# EXPERT REPORT

PREPARED BY

PROFESSOR JOHN FAWELL

Expert Witness appointed by the Commission of Inquiry into Excess Lead Found in Drinking Water

4 February 2016

**Professor John Fawell**

Biologist/Toxicologist

(Consultant on drinking water and environment)

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| Specialist Field | : | Assessment and management of risks from drinking water contaminants. |
| Appointed on behalf of | : | The Commission of Inquiry into Excess Lead Found in Drinking Water (the "**Commission**") |
| Prepared for | : | The Commission |
| On instructions of | : | Messrs. Lo & Lo, Solicitors for the Commission ("**Lo & Lo**") |
| Subject matter / Scope of engagement: | : | To assist the Commission in discharging its duties under the Terms of Reference and by acting as an expert witness in the inquiry hearings |
| Documents reviewed | : | Selected documents from the Hearing Bundles |
| Date of Inspection of some of the Affected Estates (*name of the estates*) | : | **10 November 2015**<br>Kwai Luen Estate Phase 1 (Luen Yat House)<br>Kai Ching Estate Phase 2 (Hong Ching House)<br>Tak Long Estate (Tak Long House) |
| Other Site Visits | : | **9 November 2015**<br>Shatin Water Treatment Works<br>Government Laboratory<br><br>**12 November 2015**<br>Ngau Tam Water Treatment Works<br>Hong Kong University of Science and Technology (Materials Characterization and Preparation Facility and Health, Safety & Environment Laboratory) |

**Instructions**

I have been instructed to give my opinion on the matters under the Terms of Reference of the Commission.

In providing my opinion, I have also been instructed to consider the following areas and undertake the following tasks:

(a) review and verify the findings of the Interim and Final Reports of the Task Force led by the Water Supplies Department (WSD) in respect of the Waterworks system and the Inside Service system in public rental housing developments, including the overall methodology adopted in the investigation;

(b) identify and explain the international standards (particularly those laid down by the World Health Organisation (WHO)) in respect of the following matters for the purpose of ensuring safety and quality of drinking water in Hong Kong :

- (i) hazards and hazardous events;
- (ii) risk assessment, prioritization and management;
- (iii) control measures;
- (iv) construction and maintenance;
- (v) inspection and monitoring;
- (vi) management procedures;
- (vii) rectification;
- (viii) the supply and use of plumbing materials; and
- (ix) the procedures and protocols regarding the use and installation of plumbing materials;

(c) in the context of the international standards in (b) –

- (i) review and evaluate the adequacy of the existing Water Safety Plans of the WSD;
- (ii) review and evaluate the existing regulatory and monitoring regimes (both prior and subsequent to the excess lead in drinking water incidents as a result of which new measures have been put in place by public authorities) on quality of drinking water :
  - (1) at the pre-construction stage;
  - (2) at the construction stage;

(3) at the completion of construction (before the WSD issues the certificate for water supply connection); and

(4) at the maintenance stage;

(iii) opine on whether any further metal(s), chemical(s) and/or microorganism(s) should be included as parameter(s) in addition to those set out in the WSD Circular Letter No. 1/2015 for testing of water samples, and if so, the thresholds, benchmarks and/or the acceptance criteria to be set for them; and

(iv) the effectiveness of the recommendations made by the Review Committee;

(d) opine on how the inadequacies (if any) identified for the matters above may be rectified or improved and to make recommendations with regard to the safety of drinking water in Hong Kong; and

(e) state, provide advice and recommendations on other areas of concern (if any).

## Introduction

1. I Professor John K Fawell, independent consultant on drinking water and environment of Bourne End in the county of Buckinghamshire in the United Kingdom, have been appointed as one of the Commission's experts to assist the Commission in determining the matters under the Terms of Reference.

2. Lead in drinking water arises from lead leached from lead pipes, lead solder and other lead containing fittings, including brass and gun metal and also unplasticised PVC (uPVC) pipe not manufactured to current standards, i.e. containing high concentrations of lead stabilizer. It is not normally found due to contamination of source water or in water up to the boundary of buildings unless there are lead service connections or lead stabilized PVC pipe (service connections are the pipes that deliver water from the water main to the building). Leaching can be exacerbated by galvanic corrosion as a result of other metals being joined to lead and will be dependent on factors such as hardness and pH. The level of leaching can be very variable from property to property, depending on the configuration of plumbing and also on whether there are lead service connections. The concentration of lead in water is also a function of the surface area of the lead source in relation to the volume of water, so a small surface area in relation to a large volume will result in lower concentrations than a large surface area of a similar source in a similar volume. The concentration at any tap will also vary according to the temperature and the period during which the water has been in contact with the lead source. Typically first draw water will have a much higher concentration of lead but this may not reflect the concentrations of lead in water ingested in normal use. Equally, flushed samples would be expected to underestimate the concentration of lead in water ingested in normal use.

3. There are no internationally agreed sampling protocols that can truly reflect average consumption of lead from drinking water and which are reasonably practical to apply. The most effective approach is to identify whether lead is present in the pipework leading to the tap used for drinking water and cooking. This is achieved by taking samples of sufficient magnitude to provide a sample of the water in the internal plumbing that is likely to have been in contact with any lead in the system for a sufficient period of time to allow measurable

concentrations of lead to be reached. A positive result, i.e. a lead concentration close to or in excess of the WHO provisional guideline value of 10 µg/litre, or another chosen trigger value, e.g. 5 µg/litre, would then trigger an investigation as to the source of the lead, e.g. leaded solder, and the necessary remedial steps to reduce exposure. (See preliminary joint expert report 12 November 2015 **[V1/1/1-44]**). Samples taken from the freshwater roof tanks of three public housing blocks show no lead, which suggests that there are no lead service connections or lead stabilized uPVC pipes **[A1/19/658, Section 2.2.2 ]**.

4. The World Health Organization develops Guidelines for Drinking Water Quality, which are revised on a regular basis. The current edition is the fourth and was published in 2011 **[C2/18/1244+]**. The Guidelines outline a Framework for Safe Drinking Water, which considers the overall management of water supplies and includes the concept of Water Safety Plans which provide a proactive means of preventing and managing hazards and risks from the catchment to the point at which consumers receive their drinking water, frequently referred to as the source to tap approach **[C2/18/1277]**. The Guidelines are regarded as the scientific point of departure for the development of National Standards which should take into account the specific circumstances of the country concerned. The guideline values for chemical contaminants provide a basis for assessing the risks to health from drinking water but WHO indicates that local circumstances should always be taken into account in setting national standards and recommend that individual guideline values should be considered in the appropriate context. In this respect the statement that "A guideline value (*for a chemical constituent*) **normally** (my emphasis) represents the concentration of constituent that does not result in any significant risk to health over a lifetime of consumption"**[C2/18/1258]** should be treated with caution because it does not mean that contamination can be allowed to increase to the guideline value. In addition, some guideline values for chemicals are designated provisional and may be set at a higher value than would be the case for a strictly health-based value because of practical considerations, e.g. lead. It is appropriate to try and achieve as low a concentration of a contaminant as possible within the constraints of cost and practicality.

5. Lead has been included in all editions of the Guidelines. In the second edition, published in 1993 **[C21/175-2/18941]**, a guideline value of 10 µg/litre was

proposed for lead based on a provisional tolerable weekly intake (PTWI) developed by the WHO/FAO Joint Expert Committee on Food Additives and contaminants (JECFA), this guideline value was retained in the third edition in 2004 and 2008 **[A3/38/2101-2103]**. JECFA re-evaluated lead in 2011 and withdrew the PTWI, stating that it was not possible to establish a new PTWI that would be health protective because the dose-response analyses did not provide any indication of a threshold. The fourth edition was published in 2011 **[C2/18/1244+]** and although the guideline value of 10 µg/litre was retained **[C2/18/1246-1447]**, this was because of practicality in dealing with older systems with existing lead pipes, fittings and solder and cannot be considered in the same light as in the previous editions of the Guidelines. Lead solder was identified as a source of lead in drinking water in the second, third and fourth editions of the Guidelines **[C21/175-2/18940, A3/38/2101, C2/18/1246]**.

6. In spite of the fact that leaded solder is known to be a significant source of lead in drinking water installations in buildings and that lead solder is banned from use for drinking water systems in many countries, incidents in which lead solder has been used in new buildings continue to occur. In 1997 a new housing estate in Scotland was found to have been plumbed with copper piping installed with lead solder **[A1/14/198+ and A1/15/244+]** and in 2001 new properties in Wales were also identified has having lead solder **[A1/13/190+]**. New guidance to health professionals, with regard to lead in drinking water was issued by Health Protection Scotland in 2012, which included guidance on investigations and water sampling at the tap to identify if lead is present **[A1/12/148+]**.

(a) **Review and verify the findings of the Interim and Final Reports of the Task Force led by the Water Supplies Department (WSD) in respect of the Waterworks system and the Inside Service system in public rental housing developments, including the overall methodology adopted in the investigation.**

**Background of the Incident**

7. It is my understanding that between April and June 2015, samples of water taken from taps in some public rental housing in Hong Kong (Kai Ching Estate, Kowloon) were shown to have lead levels above the World Health Organization provisional guideline value of 10 µg/litre (0.01 mg/litre)**[A1/3/24 LegCo Paper, 21.07.2015 §2]**. This finding was in spite of the fact that, in drinking water systems in buildings in Hong Kong, there are no recently installed lead pipes, lead in the form of lead solder is not permitted and the level of lead in metal alloy fittings is restricted

**[B15.1/337/37521-37522, §§30-32]**. Subsequently further samples showed that some met the WHO provisional guideline value and others did not. As a consequence the Water Supplies Department (WSD) established a Task Force with the following terms of reference:

(a) To carry out investigation to ascertain the causes of the recent incidents leading to the presence of lead in water drawn by households;

(b) To recommend measures to prevent recurrence of similar incidents in future; and

(c) To follow up on a recent case of Legionnaires' Disease found at Kai Ching Estate. **[C5/69/4116]**.

This last issue is dealt with separately later in my report.

**Final Report of the Task Force led by the Water Supplies Department (WSD)**

8. I have studied the final report prepared by the Task Force set up to investigate the source of elevated lead concentrations in drinking water in some housing units in Hong Kong **[A1/19/650+]**.

9. As a consequence I made further enquiries to ascertain the sampling protocol that had been used to take water samples at the tap to identify the proportion of affected properties. It was confirmed that where samples had been taken at the kitchen tap inside apartments the water had been flushed for 2 to 5 minutes before a sample was taken for analysis. The consequences of this approach for identifying properties in which lead solder has been used are considered in more detail below.

10. In order to answer this and other questions regarding the quality of drinking water in Hong Kong and the procedures in place to assure drinking water quality, I made a visit to Hong Kong from the 9th to the 13th November 2015. During this visit I met with staff from the WSD, the WSD led Task Force on Lead in Drinking Water, the Housing Department and the Government Laboratory. I also made two visits to Water Treatment Works in Hong Kong, WSD Laboratories and

Public Housing Developments at which investigations had been carried out. I was able to see the samples of pipework and fittings, including soldered joints and to ascertain the quality assurance procedures in place to ensure that the analysis for lead and other metals was of an appropriate standard. At all points I was afforded access to all the information that I requested and all questions were answered openly.

11. I have read statements and depositions regarding the detection of elevated concentrations of lead in drinking water in some public housing estates in Hong Kong and also on mechanisms in place in Hong Kong to ensure the safety and quality of fresh water (drinking water). These have formed the basis for my conclusions regarding the current situation in Hong Kong.

**My Opinion Regarding the Investigations and Conclusions of the Task Force**

12. The WSD led Task Force has carried out a thorough investigation of the affected systems using appropriate methodology. They have taken a sound systematic approach using techniques that have proved of value in similar investigations in other parts of the world such as in Scotland **[A1/14/198+ and 15/244+]**. The source of lead is confirmed as being primarily within the final stages of the distribution system inside the housing blocks, i.e. after the water meter.

13. The conclusions of the Task Force that lead solder used for soldering copper pipe joints is the major cause of the lead concentrations that were shown to exceed the WHO guideline value is supported by the evidence presented and the results from the investigations carried out by and on behalf of the Task Force.

14. Detailed examination has revealed that in some places solder containing very high levels of lead (basically lead solder) has been used in installing copper pipe and fittings **[A1/19/667, section 2.5.10]**. This lead solder has resulted in the deposition of lead carbonates and hydroxides downstream of soldered joints on the inside of the pipes **[A1/19/665-666, section 2.5.5]**.

15. Static tests have shown significant leaching of lead from these joints. In view of lead concentrations greater than 10 μg/litre observed in some flushed tap samples, I would conclude that there is the additional possibility of particles of lead carbonates/hydroxides appearing in water samples taken to assess lead

concentrations at the tap. A number of copper alloy fittings were also shown by elemental analysis to contain more lead than would be allowed if they were to meet the requirements of the relevant British Standard **[A1/19/691, section 3.3.2 and A1/19/779-781, Annex 3.2]**. However, all copper alloy fittings do contain some lead and leach some lead into water, although at very much lower rates than lead solder **[A1/19/ 664, 666, 668-671, section 2]**.

16. Isotope analysis of the lead in the water does, however, confirm that lead solder is the main source of the lead in the water where elevated concentrations of lead have been found **[A/19/674-677, section 2.9]**.

17. The potential for cumulative leaching of lead from copper alloy fittings, valves, water meters and taps, appears to be small in relation to the leaded solder joints, although there are copper alloy fittings containing a greater proportion of lead in the alloy than permitted by the relevant British Standard. A number of the copper alloy fittings are associated with the down pipe and here the surface area available for leaching in relation to the volume of water is small. In addition the down pipe is unlikely to have extended periods of zero flow. This means the concentration of lead in the water will be small. The contribution of copper alloy fittings will primarily come from the meter to the tap and the volume of water is small enough to allow it to be flushed quite quickly and the contribution to lead concentrations will be much lower than lead solder joints. In the absence of lead solder the concentrations will be much lower, although lead may be detected at low concentrations. The modelling carried out by the Task Force supports the conclusion that, although these components do contribute to the lead in water, they on their own are very unlikely to result in concentrations in excess of the WHO provisional guideline value [**A/19/687-689, Section 3.1, § 3.1.7**].

18. In paragraph 3.2 of the Task Force Report **[A1/19/689-690]**, the Task Force considered that the design of the inside service and the specifications of the pipes and fittings in the other 9 affected developments were similar to Kai Ching and Kwai Luen Estates and suggest that all findings in the report should be applicable to all the 11 affected developments. The design, construction of and the contractors used in building all of the 11 estates were similar and there is no clear evidence to suggest that the level of supervision of the plumbing installations was greater or less than with Kai Ching and Kwai Luen,

Consequently, it is reasonable to make a worst case assumption that the findings of the report would apply to all of the developments and to assume that lead solder was also used in those developments. While sampling and examination of the additional estates would have taken more time and delayed the publication of the report and the process of identifying suitable remedial actions, the assumption would need to be confirmed by further testing for lead solder in joints or by suitable water sampling.

19. Samples taken from water supplies in a number of housing blocks might be considered to show that the extent of contamination giving rise to lead concentrations above the WHO provisional guideline value is limited **[A2/915+]** but these findings must be treated with caution because the approach used for taking samples may underestimate the presence of lead.

**Sampling Protocol of the WSD and the WSD Task Force**

**(a) WSD**

20. According to information provided by the WSD [WSD Sampling Manual 2014 **(C2/22/1635+)**, and in particular **Section 7** thereof **(C2/22/1666-1669)**, Water Sampling Procedure with reference to ISO5667 Part 5 **(C5/45/3735+)** and Fourth Witness Statement of Chan Kin Man **(C19.6/145/14517+)**], the practice of taking samples for water quality testing in Hong Kong has been based on using samples in which the system is flushed i.e. the pipes were flushed for 2-5 minutes or longer if necessary at a uniform rate before samples were collected **[C19.6/145/14518** and **C5/45/3735]**. Where the sample is to be taken from a consumer's tap, the water actually sampled is likely to represent the water as supplied from the public water supply distribution system, or at least the water in the roof storage tank and down pipe, and does not fully reflect the water in the internal distribution system that has been in contact with the associated plumbing after the meter for an extended period of time. While this is appropriate for examining the water quality parameters that will not be affected by the internal distribution system, it is not suitable to ascertain the concentration of parameters that will change as a result of contact with or which arise wholly from the internal distribution system. These last parameters include, lead, copper, nickel and sometimes cadmium and zinc where galvanised pipes have been used, as was the case in Hong Kong in the past and possibly antimony. While it is quite possible that there is only limited contamination with lead in the public housing

stock, the data cannot be used to conclude that under normal conditions of use there is no possibility of the WHO guideline value being exceeded in any sample unless it is known and verified that plumbing standards were met during construction or alteration, i.e. no leaded solder was used and fittings all meet the requirements for low lead. In this case there is no need to take water samples for lead because no source of excessive lead will be present in the system. Equally, because lead concentrations can vary widely over a 24 hour period, compliance with the guideline value cannot be assured with single samples, unless these reflect the worst case.

21. It is not possible to identify a threshold for the adverse effects of lead so there should ideally be no measurable lead in drinking water. WHO recognises that this is not practical because there will be many existing systems with lead service connections or lead pipe from a time when the adverse effects of lead were not fully recognised. It is not possible to get to average concentrations well below the provisional guideline value in such systems just by treating the water to reduce plumbosolvency (the tendency of the water to dissolve lead) by such means as dosing orthophosphate. It is not intended that meeting the guideline value should be an excuse to install new lead, which best practice dictates should not happen, hence the strictures on lead solder and copper alloy fittings in Hong Kong. Meeting the guideline value is not a means of protecting health, it is a means of reducing exposure while further actions can be taken to remove lead from the systems and to achieve as low a level of lead exposure from drinking water as possible. The situation in the new Hong Kong public housing developments is different to other older systems since the use of lead solder and "high lead" copper alloy fittings is not allowed and there should be no lead in the system except traces that arise from copper alloy fittings that meet the requirements for low lead. The object of sampling water at consumers' taps in this case should be to identify where lead solder may have been used.

22. If the lead concentration in the water after an extended period of contact is less than 10 μg/litre then it is reasonable to assume that the concentration will always be less than 10 μg/litre and there is unlikely to be significant lead in the system. The study carried out by Professor Lee on behalf of the Commission of Inquiry was designed to determine how the time the water flows will impact on the concentrations of lead in a range of domestic systems in the public housing

developments and to inform the development of a suitable sampling protocol. It also provides supporting data regarding the presence of lead in significant concentrations in the public housing developments.

23. In the interim report issued by myself and Professor Lee we used the term fully flushed in the context of lead in domestic plumbing between the meter and the tap indicating that the system is likely to be flushed after 5 minutes and the water sampled would be from the down-pipe from the fresh water storage tank with a minimal contact time with the plumbing.

24. Mr Chan in his fourth statement **[C/19.6/14517-14529]** states that samples taken after a period of stagnation cannot be considered representative of the average concentration of lead at the tap to which the consumer is exposed on a routine basis. This is correct but neither can flushed samples. This is dealt with above in more detail in paragraphs 2 and 3. Mr Chan also makes a statement in paragraph 11 of his fourth statement regarding compliance with the WHO guidelines, or rather the guideline values. This is a misunderstanding of the guideline value for lead and I have dealt with this in more detail in paragraph **21** of this Report.

25. Under the circumstances described above, the most probable cause of the lead exceeding 10 µg/litre in flushed samples is particles of lead compounds mobilised by the flushing process from the deposits downstream of the joints containing lead solder.

**(b) WSD Task Force**

26. The investigations of the Task Force into the effects of stagnation and flushing of water in pipework on lead concentrations are helpful in making a preliminary assessment of the impact of the intermittent use of water by consumers on the average exposure to lead in water over time, i.e. the effect of the normal use of water from the drinking water tap on lead concentrations. The Task Force commissioned studies showed that the concentration of lead in affected systems increased significantly with the period of stagnation in the pipes but that the concentration fell very quickly with a relatively short flushing time due to the short lengths of pipe involved **[A1/19/685-686, section 2.12 and A1/19/685-773, Annex 2.8]**. While much of the water consumed would be expected to have contained low lead concentrations, concentrations in the initial quantities of

water drawn after standing for extended periods would be expected to contain much higher concentrations of lead as would water drawn from the hot water supply **[C19.6/140/14205+]**. The quantity of lead ingested would depend on individual habits. This is demonstrated by the evidence given by four residents who described their patterns of use of water for drinking and cooking and who fall into two categories, those who flush the water for a period in the morning and those who use first draw water **[AC1/7-10/46-76]**. However, this evidence does not provide sufficient information to estimate the potential for exposure to lead contaminated water through the day following varying periods of standing time.

27. The study by Professor Lee has provided significant data that assists both in assessing the extent of lead contamination and the short to medium term means of ameliorating the problem. This is the most comprehensive study carried out to date and allows a number of important conclusions to be drawn. Firstly, the extent of contamination is significantly greater and more widespread than was indicated by the WSD/HD data, primarily because the sampling method was designed to detect the presence of lead in the system. Secondly, a relatively short flushing period will generally reduce the lead in the drinking water drawn from the tap to a low level, although the necessary flushing period required does vary. It would be helpful to make a more detailed study of the patterns of stagnation and use throughout the day in order to formulate the best advice to consumers as to how to manage lead concentrations in their domestic systems. Thirdly, the study provides some evidence that there may be passivation (reaction of lead at the surface forming coatings of lead carbonates, hydroxides and phosphates) of the exposed lead surfaces over time in the older systems resulting in a lower level of leaching. However, changes in the water system can destabilize these layers and this has caused problems elsewhere, e.g. USA. Fourthly, the study shows that the problem is complex and that care will be required in designing a sampling protocol that is suitable for verifying that lead has not been used in new developments. This is important for the quality assurance procedures to be adopted in the future.

**Task Force Recommendations**

28. I am generally in agreement with the recommendations of the Task Force **[A1/19/702-704, Chapter 5]**.

29. In the case of recommendation a (ii) **[A1/19/703]**, I would stipulate that samples for heavy metals should not be based on flushed samples but that a suitable sampling regime should be adopted that will reflect a reasonable worst case for the leaching of heavy metals. In addition I would recommend adding copper, antimony and zinc to the list of metals for a limited period until sufficient data are collected to show exactly which metals are leached from the system. Copper can leach from copper piping used in internal plumbing systems and is known to cause acute gastric irritation when concentrations exceed about 2 mg/litre, which is the WHO guideline value. Copper is usually only a problem in new copper plumbing systems after extended periods of standing although other circumstances can give rise to high copper concentrations. Antimony is seen in samples at the tap in Europe and although concentrations are relatively low (5 µg/litre or less) it would be prudent to collect some information on concentrations at the tap in Hong Kong. Zinc may be released from galvanised pipes and although it is not a concern for health it can cause problems with acceptability at concentrations above about 3 mg/litre. If antimony, zinc, cadmium and possibly chromium are subsequently shown not to be an issue in Hong Kong, then they could be dropped from the monitoring suite of parameters influenced by leaching from distribution systems. However, it would be prudent to maintain the full suite for initial samples taken from new buildings to ensure there are no unexpected sources.

**(b) identify and explain the international standards (particularly those laid down by the World Health Organisation (WHO)) in respect of the following matters for the purpose of ensuring safety and quality of drinking water in Hong Kong :**

- **(i) hazards and hazardous events;**
- **(ii) risk assessment, prioritization and management;**
- **(iii) control measures;**
- **(iv) construction and maintenance;**
- **(v) inspection and monitoring;**
- **(vi) management procedures;**
- **(vii) rectification;**
- **(viii) the supply and use of plumbing materials; and**
- **(ix) the procedures and protocols regarding the use and installation of plumbing materials**

**The WHO Provisional Guideline Value for Lead**

30. The WHO guideline value of 10 µg/litre was originally based on a provisional tolerable weekly intake (PTWI) of 25µg of lead per kilogram of body weight in

infants and children on the basis that lead is a cumulative poison and there should be no accumulation of body burden of lead. The guideline value was derived by assuming a 5 kg formula-fed infant, considered to be the most sensitive sub-group of the population, drinking 0.75 litres per day and assuming 50% of the PTWI came from water. The PTWI was developed by the WHO/FAO Joint Committee on Food additives and Contaminants (JECFA) in 1986. This guideline value was adopted in the second edition of the Guidelines in 1993 **[C21/175-2/18941]** but was designated as provisional in the fourth edition in 2011 **[C2/18/1244+, see 1258 and 1446]** on the basis of the JECFA re-evaluation of the PTWI in 2011. In that re-evaluation JECFA concluded that there is currently no measurable threshold for effects on childhood IQ and learning or on systolic blood pressure. The previously established PTWI was withdrawn and it was not considered possible to establish a new PTWI that would be considered protective of health. The reason for WHO retaining the existing guideline value was that it is extremely difficult to achieve a lower concentration in systems by central conditioning, such as phosphate dosing **[A1/17/422-424]**. This consideration is based on systems with a significant existing amount of lead but it presumes that no lead will be introduced into new systems that should be effectively lead-free.

**Legionella**

31. *Legionella* are heterotrophic bacteria that are found in a wide range of aquatic environments. They are all considered to be potential pathogens for man. *Legionella pneumophila* is the cause of Legionellosis, a severe form of pneumonia, and Pontiac fever, which is milder and usually self limiting with flu-like symptoms. The route of transmission is almost invariably by inhalation of infected droplets of water that carry organisms. *Legionella* are unusual for water borne pathogens in the route of infection and the fact that they grow readily in biofilms and sediments at temperatures between about 25° C and 50° C. They can and do infect water systems in buildings, mostly associated with biofilms and frequently in association with free living amoebae, where these are present.

32. The best approach to prevention is considered to be management of water in buildings and in this case water in the hot and possibly cold water distribution systems in buildings. Disinfection and temperature control are normally the way this is managed but it should be noted that monochloramine is a more effective

disinfectant in this regard than free chlorine, probably because it is more effective at penetrating biofilms.

33. There is a clear potential for the growth of *Legionella sp* in apartment blocks in Hong Kong and this requires a suitable building management plan to be formulated and properly executed. Such a plan should also include advice to tenants regarding regularly cleaning items, such as shower heads, that can generate aerosols and in which biofilms can thrive. The recommendations from the WA that tanks in housing blocks should be cleaned every 3 months **[C20.1/167-1/15545]** is to be welcomed but it would be best to develop a comprehensive strategy for managing the internal fresh water supply in large buildings to prevent *Legionella*.

**Description of the WHO Guidelines for Drinking Water Quality as the International Norm**

34. The World Health Organization develops Guidelines for Drinking Water Quality which are revised on a regular basis. The current edition is the fourth and was published in 2011 **[C2/18/1244+]**. The Guidelines for Drinking Water Quality were first published in 1984 and superseded the International Standards for Drinking Water. The change from Standards to Guidelines was in recognition that the WHO Guidelines had no legal force and there was a need for member states to develop their own legally enforceable drinking water standards taking into account local requirements and local circumstances. WHO do not encourage member states to simply adopt the guideline values as standards without due consideration of the local situation.

35. The Guidelines have evolved over time and in 2004 introduced the concept of the Guidelines as a framework for safe drinking water. It was recognised that assuring safe drinking water requires more than simply measuring microbial indicators and standards for individual chemicals in the water as supplied (often termed end of pipe monitoring). The concept of water safety plans was introduced in order to encourage a proactive preventive approach to managing risks to drinking water from the catchment to the point at which consumers receive their drinking water, frequently referred to as the source to tap approach. **[A3/38/1687+, Chapter 4]**.

36. Water Safety Plans (WSP) require a system assessment from catchment to tap, identifying hazards, assessing risks from those hazards, establishing mitigation measures and ensuring that the measures are working. It also includes monitoring and surveillance, usually by an independent authority or regulator. There are recommended supporting activities such as ensuring that materials in contact with drinking water do not cause degradation of the quality of the supply or introduce new risks to health. The Guidelines are supported by a range of documents including a Water Safety Plan Manual and documents such as Water Safety in Distribution Systems and Water Safety in Buildings **[A2/35/1066+ and 36/1230+]** and Health Aspects of Plumbing **[A4/50/2590-2728]**. The Guidelines emphasise the need for close stakeholder liaison with different groups who have responsibility for different parts of the water supply or who have influence on the water supply.

37. The Guidelines are regarded as the scientific point of departure for the development of National Standards providing guidance on microbiological, chemical and radiological quality and on acceptability to consumers. The guideline values for chemical contaminants provide a basis for assessing the risks to health from drinking water but WHO indicates that local circumstances should always be taken into account in setting national standards and recommend that individual guideline values should be considered in the appropriate context. In this respect, and as mentioned above, the statement that "A guideline value (*for a chemical constituent*) **normally** (my emphasis) represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption"**[C2/18/1258, §1.1.4]** should be treated with caution because it does not mean that contamination can be allowed to increase to the guideline value. In addition some guideline values for chemicals are designated provisional and may be set at a higher value than would be the case for a strictly health-based value because of practical considerations. It is appropriate to try and achieve as low a concentration of a contaminant as possible within the constraints of cost and practicality. WHO has introduced the concept of health-based values for a number of potential contaminants rather than formal guideline values. This approach will, for example, include pesticides to discourage simply copying the list of guideline values into national standards.

38. Chemicals present in water can vary significantly between water sources, and because water supplies vary significantly in size and resources, the Guidelines emphasise the need to be selective and to prioritise chemicals so that the most important for the country or local region are considered for inclusion in national standards and monitoring programmes. The most important parameters should be identified during the hazard and risk assessment phases of the Water Safety Plans. Monitoring programmes for chemical contaminants should be designed to provide the greatest focus on those parameters that are likely to be present in significant concentrations. Sampling points should reflect whether the parameter is likely to change between the treatment works and the tap. Those substances that either change in distribution such as trihalomethanes or are introduced from materials in the distribution system, such as lead, should be monitored close to or at the tap to reflect the worst case. Sampling frequency should reflect the variability of the concentration of a parameter over time. However, WHO emphasises that the Guidelines do not cover all possible chemical contaminants and other contaminants identified as a risk under the Water Safety Plan may need to be considered.

39. The International Organization for Standardization (ISO) also develops standards that may contribute to the process of assuring drinking water quality. These standards provide guidance in the field of water quality, including definition of terms, sampling of waters, measurement and reporting of water characteristics, including numerous standards relating to analytical methods, but it specifically excludes standards on the limits of acceptability for water quality.

40. As part of the process of developing Water Safety Plans it is important to identify hazards, which are pathogenic microorganisms or chemicals, including radionuclides, which are of possible concern for health or which could render drinking water unacceptable to consumers. In the process of understanding the water supply it is also considered important to identify hazardous events. These are circumstances in which the probability of a hazard reaching consumers at concentrations of concern is increased. Examples would be heavy rainfall resulting in a significant increase in raw water turbidity or the number of pathogens in raw water, a failure in a treatment process, a sudden drop in mains pressure allowing ingress of contamination, the installation of inappropriate

materials such as lead solder or cross connections between drinking water systems and salt water or wastewater systems.

41. In each case when deciding the preventive or mitigation measures necessary it is usually appropriate to consider the possible risks associated with a particular hazard, taking into account existing barriers and mitigation procedures such as water treatment. In this case it is important to consider the likelihood of a hazard reaching the consumer and the severity of the outcome. While this may be related to health, such as disease caused by pathogens, it may also be related to the effects on consumer acceptance of the water or the probability of exceeding a standard or guideline value. This process allows prioritization of those hazards that are of greatest concern and for which management steps are the most important. It also allows prioritization of monitoring for chemicals so that the focus is on the most important. Normally managing the risks begins in the catchment but much of Hong Kong's water comes from catchments outside the control of the Hong Kong authorities. Even when this is the case some understanding of the probable hazards in the catchment and their risks is still necessary for establishing the appropriate barriers by blending sources or in treatment and the ability of those barriers to meet the challenges when they are at their greatest. These hazards may or may not be covered by guideline values.

42. There is a clear difference between the ways in which the risks from pathogens are considered compared to the ways in which chemical contaminants are considered. Pathogens pose an acute risk, i.e. a single exposure through ingestion of water containing pathogens can lead to disease in susceptible individuals. Even after exposure has stopped, if infection has taken place the disease will develop. This is not the case with most chemicals for which extended exposure at a sufficiently high concentration would be required to cause adverse effects on health and those effects might not be obvious. The exposure period may be for weeks to months in the case of a chemical like lead, to years in the case of a chemical such as arsenic. For many chemicals there is no direct evidence that they do cause adverse health effects through consumption of drinking water but there is indirect evidence that they can cause harm if exposure is great enough. The guideline values for chemicals are developed to provide a benchmark against which to judge concentrations of concern and there is usually a significant margin of safety built into these guideline values. There are exceptions and lead is one of

those since the provisional lead guideline is not based directly on health but on what can be achieved by treatment without removal of all lead in the system.

43. Pathogens can take the form of bacteria, viruses or protozoa, such as *Cryptosporidium* but these cannot be easily measured and so the absence of indicators of faecal contamination in 100mls of water is used, i.e. *Escherichia coli* (*E. coli*) or *Enterococci.* Meeting the guideline values for microbiological quality does not, on its own, assure microbiological safety. They are indicators of the potential for faecal pathogens to be present but rely on very small samples in relation to the total amount of water supplied. By the time results are available the water will most probably have reached the consumer. The numbers of pathogens can be highly variable in space and time and a single exposure can lead to disease, particularly since the infective dose can be very small. As a consequence the approach to assuring safe drinking water is also to monitor operational parameters such as turbidity and free chlorine to ensure that barriers such as treatment processes are operating at their optimum at all times with a rapid response to correct the system when the operational parameters start to indicate that the processes are becoming less than optimum.

44. Other microbial indicators are used, such as total coliforms or plate counts of heterotrophic bacteria. These are not indicators of the presence of pathogens but can be general indicators of ingress into the distribution system, a change in the system or deterioration in water quality. In certain cases a sharp increase in plate counts can be an indicator of the presence of opportunist pathogenic bacteria such as *Pseudomonas aeruginosa* which can grow in distribution or in water systems in buildings.

45. The control measures outlined above should start in the catchment with the prevention or amelioration of contamination of the source. Where this is not possible or inadequate, water treatment processes may be installed and monitored to ensure that they continue to work efficiently. Prevention of contamination of the drinking water in distribution requires that the system is properly maintained and operated. This would include prevention of ingress of contaminated water into service reservoirs and distribution, and management procedures to operate the distribution system to minimise risks, for example

operating valves to minimise surges. Control measures also include preventing contamination from materials and chemicals in contact with drinking water.

46. The Guidelines recommend that chemicals and materials in contact with drinking water should be of an appropriate quality to prevent contamination of water by chemicals leaching in significant quantities from the materials, i.e. that cause or contribute to a failure of a standard or guideline value. However, it should be borne in mind that concentrations of chemicals should always be kept as low as is feasible within the constraints of cost and resources. While there is no formal international approval scheme for materials in contact with drinking water, there are a number of approval systems in place in different countries and these can form the basis of assuring the suitability of chemicals and materials more widely, for example, NSF International in North America and Regulation 31 of the Water Supply (Water Quality) Regulations 2000 managed by the Drinking Water Inspectorate ("**DWI**") in the UK. The European Union is also discussing the establishment of an EU wide scheme. There are also systems to ensure that materials used in buildings do not result in contamination or deterioration of the quality of the supply, for example the Water Regulations Advisory Scheme (WRAS) in the UK. All of these schemes require that materials and/or fittings are submitted for testing to demonstrate that they will not result in contamination of the water. NSF also carries out inspections of factories and all require some retesting at various intervals to demonstrate that the quality has not changed. NSF has their own testing laboratories but the UK regulation 31 allows the testing to be carried out by accredited laboratories. In all cases, any change in the formulation of materials or in manufacturing practice must be notified and if necessary retesting will be required to retain approval. By specifying the use of approved materials, such as those meeting specified British Standards, Hong Kong has in place the fundamental structure to take advantage of other approval systems without the cost and difficulties associated with establishing a separate scheme. The problem has been the implementation of the existing arrangements for listing acceptable (approved) products and ensuring that the lists are both current and easily accessible. The introduction of a modern website that categorises different materials and fittings in accordance with their purpose and where they are used with a listing of approved products would be helpful, easy to use and encourage submission of locally manufactured materials and fittings to one of the designated approval procedures. The site would also be a useful way of

explaining why using approved products is important. Currently this process is the responsibility of the WSD/WA but it is essential that the process and the requirement are taken seriously. However, no system will be truly effective unless there is enforcement of the rules.

47. The Housing Authority (HA) specify in their contractual arrangements that low lead copper alloy fittings and lead free solder should be used. However, there also needs to be an active process by which checks are made that the requirements are being met. This is the responsibility of the HA but, because there appeared to be a lack of understanding of the importance of the specification, clear allocation of this supervisory task does not seem to have taken place. The HA must understand and act upon the contractual requirements for construction and not just assume that because it is in the contract it will happen. If staff in the HA are unaware or unsure why a contractual requirement is included then this should be rectified before the contract is let. The proposals from HA and discussions with senior HA staff during my visit show that the HA do now understand the problem and are taking steps to correct the situation. The HA Review Committee have made a number of appropriate and constructive suggestions to improve this situation **[B15.4/398/40288+].** However, significant responsibility also lies with the main contractor to ensure that both it and its sub-contractors fulfil the requirements of the contract. In this respect, Licensed Plumbers also have a key role in ensuring that their plumbing workforce has been properly trained and comply with the specifications for the materials to be used. Part of the tender process should also be a demonstration that quality assurance procedures are in place and are sufficiently robust to deliver the requirements of the contract in all areas. In this case, none of the responsible parties had carried out the basic checks. It would seem that it is particularly unfortunate that the Licensed Plumbers who should have been fully aware of the potential for using the wrong kind of solder, which is both cheaper and easier to use, did not ensure that installation of plumbing met all the specifications of the contract. Once the labels have been removed and solder cut into strips, it is difficult to identify leaded solder from unleaded. The suggestion by HA that it may be appropriate to have central purchasing of items such as unleaded solder has considerable merit. However, if there are circumstances in which leaded solder can be used on non-potable systems then appropriate steps will need to be taken to ensure the unleaded and leaded solders are kept apart and the two cannot get mixed up.

Effectively the responsibility for monitoring what is actually being used, both unleaded solder and low lead copper alloy fittings, lies with the main contractor and the Licensed Plumber(s). The HA has a higher level supervisory role but this role is key in the early stages of a contract ensuring that the main contractor or its sub-contractors are proposing to use appropriate approved materials and are aware of their responsibility to ensure that there is no deviation during construction.

48. The Benchmarking Study of Overseas Regulations and Practices on Management and Control of Inside Plumbing Services identifies a number of schemes along with different practices regarding licensing and certification of plumbers **[C19.6/143/14398+]**. I broadly agree with the conclusions from that study but I have reservations regarding reliance on testing post installation. Hong Kong has procedures in place to ensure that inappropriate materials are not installed, at least in public housing and these procedures should be simplified and strengthened. There should be consequences for Licensed Plumbers, who do not properly fulfil their responsibilities with regard to using craft trained plumbers who will carry out much of the actual work, e.g. removal of license or suspension of license with a requirement for re-examination and demonstration of competence over a suitable period, reflecting the severity of the breach of conditions, before the license could be restored. There should also be a requirement for all Licensed Plumbers to attend periodic short courses to ensure that their knowledge is up to date. Hong Kong has one of the few national public certification and training schemes for plumbers (Scotland also established such a scheme in 2002) but it is essential that the system is not undermined by not being properly and rigorously applied. It is important that all individuals in plumbing, including those trained practically through apprenticeships and similar schemes, understand the reasons why certain materials should not be used and why system design is important.

49. Construction and maintenance of water supply systems not only requires that the correct materials are used. It also requires that under the Water Safety Plans there are appropriate procedures in place to ensure that the safety and quality of the drinking water is not compromised by the design of the system. Similarly it is essential that management procedures are in place for maintenance. Not only is it necessary that procedures are in place for construction and maintenance but

training is required to make sure that the reasons for the procedures, e.g. lead is hazardous to health and dead ends result in deterioration of quality because of microbial growth, are fully understood. This also applies to maintenance procedures because understanding why procedures are necessary is an important step in ensuring that they are taken seriously, e.g growth of *Legionella*.

50. Maintenance of systems is emphasised under water safety plans including preventive maintenance and regular planned maintenance of important equipment and fittings. Maintenance is particularly important in the water treatment works and the distribution system but it is also important in the water infrastructure in buildings, for example the requirement now proposed by WSD for disinfection and cleaning of systems every 3 months.

51. There are currently no formal international standards for inspection and monitoring of water supplies or for the building and construction of water systems although there are a number of areas in which guidance is available, either through WHO documents that support the Guidelines or through other networks such as the International Water Association (IWA) Operation and Maintenance Network. The reason for this is that inspection and monitoring needs to be tailored to specific circumstances and requirements which vary significantly around the world.

52. Management procedures are a key part of Water Safety Plans. They are vital in ensuring that water supplies are capable of delivering safe drinking water and continue to do so. In the fourth edition of the WHO Guidelines it is stated that "a Water Safety Plan comprises, as a minimum, three key components that are the responsibility of the drinking water supplier in order to ensure that drinking water is safe. These are a system assessment, effective operational monitoring and management and communication **[C2/18/1278]**". Management and communication are key parts of any process to assure quality. Management procedures that are clearly laid out and understood underpin the delivery of safe water from source to tap. In addition the Guidelines state "effective management implies definition of actions to be taken during normal operational conditions, of actions to be taken in specific 'incident' situations where a loss of control of the system may occur and of procedures to be followed in unforeseen (emergency) situations. Management procedures should be documented alongside system

assessment, monitoring plans, supporting programmes and communication required to ensure safe operation of the system" **[C2/18/1289, §4.4]**. Supporting programmes would include systems for ensuring that only appropriate materials are used both in terms of approval and ensuring that only approved materials and chemicals that meet the appropriate quality criteria are used.

53. The documented management procedures should ensure that when any part of the system has a problem that problem is rectified in due time to prevent any unnecessary risk to consumers. Systems must be capable of responding quickly at any time because water is supplied for 24 hours per day and 7 days per week. This also means that staff must be properly trained and understand the limits of their authority to take decisions, however decisions should be delegated to the lowest appropriate level to ensure rapid response. It is also important that there is an appropriate on-call support system that is properly staffed and able to function at any time.

**Plumbing Materials and their Installation**

54. The development of detailed Water Safety Plans that include buildings is difficult because of the variations in building design and ownership. However, one of the key areas that can be included is the approval of plumbing materials to ensure that only those that do not cause an unacceptable deterioration of the water quality are used. Lists of approved products need to be up to date and readily available and stakeholders such as construction companies, plumbers and suppliers of plumbing material need to made aware of the requirements and why those requirements are in place. The WHO document entitled Water Safety in Buildings mentions the use of inappropriate materials and specifically mentions lead in this context **[A2/35/1083]**. Lead is also specifically mentioned as a potential hazard in the drinking water system in buildings **[A2/35/1089]** and as a chemical that can leach from materials used in pipework with particular mention of solder **[A2/35/1126]**. These mentions of lead in the context of building construction reinforce the statements regarding lead in the Guidelines for Drinking Water Quality **[C2/18/1446]**. In terms of installation, requirements such as not leaving dead ends in systems should be made clear to architects, construction companies and plumbers along with their responsibilities with regard to ensuring safe water. The WHO document Water Safety in Buildings

states "This should include minimizing sources of hazards (e.g. stagnant water, long branch pipes and dead legs), as well as enabling access for monitoring and maintenance" **[A2/35/1089]**.

**(c) in the context of the international standards in (a) –**

**(i) review and evaluate the adequacy of the existing Water Safety Plans of the WSD;**

**(ii) review and evaluate the existing regulatory and monitoring regimes (both prior and subsequent to the excess lead in drinking water incidents as a result of which new measures have been put in place by public authorities) on quality of drinking water :**

**(1) at the pre-construction stage;**

**(2) at the construction stage;**

**(3) at the completion of construction (before the WSD issues the certificate for water supply connection); and**

**(4) at the maintenance stage;**

**(iii) opine on whether any further metal(s), chemical(s) and/or microorganism(s) should be included as parameter(s) in addition to those set out in the WSD Circular Letter No. 1/2015 for testing of water samples, and if so, the thresholds, benchmarks and/or the acceptance criteria to be set for them; and**

**(iv) the effectiveness of the recommendations made by the Review Committee.**

**(i) My Opinion on the introduction of Water Safety Plans by WSD**

55. WSD has adopted the concept of Water Safety Plans (WSPs) **[C1/5.1-5.20/47-812]** and it is to be expected that these will be developed further in the future. It is difficult to give a comprehensive opinion regarding WSD's development and implementation of WSPs from the documents available and from the short time available to discuss the plans with WSD staff. The following comments reflect the information available from the documents submitted.

56. WSD's understanding of WSPs would be enhanced by consultation with organisations in other countries that are also actively involved in the process of developing and implementing WSPs. There appears to be some complacency about water quality and the approach appears to be top down with no clear indication of how the Water Safety Plan teams work, which is an important part of the process. How well external stakeholders are engaged is also unclear but the involvement of other stakeholders is key in ensuring full understanding of what WSPs are and their role in assuring safe drinking water.

57. It appears that there may not be clear understanding of the purpose of health-based targets for pathogens: for example in the WSP General Plan **[C1/5-1/57+]** it states that the "absence of thermo-tolerant Coliforms and *E. coli* in 100 ml of treated water is taken as the performance target in ensuring the microbiological quality of treated water". While performance targets are an important part of WSPs, one of the reasons for establishing WSPs is that simply monitoring for faecal indicators is inadequate for ensuring the supply of safe water and so this would not be a suitable performance target. The target would be a removal target for pathogens by treatment processes. Hong Kong has well established multi-barrier treatment in place and performance targets would relate to operational parameters that reflect the efficiency of treatment such as filtration and disinfection.

58. While the overall structure and purpose of WSPs appears to be understood and the WSPs as presented form a very good starting point there are areas that would repay closer examination.

59. It is not clear how the WSPs were prepared but the General Plan **[C1/5-1/47+]** implies they were prepared by one department for others. In fact the WSPs were prepared under the auspices of a WSP team with representatives from various sections to ensure that it reflects actual practice and has the commitment of the different sections. The situation in Hong Kong is complex and so an overarching team that links into external stakeholders on a day to day basis and ensures consistency would be appropriate. This would be supported by small teams associated with each supply train. In terms of distribution this would be much more of a common plan but there would be a clear need to have a proper schematic, preferably using GIS with the associated data on materials, condition and flows in the different sections. There would also need to be records for the position and status of valves, procedures for opening and closing valves and planned maintenance, such as periodically operating valves to ensure that they are still fully operational and flushing mains. Consideration of the operation and maintenance of service reservoirs is also important. As indicated above it is difficult to determine to what extent this is the case due to the lack of time to specifically study the WSPs with WSD staff.

60. For the future it would be beneficial to have a more systematic understanding of the possible hazards and risks from the Dongjiang River in particular, because it is such an important source. This would also apply to the catchments, with less reliance on lists of chemicals that may or may not be there and so may or may not be adequately monitored.

61. The approach to water treatment is sound but the extent that continuous monitoring technology is used to support operational monitoring is less clear. This is an important step to assuring safe water.

62. Distribution system management plans do not appear to be so well developed. It is not clear how the distribution system, including service reservoirs, is managed to minimise the risks of contamination, for example management of operations to open or close valves to prevent surges, which are followed by pressure drops and the extent to which pressure falls after a burst will affect the wider distribution system.

63. There is mention of water distribution systems in buildings as a responsibility of the Customer Services Branch (CSB) but this can only be achieved by appropriate collaboration with other agencies such as the HD. Paragraph 3.8 of the minutes of the First Working Group Meeting on the Development and Implementation of Water Safety Plan for WSD held on 28 February 2005 **[C21/179/18998+, see 19000]** indicates that WSD does have indirect control of systems in private premises after the connection points but it is unclear what actions were put in place to extend WSPs to buildings, possibly through another agency. This is important since WSD do not take responsibility for water quality beyond the supply point into a building. In addition, responsibility for continuing water quality and maintenance associated with water quality, e.g. *Legionella* control, lies with the building manager and individual householders or tenants. WSD have previously taken samples from the buildings before the systems are approved for use but this has been to ensure that there is no danger of back flow contaminating the public water supply and the parameters considered were limited to those that could be indicators of the potential for such contamination. Since the identification of the lead problem the proposal is to take samples at representative sampling points for several metals **[C5/60/4066 and C5/63/4072-4075]** but the objective of such sampling needs to be carefully considered and

clearly stated. In particular, sampling needs to reflect a worst case in order to identify hazards and to determine whether further investigation is required to determine the risks and interventions. In the case of lead, the presence of elevated lead above 5 µg/litre, and possibly less, in a suitable sample indicates a failure of the procedures intended to prevent there being any excess lead in the system. It is important that there is someone responsible for water quality and monitoring water quality at the tap within buildings. Following the source to tap principle of WSPs, WSD would be best placed to do this.

64. While the WSPs developed by WSD broadly cover the recommended steps in a water safety plan, with the reservations indicated above, the WSPs would benefit from an external audit because this can help to identify improvements that are not readily obvious to those who are closely involved. It is not clear how extensively staff have been trained in the development of the plans and how closely involved the operators of the various stages of the supply chain have been. The water treatment sections of the WSPs are the most extensively described. My visits to two water treatment plants and conversations with senior supervisory staff indicate that there is a good understanding of the overall requirements. However, WSPs are also about continuous improvement and it is important that the need for improvement is properly and openly discussed and recognised.

65. The monitoring regimes need to be reassessed and modified to meet the contaminants known to be likely to be present and the points and frequency of sampling adapted to reflect behaviour, presence and concentration. This is referred to as risk-based monitoring and is intended to target resources where they will deliver the greatest benefit.

**(ii) Regulatory and Monitoring Regimes for Internal Distribution Systems in Buildings**

**(iii) Opinion on whether any further metal(s), chemical(s) and/or microorganism(s) should be included as parameter(s) in addition to those set out in the WSD Circular Letter No. 1/2015 for testing of water samples, and if so, the thresholds, benchmarks and/or the acceptance criteria to be set for them**

66. The regulatory and monitoring regime prior to the excess lead in drinking water incident should have prevented the incident occurring if it had been fully

implemented. The failure of implementation was largely due to a lack of understanding of the importance for health of lead and other potential contaminants from the internal distribution system. However, the clearly stated requirement that only unleaded solder must be used should have raised questions as to why this was sufficiently important to merit a specific mention. It would appear that no-one had specific responsibility regarding water quality at the tap. This was not helped by WSD's responsibility for water quality ending at the point at which water enters the building and the fact that the HD has no clear mandate in this respect. All depended on meeting the requirements for materials set out by the WA. That a similar situation has occurred elsewhere in the world indicates that unless explicit steps are in place to cover water quality in buildings then what are seen as relatively minor items may be overlooked, particularly when the consequences are not visible.

67. Subsequent to the discovery of the lead in water incident a number of steps have been taken to heighten awareness and to improve the final monitoring step. WSD Circular Letter No. 1/2015 **[C5/60/4066]** and No. 5/2015 **[C5/63/4072-4075]** reiterate the requirement not to use lead solder but do not mention the concern for health. The circular letter adds four metals to the analysis of samples already required but does not add anything about the need to take separate samples with an appropriate sampling protocol to maximise the detection of metals. I would suggest the addition of copper, antimony and zinc to the list of parameters, at least in the short-term, to gather data on concentrations. This has been discussed above in paragraph 29 but the lack of data on metals from plumbing needs to be rectified. However, both the WSD and HD have shown that they are aware of the need to tighten up the supervisory measures at all stages to ensure that drinking water quality in buildings, particularly public housing blocks, is maintained.

68. There is a need to produce guidance for building managers on the continuing maintenance of water systems in buildings to minimise the risk of *Legionella.*

69. The approaches to monitoring the quality of water at the tap in buildings, particularly apartment blocks, proposed by the Task Force have significant merit for newly built or refurbished properties. These ought to provide a final check on materials being used, in particular lead solder. The use of hand held x-ray fluorescence spectrometers to check soldered joints for lead would be highly

beneficial in ensuring that lead solder has not been used (non-destructive testing). The sampling of water at the tap for heavy metals would be in addition to sampling for the eight parameters to protect the public supply in the event of back flow because the sampling protocol would need to be different to ensure detecting these contaminants, e.g. first draw of sufficient quantity or fixed stagnation time. In addition it would be useful to add copper, antimony and zinc to the list of metals for the reasons outlined in paragraphs 29 and 67. Cadmium is unlikely to be present unless lower quality galvanised pipe is present or fittings are used that do not meet the relevant British Standard. Similarly zinc is unlikely to be present unless galvanised pipe is present. Chromium does not appear to leach in significant concentrations from chromium plating. The surface area for chromium in taps in contact with the water will be small but nickel does leach from the nickel base plating onto which the chromium is plated. However, the volume in the taps is very small and will be cleared in a very short flush. This is important because there is significant nickel in the water as supplied. Copper from copper piping is not likely to reach concentrations of more than a few hundreds of micrograms per litre unless there is significant corrosion combined with extended standing times when concentrations can increase significantly but this needs to be confirmed. Copper can cause acute gastric irritation when concentrations exceed about 2 mg/litre, which is the basis for the WHO guideline value. One difficulty with such sampling is determining how many apartments to take samples from if the pattern of lead solder use is not consistent and this will not be known until a significant problem is encountered. It would, therefore, seem appropriate to choose a manageable number of apartments at random depending on the resources that HD and WSD are able to commit.

70. What remains uncertain is to what extent lead has been used in plumbing in other buildings in Hong Kong in the past. To determine this would require an investigative study that could be achieved by random sampling using a suitable sampling protocol but this approach would need to be considered carefully in order to make sure that it was cost effective.

71. In relation to additional microbiological parameters that could be useful to include, enterococci are used in a number of countries. How much information these would add as faecal indicators, along with or instead of *E. coli*, is under consideration by a number of authorities, including WHO. Enterococci tend to

survive longer in the environment than *E. coli* and are more resistant to chlorine although the numbers in human faecal matter are fewer than *E. coli*.

**(iv) My opinion on the effectiveness of the recommendations made by the Review Committee**

72. The Review Committee have made comments and recommendations to the HD **[B15.4/397/40286-40328]** following the excess lead in water incident. The primary recommendation is that existing procedures should be tightened up and I fully agree with this recommendation. I would strongly support their recommendations regarding education and training to raise awareness of the importance of using lead-free soldering and the consequences of using inappropriate plumbing materials. There is value in establishing a Review Committee because it means that the messages with regard to lead and the potential for what appear to be relatively minor plumbing components to have a significant impact on drinking water quality will be more widely disseminated.

73. However, their view that the incidence of excess lead in water is very low cannot be substantiated by the data because of the sampling protocol requirement for flushed samples. They also show that there is a general misunderstanding as to what the WHO provisional guideline value is intended to achieve and that the provisional guideline value is a health-based standard, which it is not.

**(d) opine on how the inadequacies (if any) identified for the matters above may be rectified or improved and to make recommendations with regard to the safety of drinking water in Hong Kong; and**

**(e) state, provide advice and recommendations on other areas of concern (if any).**

**Opinion, advice and recommendations.**

74. It is my opinion that there is a need for formal drinking water standards and a regulatory structure for drinking water for Hong Kong to ensure that there is coordination of all matters relating to drinking water quality. The standards would incorporate WHO guidelines in the manner recommended by WHO and focus on the most important contaminants. This would also allow external examination of the WSPs and provide an external stimulus to encourage more focused risk-based monitoring of raw and treated drinking water. The regulatory

structure could be quite small but would provide independent oversight of drinking water quality.

75. In the UK and many other countries there is an independent regulator for drinking water quality[1]. The formal structure varies but the regulator reviews and assesses the performance of the water supplier(s) with regard to the quality of the water supplied. In the case of the UK there are three regulators, one for England and Wales and one each for Northern Ireland and Scotland. The model for Northern Ireland and Scotland is more relevant for Hong Kong as there is a single water supplier and the supplier is in public ownership. The regulator assesses compliance with drinking water standards and also determines the risks, in consultation with health professionals, associated with parameters that are found in drinking water or drinking water sources but are not included in the standards, e.g. PFOS (perflurooctane sulfonate). The regulator also agrees the sampling programme and audits the analysis and the results for quality and agrees any remedial steps or improvements. In the UK the three regulators also audit water safety plans, providing a beneficial second view. The inspector has complete and open access to the data and operations of the Water Supplier. It is, however, important that any regulatory structure is appropriate for Hong Kong's particular circumstances.

76. I believe that it would be appropriate for WSD to consider creating the position of water quality manager who would report to the Director and who would have the role of overseeing drinking water quality data and activities from all parts of the organisation. This role would also involve evaluation of the particular trends in water quality data and working to assist operational sections to work towards gradual improvement, which is a key part of the WHO framework for safe drinking water. Hong Kong will undoubtedly face significant challenges to its drinking water supplies in the future and a water quality manager would be a positive step to looking towards the future.

[1] http://dwi.defra.gov.uk/about/index.htm (UK)
http://dwqr.scot/ (Scotland)
https://www.doeni.gov.uk/topics/water/drinking-water-quality (Northern Ireland)
http://www.epa.ie/water/dw/ (Ireland)

77. While I understand the need for and importance of bureaucracy, many of the policies and procedures seem to be fragmented between various documents. I also understand that this gradually happens in many organizations as changes are made but it would be beneficial to consolidate and streamline all documents, particularly as changes are incorporated over time to make the documents easier to access and more transparent, and to ensure that the chance of misunderstanding and using out of date procedures is minimised.

78. While HA has now started to allocate a specific quality assurance role with regard to drinking water, I find the statements that the HA were unaware of the issue of lead rather difficult to understand in view of the HA's specific requirement for using unleaded solder and low lead fittings. This implies that little thought was being applied to the contract. Rather, standard terms were being applied without understanding the reason for their inclusion. It will be important that the new quality assurance regime is proactive in preventing the unauthorised use of materials by a process of simple inquiry. The water sampling provides retrospective verification but this will only be reliable if a suitable sampling method is adopted to maximise the chance of finding unwanted heavy metals. It is also clear that because the WSD did not take any responsibility for water at the tap and had not formally delegated that authority, no one took that responsibility. It is not, therefore, entirely surprising that the current situation occurred. I would anticipate that the HA and the WA will now be aware and will ensure that quality assurance checks are properly carried out. Ultimately, quality assurance to prevent things going wrong will depend on individuals carrying out their responsibilities and in this, I would include Licensed Plumbers and Main Contractors. A central purchasing arrangement for unleaded solder and possibly for low lead copper alloy fittings would assist this greatly but thought should be applied to any other components of the plumbing system from which quality problems could arise, e.g. taps and copper piping.

**Summary of Conclusions**

79. The WSD led Task Force has carried out a thorough investigation of the affected systems using appropriate methodology.

80. The reason for the exceedance of the provisional WHO guideline value for lead in drinking water in Public Housing was primarily due to the use of lead solder for

joints in copper pipes contrary to the clearly stated requirements for plumbing materials in Hong Kong.

81. The sampling protocol used to take samples of drinking water at consumers' taps for lead was not designed to detect the presence of lead in the plumbing systems in apartments and so may underestimate the scale of contamination; this was confirmed by Professor Lee's study. A suitable sampling protocol should be developed to address this problem.

82. The WHO provisional guideline value is based on practicality and is not a health-based value because it is not currently possible to determine a suitable threshold for the adverse effects of lead. It is based on the premise that no new lead materials will be installed.

83. It would be valuable to investigate whether other metals that can arise from distribution are likely to be present in drinking water at the tap in Hong Kong, these include nickel, chromium, cadmium, copper, antimony and zinc. Those that are shown to be present should be included in the suite of metals to be measured in tap samples along with lead.

84. The possibility of *Legionella* bacteria growing in the internal fresh water systems of housing developments in Hong Kong has been demonstrated. There is a need to develop suitable management strategies to be implemented by building managers and consumers to minimise the risk of *Legionella*.

85. WSD has implemented Water Safety Plans, which are a key part of ensuring the ability of water systems to supply safe drinking water as recommended by WHO. While it is difficult to judge how well this has been done from the documents provided and the short time available for discussions with WSD on this topic, the work on Water Safety Plans would benefit from an external view and external audit.

86. There is a gap in the Water Safety Plans because they do not cover the supply to the tap. Even if WSD do not take responsibility beyond the point at which water is delivered to a building, it is important that someone has clear overall responsibility for water quality in buildings.

87. WSD should develop a risk-based strategy for monitoring contaminants and to improve the approach to operational monitoring to ensure that systems are always operating at their optimum.

88. It is not clear how systematically the hazards from the Dongjiang River have been characterised, particularly with regard to chemicals that are not listed in the WHO Guidelines. For the future it would be beneficial to address this issue as far as possible since it is a key water source. This does not mean that the source is unsafe but it is important to be aware of emerging issues.

89. Systems are in place for regulation and monitoring of plumbing installations but these need to be properly implemented by inspection rather than just documentation. Licensed plumbers must take responsibility for trade trained plumbers who they employ or are sub-contractors and ensure that they follow the requirements to ensure plumbing that is safe.

90. Hong Kong has the elements of a system to ensure that only suitable materials are used in contact with drinking water either in the public supply or in the distribution systems within buildings. This is based on other international approval systems. While there is no need for Hong Kong to develop its own approval system, it should specify more clearly the requirements for acceptance using other international approvals and which international approval systems can be accepted.

91. Hong Kong should develop formal drinking water standards based on the WHO Guidelines but adapted to its own needs.

92. Hong Kong would benefit from the establishment of an independent regulator who would provide a means of reassuring the public about the quality of drinking water in Hong Kong and would provide a means of ensuring that quality is integrated from source to tap. The regulator would also be responsible for auditing Water Safety Plans and for ensuring that drinking water standards are sufficiently up to date in conjunction with other departments.

93. WSD should consider creating the post of water quality manager, independent of operations, to report to the director and to act as a first contact point with the regulator.

94. In responding to this incident HD and particularly WSD have issued a series of documents and memoranda over several months. At no point can I find a desire for the two departments to work together to develop a single document with the input of other stakeholders, which would effectively be a manual covering the installation of plumbing in buildings in Hong Kong. The result is that, to date, there is a fragmented response, when a coordinated response would ensure that all of the key information was in one place and would be much more effective in preventing future problems without excessive effort.

95. It is important that now that a problem with the installation of lead solder in new public housing developments has been identified, the scale of the problem should be properly assessed and actions identified and implemented to rectify the situation and to protect consumers from lead in their drinking water.

## Expert's Declaration

I, PROFESSOR JOHN FAWELL DECLARE THAT:

1. I declare and confirm that I have read the Code of Conduct for Expert Witnesses as set out in Appendix D to the Rules of High Court, Cap. 4A and agree to be bound by it. I understand that my duty in providing this written report and giving evidence is to assist the Commission. I confirm that I have complied and will continue to comply with my duty.

2. I know of no conflict of interests of any kind, other than any which I have disclosed in my report.

3. I do not consider that any interest which I have disclosed affects my suitability as an expert witness on any issues on which I have given evidence.

4. I will advise the Commission if, between the date of my report and the hearing of the Commission, there is any change in circumstances which affect my opinion above.

5. I have exercised reasonable care and skill in order to be accurate and complete in preparing this report.

6. I have endeavoured to include in my report those matters, of which I have knowledge or of which I have been made aware, that might adversely affect the validity of my opinion. I have clearly stated any qualifications to my opinion.

7. I have not, without forming an independent view, included or excluded anything which has been suggested to me by others, including my instructing solicitors.

8. I will notify those instructing me immediately and confirm in writing if, for any reason, my existing report requires any correction or qualification.

9. I understand that:

(a) my report will form the evidence to be given under oath or affirmation;

(b) questions may be put to me in writing for the purposes of clarifying my report and that my answers shall be treated as part of my report and covered by my statement of truth;

(c) the Commission may at any stage direct a discussion to take place between the experts for the purpose of identifying and discussing the issues to be investigated under the Terms of Reference, where possible reaching an agreed opinion on those issues and identifying what action, if any, may be taken to resolve any of the outstanding issues between the parties;

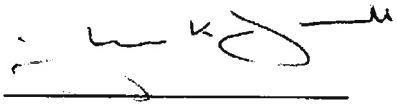
(d) the Commission may direct that following a discussion between the experts that a statement should be prepared showing those issues which are agreed, and those issues which are not agreed, together with a summary of the reasons for disagreeing;

(e) I may be required to attend the hearing of the Commission to be cross-examined on my report by Counsel of other party/parties;

(f) I am likely to be the subject of public adverse criticism by the Chairman and Commissioners of the Commission if the Commission concludes that I have not taken reasonable care in trying to meet the standards set out above.

Statement of Truth

I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. I believe that the opinions expressed in this report are honestly held.



Professor John Fawell
4 February 2016