The quality of drinking water and the distribution system in Aruba: chemical aspects

by

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Abstract

Aruba doesn't have natural fresh water sources such as ground water, rivers or lakes, therefore drinking water is produced by seawater desalination. W.E.B. Aruba N.V. produces drinking water by seawater thermal desalination in a cogeneration process configuration with electrical power production by steam turbines using fuel oil as the energy source.

Drinking water of the highest quality in the world happens through a dedicated organization to quality and continuous improvement. The quality is recognized and appreciated by the consumers: local and international visitors. The needs and requirements of the users, development of new technologies and international potable water standards, norms and guidelines directs the ways for improvement of drinking water production, storage and distribution, quality and service at W.E.B. Aruba N.V.

Introduction

Water is essential to sustain life, and a satifactory supply must be made available to consumers. Every effort should be made to achieve a drinkingwater quality as high as practicable. Protection of water supplies from contamination is the first line of defence.

The primary aim of the Guidelines for drinking water quality is the protection of public health. The guidelines are intended to be used as basis for the delevelopment of national standards that, if properly implemented, will ensure the safety of drinkingwater supplies through the elimination, or reduction to a minimum concentration, of constituents of water that are known to be hazardous to health.

The fact that chemical contaminants are not normally associated with acute effects places them in a lower priority category than microbial contaminants, the effects of which are usually acute and widespread. Indeed, it can be argued that chemical standards for drinkingwater are for secondary consideration in a supply subject to severe bacterial contamination. The problems associated with chemical constituents of drinkingwater arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties, such as heavy metals, and substances that are carcinogenic.

In assessing the quality of drinking-water, the consumer relies completely upon his senses. Water constituents may affect the appearance, smell or the taste of the water and the consumer will evaluate the quality and the acceptability essentially on this criteria.

The WEB Aruba N.V. produces drinking water and industrial water since 1932 by thermal seawater desalination for more than 70 years. The vision of W.E.B. Aruba N.V. is to be a model in the Caribbean region for the production of high quality drinking water and to contribute to the solution of water shortage problems in the world. To realize this vison, great effort has also been done by the laboratory personnel, by creativity and improve work relationship with supporting Water Production Department, Water Distribution Department, Technical Support Department and Public Health Department of Aruba. W.E.B Aruba N.V. invested in state of the art analystical instruments and a Laboratory Management Information System for helping control product quality and process variables. The laboratory has always served an important function by providing data and independently interpret these data and give the necessary recommendations.

Figure 1: Analytical Laboratory

Figure 2: Fume Hood at the Laboratory

3. Seawater Analysis

The only source to produce drinkingwater is the saltwater that is pumped into the plants to produce distillate. This table shows some of the constituents in our seawater the analysis is done by WEB-Laboratory.

Seawater analysis

parameters	units	results
PH		8.1
Conductivity at 22 C	uS/cm	50000
Tot Dissolved Solids(TDS)	ppm	35000
Chloride as Cl	ppm	21000
M-Alkalinity as CaCO3	ppm	120
Total Hardness as CaCO3	ppm	6100
Calcium as Ca	ppm	448
Magnesium as Mg	ppm	1223
Total iron as Fe	ppm	0.03
Total Copper as Cu	ppm	0.09
Zinc as Zn	ppm	0.02
Turbidity	NTU	0.2
Specific Gravity	kg/m	1.028

Figure3: Table content of seawaterquality at the intake of the WEB-plants

Heavy metals in the seawater taken at the intake of AC#5. These analysis has been performed by GeBETZ in Houston Laboratory.

Metals	Results
Total Sulphur as SO4, ppm	2610
Total Barium as Ba, ppm	<0.1
Total Strontium as Sr, ppm	7.8
Total Potassium as K, ppm	809
Total Aluminium as Al, ppm	6.3
Total Manganese as Mn, ppm	<0.1
Molybdenum as Mo, ppm	<0.6
Total Silica as SiO2, ppm	<5
Total Arsenic as As, ppm	<1
Beryllium as Be, ppm	<0.1
Boron as B, ppm	6.1
Cadmium as Cd, ppm	<0.1
Total Chromium as Cr, ppm	<0.3
Total Cobalt as Co, ppm	<0.1
Total Lead as Pb, ppm	<0.5
Total Nickel as Ni, ppm	<0.1
Total Selenium as Se, ppm	<1
Total Tin as Sn, ppm	<0.5
Total Titanium as Ti, ppm	<0.1
Total Vanadium as V, ppm	<0.1

Figure 4 : Table content with heavy metal analysis in seawater.

4. Drinking water treatment

The distillate quality produced by MSF process is of the highest purity and does not contain microbiological contamination and very low level of dissolved chemical components content such as sodium and calcium salts. The conductivity is less than 2 uS per cm. The distillate pH is about 6.3 which is corrosive to iron and cement lined piping.

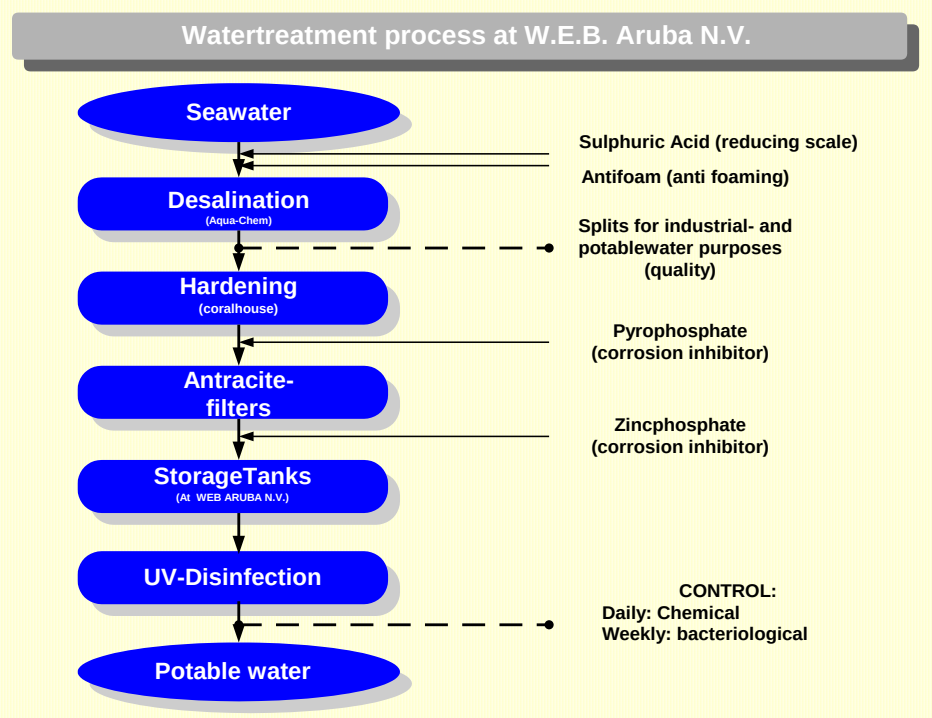


Figure 5: A schematic of the chemical treatment of the distillate system

Before 1990 sodium hexametaphosphate was dosed as iron and copper corrosion inhibitor. This corrosion inhibitor was not very efficient and in the period befor 1990 red water was often experienced. In 1990 together with GeBetz a thorough evaluation of the drinkingwater quality and the corrosiveness of the drinkingwater for the distribution system were done. As result of this evaluation the chemical treatment was changed to the dosing of pyrophosphate and zincsulfate at the concentration of respectively 3 and 4 ppm to cure the distribution system. In 1996 the zinc sulfate was changed to zinc orthophosphate to optimize the chemical treatment for at that time experienced blue water due to copper corrosion. The dosage of pyrophosphate and zinc orthophosphate is now set at 1.5 ppm and 2.5ppm respectively. All chemical treatments are according to NSF approved chemicals and dosage limits for potable water.

5. Balashi Cocktail

- To increase the water pH the distillate is mineralized by spraying over porous natural lime stone containing calcium carbonate to add calcium and magnesium to the water. The final pH is 9.0-9.3 after this treatment.

Figure 6: Picture of the coralhouse

In the coralhouse mineralization of the distillate takes place. Here the distillate is aerated by incoming air and flows over beds of coral stones. The coral stone is excavated around the Island. It consists mainly of Calciumcarbonate about 95%. The coral stones dissolve in the waterphase according to the following chemical reaction given in equation [1] to form calcium and calciumbicarbonates.The pH of the distillate is hereby increased to 9.0-9.3. Due to aeration the distillate is in natural equilibrium with air and saturated with carbon dioxide.. Carbon dioxide dissolved in the distillate enhances the dissolution of the carbonates, though the concentration is very small.

$$CO2 + CO_3^{2-} + H_2O \quad \text{-----}\rightarrow 2HCO_3 + OH^- \qquad [1]$$

After mineralization in the coral house the water is still very soft, containing a total alkalinity of 6 ot 10 ppm as calcium carbonate.
According to analyses the Langelier Saturation Index (LSI) is about –1.5 and the Ryzner stability index is about 10 , incidicating that the inffluent of the coral house is still very corrosive for iron pipes in the distribution system.

6. Drinkingwater parameters at W.E.B. Aruba N.V.

W.E.B Aruba N.V. uses a sequence of water treatment to make this pure distillate into drinking water quality that meets WHO standards.

DRINKINGWATER PARAMETERS AT W.E.B. ARUBA N.V. IN ACCORDANCE WITH THE WHO-STANDARDS FOR DRINKINGWATER
(WHO=WORLD HEALTH ORGANISATION)

Physical & chemical properties	Expressed as	Units	*WEB guideline value:	WHO guideline value:
Odor & Taste			satisfactory	No offensive for most consumers
Color			clear	
Temperature		Degree C	32-40	
Turbidity		NTU	1.0	15 true color units-5,preferable <1.0 for disinfection efficiency
		-		
pH			8.8-9.2	6.5-8.5
Conductivity		uS per cm	<150	-
Total Dissolved Solids		ppm	<75	1000
Chloride	as Cl	ppm	<50	250(sodium:200 ppm)
Hardness	as CaCO3	ppm	<20	500
Calcium	as CaCO3	ppm	2-5	-
M.Alkalinity	as CaCO3	ppm	6-10	-
Total Phosphate	as PO4	ppm	0.5-1.5	-
Zinc	as Zn	ppm	0.05-1.0	5.0
Total Iron	as Fe	ppm	max 3.0	0.3
Total Copper	as Cu	ppm	max 1.0	1.0
Total Aluminium	as Al	ppm	max 0.2	0.2
Lead	as Pb	ppm	max 0.01	0.01
Microbiological aspect:				
Total bacterial plate count		Cfu per 10 ml	<50 no action	5000
Detection of Faecal coliform organism means immediately action.			50-100 confirm 101-200 investigacion of source: within 72hours. >200 after confirmation; desinfection of system	

*WEB guidelines were establish according to historical data and based on the watertreatment proces. No guidelines set for legionella yet.
A complete analysis(inorganic, organic, radioactive) of our potable water have been performed by **National Testing Laboratories.Ltd** and the results were within the MCL(maximum concentration level) levels.

Figure 7: Table contents with the WEB and WHO guidelines.

7. Disinfection by UV

In 2003 W.E.B. Aruba N.V. added a final water disinfections step with UV treatment for microbiological quality control purposes before the finished drinking water is pumped to storage tanks on the island.

Figure 8: UV installed at the descharged pumped of the storage tanks at W.E.B. ARUBA N.V.

8.Drinkingwater quality at the WEB-HEADER

The W.E.B Aruba N.V. laboratory is dialy monitoring the drinking-water quality at the HEADER, which is the point where the water is distributed to different areas. At this point the water is also monitored weekly by the Public Health Laboratory for bacteria count. The table below shows an average of the constituents determine at the WEB laboratory in 2002 and 2003.

Waterquality at the HEADER in 2002 and 2003

Chemical Constituents:		2002	2003
Odor	----	satisfactory	idem
Colour	----	clear	idem
Temperature	C	32	32
Turbidity	NTU	0.12	0.11
pH		8.8	8.9
Conductivity	uS/cm	16.7	17.0
Total Dissolved Solids	ppm	8.4	8.5
Chloride	ppm as Cl	0.61	0.46
Hardness	ppm as CaCO3	5.2	5.2
Calcium	ppm as Ca	2	2
M.Alkalinity	ppm as CaCO3	6.2	7.4
Phosphate	ppm as PO4	1.03	0.90
Zinc	ppm as Zn	0.18	0.18
Tot.Iron	ppm as Fe	0.01	0.01
Tot.Copper	ppm as Cu	0.01	0.01

Figure 9: Table contents of the waterquality at the WEB Header.

9. Optimum control on the quality

For a optimum control on the waterquality there are different organisations involved.
The waterquality is primarily based on the two aspects which are the microbiological and the chemical aspect of the water. The W.E.B. Aruba N.V.laboratory perform all analysis on the chemical constituents and the Public Health Laboratory perform the microbiological parameters of the potablewater. The inspection and sampling of the water is the responsibility of the inpectors of the Public Health Department. All these departments makes together a yearly watermonitoring program to maintain the water within the watercriteria for drinkingwater. To strength a optimum control on the waterquality we have formed a continues strong communication triangle proces between these organisation. This communication triangle process is very important to ensure that the waterquality remains continuosly under a professional control.

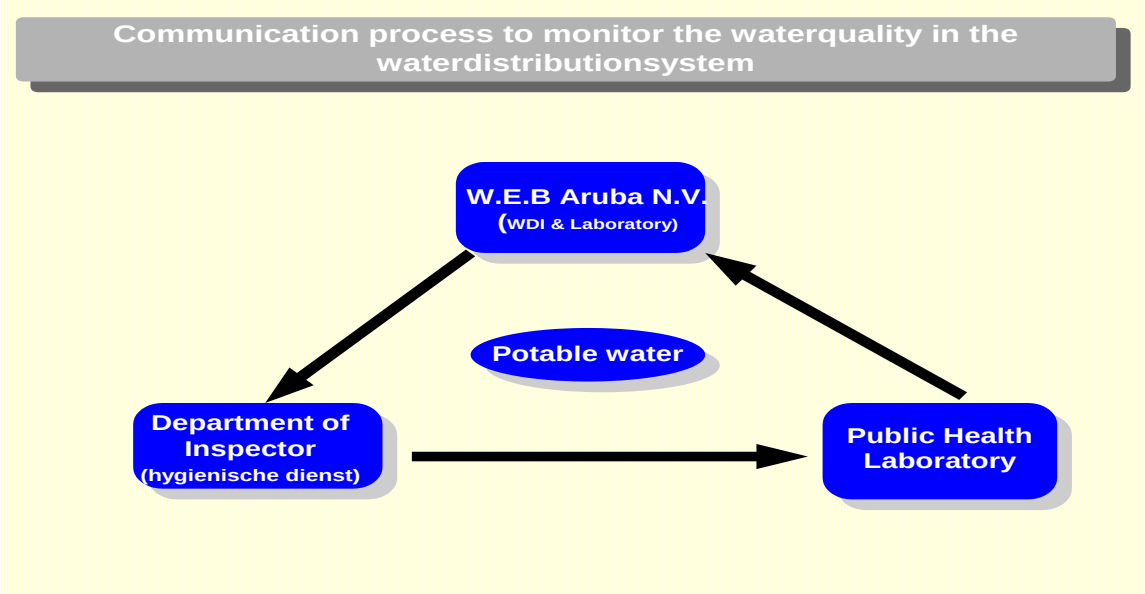


Figure 10: a schematic communication process between the departments involved

10. W.E.B. Aruba N.V. Test program

Quality Control of the drinkingwater.
WEB Aruba NV. laboratory perform the chemical analysis using the state of art analytical techniques. Twice a year the WEB laboratory send several watersamples to GEBETZ laboratory in Houston to perform a complete analysis of WEB proces- and potable-water.

Water are tested by World standard:
LAB used different techniques to test the waterquality.

1. HACH methods
2. GEBETZ methods
3. Dionex-Ion Chromatography
4. AAS Perkin Elmer-Trace Metals
5. Metrohm Autotitrator.

Hach and Gebetz are using the same procedures for the examination of the constituents.

Analytical Technique.
HACH and GEBETZ has developed analytical methods that are equivalent to USEPA-approved methods. The USEPA has developed some of these methods. Most of the procedures are adapted from the APHA(American Public Health Association) Standard Methods for the Examination of Water and Wastewater and are simplified where possible without sacrificing accuracy or reliability. These methods originate from several sources such as AWWA, WEF, ASTM, AOAC.

AWWA=American Water Works Association
WEF=Water Environment Federation
AOAC=Association of Official Analystical Chemists.
ASTM=American Society of Testing Materials.

IC
Ionchromatography is a technique for sequential determination of anions or cations using ion exchange and conductivity, amperometric or colorimetric. Water samples are tested without the need for prior concentration of or extensive sample treatment.

AAS
Atomic **A**bsorption **S**pectrometry(AAS) has been applied to the determination of metals in water without the need for piror concentration of or extensive sample treatment.

Both techniques have a great advange that they can determine any ions in very low concentration e.g. in ppb (=ug per liter)or ptt(parts per trillion)levels. For s**oft water** as we have on Aruba these type of analytical techniques are very important. With the conventional techniques is impossible to determine concentrations in ppb levels.

Figure 11: Picture of the Perkin Elmer AAS at the WEB Laboratory

LABWORKS (LIMS)

The LAB use for all there results a database which is a Laboratory Information Management System. It generates for all the departments involved a dialy, monthly and a yearly reports. Also it shows us a trend of all the parameters with there maximum and minimun contration in percentage. If a concentration of a parameter is out of target it shows you a RED mark that means that actions should be taken to bring this back within the maximum and minimum target.

LAB PERSONELL:

The LAB personell are well trained and qualify to perform all analysis according to the World Standard Methods.

11. Waterquality control in the distributionsystem:

The water is distributed to 7 storage tanks around the Island and one concrete storage reservoir situated in San Nicolas. Not all of them has the same capacity , but we have tanks with a capacity of 24000m3. The concrete storage has a capacity of 750 m^3.
In figure 9 shows all the control points for the determination of the chemical contituents and bacteriological counts of the drinkingwater. The distribution department takes once a month a sample on all these locations and deliver this at the WEB laboratory for quality control and the same sample locations are sampled two times a month by the Public Health Inspectors and these are delivered at the Public Health Laboratory for the determination of the total bacterial count. The storage tanks are also sampled once a month at the inlet and outlet of the tank by the Public Health Inspectors.

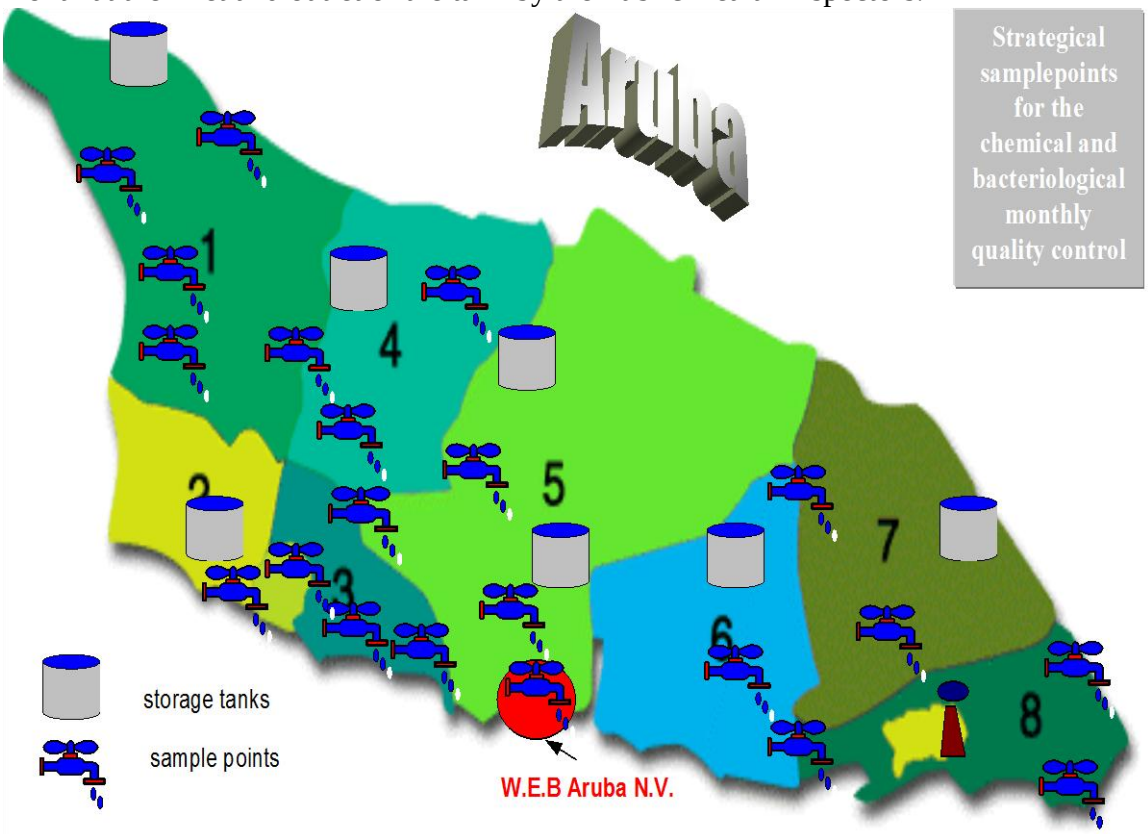


Figure 12:Storage tanks and samplepoints in the distributionsystem.

12. Some results of the chemical constituents of the waterquality

The following graphics shows the concentrations of the chemical constituents in our drinkingwater over the years.

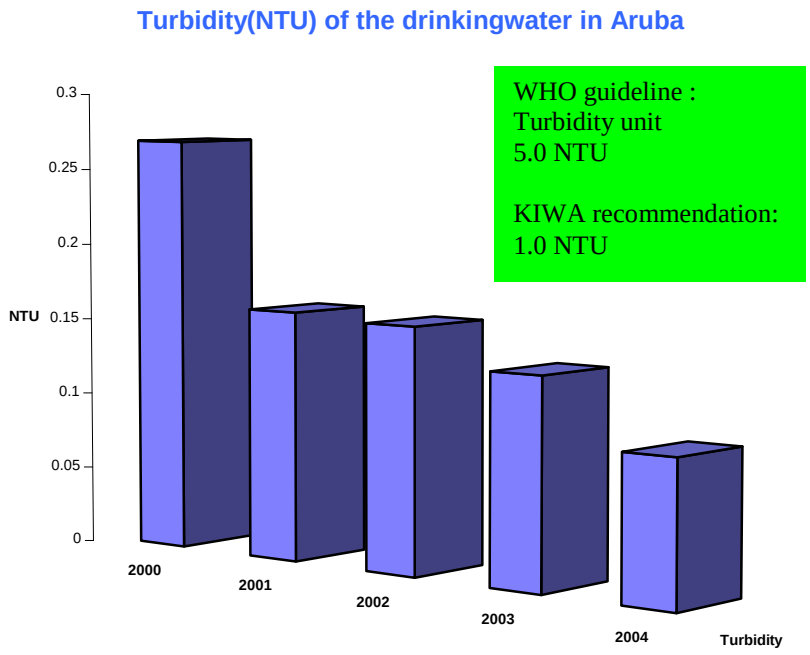


Figure 13: Graphic shows the Turbidity in the drinkingwater. Always below 1.0 NTU.

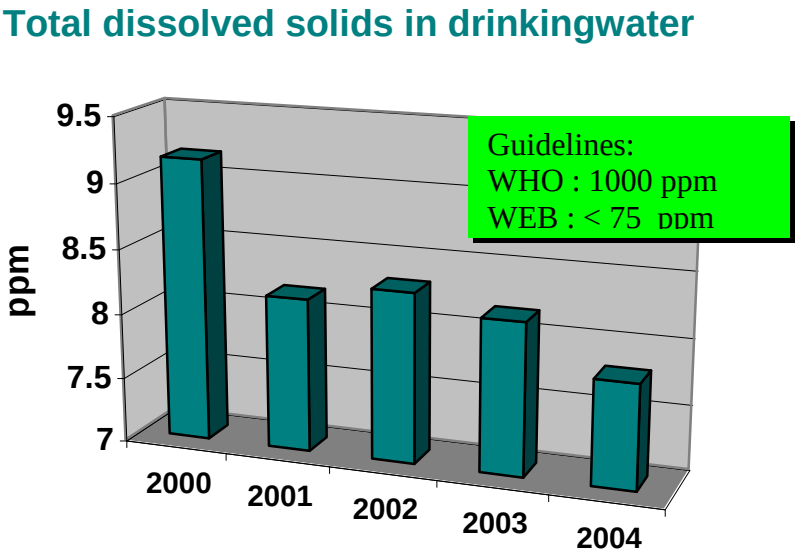


Figure 14: Graphic shows the total dissolved solids.

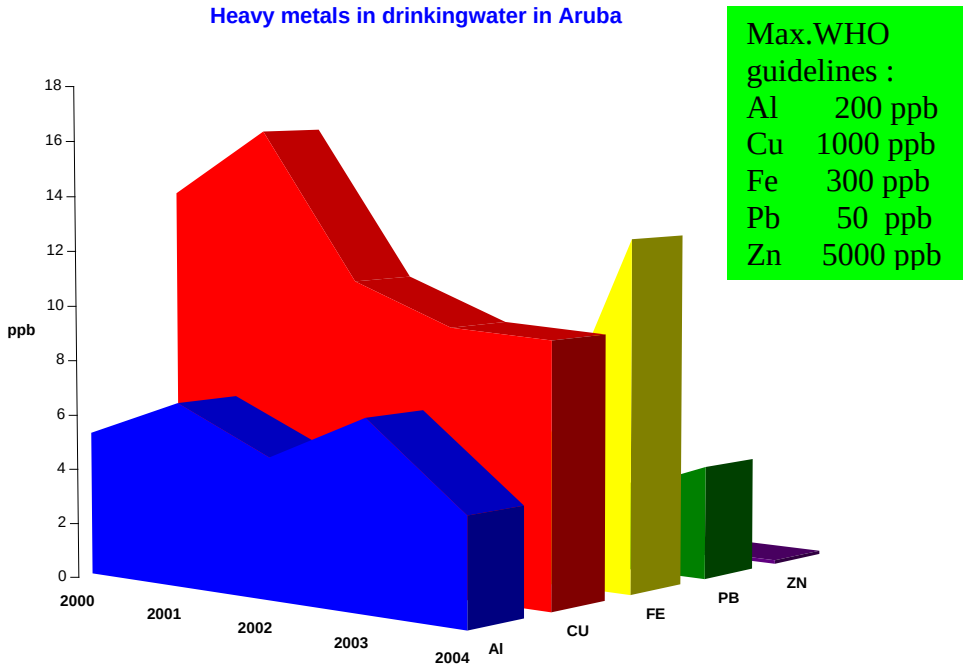


Figure 15: Graphic shows the fluctuacion of the metals in de distributionsystem.

The turbidity is always far below the KIWA recommendacion which is 1.0 NTU. Besides the fact that we produce high quality distillate water, the Water Production Department has a flushingprogram for the Antracite filter and the Water Distribution Department also apply a yearly flushingprogram at different location. These actions helps to keep the amount of suspended matter out of the water.

The total dissolved solids since 2000 never went up to a higher concentracion. It is always below 10 ppm. The fact that it shows the tendency to fluctuate between 7 en 8 ppm is due to the fact that the Water Production Department and the Maintenance Department have together a optimum yearly service program to avoid that the destillate conductivity of each plants increase innecessary.

11. Aruba's water quality for 2002 and 2002.

Waterquality in distribution system in 2002 and 2003			
		2002	2003
Chemical Constituents:			
Odor	----	satisfactory	idem
Colour	----	clear	idem
Temperature	C	23	23
Turbidity	NTU	0.16	0.13
pH		9.1	9.2
Conductivity	uS/cm	16.4	16.1
Total Dissolved Solids	ppm	8.2	8.1
Chloride	ppm as Cl	0.53	0.38
Hardness	ppm as CaCO3	6	6
Calcium	ppm as Ca	2	2
M.Alkalinity	ppm as CaCO3	8	8
Phosphate	ppm as PO4	0.96	0.94
Zinc	ppm as Zn	0.14	0.15
Tot.Iron	ppm as Fe	0.004	0.004
Tot.Copper	ppm as Cu	0.011	0.010
Tot.Aluminium	ppm as Al	0.005	0.007
Lead	ppm as Pb	0.003	0.003

Figure 16: Table of drinkingwater average in 2002 and 2003.

12. What to do when the consumer claim on the waterquality

If we have a waterquality complain, which occurs around 2 or 3 times per year, the laboratory together with the Water distribution department follow a procedure to verify the possible cause of contamination. This procedure has been made for controlling the chemical aspect and the microbiological aspect of the drinkingwater.

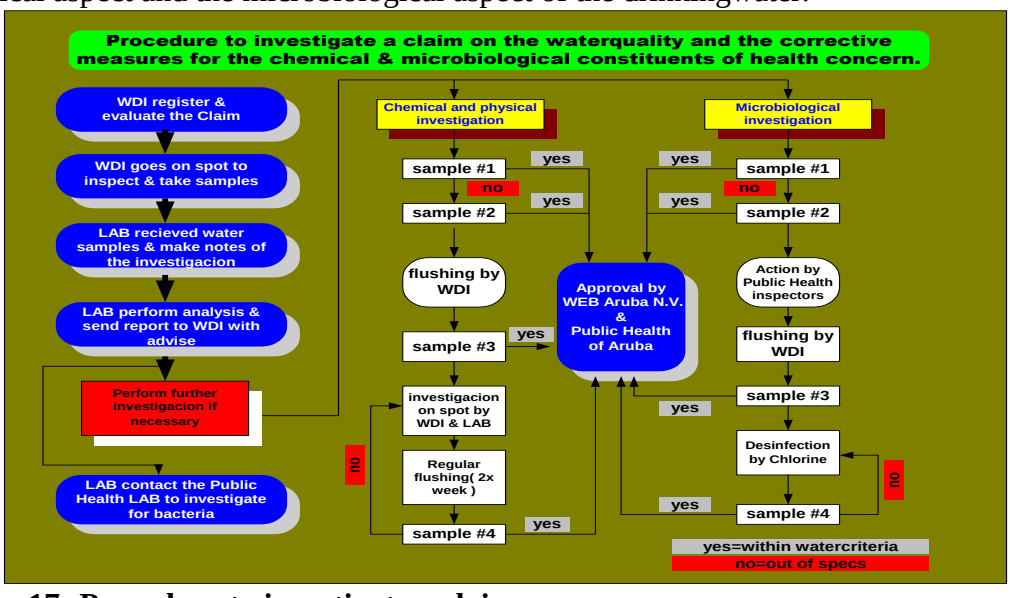


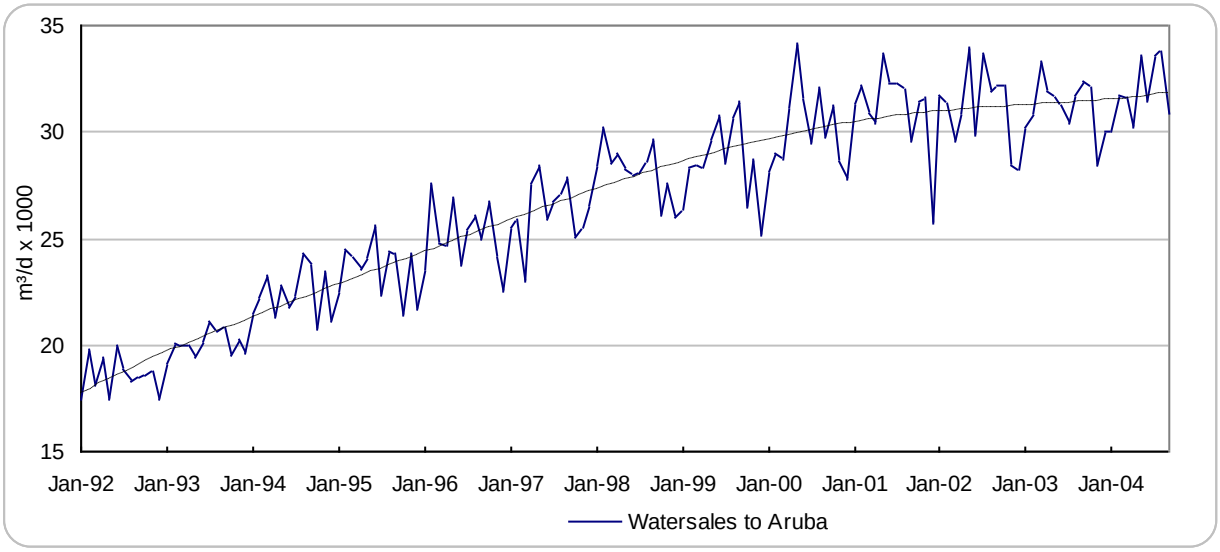
Figure 17: Procedure to investigate a claim.

The departments involved in this investigation are the Water Distribution Department, WEB Laboratory, Public Health Laboratory and the Public Health Inspectors.
Depends on the complain of the consumer we start the investigacion right away. The investigacion can go two direction one is to investigate the chemical aspect of the water or we can involved the Public Health Inspector to make the necessary investigacion.

13.How does we control the waterquality in distributionsystem:

1. Yearly Flushing program on all the dead ends.
2. Inspection of the Storage tanks.
3. Yearly monitoring program on the Chemical constituents and the Bacteriological count test.

Drinking water storage and distribution
Consumption



Future Projects

1 Fine tunning of the Analytical Techniques. To ensure a better results in all wateranalysis.
2. Ring-research which is organize and prepared by KIWA. This is a sample with a well-know concentrations and these samples are send to many Laboratories in the World. A final report will be send to all participants with the final score.
3. A quick scan of the analytical methods. This is a first step for the preparation for the ISO certification. LAB can be in the nearest future a star LAB.