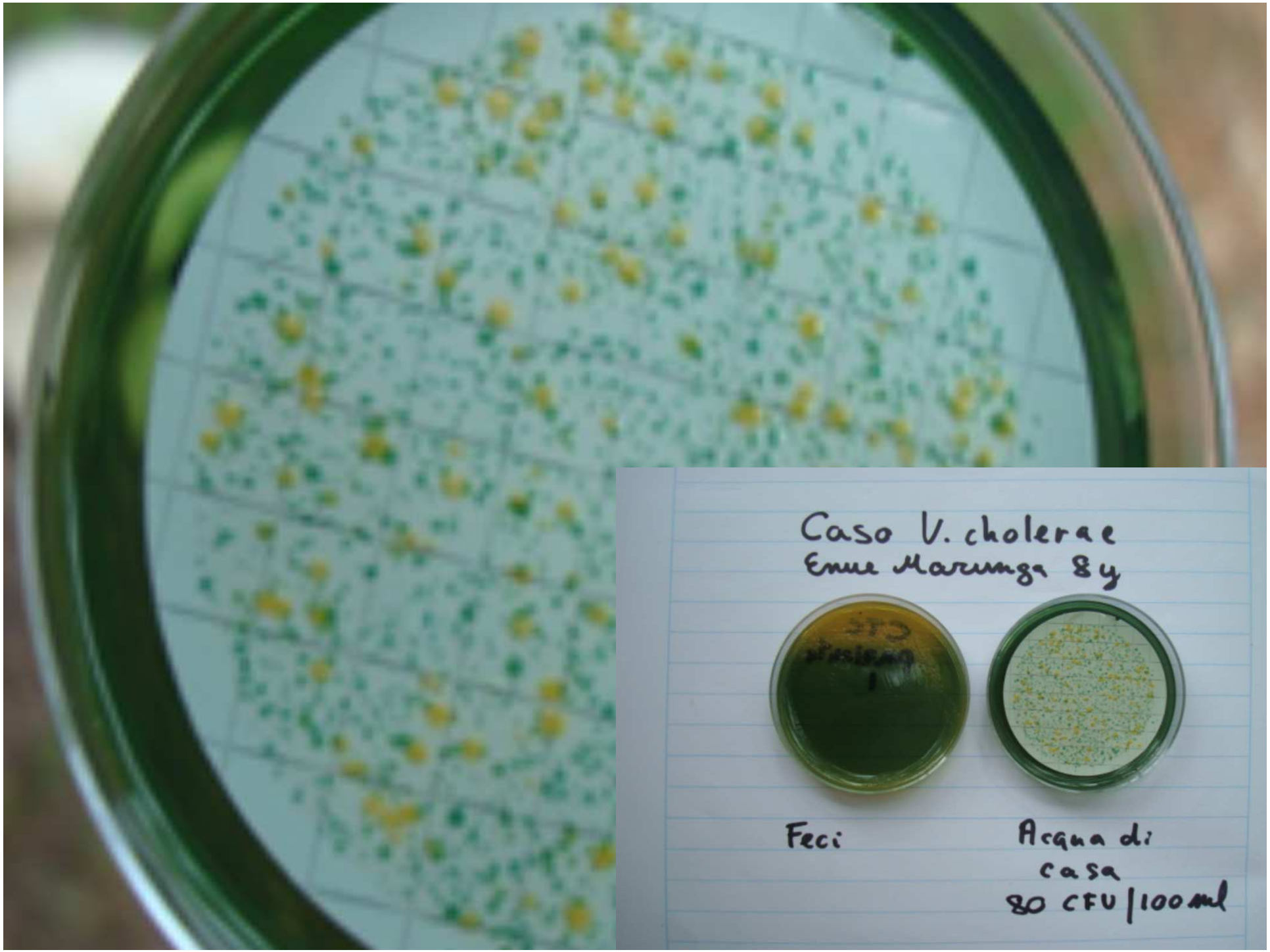

entérite virus


grippe virus


hépatite A virus

Indicator Organism Concept

- Correlated to the presence of pathogens
- Population large enough to isolate in small water samples (100 mL)
- Rapid
- Inexpensive
- Safety, not culturing pathogens


Caso V. cholerae
Enne Marunga 8y
Feci
Acqua di
casa
80 CFU/100ml

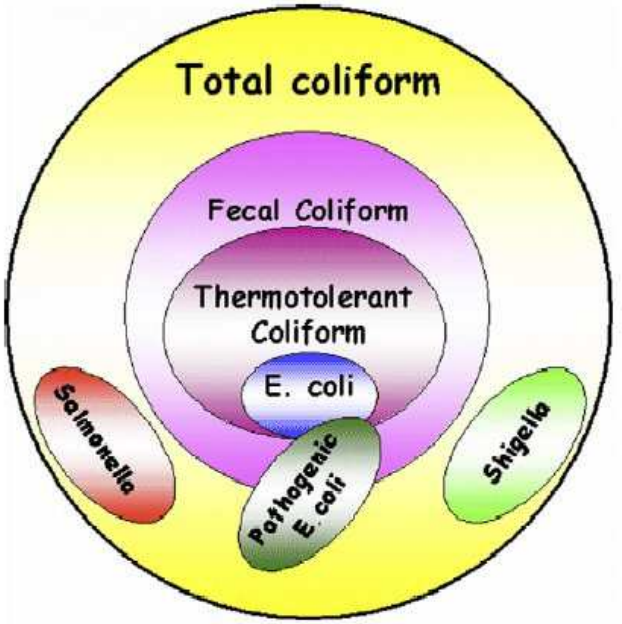
Bacteriological analysis

Looking for an "**indicator**" of faecal pollution

→ **E. coli** is the main faecal coliform

Estimation and counting

Unit of measure : Colony Forming Units (CFU) / 100 ml.



0 faecal coliforms / 100 ml	Drinking water
0 to 100 faecal coliforms / 100 ml	Water to be treated
+ than 1000 faecal coliforms / 100 ml	Highly polluted water : a) find an alternative water source **OR** b) ensure a full treatment process

Bacteriological analysis

- Filtration technique (0.45 µm) and incubation (37 or 42, 44° C)
- Micro-organisms present in water : size > 1 µm
- Artificial medium (magenta-Gal sugar) allows, with the β-galactosidase enzyma the red/pink coloration of the colonies
- A 2nd sugar (X-Gluc), with the β-glucuronidase enzyma, colors the E.coli in blue
- The combination of both colorants allows the differenciation between coliforms and E.coli

Blank and Positive tests
→ allows to tell if the incubation was successfull

Comparative results

Bacteriological analysis

Treatment

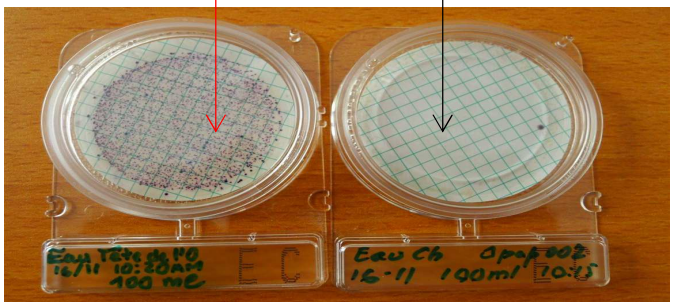
- Filtration, **disinfection with chlorine**, ozone, boiling,…

Sample **PRIOR** to chlorination

→ massive contamination

Sample **AFTER** chlorination

→ efficient disinfection



Free Residual Chlorine
1.2 mg/l

Effects on health and other considerations

- Exposure to bacteria, viruses and pathogenic protozoons varies, but waterbourne diseases: gastroenteritis problems (nausea, vomititing and diarrhea), usually short-term
- On sensitive persons (babies, elderly or with an immune deficiency)

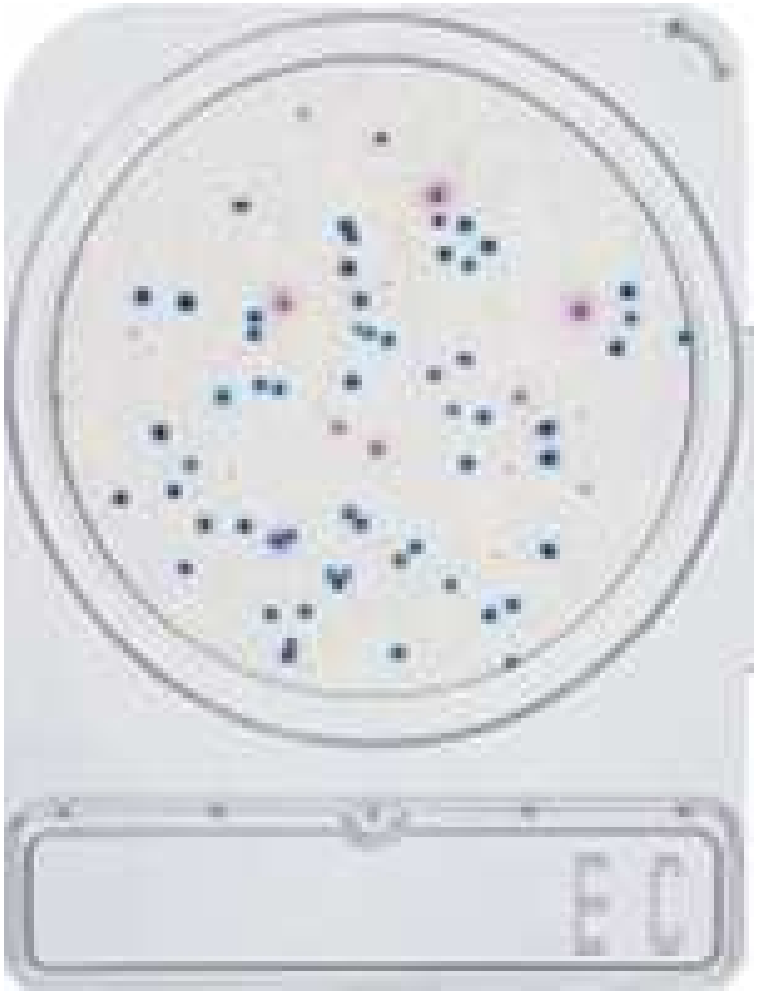
  → more serious, more chronic and fatal effects

Standard operating procedure for bacteriological analysis of water

Analysis of E.coli and Coliforms

Enzyme Substrate or Chromogenic Substrate Method

- Coliforms have the enzyme
  - β-D-galactosidase
  - Can be detected with Magenta-Gal artificial sugar: Pink
- *E. coli* has the enzyme
  - β-glucuronidase
  - Can be detected with X-Gluc artificial sugar: Blue



Manipulations

- Samples have to be collected in a sterile vial. If no sterile vial is available, clean new PET bottles of mineral water (0.3-0.5 l) can be used, rinse 3 times with sampling water. If using an inox vial than sterilize it with alcohol tissue.
- Water testing has to be done during the day of collection, never analyze samples collected more than 24 h before.
- Avoid elevated temperature during transport of water samples, keep cool do not expose to sun, do not freeze.

- Identify a clean place to install your WATER LAB.
- Wash your hands.
- Arrange the equipment in a confined space. Power on incubator and attach water pump to funnel. Pretest correct operation of water pump.
- Define a small sterile area: surface corresponding to max. 1 A4 paper sheet (you can use inox plate by sweeping it with alcohol tissues).

- Prepare samples to be analyzed and plates with artificial medium (10-15 samples). Samples and plates must be correctly identified (codes, numbers, dates, etc.).
- Always include a positive sample (e.g. toilet or river water) and a negative sample (mineral water from bottle).

Manipulations

coliforms and *Escherichia coli* only)

- Sterilize filtration funnel and the porous filter below with alcohol tissues.

- Sterilize forceps with alcohol tissues.

- Rehydrate medium (Compact EC) with 1 ml of sample water (use sterile plastic pipette, one for each sample).

Manipulations

- Remove a sterile filter membrane (0.45 microns) from its envelope using the sterile forceps (do not touch filter with hands).

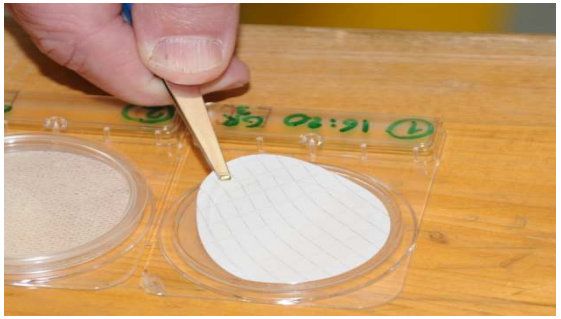
- Place the sterile filter membrane on the filtration equipment (do not touch filter with hands).

- Close tightly the funnel (clamps do not have to be loose otherwise it will leak!).

Manipulations

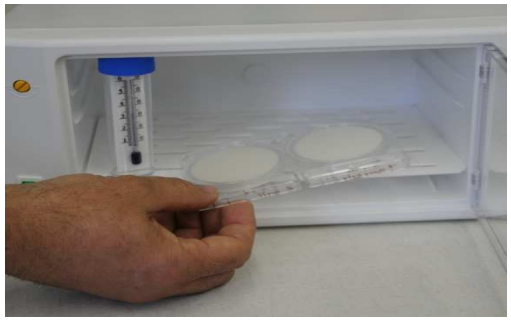
- Pour 100 ml of sample water into funnel. Filtered water is supposed to be sterile, bacteria remains on the filter surface.

- Operate the water pump in order to suck water through the filter.

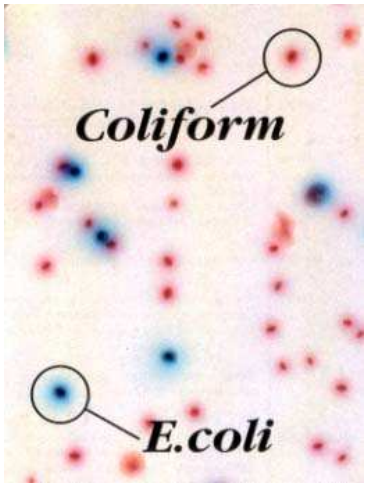


- Remove funnel from filtration equipment and place filter on rehydrated medium (plate) by using forceps. Close with lid.

Manipulations



- Incubate plates upside down (to avoid condensation) for at least 18 h (preferably 24 h) at 37 °C. At this temperature total coliforms and E. coli can grow.



- Count colonies: E. coli are blue, coliforms are pinkish

Express results in CFU (Colony Forming Units). If more than 100 CFU express results as TNTC (Too numerous to count).

Interpretation: drinking water is free of E. coli. Water treated with chlorine is free of coliforms.

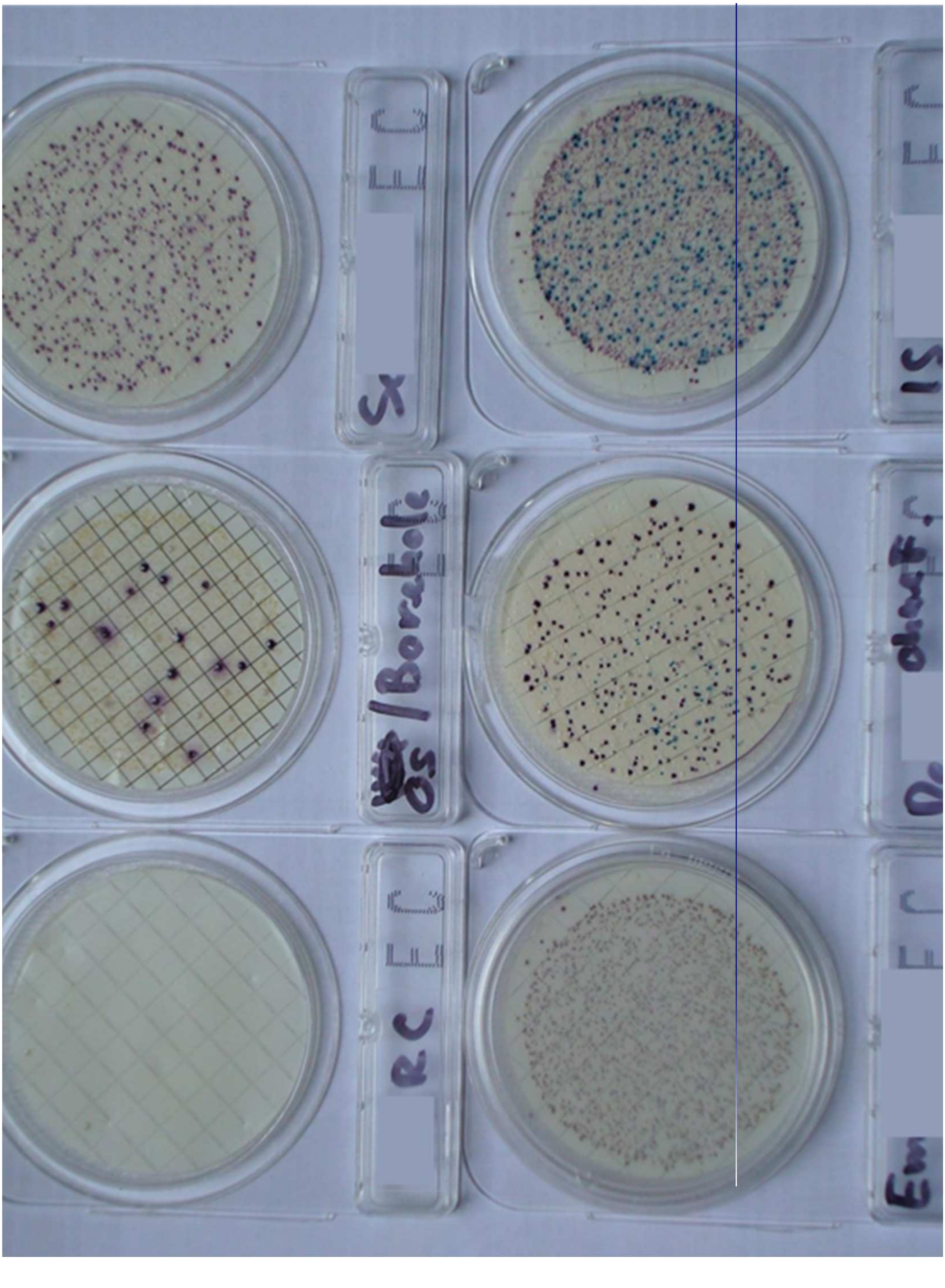
Interpretation

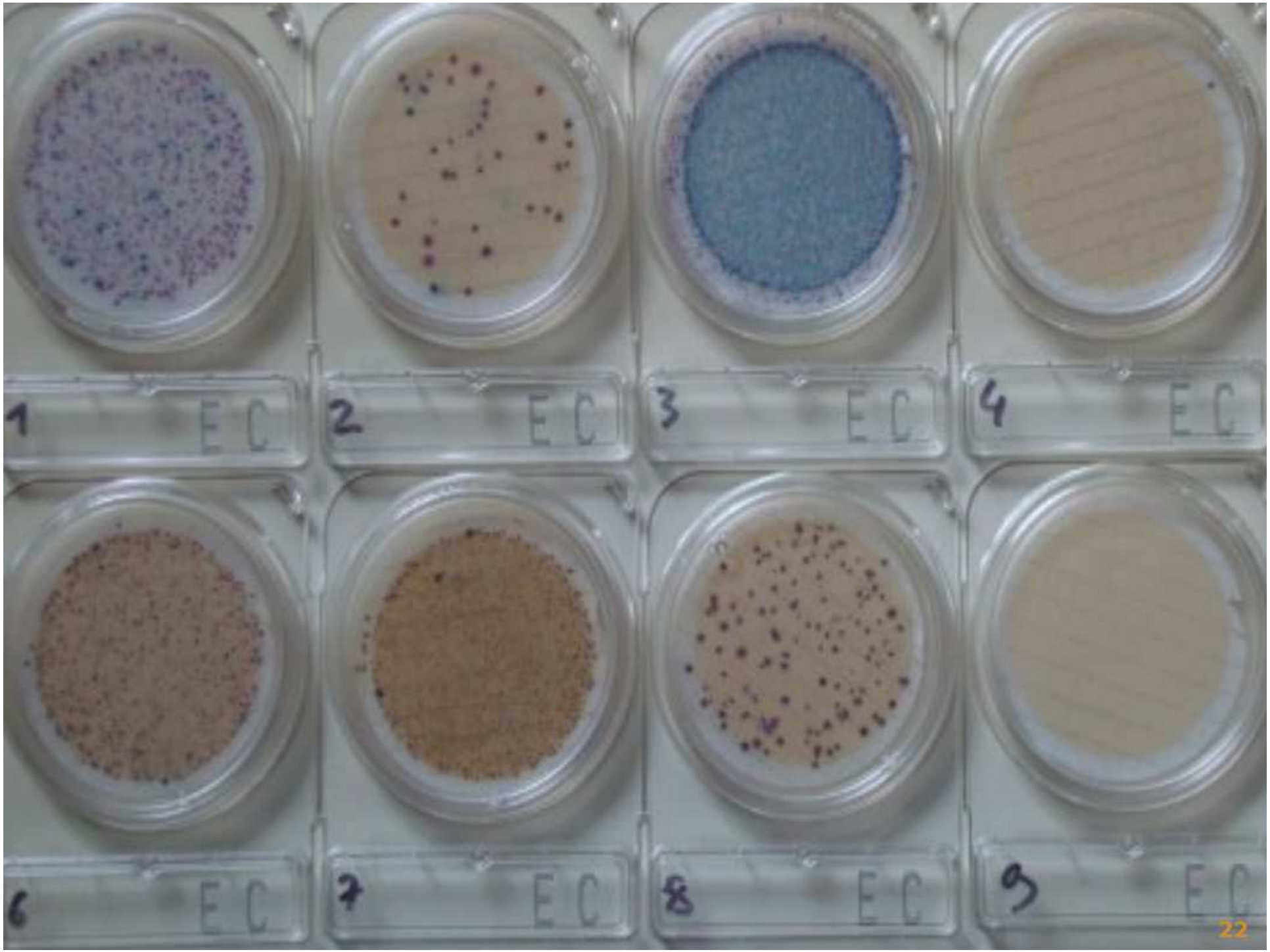
Potable Water IF :

→ E.Coli = 0

AND

→ Coliforms = 0




1 EC
2 EC
3 EC
4 EC
6 EC
7 EC
8 EC
9 EC

14 Jan 2009
Hotel
H2O
before
treatment
E.coli 100 CFU/100ml
after
treatment
0 CFU/100ml
MICROPUR®
FORTE
KATADYN®
MAKING WATER DRINKING WATER
MF 1T | DCCNa
Zur Wasserdesinfektion & Konservierung auf Reisen
For Water Disinfection & Conservation when Travelling
Le plus efficace des comprimés désinfectants; conservation de l'eau purifiée jusqu'à 6 mois
Voor ontsmetting & conservering van water op reis
Per la disinfezione e la conservazione dell'acqua in viaggio
100 tab./compr.
Natriumdichlorisocyanurat
Dichloroisocyanurate de sodium
DCCNa 4,5 mg
Silberionen/silver ions/ions d'argent/zilverionen/ioni argento
Ag+ 0,1 mg

water is a symbol of purification

… why should we purify it?

… why do we pollute it?