# Water Plumbing System Components Analysis

## Typical Fresh Water Supply System

In Hong Kong, the fresh water supply systems of building make integrated of direct supply system and indirect system. Fresh water is supplied directly from the public mains to apartment at lower floors under hydraulic pressure in the mains. Fresh water can be also pumped to the rooftop water tank, which is then transmitted to each apartment through a network of sub-mains.

The fresh water supplied from the Water Treatment Works is comply to Guidelines for Drinking-water Quality recommended by the World Health Organization (WHO) which is continuously monitored by professionally qualified chemists under the Water Science Division of the Water Supplies Department (WSD) through a series of physical, chemical, bacteriological, biological and radiological examinations. Under the water supply system, the fresh water can be contaminated by the pipelines, valves and sink mixers. Therefore, the water quality at the end user and the components in the water plumbing system should be checked.

## Test Related to Fresh Water and the component of water supply system

In Quality Water Supply Scheme, there are seven parameters (pH, color, turbidity, conductivity, iron, coli, E. coli) and four heavy metal parameters (chromium, cadmium, nickel and lead) shown in Table 2. The residual free chlorine content and the heterotrophic plate count are additional to the Quality Water Supply Scheme for the new building shown in Table 3. The residual free chlorine content will be high due to not enough flushing after initial chlorine sterilization. The heterotrophic plate count show whether bacteria are absent in sample, thus the cleanness of water system achieve. Both parameters will not change in the long run, so those parameters will not be monitored in the Quality Water Supply Scheme. Assume that no rusting of component in new building system, therefore iron content is not included in new building.

For the components (pipe, fitting, brazing, solder, sink mixer) related to water plumbing system, the chemical compositions, leachable metals of those components should comply with the following specification (in Table 3).

**Table 2. The acceptance criteria set by Water Supplies Department in Quality Water Supply Scheme for Buildings – Fresh Water (Plus)**

| Water Test parameters | Acceptance Criteria |
|---|---|
| 1. pH value | 6.5 – 9.2 |
| 2. Color, True Color Units | ≤15 |
| 3. Turbidity, N.T.U. | ≤3.0 |
| 4. Electrical conductivity, μmhos/cm | ≤300 |
| 5. Iron content, mg/L | ≤0.3 |
| 6. E. coli count, cfu/100ml | 0 |
| 7. Total coliform count, cfu/100ml | 0 |
| 8. Cadmium Content (μg / L) | ≤ 3 |
| 9. Chromium Content (μg / L) | ≤ 50 |
| 10. Lead Content (μg / L) | ≤ 10 |
| 11. Nickel Content (μg / L) | ≤ 70 |

**Table 3. The acceptance criteria of water for new buildings**

| Water Test parameters | Acceptance Criteria |
|---|---|
| 1. Color, True Color Units | ≤20 |
| 2. pH value | 5.5 – 9.5 |
| 3. Turbidity, N.T.U. | ≤4.0 |
| 4. Residual free chlorine content, mgCl2/L | >0 and <1.5 |
| 5. Electrical conductivity, µmhos/cm | - |
| 6. E. coli count, cfu/100ml | 0 |
| 7. Total coliform count, cfu/100ml | 0 |
| 8. Heterotrophic plate count, cfu/ml | <600 |
| 9. Cadmium Content (µg / L) | ≤ 3 |
| 10. Chromium Content (µg / L) | ≤ 50 |
| 11. Lead Content (µg / L) | ≤ 10 |
| 12. Nickel Content (µg / L) | ≤ 70 |

**Table 4. Specification of components**

| Components | Standard | Specification |
|---|---|---|
| Copper pipe | BS EN 1057:1996<br>BS EN 13348:2008 | Grade Cu-DHP or CW 024A<br>Copper + Silver: 99.90 % min.<br>Phosphorus: 0.015 – 0.040% |
| Copper valve | BS EN 1982 Grade CC333G | Copper: balance<br>Tin: 0.1%<br>Zinc: 0.5%<br>Lead: 0.03%<br>Nickel: 4.0-5.5%<br>Iron: 4.0-5.5%<br>Silicon: 0.1%<br>Aluminium: 8.8-10.0%<br>Manganese: 3.0%<br>Magnesium: 0.05% |
| Sink mixer body | BS EN 1982 | No specific grade required |
| Soldering | BS EN 1254-1<br>BS EN ISO 9453:2014 | Commonly used: SnAg alloy with 95/5%<br>or SnCu alloy with Cu 0.4 - 3%<br>Lead < 0.07% |
| Brazing | BS EN 1254-1<br>BS EN ISO 17672:2010 | BS EN 1254-1<br>Commonly used:<br>AgCu with Ag 40 – 55%;<br>CuP 94/6%;<br>CuPAg 92/6/2%<br>Cadmium < 0.01%<br>Lead < 0.025%<br>Zinc + Cadmium < 0.05% |

| | | |
|---|---|---|
| Metallic components<br>(In-product test) | AS/NZS 4020-2005 Appendix H7.1.1 & H7.1.2<br>AS/NZS 4020-2005 Appendix I 6.3 (55 °C)<br>GB18145-2014 Annex B<br>(23°C 19 days for components) | Concentration of extracted metals:<br>Antimony < 3 µg/L<br>Arsenic < 7 µg/L<br>Barium < 700 µg/L<br>Cadmium < 2 µg/L<br>Chromium < 50 µg/L<br>Copper < 2000 µg/L<br>Lead < 10 µg/L<br>Mercury < 1 µg/L<br>Molybdenum <50 µg/L<br>Nickel < 20 µg/L<br>Selenium < 10 µg/L<br>Silver < 100 µg/L |
| Non-metallic components | BS 6920:2014 | Odour & Flavour of Water Test :<br>No odour and flavour in extracted water<br>Appearance of Water :<br>Colour < 5 mg/L Pt<br>Turbidity < 0.5 FNU<br>Growth of Aquatic Microorganisms :<br>MDOD ≤ 2.39 mg/L<br>The extraction of substances that may be of concern to public health:<br>Cell morphology Satisfactory and Monolayer confluence<br>Extraction of Metals:<br>Aluminium < 200 µg/L<br>Antimony < 5 µg/L<br>Arsenic < 10 µg/L<br>Boron < 1000 µg/L<br>Cadmium < 5 µg/L<br>Chromium < 50 µg/L<br>Iron < 200 µg/L<br>Lead <10 µg/L<br>Manganese <50 µg/L<br>Mercury <1 µg/L<br>Nickel <20 µg/L<br>Selenium < 10 µg/L |

## Testing Method used for the general parameter in water

For the pH value, color, turbidity and conductivity, the corresponding calibrated meters can detect those parameters.

## Testing Method used related to biological test

For microbiological test, the method of E. coli count test refers to "The Bacteriological Examination of Drinking Water Supplies 1982, DoE (1983) Membrane Filtration Procedure: Sections 7.8, 7.9.4.2 Bacterial Confirmation: Section 7.9.4.4 & in-situ urease test". The method of total coliform count test refers to "The Bacteriological Examination of Drinking Water Supplies 1982, DoE (1983) Membrane Filtration Procedure: Sections 7.8, 7.9.4.1 Bacterial Confirmation: Section 7.9.4.3". Both tests require at least 100 ml of samples. After sample receipt, 100ml of sample will be filtered using a 0.45 um pore size sterile filter membrane. Then the filter membrane will be placed in culturing medium and incubated at specific temperature. After incubation, the filter membrane will be examined for any microbiological growth.

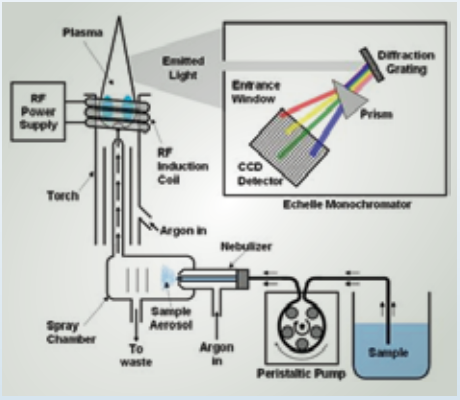
Growth of Aquatic Microorganisms is a test for the non-metallic components, water immersed sample with microorganism incubated at specific temperature. Water is exchanged every 3 or 4 days. The dissolved oxygen (DO) will be measured in week 5 to week 7. The DO difference of the sample and blank show whether the microorganism is alive since microorganism uptake the oxygen in the water.

The extraction of substances that may be of concern to public health is a cytotoxic test refers to BS6920:2014 part 2 Section 2.5.VERO cell line of African green monkey kidney cells (ATCC number CCL 81) will be cultured in growth medium with the sample extracted water. After incubation, microscopically examine the condition of the cells.

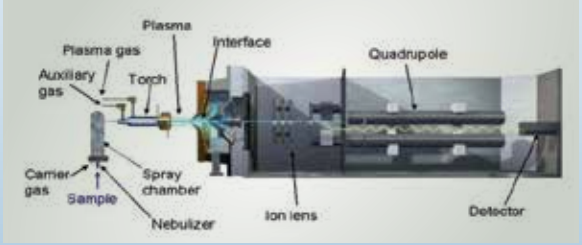
## Testing Method used for metal in water/ components

For the metal content in water and components, there is a long list in the specification. There are many elements with large range of detection level (% to µg/L), following instruments can be used for the heavy metal analysis.

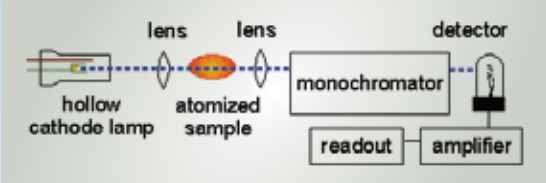
**Inductively coupled plasma optical emission spectrometry (ICP-OES)**, is an analytical technique used for the detection of trace metals. It is a type of emission spectroscopy that uses the inductively coupled plasma (flame temperature in a range from 6000 to 10000 K) to produce excited atoms and ions that emit electromagnetic radiation at wavelengths characteristic of a particular element. The intensity of this emission is indicative of the concentration of the element within the sample.



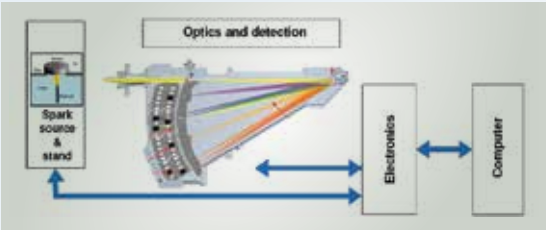

**Inductively coupled plasma mass spectrometry (ICP-MS)** is a type of mass spectrometry which is achieved by ionizing the sample with inductively coupled plasma (same as ICP-OES) and then using a mass spectrometer to separate and quantify those ions.



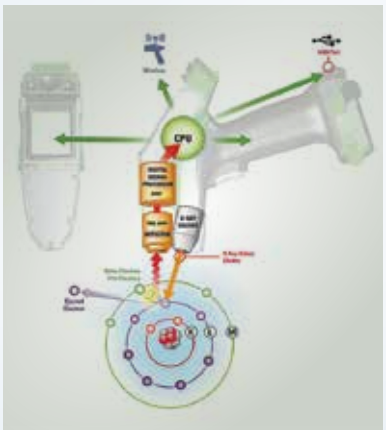
**Atomic absorption spectroscopy (AAS)** is a spectroanalytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. The electrons of the atoms in the atomizer (flames, principally the air-acetylene flame with a temperature of about 2300 °C and the nitrous oxide system -acetylene flame with a temperature of about 2700 °C) can be promoted to excited state for a short period of time by absorbing a defined quantity of energy. This amount of energy is specific to a particular electron transition in a particular element. The radiation flux without a sample and with a sample in the atomizer is measured using a detector, and the ratio between the two values (the absorbance) is converted to analyte concentration using the Beer-Lambert Law.




**Arc/Spark Optical Emission Spectroscopy (spark OES)** is optical emission spectroscopy which is achieved by vaporizing sample material with the testing probe by an arc spark discharge. The atoms and ions contained in the atomic vapor are excited into emission of radiation. The radiation emitted is passed to the spectrometer (arc spark OES) optics directly or via an optical fiber, where it is dispersed into its spectral components. From the range of wavelengths emitted by each element, the most suitable line for the application is measured by means of a CCD or PMT. The radiation intensity, which is proportional to the concentration of the element in the sample, is recalculated internally from a stored set of calibration curves and can be shown directly as percent concentration




**X-ray fluorescence (XRF)** is a non-destructive analytical technique used to determine the elemental composition of materials. A solid or a liquid sample is irradiated with high energy X-rays from a controlled X-ray tube. Each of the elements present in a sample produces a set of characteristic fluorescent X-rays ("a fingerprint") that is unique for that specific element, which is qualitative and quantitative analysis of material composition.



The running cost, turnover time, matching of the detection limit and dynamics range to criteria in the specification are the major factors for instrument and method selection. The dynamics range is shown in Fig 5.The comparison between the instruments is shown in Table6.

Fig 5. The detection limit and working range of the instrument

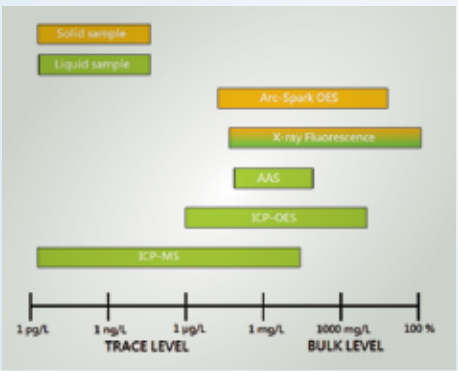


**Table 6. Comparison between the ICP-MS, ICP-OES, AAS, Spark-OES and XRF**

| | Pro | Cons | Application |
|---|---|---|---|
| ICP-MS<br>ICP-OES<br>AAS | Most accurate method with low detection limit (ICP-MS > ICP-OES > AAS)<br>Smallest interference<br>Can be calibrated to required range | Destructive test – digest sample in acid solution<br>Complicate sample preparation<br>Long turnaround time<br>High testing cost | Fresh Water (ICP-MS)<br>Copper pipe<br>Copper casting<br>Copper fitting<br>Solder rod<br>Thin solder metal layer on copper pipe |
| Arc Spark-OES | Little sample pretreatment<br>Relatively fast<br>Reasonable testing cost<br>More accurate than XRF with less interference | Destructive test – cut into piece with certain cross section surface<br>Can be calibrated (limited by available CRM)<br>Cannot test thin layer sample on base metal<br>Cannot test small sample | Copper pipe<br>Copper casting*<br>Copper fitting*<br>Solder rod*<br><br>*Need certain cross section surface |
| XRF | Non destructive<br>Minimal sample pretreatment<br>Fast<br>On-site test possible<br>Fit for thin surface layer analysis<br>Low testing cost | Significant interference in different matrix<br>Cannot be adjusted by CRM<br>Inaccurate for low conc. element<br>Software induced error of content calculation | Copper pipe<br>Copper casting<br>Copper fitting<br>Solder rod<br>Thin solder metal layer on copper pipe |

References

http://www.buildingmgt.gov.hk/en/daily_operation_of_building_management/6_3_15_1.htm

https://en.wikipedia.org/wiki/Atomic_absorption_spectroscopy

https://en.wikipedia.org/wiki/Inductively_coupled_plasma_mass_spectrometry

https://en.wikipedia.org/wiki/Inductively_coupled_plasma_atomic_emission_spectroscopy

http://www.spectrolabsystems.net/products/analytical-instruments/arcspark-optical-emission-spectroscopy-oes/index.html

http://www.spectro.com/products/optical-emission-spectroscopy/arc-spark-stationary-oes-working-principle

http://sites.cord.edu/chem-330-lab-manual/experiments/icp-aes

https://web.nmsu.edu/~kburke/Instrumentation/AAS.html

http://www.shimadzu.com/an/elemental/oes/oes.html

https://www.thermofisher.com/hk/en/home/industrial/spectroscopy-elemental-isotope-analysis/spectroscopy-elemental-isotope-analysis-learning-center/elemental-analysis-information/xrf-technology.html

http://eecelabs.seas.wustl.edu/ICP-MS.aspx

New Products and Applications in XRF, XRD, OES and Automation, D. Bonvin, Thermo Fisher Scie