

## **Metal release from drinking water installations**

### **Screening survey of metal release in 51 domestic installations on Zealand, Denmark**

Requested by: The Danish Enterprise and Construction Authority

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## **Material and Analysis**

## **Metalaflgvelse fra drikkevandsinstallationer**

### **Screening af metalaflgvelse i 51 husinstallationer på Sjælland, Danmark**

Nærværende rapport beskriver en undersøgelse for metalaflgvelse til drikkevand i husinstallationer på Sjælland. Metalaflgvelsen er målt ved forbrugernes vandhane i køkkenet.

Formålet med undersøgelsen var at måle metalkoncentrationen i fraktionerede vandprøver, for at identificere kilder til metaller i drikkevandet.

Undersøgelsen er en screening med målinger fra et begrænset antal installationer, og de kan ikke antages at være repræsentative for alle vandinstallationer i Danmark. Da der er målt i områder med hårdt vand med høj ledningsevne, vil zink- og kobberaflgvelsen være højere end i områder med blødere vand, mens aflgvelsen af de resterende metaller kun i mindre grad vil variere med vandkvaliteten.

Vandprøver blev udtaget i 3 fraktioner for at adskille bidrag fra forskellige kilder. Der blev udtaget 3 vandprøver fra hver installation.

A-prøve: 500 ml udtaget efter gennemskylning med fuldt åben hane i 5 minutter. Denne prøve repræsenterer forsyningsvand fra hovedledninger.

B-prøve: Første 200 ml udtaget efter 4 timers henstand. Denne prøve udgør stagnationsvand fra vandhane, hanerør og afspærringsventil

C-prøve: Næste 800 ml udtaget efter 4 timers henstand (umiddelbart efter B-prøven). Denne prøve udgør stagnationsvand fra den resterende installation (rør, fordelerrør, vandmåler, ventiler).

Vandprøverne blev analyseret for de 9 metaller arsen, cadmium, antimon, tin, krom, zink, kobber, bly og nikkel.

For flere af metallerne er grænseværdierne fastsat for et ugentligt gennemsnit af det vand, som tappes til mad og drikke. Resultaterne i denne rapport kan ikke sammenlignes med disse grænseværdier, og der findes ingen metode til at omregne fra stagnationsværdier til ugentligt gennemsnit. Dette skyldes blandt andet, at det ugentlige gennemsnit vil afhænge af forbrugernes måde at bruge vand på og mange andre faktorer.

De målte koncentrationer af arsen, cadmium, antimon, tin og krom var alle meget lave og generelt sås der ingen stigning i koncentrationen efter stagnation i husinstallationerne. Dette er i overensstemmelse med erfaringer fra tidligere undersøgelser.

Zinkkoncentrationen var lav i A-prøverne som forventet. Zinkkoncentrationer op til 3891 µg/l blev målt i B-prøverne og op til 1271 i C-prøverne. I installationer med varmforzinkede stålør blev hovedparten af zink afgivet fra ørene. I installationer med andre ørmaterialer blev en større andel af zinken afgivet fra messingkomponenter (vandhaner, ventiler). Det anbefales generelt ikke at anvende varmforzinkede stålør i de hårde vandtyper med høj ledningsevne og højt indhold af hydrogenkarbonat på grund af stor risiko for korrosionsskader og høj metalaflgvelse.

Kobberkoncentrationen var lav i A-prøverne og stigende i B- og C-prøverne. Den totale afgivne kobbermængde var højest i installationer med kobberør, hvor C-prøverne gav det højeste bidrag til kobber. I installationer med andre ørmaterialer blev en større del af kobberet afgivet fra den første del af installationen. For alle installationer blev gennemsnitligt 72 % af den totale kobbermængde afgivet til C-prøverne (hovedsageligt rør). Maksimumkoncentrationerne var 2369 µg/l i C-prøver og 2049 i B-prøver, og begge disse værdier overstiger den danske grænseværdi på 2000 µg/l efter 12 timers henstand, selvom en kortere stagnationstid blev anvendt i denne undersøgelse. Resultaterne bekræfter, at kobberør på grund af kobberaflgvelsen ikke bør anvendes til nye

installationer i vandtyper med høj ledningsevne og højt indhold af hydrogenkarbonat, hvilket har været den generelle anbefaling i omkring 10 år.

Blykoncentrationen var lav i A-prøverne og stigende i B- og C-prøverne. Maksimumkoncentrationen var 110 µg/l i en B-prøve. Den gennemsnitlige blykoncentration var 2,8 µg/l i C-prøverne og 7,3 µg/l i B-prøverne. Den gennemsnitlige blyafgivelse i B-prøverne var væsentligt højere for vandhaner der var mindre end 1 år gamle end for ældre vandhaner. Dette skyldes formentlig udtværet bly på overfladen af messing, der erfaringsmæssigt opløses i løbet af de første par måneders anvendelse. For installationer, hvor vandhanerne var mindre end 2 år gamle, blev størstedelen af den totalt afgivne blymængde (60 %) afgivet til de første 200 ml vand (B-prøven). De målte koncentrationer kan ikke sammenlignes med grænseværdien for ugentligt gennemsnit. Kilder til bly i husinstallationer er kobberlegeringerne messing og rødgoods, og i ældre installationer (> 30 år) kan blyholdige loddemetaller også bidrage.

Nikkelkoncentrationen var lav i de fleste A-prøver, men i 7 prøver var den over 5 µg/l og i 2 tilfælde var den over 20 µg/l, som er grænseværdien for ugentligt gennemsnit. Nikkelkoncentrationen steg ikke meget i C-prøverne, og var i 4 tilfælde over 20 µg/l. Den gennemsnitlige koncentration var i A-prøverne 3,5 µg/l og i C-prøverne 4,9 µg/l. B-prøverne havde den højeste nikkelkoncentration med 11 prøver over 20 µg/l. Den gennemsnitlige nikkelkoncentration i B-prøverne var 11,8 µg/l og maksimumværdien var 68 µg/l. I mange tilfælde indeholdt de første 200 ml mere end halvdelen af den afgivne mængde nikkel, der blev afgivet i installationen. I gennemsnit blev 61 % af den totale mængde nikkel afgivet til B-prøverne (vandhane og ventil). For installationer, hvor vandhanerne var mindre end 2 år gamle var det tilsvarende tal 72 %. Dette tyder på, at hovedparten af nikkel blev afgivet for forkromede vandhaner og ventiler af messing. Den gennemsnitlige nikkelafgivelse i B-prøverne var højere fra installationer, hvor vandhanerne var mindre end 2 år gamle end fra installationer med ældre vandhaner. De målte nikkelkoncentrationer kan ikke sammenlignes med grænseværdien på 20 µg/l for ugentligt gennemsnit, men det er dog klart, at hvor A-prøverne har nikkelindhold på over 10 µg/l er der ikke plads til meget nikkelafgivelse i installationerne.

## **Preface**

This report was written in the Department of Corrosion and Metallurgy, FORCE Technology, Denmark. The report presents results from a screening survey of metal release at consumers' kitchen taps in 51 domestic installations on Zealand, Denmark. The scope of work was to analyse the metal concentration in fractioned water samples in order to identify possible sources to metal release in domestic drinking water installations.

It is emphasised that the investigation was a screening only, and due to the limited number of installations it cannot be considered representative of metal release in all Danish domestic water installations.

All test persons are thanked for their cooperation in the project.

The report shall only be published in full and with source reference. Extracts shall only be quoted upon prior permission in writing.

The work was funded by the Danish Enterprise and Construction Authority.

Asbjørn Andersen and Frank Fontenay  
July 2008

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## Introduction

The present report describes results from a screening survey of metal release at consumers' kitchen taps in 51 domestic installations on Zealand, Denmark. The scope of work was to analyse the metal concentration in fractionated water samples in order to identify the possible sources of metal released to drinking water in domestic installations.

Due to the relatively low number of installations involved, it must be emphasised that the investigation was a screening only, and that it cannot be considered representative of metal release in all Danish domestic water installations.

All samples were taken from installations on Zealand, Denmark, and primarily in the vicinity of Copenhagen. In these areas the drinking water is characterised by high conductivity and high contents of hydrogen carbonate and dissolved salts. In these water qualities copper and zinc releases are higher than seen in water qualities with less hydrogen carbonate and dissolved salts. The release of other metals is less dependent on water quality.

To be able to separate the contribution of metals to drinking water from different sources, fractionated sampling was used. Three water samples were taken representing water from mains, stagnation water from mixer tap and stop valve and stagnation water from remaining installation, respectively. For practical reasons fixed sample volumes were used despite of the different types and sizes of installations. The fully flushed sample represents water from waterworks/mains, and was used also for blind values that were subtracted from stagnation samples to calculate net contribution from different sections of the installation. However it is worth noting that stagnating water may react chemically with the pipe materials or by chemical reactions in the water phase itself, which may change the water characteristics in different ways. Metal contents may increase or decrease during stagnation. The most well known example of decreasing metal content is probably the reduction in copper concentration due to deposition of metallic copper upon water in hot dip galvanised steel pipes.

This report only briefly describes materials and metal release principles in the results chapter. For a more detailed description of metal release from the commonly used materials, we refer to our recent report on this subject and the references herein [Ref.1].

For some of the metals, the regulatory parametric values are set as a weekly average of the water ingested by the consumer. This average is not easily measured, and a separate project report from the Technical University of Denmark describes an investigation where the weekly average was measured in selected installations [Ref. 2]. The stagnation values measured in this work cannot be recalculated to weekly average values, and are therefore not comparable to the parametric values. Consequently, it was generally not possible to conclude whether the drinking water fulfilled the requirements for all metals. However previous investigations in other European countries have suggested that the weekly average values for lead correspond to a stagnation time of no more than 0.5 to 1 hour [Ref. 1 and references herein]. In Germany 4 hour stagnation samples are considered higher than the weekly average for all metals, and 4 hour stagnation samples are used as a safe approach for comparing with the weekly average values.

### **Sampling procedure**

The water samples were taken by the test persons as fractioned samples from the kitchen mixer tap as follows (instruction for test persons see Appendix 1):

Sample A: Fully flushed (FF) 500 ml sample taken after 5 minutes of flushing with the tap fully open. This sample represents the water delivered from the mains to the consumer's premises.

Sample B: Fixed stagnation 200 ml sample taken after 4 hours stagnation, during which no water was drawn from any place in the domestic installation. This sample represents stagnation water from the mixer tap, the small connecting pipes and the last stop valve.

Sample C: Fixed stagnation 800 ml sample taken after 4 hours stagnation (immediately after the B-sample) representing stagnation water from the remaining installation.

Samples were analysed for arsenic, antimony, tin, chromium, cadmium, zink, copper, lead and nickel. For description of analyses techniques, see Appendix 3.

## Results

In this section selected results are presented graphically and in tables. For some metals only very low concentrations were found, and these data are discussed below but not illustrated. All analysis results are collected in Appendix 1 along with some information on the installations, Appendix 2.

### ***Arsenic, As***

Arsenic can be present in groundwater, and in some cases must be removed at the waterworks. Trace amounts of arsenic are added to dezincification resistant brasses in order to improve corrosion resistance.

In Denmark the parametric value for arsenic is 10 µg/l as weekly average. In the DWD the parametric value is 10 µg/l (no method described).

All results were low and the highest measured arsenic content was 2.7 µg/l in an A-sample. Generally the results were below 2 µg/l and no apparent increase in arsenic content was observed after stagnation. This is in good accordance with previous investigations.

### ***Antimony, Sb***

antimony is not generally present in the groundwater or added to the materials used for conveying drinking water.

In Denmark the parametric value for antimony is 5 µg/l as weekly average. In the DWD the parametric value is 5 µg/l (no method described).

All results were very low and the concentrations were generally below 0.5 µg/l. As expected no increase in antimony content was observed after stagnation.

### ***Tin, Sn***

Tin can be present in drinking water installations as solders, in brasses or as tin plated surfaces. Tin is generally only slightly soluble in drinking water.

The Danish parametric value for tin is 1500 µg/l after 12 hours stagnation in the consumer's installation. The DWD does not have a parametric value for tin.

Only 2 results were above the quantification limit of 0.5 µg/l, and the highest measured tin content was 25 µg/l in a C-sample. Generally no increase in tin content was observed after stagnation, which is in good accordance with previous investigations.

### ***Chromium, Cr***

Chromium is used for decorative electroplating of taps, fittings and valves and as an alloying element in stainless steel pipes and fittings.

In Denmark the parametric value for chromium is 50 µg/l as weekly average. In the DWD the parametric value is 50 µg/l (no method described).

All results were low and the highest chromium content measured was 3.5 µg/l in an A-sample. Generally no increase in chromium content was observed after stagnation, as chromium is passive and only very slightly soluble in drinking water. This is in good accordance with previous investigations.



### ***Cadmium, Cd***

Cadmium may be present in solders for copper and copper alloys in older installations (more than 30 years in Denmark), but cadmium containing solders are now banned. Furthermore older hot dip galvanised steel pipes may contain traces of cadmium in the zinc layer, and cadmium may also be present in trace amounts in brasses.

In Denmark the parametric value for cadmium is 5 µg/l as weekly average. In the DWD the parametric value is 5 µg/l (no method described).

In general, the concentrations found were below 0.5 µg/l, and the maximum value was 1.8 µg/l in a C-sample. No general increase in cadmium content was observed after stagnation, which is in good accordance with previous investigations.

### ***Zinc, Zn***

The DWD does not have parametric values for zinc, but in the Danish regulations 2 parametric values are set for zinc, being 5000 µg/l after 12 hours stagnation and 3000 µg/l as weekly average. These values are set for aesthetic reasons (taste and appearance of water).

Zinc may be released to drinking water from hot dip galvanised steel pipes or from brass fittings and mixer taps, as zinc is the main alloying element in brass.

Previous investigations have shown, that in high conductivity waters with high contents of hydrogen carbonate the Danish parametric values may not be met for stagnation water from hot dip galvanised steel pipes for the first years, and alternative pipe materials are recommended. In the same water supply areas hot dip galvanised steel pipes have not been used much in the last years due to numerous cases of rapidly perforated pipes caused by pitting corrosion.

Zinc concentrations were generally low in the A-samples, and increasing in most of the B- and C-samples, see Table 1 and Figure 1. The maximum value of the C-samples was 1271 µg/l, and the maximum value of the B-samples was 3891 µg/l. Mainly installations with hot dip galvanised steel pipes had high zinc contents in the C-samples (figure 3), whereas the B-samples generally had high zinc contents due to zinc release from brass mixer taps and stop valves.

The weighted average values in Figure 3 shows that the average zinc release was higher from installations with hot dip galvanised steel pipes. In installations with other pipe materials the zinc values are lower, and a larger fraction of the zinc is released to the first 200 ml. Figures 13 and 14 show that for an average of all installations the majority of the total zinc was released from the pipes (C-samples).

	As analysed				Net values	
	A Fully flushed [µg/l]	C 4 h stagnation [µg/l]	B 4 h stagnation [µg/l]	(C+ B) <sup>1</sup> 4 h stagnation [µg]	C 4 h stagnation [µg/l]	B 4 h stagnation [µg/l]
Average	35	279	730	376	244	694
Max	155	1271	3891	1468	1227	3856
Min	2.7	11	37	36	0 <sup>2</sup>	1.2

Note 1: Weighted average based on sample volumes. The total sample volume is approximately 1 litre.

Note 2: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

**Table 1.**

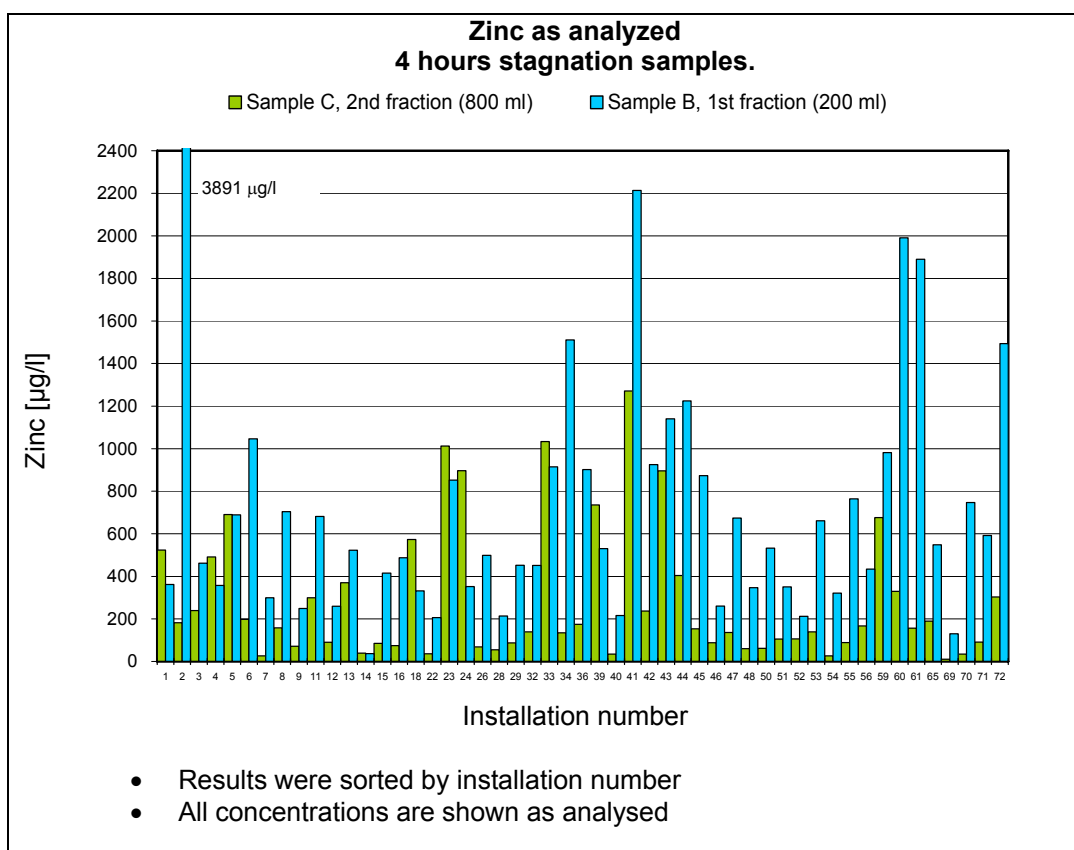


Figure 1.

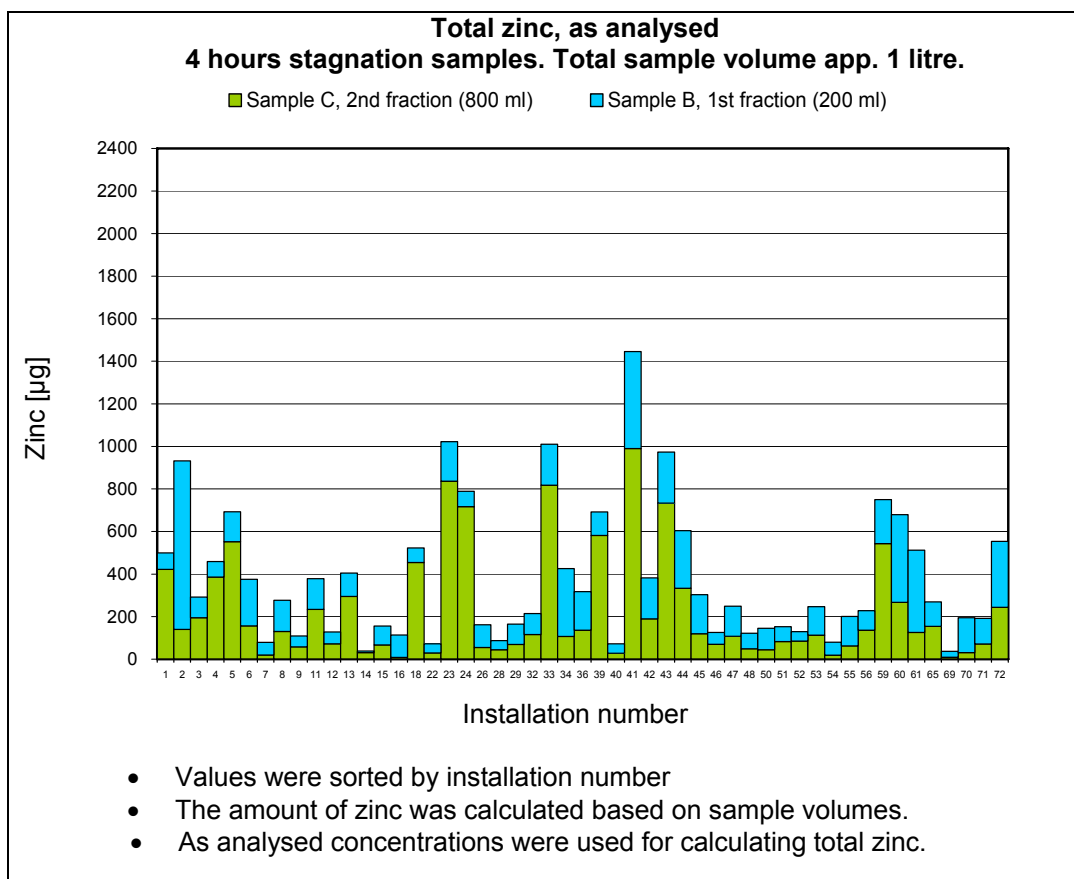
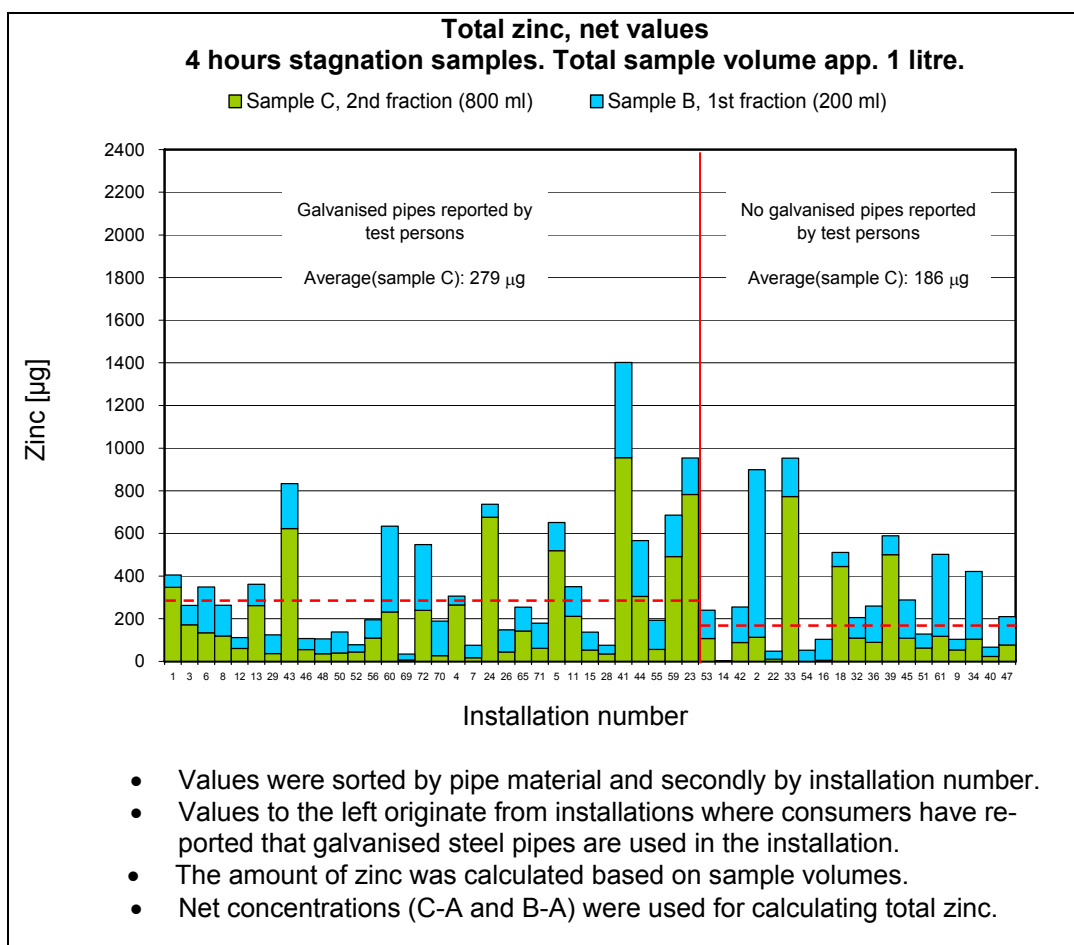


Figure 2.



**Figure 3.**

### ***Copper, Cu***

The Danish parametric value for copper is 2000 µg/l after 12 hours stagnation. In the DWD the same parametric value is set for weekly average. Previous investigations have shown that the parametric values may be exceeded in the high conductivity waters with high hydrogen carbonate contents. In many parts of Denmark copper pipes cannot be used in new drinking water installations for this reason. In practice copper pipes are rarely used for new installations in areas where copper release is high. Short, small diameter pipes are used for connecting pipes to mixer taps, as they contain only small water volumes.

Copper concentration was generally low in A-samples, and increasing in the B- and C-samples, see Table 2 and Figures 4 and 5. As expected, the highest copper values were observed in installations with copper pipes (Figure 6), where the copper pipes were the major copper contributors. In installations with other pipe materials, copper release was lower, and copper from the first 200 ml contained a larger fraction of the total copper in the water (mainly mixer tap, connecting pipes, stop valve). Figure 13 shows that as average for all installations 72 % of the total copper was released to the C-samples (pipes).

The maximum value of the C-samples was 2369 µg/l, and the maximum value of the B-samples was 2049 µg/l, both above the Danish parametric value for 12 hours stagnation despite the shorter stagnation time of 4 hours used in this investigation. The results confirm that the general recommendation should still be not to use copper pipes for new drinking water installations in the present water types.

	As analysed				Net values	
	<b>A</b>	<b>C</b>	<b>B</b>	<b>(C+ B)<sup>1</sup></b>	<b>C</b>	<b>B</b>
	Fully flushed [µg/l]	4 h stagnation [µg/l]	4 h stagnation [µg/l]	4 h stagnation [µg]	4 h stagnation [µg/l]	4 h stagnation [µg/l]
Average	24	325	464	359	301	440
Max	178	2369	2049	2202	2238	2006
Min	1.0	3.5	6.4	4.1	0 <sup>2</sup>	3.9

Note 1: Weighted average based on sample volumes. The total sample volume is approximately. 1 litre.

Note 2: Calculated net values showing negative values, e.g. due to precipitation, are reported 0.

**Table 2.**

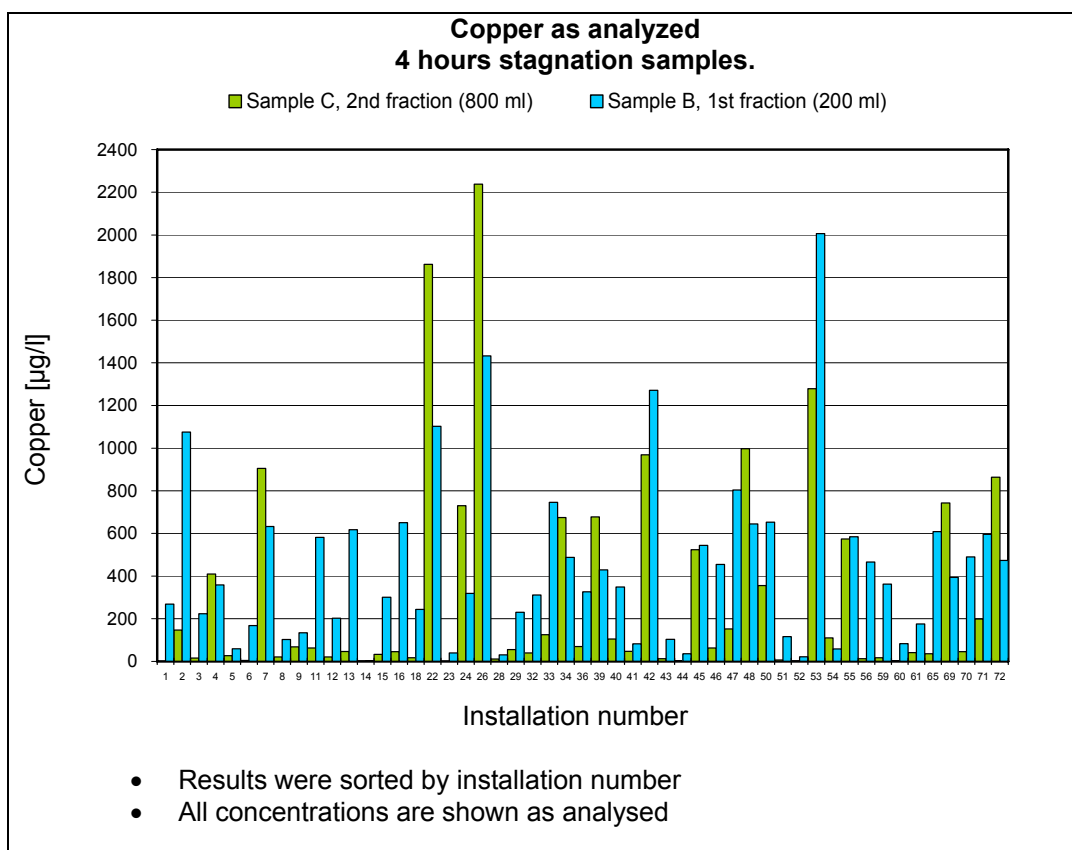


Figure 4.

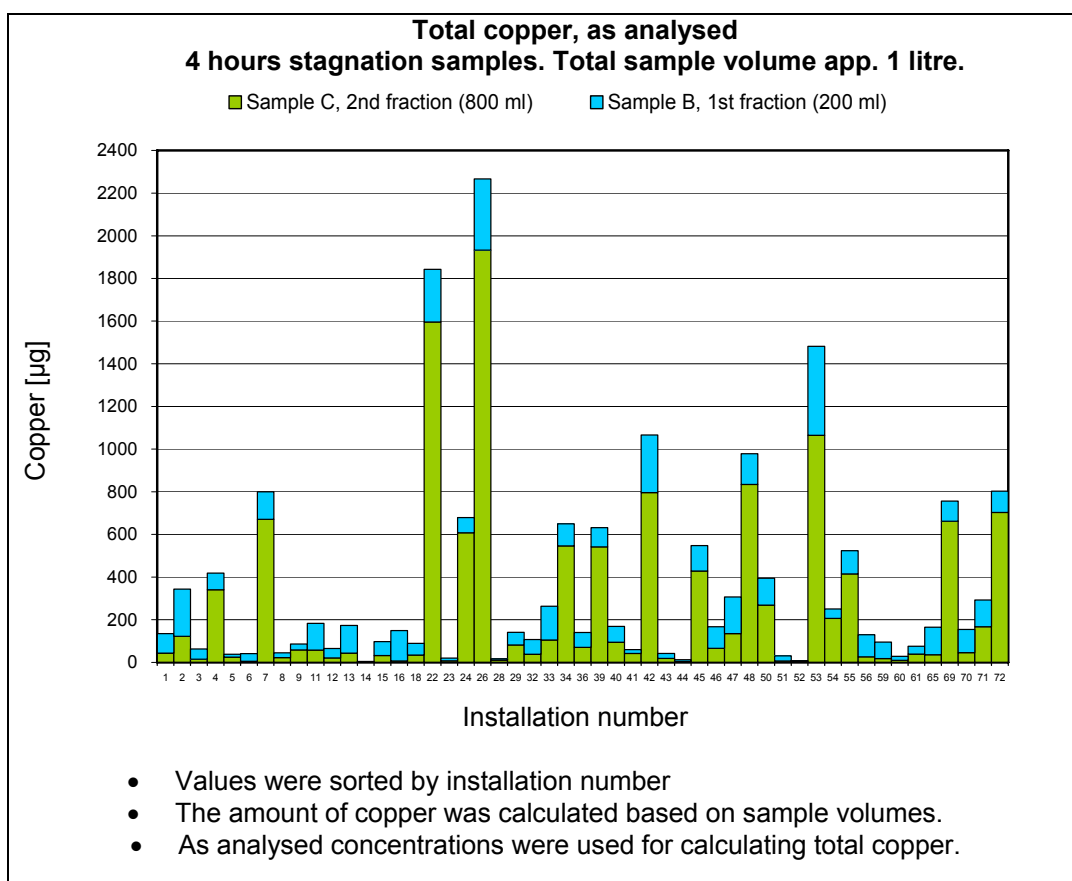
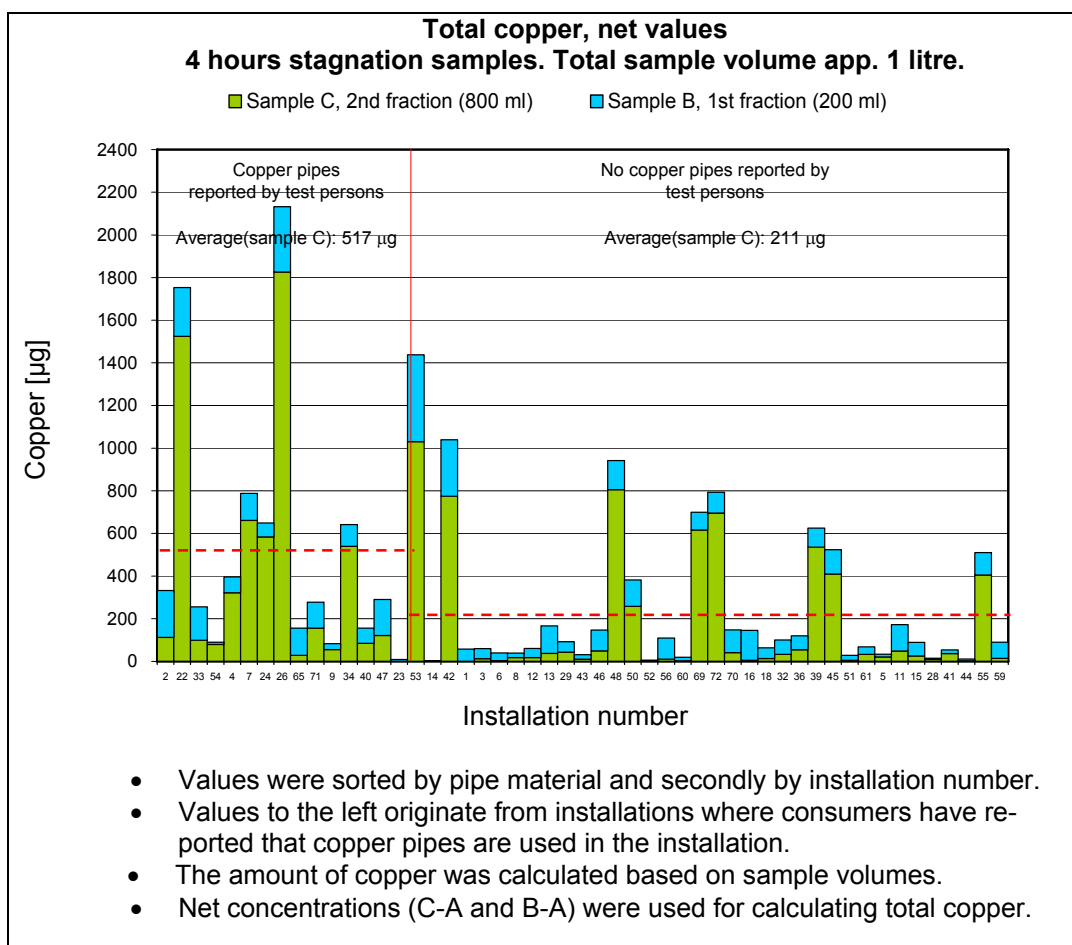


Figure 5.



**Figure 6.**

### Lead, Pb

In Denmark and in the DWD the parametric value for lead is 10 µg/l as weekly average.

In Denmark lead is primarily released to drinking water from the copper alloys brass and gunmetal, as they contain lead as an alloying element. Furthermore lead may be released from leaded solders in older installations (more than 30 years old) and from the zinc layer of older hot dip galvanised steel pipes. Today both the lead and cadmium contents of hot dip galvanised steel pipes' zinc layer are very low and the release of these metals from this material is negligible.

The A-samples had low lead contents, the maximum value being 2.6 µg/l. The C-samples also had low lead contents in most cases, and only 1 sample was above 10 µg/l. The lead contents of the B-samples were higher with 7 samples above 10 µg/l. The maximum lead content was 110 µg/l in a B-sample, Table 3.

Figure 7 shows the lead concentration in the various sample fractions, and indicates that the highest lead concentrations were found in the stagnation water from the mixer taps, though the difference in average lead concentration was not very large (table 3). In figure 8 the lead mass contributions from the different samples are presented. When compared to figure 7 this figure clearly illustrates that high lead concentration in the C-sample will add more lead to the water due to the high volume of the C-sample. The high lead content in the B-samples must be caused by lead release from the brass mixer taps and valves. The high lead release in some of the C-samples is more difficult to explain. Large valves of brass or gunmetal may be the source of lead, but the highest concentrations are higher than would be expected. Other sources could be old leaded solders.

	As analysed				Net values	
	A Fully flushed [µg/l]	C 4 h stagna- tion [µg/l]	B 4 h stagna- tion [µg/l]	(C+ B) <sup>1</sup> 4 h stagna- tion [µg]	C 4 h stagna- tion [µg/l]	B 4 h stagna- tion [µg/l]
Average	0.6	2.8	7.3	3.7	2.2	6.8
Max	2.6	37	110	32	36	109
Min	0.2	0.0	0.5	0.1	0 <sup>2</sup>	0 <sup>2</sup>

Note 1: Weighted average based on sample volumes. The total sample volume is approximately 1 litre.

Note 2: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

**Table 3.**

The average lead release was considerably higher in B—samples taken from installations where mixer taps were less than one year old, see Figure 9. Figure 13 shows that for all installations 44 % of the total lead was released to the B-samples (mixer tap and valve). For installations with mixer taps less than 2 years old, 60 % of the total lead was released to the B-samples. The high lead release from new brass product is known to be caused by smeared lead on the brass surfaces. Previous investigations have shown that the surface lead is usually dissolved during the first months of operation.

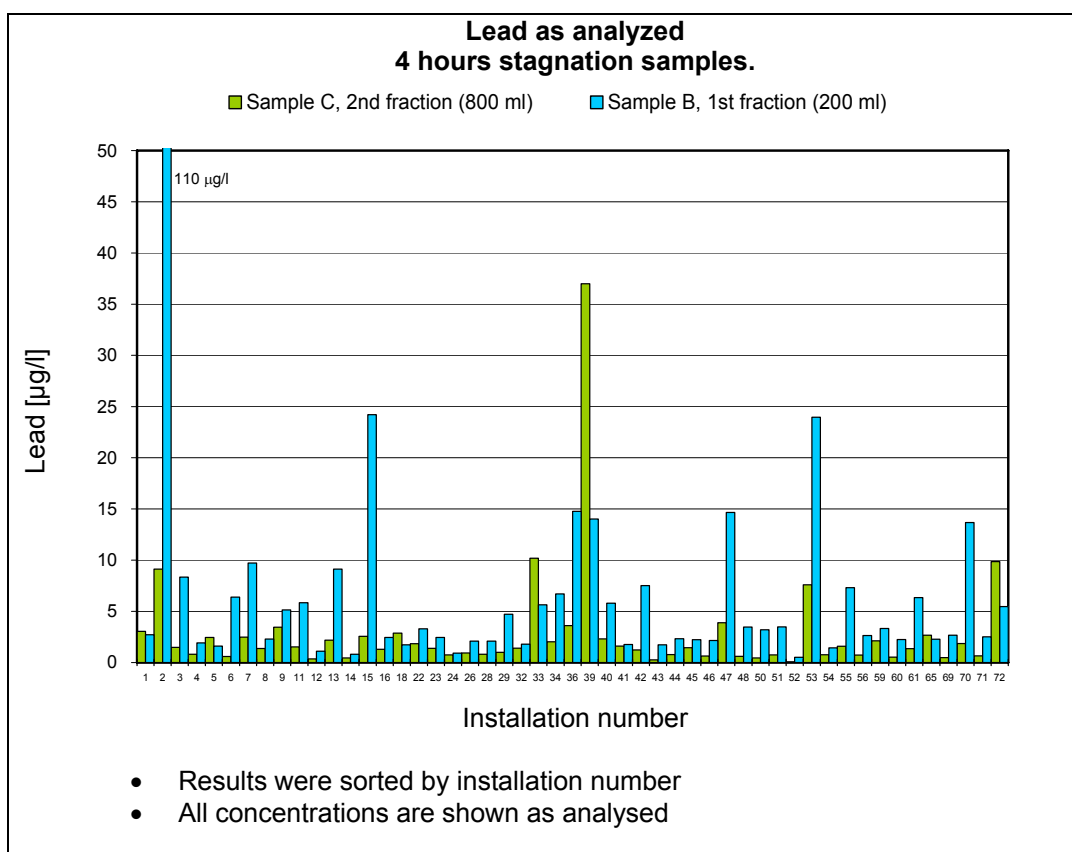


Figure 7.

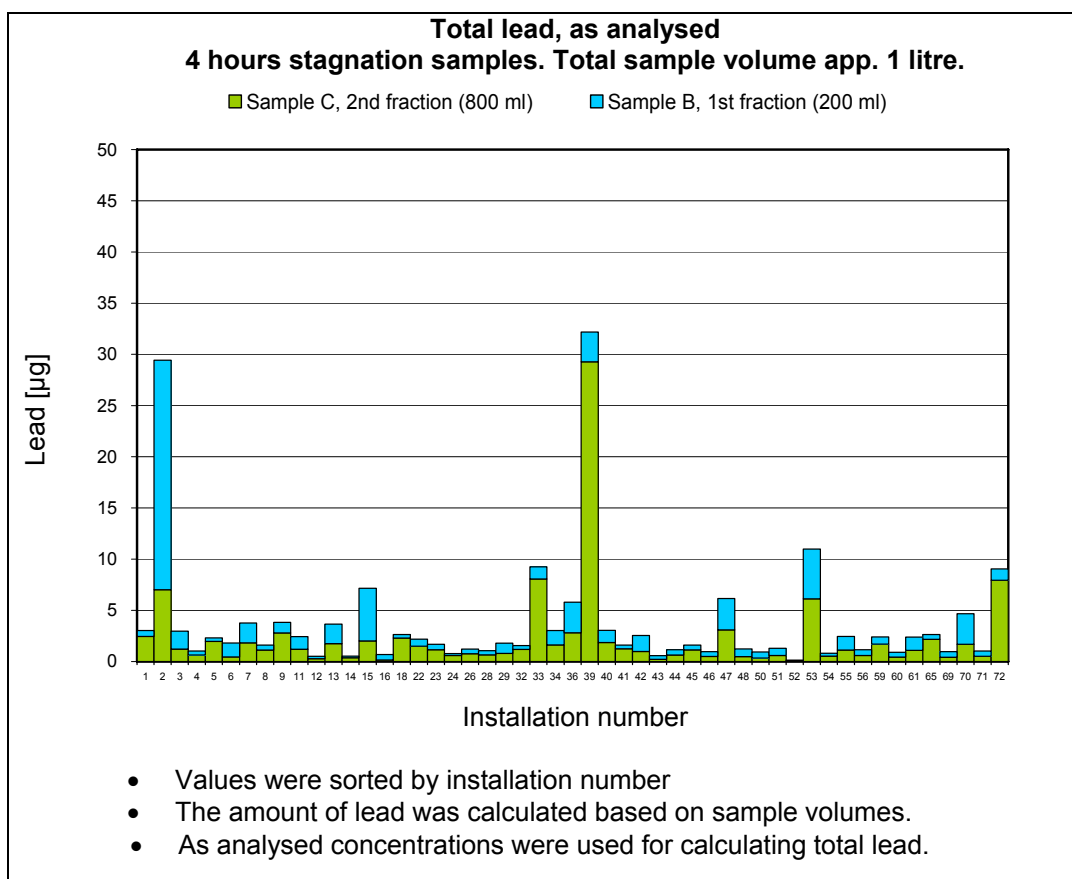
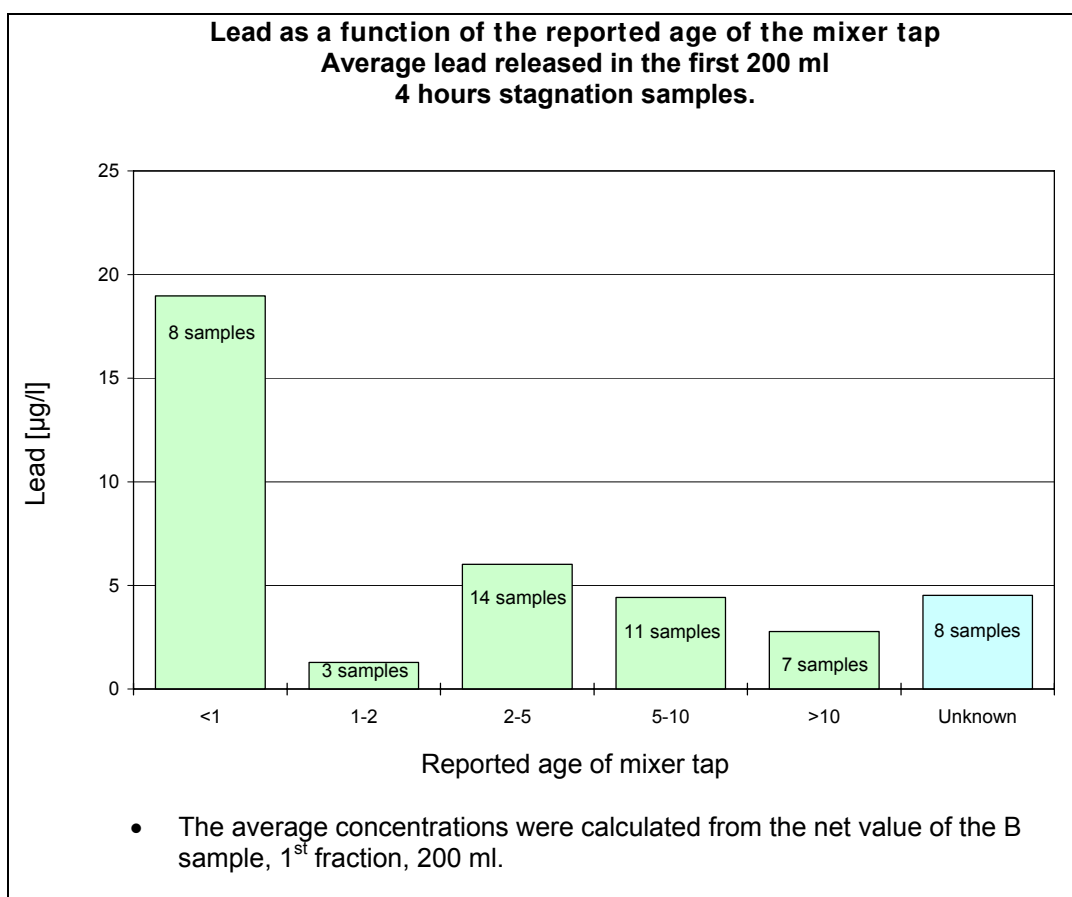


Figure 8.





**Figure 9.**

## Nickel, Ni

In Denmark and in the DWD the parametric value for nickel is 20 µg/l as weekly average.

Nickel is used in many parts of domestic water installations. Brasses contain nickel as a trace metal and in gunmetal nickel is an alloying element. Generally nickel release is low from modern brasses and gunmetal, as the nickel content is low in the copper alloys. Stainless steel types used in drinking water installations usually have nickel contents of 10-14%, but nickel is not released to the drinking water as stainless steel is passive, and no measurable metal dissolution will take place.

Brass components such as mixer taps and valves are normally nickel chromium plated on the outside for improved corrosion and wear resistance and for improved appearance. However the inside of the components will also get nickel plated near the apertures, and this nickel may be released to the water during the components' service life. Previous investigations have shown that nickel release may be very high for new faucets, and that nickel release may continue to be relatively high for years [ref. 1].

Furthermore water from some waterworks has high nickel concentrations, and in some cases it must be precipitated at the waterworks in order to meet the parametric value of 20 µg/l.

The nickel concentration was generally low in the A-samples, but in 7 cases it was above 5 µg/l and in 2 cases even above 20 µg/l. The nickel concentration did generally not increase much in the C-samples, but in 4 cases the concentrations were above 20 µg/l; the maximum value being 27 µg/l. The average concentration of A-samples was 3.5 µg/l and of the C-samples was 4.9 µg/l, Table 4 and Figure 10.

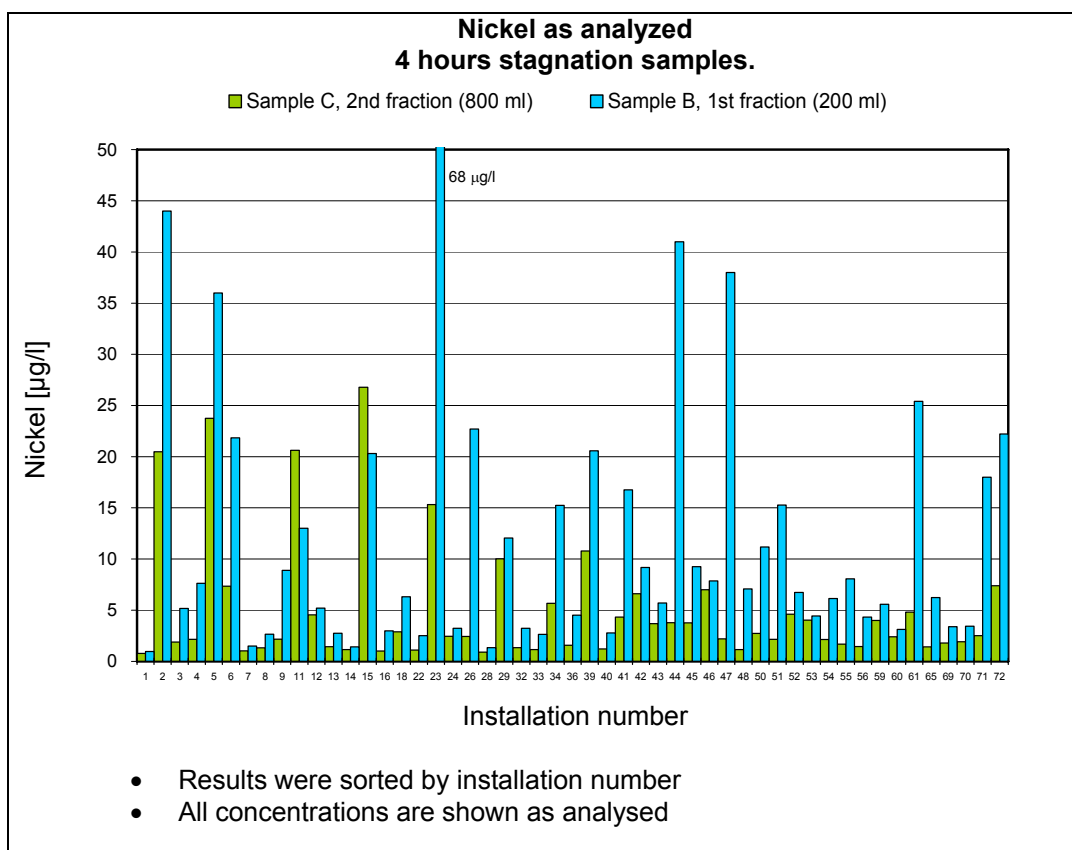
	As analysed				Net values	
	A Fully flushed [µg/l]	C 4 h stagnation [µg/l]	B 4 h stagnation [µg/l]	(C+B) <sup>1</sup> 4 h stagnation [µg]	C 4 h stagnation [µg/l]	B 4 h stagnation [µg/l]
Average	3.5	4.9	12.1	6.4	1.5	8.6
Max	27	27	68	26	17.4	61
Min	0.6	0.8	1.0	0.8	0 <sup>2</sup>	0 <sup>2</sup>

Note 1: Weighted average based on sample volumes. The total sample volume is approximately. 1 litre.

Note 2: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

**Table 4.**

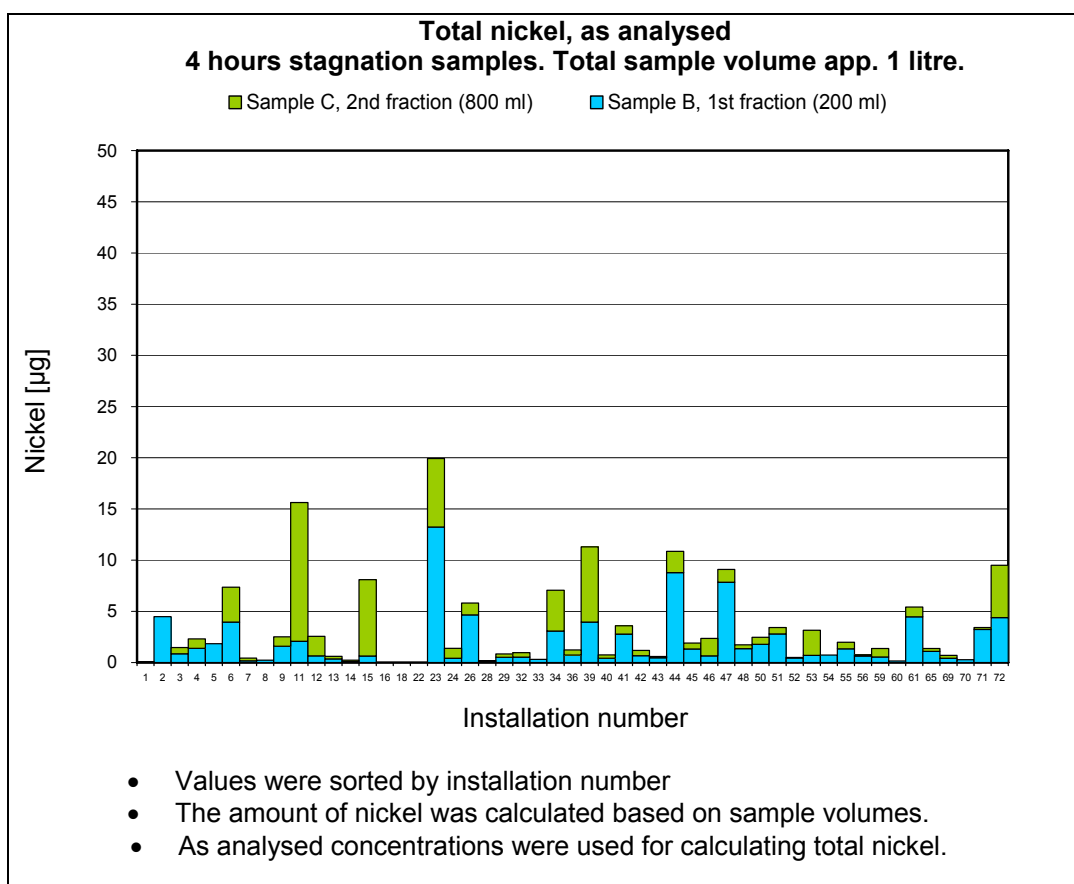
The B-samples had the highest nickel concentration. 11 of the B-samples were above 20 µg/l, the average was 12.1 and the maximum value was 68 µg/l. Figures 11, 13 and 14 show the total nickel contribution of the 2 different stagnation samples. It is observed that though the B-sample only has a volume of 200 ml it contributes with a large fraction of the total nickel released in the installations. In most cases the first 200 ml contains more than half of the nickel released in the installation. For all installations the average fraction of the total nickel released to the B-samples was 61 %, Figure 13. For installations where mixer taps were less than 2 years old the B-samples contained 72 % of the total nickel released in the installations, Figure 14. This confirms that the majority of the nickel released to the water often originates from mixer taps and nickel plated brass valves.



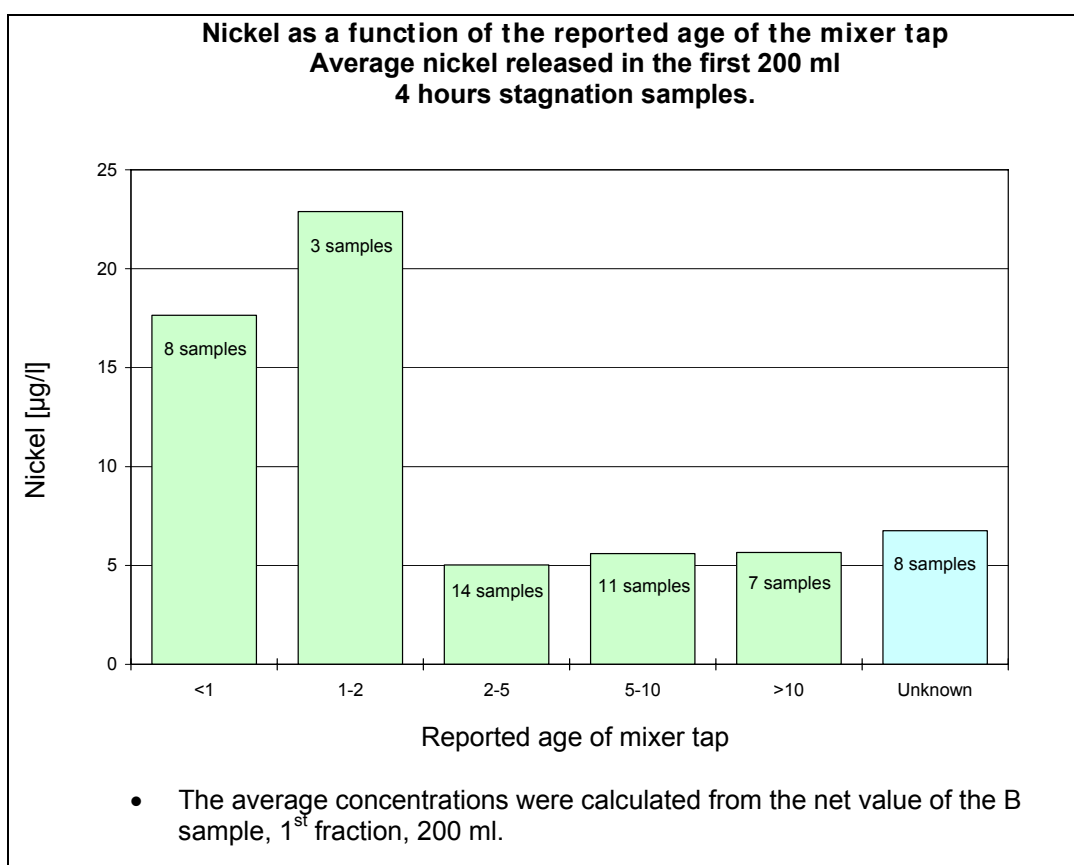
**Figure 10.**

Figure 12 shows nickel release as a function of the reported age of the mixer tap. As a lot of other parameters change from one installation to another, the picture was not very clear, but still some general remarks may be made. It may be observed that nickel release was higher from the mixer taps for the first 1-2 years after which it declined to a lower level. Even for mixer taps older than 10 years some nickel release was observed, the average level being around 5 µg/l. When compared to previous investigations, the nickel concentrations measured were rather low in the first 200 ml. In previous investigations overnight stagnation has been used mostly, meaning that stagnation times were in the range of 8-16 hours. As the nickel release rate is normally constant up to at least 16 hours, this means that the net concentrations should be multiplied by 2-4 for comparison with these data. Still the current figures are relatively low when compared to previous investigations where values of about 200 µg/l were measured from mixer taps after 1 year, and about 50 µg/l for mixer taps of the same make after 5-7 years [ref. 1 and references herein].

The measured concentrations cannot be compared to the parametric value of 20 µg/l as weekly average. It has not proved possible to determine or calculate a conversion factor between stagnation samples and weekly average. However it is clear, that where A-samples were above 10 µg/l, there was not much room left for nickel release in the installation. Among other factors, the weekly average will depend on the consumer's habits and the number of people living in the house or apartment. For discussion of methods for measuring weekly average see reference 2.

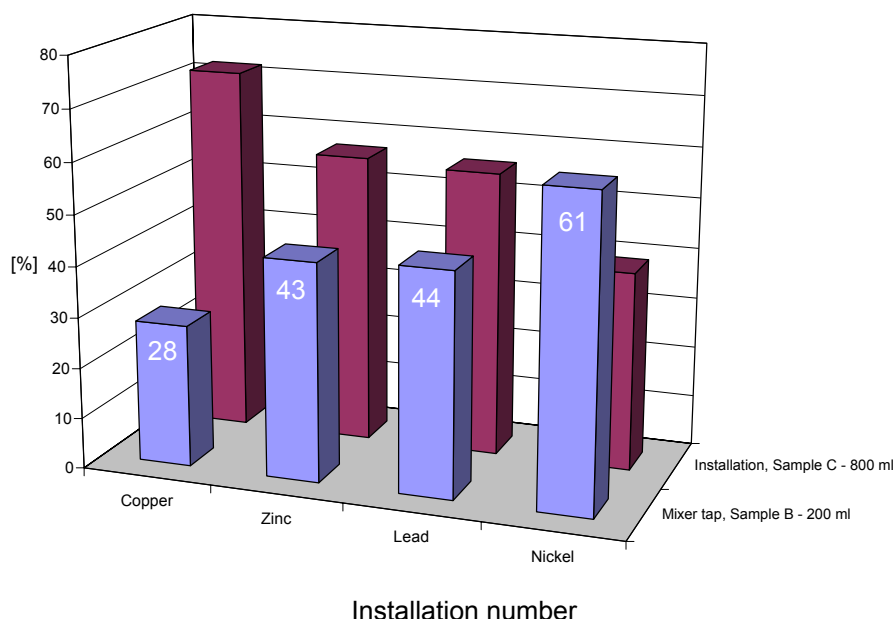


**Figure 11.**



**Figure 12.**

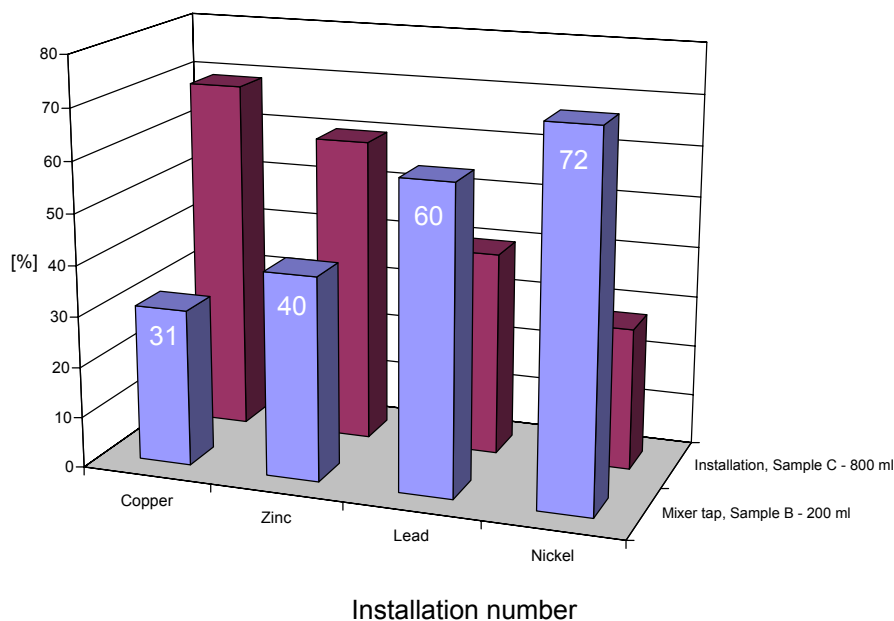
**Relative distribution of metal release in the installations  
Calculated for a 1 litre sample taken after 4 hours stagnation.**



- Distribution was calculated from average net values from all installations (51 installations). For example the average net mass of nickel in the B- and C-samples was  $1.8 \mu\text{g}$  and  $1.2 \mu\text{g}$ . Thus 61% of the total nickel released to the first litre taken after 4 hours stagnation was released from materials in contact with the first 200 ml water in the installation (e.g. mixer tap, connecting pipe and stop valve).

**Figure 13.**

**Relative distribution of metal release in the installations  
Calculated for a 1 litre sample taken after 4 hours stagnation.**



- Distribution was calculated from average net values from installations having mixer taps that are less than two years old (11 installations).

**Figure 14.**

## Summary and Conclusions

Metal release was measured in 51 domestic drinking water installations on Zealand, Denmark. Water samples were taken by fractioned sampling, taking a fully flushed sample (A-sample) and two 4-hour stagnation samples of 200 ml (B-sample) and 800 ml (C-sample) respectively. The three samples were chosen in order to represent water from mains, first part of installation (mixer taps, connecting pipe, stop valve) and remaining part of installation (pipes, manifolds, water meter, valves).

All water samples were analysed for the 9 metals arsenic, cadmium, antimony, tin, chromium, copper, zinc, lead and nickel.

The concentrations of arsenic, cadmium, antimony, tin and chromium were all very low and generally no increase was observed upon stagnation in the domestic installations.

The concentration of zinc was generally low in the fully flushed samples as expected. Zinc concentrations up to 3891  $\mu\text{g/l}$  were found in the B-samples and up to 1271  $\mu\text{g/l}$  in the C-samples. In installations with hot dip galvanised steel pipes, the major part of the zinc was released from the pipes. In installations with other pipe materials a larger fraction of the zinc was released from the brass in the mixer tap and the first part of the installation. Hot dip galvanised steel pipes are generally not recommended in water types with high hydrogen carbonate content due to high risk of corrosion and high zinc release.

The copper concentration was low in the fully flushed samples and increasing in the B- and C-samples. The total amount of copper released was highest in installations with copper pipes, where the C-samples contributed with the highest copper amounts. In installations with other pipe materials, the first part of the installation released a higher fraction of the total copper. As average for all installations 72 % of the total copper was released to the C-samples (pipes). The maximum concentrations measured were 2369  $\mu\text{g/l}$  in a C-sample and 2049  $\mu\text{g/l}$  in a B-sample, which are both higher than the Danish parametric value of 2000  $\mu\text{g/l}$  after 12 hours stagnation, despite the lower stagnation time used in this investigation. The results confirm that copper pipes should not be used for new installations in the high conductivity waters with high hydrogen carbonate content, which has been the general recommendation for some 10 years.

The lead concentration was low in the A-samples, and generally increasing in the B- and C-samples. The maximum concentration found was 110  $\mu\text{g/l}$  in a B-sample. The average lead concentrations were 2.8  $\mu\text{g/l}$  in the C-samples and 7.3  $\mu\text{g/l}$  in the B-samples. Sources of lead in domestic water installations are copper alloys brass and gunmetal, and in older installations leaded solders may also contribute. The measured concentrations cannot be compared with the parametric value of 10  $\mu\text{g/l}$  as weekly average.

The average lead release was considerably higher in B-samples taken from installations where mixer taps were less than one year old. As average for all installations 44 % of the total lead was released to the B-samples (mixer tap and stop valve). For installations with mixer taps less than 2 years old, 60 % of the total lead was released to the B-samples. The high lead release from new brass product is known to be caused by smeared lead on the brass surfaces. Previous investigations have shown that the surface lead is usually dissolved during the first months of operation.

The nickel concentration was low in most of the A-samples, but in 7 cases it was above 5 µg/l and in 2 cases even above 20 µg/l, which is the parametric value for weekly average. In general, the nickel concentration did not increase much in the C-samples, but in 4 cases the concentrations were above 20 µg/l. The average concentration for A-samples was 3.5 µg/l and for the C-samples it was 4.9 µg/l.

The B-samples had the highest nickel concentration with 11 of the B-samples being above 20 µg/l. The average concentration was 12.1 µg/l and the maximum value was 68 µg/l. In most cases the first 200 ml (B-samples) contained more than half of the nickel released in the installation. For all installations the average fraction of the total nickel released to the B-samples was 61 %. For installations where mixer taps were less than 2 years old the B-samples contained 72 % of the total nickel released in the installations. This confirms that the majority of the total nickel released to the water originated from nickel chromium plated mixer taps and valves of nickel plated brass.

The average nickel release was higher from mixer taps less than 2 years old after which it declined to a lower level.

The measured nickel concentrations cannot be compared to the parametric value of 20 µg/l as weekly average. The weekly average will depend on consumers' habits and many other parameters. However it is clear, that where A-samples were above 10 µg/l, not much room was left for nickel release in the installation.

List of references:

1. Fontenay, F. and A. Andersen, "Metal release to drinking water – an overview of Danish and European regulation and investigations", Danish Enterprise and Construction Authority, 14. April 2008 – and references herein.
2. Corfitzen, C.B. and H. J. Albrechtsen, Sampling for drinking water quality in installations, Validation of Method, June 2008



Appendix 1  
Test results

Appendix 2  
Installations. Pipe materials and age of mixer taps

Appendix 3  
Chemical analysis method and precision.

Appendix 4  
Sampling instructions for test persons (in Danish).

Appendix 5  
Questionnaire for test persons (in Danish).

## **Appendix 1. Results**

- 1.1     Copper**
- 1.2     Zinc**
- 1.3     Nickel**
- 1.4     Lead**
- 1.5     Arsenic**
- 1.6     Cadmium**
- 1.7     Antimony**
- 1.8     Chromium**
- 1.9     Tin**

## Appendix 1.1 Copper

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours Stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	160	54	429	133	0 <sup>(4)</sup>	269
2	12	159	1088	354	147	1076
3	3.0	18	226	61	15	223
4	23	433	381	422	410	358
5	4.6	31	63	38	27	59
6	1.8	6.5	170	41	4.7	168
7	13	918	646	860	905	632
8	6.4	28	109	44	21	102
9	3.2	72	137	85	68	134
11	11	73	592	184	63	582
12	4.6	26	208	64	21	203
13	6.8	54	624	172	47	617
14	2.5	3.5	6.4	4.1	1.0	3.9
15	7.5	40	309	97	33	301
16	12	58	663	446	46	651
18	26	43	270	89	17	244
22	87	1949	1189	1795	1862	1102
23	17	9.2	56	19	0 <sup>(4)</sup>	39
24	30	760	349	676	730	319
26	131	2369	1564	2202	2238	1433
28	2.3	13	33	17	11	30
29	48	103	278	140	55	230
32	6.4	46	317	102	39	311
33	7.8	133	754	263	125	746
34	7.8	682	496	643	675	488
36	21	90	347	143	69	326
39	7.1	684	436	633	677	429
40	12	117	361	167	105	349
41	6.0	53	88	60	47	82
42	26	995	1298	1057	968	1272
43	9.7	22	113	40	12	103
44	1.0	4.9	37	12	3.9	36
45	23	547	568	552	524	544
46	20	83	476	166	62	455
47	17	169	821	305	152	804
48	36	1034	680	961	998	644
50	14	370	667	432	356	653
51	1.6	8.3	118	31	6.7	116
52	1.8	3.6	23	7.6	1.8	21
53	43	1322	2049	1469	1279	2006
54	178	289	236	277	111	58
55	15	589	599	591	574	584
56	20	32	486	126	12	466
59	4.7	22	367	94	17	363
60	8.6	12	92	28	3.2	83
61	6.9 (12) <sup>(5)</sup>	47 (43) <sup>(5)</sup>	182 (203) <sup>(5)</sup>	75 (76) <sup>(5)</sup>	41 (31) <sup>(5)</sup>	175 (190) <sup>(5)</sup>
65	8.9	44	617	162	35	608
69	55	798	449	727	743	394
70	5.5	51	495	138	45	490
71	14 (23) <sup>(5)</sup>	213 (354) <sup>(5)</sup>	610 (640) <sup>(5)</sup>	295 (414) <sup>(5)</sup>	199 (331) <sup>(5)</sup>	596 (617) <sup>(5)</sup>
72	9.2	873	482	793	864	473

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.2 Zinc

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	93	524	362	490	431	269
2	35	182	3891	960	147	3856
3	29	239	462	285	210	433
4	155	492	358	464	337	203
5	41	690	689	690	649	648
6	27	198	1046	377	171	1019
7	3.8	27	299	85	23	295
8	13	158	704	268	145	692
9	6.0	72	249	108	66	243
11	29	299	682	381	270	653
12	16	90	259	125	74	244
13	42	370	524	402	327	481
14	36	39	37	39	3.4	1.2
15	18	85	415	155	67	397
16	31	75	488	340	44	456
18	12	573	332	524	561	320
22	24	36	206	71	13	182
23	65	1012	853	979	947	788
24	52	897	353	786	845	301
26	14	68	499	157	54	485
28	12	55	213	87	44	202
29	41	87	452	164	46	411
32	8.4	140	451	204	131	443
33	56	1033	915	1008	977	859
34	3.9	134	1511	421	130	1507
36	60	174	902	324	115	842
39	103	735	531	693	632	428
40	5.4	35	216	72	29	210
41	44	1271	2213	1468	1227	2169
42	126	237	925	379	111	799
43	135	896	1140	946	760	1005
44	36	404	1224	577	368	1188
45	15	153	873	306	138	858
46	19	88	260	125	69	241
47	39	136	675	248	97	636
48	16	60	347	120	44	330
50	7.8	62	533	159	54	525
51	26	106	350	155	80	324
52	51	106	212	128	55	161
53	7.1	140	661	245	132	654
54	46	26	321	88	0 <sup>(4)</sup>	275
55	9.1	89	764	227	79	755
56	32	167	434	222	135	402
59	64	677	981	740	613	918
60	44	329	1991	666	285	1947
61	10 (29) <sup>(5)</sup>	156 (165) <sup>(5)</sup>	1890 (1321) <sup>(5)</sup>	507 (401) <sup>(5)</sup>	146 (136) <sup>(5)</sup>	1880 (1292) <sup>(5)</sup>
65	14	190	549	264	176	534
69	2.7	11	130	35	8.3	128
70	4.7	35	747	174	30	742
71	13 (22) <sup>(5)</sup>	91 (1037) <sup>(5)</sup>	592 (523) <sup>(5)</sup>	194 (929) <sup>(5)</sup>	78 (1015) <sup>(5)</sup>	579 (501) <sup>(5)</sup>
72	5.4	303	1494	547	297	1489

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.3 Nickel

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours Stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours Stagnation [µg/l]
1	0.7	0.8	1.0	0.8	< 0.5	< 0.5
2	22	20	44	25	0 <sup>(4)</sup>	22
3	1.1	1.9	5.2	2.6	0.8	4.0
4	1.0	2.2	7.6	3.3	1.2	6.7
5	27	24	36	26	0 <sup>(4)</sup>	9.0
6	3.0	7.3	22	10	4.3	19
7	0.7	1.0	1.5	1.1	< 0.5	0.8
8	1.5	1.3	2.6	1.6	0 <sup>(4)</sup>	1.1
9	1.0	2.2	8.9	3.5	1.1	7.9
11	3.3	21	13	19	17	9.7
12	2.2	4.5	5.2	4.7	2.4	3.1
13	1.1	1.4	2.7	1.7	< 0.5	1.6
14	1.0	1.1	1.4	1.2	< 0.5	< 0.5
15	17	27	20	25	9.5	3.0
16	3.4	1.0	3.0	2.3	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	7.8	2.9	6.3	3.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
22	4.1	1.1	2.5	1.4	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	7.2	15	68	26	8.1	61
24	1.2	2.5	3.2	2.6	1.2	2.0
26	1.0	2.4	23	6.6	1.4	22
28	0.8	0.9	1.3	1.0	< 0.5	0.5
29	9.6	10	12	10	< 0.5	2.4
32	0.8	1.3	3.2	1.7	0.5	2.4
33	1.2	1.2	2.6	1.5	0 <sup>(4)</sup>	1.4
34	0.7	5.7	15	7.7	5.0	15
36	0.9	1.6	4.5	2.2	0.6	3.6
39	1.5	11	21	13	9.3	19
40	0.8	1.2	2.8	1.5	< 0.5	2.0
41	3.3	4.3	17	6.9	1.0	13
42	6.0	6.6	9.2	7.1	0.6	3.2
43	3.5	3.7	5.7	4.1	< 0.5	2.2
44	1.3	3.8	41	12	2.5	40
45	3.0	3.8	9.3	4.9	0.8	6.2
46	4.8	7.0	7.9	7.2	2.2	3.0
47	0.6	2.2	38	9.7	1.6	37
48	0.7	1.2	7.1	2.4	< 0.5	6.4
50	1.8	2.7	11	4.5	0.9	9.4
51	1.3	2.1	15	4.8	0.8	14
52	4.5	4.6	6.7	5.0	< 0.5	2.2
53	1.0	4.0	4.4	4.1	3.0	3.5
54	2.3	2.1	6.1	3.0	0 <sup>(4)</sup>	3.8
55	0.7	1.7	8.1	3.0	0.9	7.3
56	1.3	1.5	4.3	2.1	< 0.5	3.0
59	3.0	4.0	5.6	4.3	1.0	2.6
60	2.4	2.4	3.1	2.6	< 0.5	0.7
61	3.6 (3.6) <sup>(5)</sup>	4.8 (97) <sup>(5)</sup>	25 (13) <sup>(5)</sup>	9.0 (80) <sup>(5)</sup>	1.2 (93) <sup>(5)</sup>	22 (8.9) <sup>(5)</sup>
65	1.1	1.4	6.2	2.4	< 0.5	5.2
69	1.4	1.8	3.4	2.1	< 0.5	1.9
70	2.2	1.9	3.4	2.2	0 <sup>(4)</sup>	1.3
71	2.3 (1.2) <sup>(5)</sup>	2.5 (5.4) <sup>(5)</sup>	18 (13) <sup>(5)</sup>	5.7 (7.1) <sup>(5)</sup>	< 0.5 (4.3) <sup>(5)</sup>	16 (12) <sup>(5)</sup>
72	1.0	7.4	22	10	6.4	21

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.4 Lead

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours Stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	0.5	3.0	2.7	3.0	2.5	2.2
2	0.9	9.1	110	30	8.2	109
3	<0.5	1.5	8.3	2.9	1.2	8.1
4	<0.5	0.8	1.9	1.0	<0.5	1.5
5	<0.5	2.5	1.6	2.3	2.2	1.3
6	<0.5	0.6	6.4	1.8	<0.5	6.2
7	<0.5	2.5	9.7	4.0	2.2	9.5
8	<0.5	1.4	2.3	1.6	1.1	2.0
9	<0.5	3.4	5.1	3.8	3.1	4.8
11	<0.5	1.5	5.8	2.4	1.2	5.5
12	<0.5	<0.5	1.1	0.5	<0.5	0.9
13	<0.5	2.2	9.1	3.6	1.7	8.7
14	<0.5	<0.5	0.8	0.5	<0.5	0.6
15	0.9	2.6	24	7.1	1.6	23
16	2.6	1.3	2.5	2.0	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	1.1	2.9	1.7	2.6	1.8	0.6
22	1.6	1.8	3.3	2.1	<0.5	1.7
23	2.1	1.4	2.4	1.6	0 <sup>(4)</sup>	<0.5
24	<0.5	0.7	0.9	0.8	<0.5	0.7
26	<0.5	0.9	2.1	1.2	<0.5	1.6
28	<0.5	0.8	2.1	1.1	<0.5	1.7
29	0.6	1.0	4.7	1.8	<0.5	4.1
32	<0.5	1.4	1.8	1.5	1.3	1.6
33	0.9	10	5.6	9.2	9.3	4.7
34	<0.5	2.0	6.7	3.0	1.8	6.5
36	1.2	3.6	15	5.9	2.4	14
39	1.2	37	14	32	36	13
40	0.5	2.3	5.8	3.0	1.8	5.3
41	<0.5	1.6	1.8	1.6	1.4	1.6
42	0.5	1.2	7.5	2.5	0.7	7.0
43	<0.5	<0.5	1.7	0.6	<0.5	1.5
44	0.6	0.8	2.3	1.1	<0.5	1.7
45	<0.5	1.5	2.2	1.6	1.3	2.0
46	<0.5	0.6	2.2	1.0	<0.5	1.8
47	0.7	3.9	15	6.1	3.2	14
48	<0.5	0.6	3.5	1.2	<0.5	3.2
50	<0.5	<0.5	3.2	1.0	<0.5	2.9
51	<0.5	0.7	3.5	1.3	<0.5	3.2
52	2.5	<0.5	0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
53	0.7	7.6	24	11	6.9	23
54	<0.5	0.8	1.4	0.9	<0.5	0.9
55	<0.5	1.6	7.3	2.8	1.3	7.0
56	<0.5	0.7	2.6	1.1	<0.5	2.3
59	1.2	2.1	3.3	2.4	0.9	2.1
60	<0.5	0.5	2.2	0.9	<0.5	1.8
61	<0.5 (0.6) <sup>(5)</sup>	1.4 (1.6) <sup>(5)</sup>	6.3 (7.6) <sup>(5)</sup>	2.4 (2.9) <sup>(5)</sup>	1.0 (1.1) <sup>(5)</sup>	6.0 (7.0) <sup>(5)</sup>
65	<0.5	2.7	2.3	2.6	2.3	1.9
69	<0.5	<0.5	2.7	0.9	<0.5	2.5
70	<0.5	1.9	14	4.2	1.4	13
71	<0.5 (2.4) <sup>(5)</sup>	0.7 (110) <sup>(5)</sup>	2.5 (4.1) <sup>(5)</sup>	1.0 (88) <sup>(5)</sup>	<0.5 (108) <sup>(5)</sup>	2.2 (1.7) <sup>(5)</sup>
72	<0.5	9.8	5.5	8.9	9.4	5.0

1: All values below 0.5 µg/l are shown as <0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.5 Arsenic

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	0.6	0.8	1.0	0.9	< 0.5	< 0.5
2	0.8	0.8	0.7	0.7	0 <sup>(4)</sup>	0 <sup>(4)</sup>
3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
4	1.0	0.8	1.3	0.9	0 <sup>(4)</sup>	< 0.5
5	2.0	2.0	1.6	1.9	0 <sup>(4)</sup>	0 <sup>(4)</sup>
6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
7	< 0.5	0.5	0.8	0.6	< 0.5	< 0.5
8	< 0.5	< 0.5	0.5	< 0.5	< 0.5	< 0.5
9	< 0.5	< 0.5	0.6	< 0.5	< 0.5	< 0.5
11	< 0.5	0.5	1.0	0.6	< 0.5	0.7
12	< 0.5	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	< 0.5
13	< 0.5	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>	< 0.5
14	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
15	< 0.5	0.6	0.8	0.6	< 0.5	< 0.5
16	< 0.5	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	< 0.5
18	2.7	0.6	0.8	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
22	0.8	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	1.1	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
24	0.5	< 0.5	0.7	0.5	0 <sup>(4)</sup>	< 0.5
26	< 0.5	< 0.5	0.6	< 0.5	< 0.5	< 0.5
28	< 0.5	0.5	0.6	0.6	< 0.5	< 0.5
29	0.7	0.6	1.0	0.6	0 <sup>(4)</sup>	< 0.5
32	< 0.5	< 0.5	0.8	0.5	< 0.5	0.6
33	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
34	1.0	1.1	1.3	1.2	< 0.5	< 0.5
36	< 0.5	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>	< 0.5
39	< 0.5	0.5	1.0	0.6	< 0.5	0.5
40	< 0.5	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>	< 0.5
41	< 0.5	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>	< 0.5
42	0.5	< 0.5	0.8	< 0.5	0 <sup>(4)</sup>	< 0.5
43	< 0.5	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>	< 0.5
44	< 0.5	< 0.5	0.9	< 0.5	0 <sup>(4)</sup>	< 0.5
45	< 0.5	< 0.5	0.9	< 0.5	0 <sup>(4)</sup>	0.6
46	0.6	< 0.5	1.7	< 0.5	0 <sup>(4)</sup>	1.1
47	< 0.5	< 0.5	1.1	< 0.5	0 <sup>(4)</sup>	0.9
48	0.5	< 0.5	0.8	< 0.5	0 <sup>(4)</sup>	< 0.5
50	0.8	< 0.5	0.8	< 0.5	0 <sup>(4)</sup>	< 0.5
51	0.5	< 0.5	1.1	< 0.5	0 <sup>(4)</sup>	0.6
52	0.7	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
53	< 0.5	< 0.5	0.7	< 0.5	< 0.5	< 0.5
54	1.7	1.7	1.7	1.7	0 <sup>(4)</sup>	0 <sup>(4)</sup>
55	0.5	0.6	0.8	0.6	< 0.5	< 0.5
56	0.5	0.6	0.6	0.6	< 0.5	< 0.5
59	0.8	0.7	0.7	0.7	0 <sup>(4)</sup>	0 <sup>(4)</sup>
60	0.7	0.5	0.8	0.6	0 <sup>(4)</sup>	< 0.5
61	0.6 (0.8) <sup>(5)</sup>	0.7 (0.9) <sup>(5)</sup>	0.7 (1.0) <sup>(5)</sup>	0.7 (0.9) <sup>(5)</sup>	< 0.5 (< 0.5) <sup>(5)</sup>	< 0.5 (< 0.5) <sup>(5)</sup>
65	1.1	0.9	1.6	1.1	0 <sup>(4)</sup>	< 0.5
69	< 0.5	< 0.5	0.7	0.5	0 <sup>(4)</sup>	< 0.5
70	0.5	0.6	0.8	0.6	< 0.5	< 0.5
71	< 0.5 (< 0.5) <sup>(5)</sup>	< 0.5 (0.7) <sup>(5)</sup>	< 0.5 (0.5) <sup>(5)</sup>	< 0.5 (0.6) <sup>(5)</sup>	< 0.5 (< 0.5) <sup>(5)</sup>	< 0.5 (< 0.5) <sup>(5)</sup>
72	< 0.5	0.9	0.6	0.8	< 0.5	< 0.5

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.6 Cadmium

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
3	<0.5	0.5	<0.5	<0.5	<0.5	<0.5
4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
11	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
12	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
13	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
15	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
16	0.7	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
22	0.8	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	0.9	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
24	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
26	<0.5	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>
28	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
29	<0.5	<0.5	0.9	<0.5	<0.5	0.6
32	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
33	0.9	1.8	1.1	1.7	0.9	<0.5
34	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
36	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
39	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
40	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
41	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
42	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
43	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
44	<0.5	<0.5	0.6	<0.5	0 <sup>(4)</sup>	<0.5
45	<0.5	<0.5	0.5	<0.5	0 <sup>(4)</sup>	<0.5
46	<0.5	<0.5	0.6	<0.5	0 <sup>(4)</sup>	<0.5
47	<0.5	<0.5	0.8	<0.5	0 <sup>(4)</sup>	0.7
48	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
50	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
51	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
52	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
53	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
54	<0.5	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>
55	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
56	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
59	<0.5	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>
60	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
61	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>
65	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
69	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
70	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
71	(<0.5) <sup>(5)</sup>	(0.7) <sup>(5)</sup>	(0.5) <sup>(5)</sup>	(0.6) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>
72	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.



## Appendix 1.7 Antimony

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
5	0.8	0.8	0.8	0.8	0 <sup>(4)</sup>	0 <sup>(4)</sup>
6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
11	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
12	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
13	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
15	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
16	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
22	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
24	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
26	<0.5	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>
28	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
29	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
32	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
33	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
34	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
36	<0.5	<0.5	0.8	<0.5	<0.5	0.8
39	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
40	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
41	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
42	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
43	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
44	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
45	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
46	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
47	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
48	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
50	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
51	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
52	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>	<0.5
53	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
54	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
55	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
56	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
59	<0.5	<0.5	<0.5	<0.5	<0.5	0 <sup>(4)</sup>
60	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
61	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>
65	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
69	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
70	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
71	(<0.5) <sup>(5)</sup>	(0.9) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>	(0.7) <sup>(5)</sup>	(0.8) <sup>(5)</sup>	(<0.5) <sup>(5)</sup>
72	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.8 Chromium

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	0.6	0.6	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
2	0.8	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
3	0.7	0.7	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>
4	0.6	0.6	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
5	0.5	0.5	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>
6	0.8	0.6	0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
7	0.9	0.7	< 0.5	0.7	0 <sup>(4)</sup>	0 <sup>(4)</sup>
8	0.7	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
9	0.7	0.6	< 0.5	0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
11	1.1	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
12	0.8	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
13	0.8	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
14	0.7	0.7	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>
15	1.0	0.8	0.5	0.7	0 <sup>(4)</sup>	0 <sup>(4)</sup>
16	1.8	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	3.5	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
22	2.3	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	2.8	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
24	0.7	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
26	0.5	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
28	0.7	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
29	0.8	0.5	< 0.5	0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
32	0.6	0.7	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
33	1.1	0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
34	< 0.5	0.7	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>
36	< 0.5	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
39	0.7	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
40	0.6	0.8	< 0.5	0.7	< 0.5	0 <sup>(4)</sup>
41	0.6	0.6	< 0.5	0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
42	0.7	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
43	0.7	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
44	0.7	0.6	0.6	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
45	0.8	0.6	0.7	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
46	0.7	< 0.5	0.7	0.5	0 <sup>(4)</sup>	< 0.5
47	0.6	0.6	0.8	0.7	< 0.5	< 0.5
48	0.6	0.6	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
50	0.9	0.6	0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
51	0.7	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
52	0.7	0.7	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
53	< 0.5	0.6	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>
54	0.6	0.6	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
55	< 0.5	0.6	< 0.5	0.5	< 0.5	0 <sup>(4)</sup>
56	0.5	0.6	< 0.5	0.6	< 0.5	0 <sup>(4)</sup>
59	0.6	0.6	< 0.5	0.6	0 <sup>(4)</sup>	0 <sup>(4)</sup>
60	0.6	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
61	(0.6) <sup>(5)</sup>	(0.7) <sup>(5)</sup>	(< 0.5) <sup>(5)</sup>	(0.7) <sup>(5)</sup>	(< 0.5) <sup>(5)</sup>	(0 <sup>(4)</sup> ) <sup>(5)</sup>
65	0.6	< 0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
69	0.6	0.5	< 0.5	0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
70	0.5	0.5	< 0.5	< 0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
71	(0.5) <sup>(5)</sup>	(0.5) <sup>(5)</sup>	(< 0.5) <sup>(5)</sup>	(< 0.5) <sup>(5)</sup>	(< 0.5) <sup>(5)</sup>	(0 <sup>(4)</sup> ) <sup>(5)</sup>
72	0.8	0.6	< 0.5	0.5	0 <sup>(4)</sup>	0 <sup>(4)</sup>

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 1.9 Tin

Installation number	As analysed <sup>(1)</sup>				Net values <sup>(1,3)</sup>	
	A Fully flushed [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]	(C+ B) <sup>(2)</sup> 4 hours stagnation [µg/l]	C 4 hours stagnation [µg/l]	B 4 hours stagnation [µg/l]
1	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
2	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
3	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
4	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
5	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
6	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
7	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
8	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
9	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
11	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
12	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
13	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
14	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
15	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
16	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
18	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
22	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
23	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
24	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
26	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
28	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
29	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
32	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
33	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
34	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
36	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
39	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
40	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
41	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
42	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
43	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
44	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
45	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
46	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
47	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
48	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
50	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
51	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
52	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
53	<0,5	<0,5	1,2	<0,5	0 <sup>(4)</sup>	1,2
54	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
55	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
56	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
59	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
60	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
61	(<0,5) <sup>(5)</sup>	(<0,5) <sup>(5)</sup>	(<0,5) <sup>(5)</sup>	(<0,5) <sup>(5)</sup>	(0 <sup>(4)</sup> ) <sup>(5)</sup>	(0 <sup>(4)</sup> ) <sup>(5)</sup>
65	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
69	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
70	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>
71	(<0,5) <sup>(5)</sup>	(25) <sup>(5)</sup>	(<0,5) <sup>(5)</sup>	(20) <sup>(5)</sup>	(25) <sup>(5)</sup>	(0 <sup>(4)</sup> ) <sup>(5)</sup>
72	<0,5	<0,5	<0,5	<0,5	0 <sup>(4)</sup>	0 <sup>(4)</sup>

1: All values below 0.5 µg/l are shown as < 0.5 µg/l.

2: Weighted average based on sample volumes. The volume of sample B is app. 200 ml and the volume of sample C is app. 800 ml (Total sample volume is app. 1 litre).

3: Net values correspond to the increase in metal concentration during stagnation in the installation and are calculated as the analysed metal concentration in the stagnation sample (sample B or C) minus the analysed metal concentration in the fully flushed sample (sample A).

4: Calculated net values showing negative values, e.g. due to precipitation, are reported as 0.

5: Results shown in brackets are results before re-sampling in the installation. Re-sampling has been carried out where results showed unexpected behaviour.

## Appendix 2. Installations. Pipe materials and age of mixer taps

As reported by test persons

Installation number	Postal code and city	Age of kitchen mixer tap [years]	Pipe materials			
			Galvanized steel	Copper	Stainless steel	Plastic
1	3480 Fredensborg	< 3	+			
2	2620 Albertslund	< 1		+		
3	2820 Gentofte	< 7	+			
4	3500 Værløse	< 7	+	+		
5	2680 Solrød Strand	< 12	+			+
6	2400 København NV	< 15	+			
7	3400 Hillerød	Unknown	+	+		
8	2800 Lyngby	< 5	+			
9	4621 Gadstrup	< 7		+		+
11	2720 Vanløse	< 5	+			+
12	2950 Vedbæk	< 1	+			
13	2820 Gentofte	< 10	+			
14	2600 Glostrup	< 9			+	
15	2605 Brøndby	< 3	+			+
16	4792 Askeby	< 7				+
18	2650 Hvidovre	< 2				+
22	4070 Kirke Hyllinge	< 9		+		
23	3520 Farum	< 2	+	+		+
24	2880 Bagsværd	< 3	+	+		
26	3450 Allerød	< 20	+	+		
28	4690 Haslev	Unknown	+			+
29	2630 Taastrup	Unknown	+			
32	2830 Virum	< 5				+
33	3460 Birkerød	< 20		+		
34	4330 Hvalsø	< 1		+		+
36	2830 Virum	< 7				+
39	2300 København S	< 3				+
40	2970 Hørsholm	< 9		+		+
41	2720 Vanløse	< 5	+			+
42	1663 København V	Unknown			+	
43	2700 Brønshøj	< 18	+			
44	2820 Gentofte	Unknown	+			+
45	2700 Brønshøj	< 5				+
46	København	< 20	+			
47	4140 Borup	< 1		+		+
48	2830 Virum	< 5	+			
50	2300 København S	< 2	+			
51	2100 København Ø	< 1				+
52	1953 Frederiksberg	Unknown	+			
53	3460 Birkerød	< 5				
54	3360 Liseleje	Unknown		+		
55	2800 Lyngby	< 1	+			+
56	2860 Søborg	< 7	+			
59	2000 Frederiksberg	< 10	+			+
60	2670 Greve	< 3	+			
61	2791 Dragør	< 1				+
65	4632 Bjæverskov	< 3	+	+		
69	2200 København N	< 5	+			
70	2200 København N	Unknown	+		+	
71	2820 Gentofte	< 17	+	+		
72	3400 Hillerød	< 1	+			

### Appendix 3. Chemical analysis method and precision.

At the reception of the samples the volumes were determined gravimetrically. Hereafter 5 ml conc. HNO<sub>3</sub> suprapur per litre was added to each sample.

The contents of metals were determined quantitatively using ICP-MS technique according to DS/EN 17294-2.

For the analysis our Varian ICP-MS was used with the following quantification limits (QL):

µg/l	As	Cd	Cr	Cu	Ni	Pb	Sb	Sn	Zn
QL	0,2	0,02	0,1	0,04	0,2	0,2	0,2	0,5	0,3

For samples with a higher content of an element (> 25 ppb) ICP-OES technique according to DS/EN 11885 was used.

For the analysis our Thermo iCAP 6500 was used.

## Appendix 4. Sampling instructions for test persons (in Danish).

### Vejledning i udtagning af vandprøver fra vandhanen i køkkenet

**Det er vigtig at læse hele vejledningen, inden du går i gang med udtagning af vandprøver.**

#### Før du går i gang

I de 4 timer vandet skal stå stille i installationen, må der ikke bruges vand fra nogen af husstandens vandhaner, brusere eller toiletter. Vaskemaskiner, opvaskemaskiner og koldtdriksautomater f.eks. i amerikanerkøleskabe må heller ikke anvendes i løbet af de 4 timer, hvor vandet står stille. Det er derfor meget vigtigt, at alle i husstanden har fået besked om, at der ikke må bruges vand. Det kan også være en god ide, at fylde en spand med vand til toiletskyl og en kande/flaske vand til kaffe, te, tandbørstning og lignende.

Kontroller først om du har fået de nødvendige flasker:



Sammen med vejledningen skal du have modtaget tre prøveflasker. Flaskerne skal være mærket A, B og C som vist på billedet. Det er meget vigtigt at flaskerne bruges i den rigtige rækkefølge.

**Fremgangsmåden er herefter følgende:**

1. Lad **det kolde vand** løbe i mindst 5 minutter fra vandhanen ved køkkenvasken og luk derefter for vandhanen. Herved erstattes vandet i rørene med nyt vand.
2. Skru proppen af flasken mærket **A**. Pas på ikke at røre ved indersiden af flaske og prop, da det kan forstyrre målingerne. Hold flasken under hanen og åbn stille og roligt for **den kolde hane**. Når flasken er fyldt helt op lukkes vandet og proppen skrues på flasken. Undgå at spilde vand. **I de næste 4 timer må der hverken bruges vand fra vandhaner, bruser, toilet, vaskemaskine m.v.!!**
3. **Notér dato og tidspunkt på prøveflaskens etiket!!**
4. Hæng eventuelt sedler med "Undgå venligst brug af vand!" på vandhaner og toilet.

**Efter 4 timer**

Efter uafbrudt henstand i 4 timer udføres følgende:

**Flaske B:** Skru proppen af **Flaske B** (den mindste flaske). Pas på ikke at røre ved indersiden af flaske og prop, da det kan forstyrre målingerne. Hold flasken under hanen og åbn stille og roligt for **den kolde hane**. Når flasken er fyldt op til den røde streg lukkes vandet og proppen skrues på flasken. Undgå at spilde vand. **Notér dato og tid på prøveflaskens etiket.**

**Flaske C:** Umiddelbart efter at **Flaske B** er fyldt, tages proppen af **Flaske C**, og denne fyldes op til den røde streg med vand fra **den kolde hane** og proppen skrues på flasken. **Notér dato og tid på prøveflaskens etiket.**

**Herefter kan der igen bruges vand fra alle installationer.**

Vandprøverne afleveres efterfølgende samme sted, som du fik flaskerne udleveret. Ved aflevering af flaskerne modtager du en flaske rødvin som tak for hjælpen.

På forhånd tak for hjælpen!

## Appendix 5. Questionnaire for test persons (in Danish).



# Spørgeskema

## Undersøgelse af metaller i drikkevand

Screening af husinstallationer

På baggrund af spørgeskemaet udvælges en repræsentativ gruppe, som efterfølgende skal udtage vandprøver for analyse af metaller.

### Oplysninger om deltageren

Navn/initialer..... :	_____
Adresse..... :	_____ _____
Kommune..... :	_____
Vandværk..... :	_____
Telefonnummer.. :	_____
E-mail adresse.... :	_____



### Generelle oplysninger om bebyggelsen

#### I hvilken type bebyggelse er husstanden?

- |   |                                    |                                      |
|---|------------------------------------|--------------------------------------|
| <input type="checkbox"/> Enfamiliehus             | <input type="checkbox"/> Rækkehus  | <input type="checkbox"/> Sommerhus   |
| <input type="checkbox"/> Delevilla/villalejlighed | <input type="checkbox"/> Lejlighed | <input type="checkbox"/> Andet _____ |

#### Oplysninger om husstanden

Antal beboere alt..... : \_\_\_\_\_ Antal hjemmeboende børn.... : \_\_\_\_\_

Antal hjemmegående..... : \_\_\_\_\_

#### Hvor mange år har du/I boet på adressen?

\_\_\_\_\_ år

#### Har husstanden egen vandmåler?

- ☐ Ja ☐ Nej

#### Husstandens samlede årlige vandforbrug i kubikmeter (f.eks. sidste års forbrug):

\_\_\_\_\_ m<sup>3</sup>

#### Er der længere perioder ud over "de normale" 5-6 ugers ferie, hvor der ikke forbruges vand?

- ☐ Ja ☐ Nej

Hvis ja, hvor mange uger årligt?

\_\_\_\_\_ uger

Evt. årsag (f.eks. længere sommerhusophold, rejser mv.):

\_\_\_\_\_  
\_\_\_\_\_

## Spørgsmål om vandinstallationen

Mange af os ved kun lidt om de installationer, vi har i vores huse/lejligheder, og nogle gange kan det være svært at finde de rigtige oplysninger. Vi vil naturligvis gerne have så mange oplysninger som muligt til undersøgelsen, men du kan nemt komme ud for, at nogle af spørgsmålene ikke umiddelbart kan besvares. I tilfælde af, at det ikke er muligt at give en besvarelse, angiver du blot dette i skemaet. Hvis du er i tvivl om besvarelsen, må du også meget gerne angive dette sammen med dit svar.

### Oplysninger om vandinstallation

<b>Hvor gammel er vandinstallationen?</b>		
<input type="checkbox"/> < 1 år	<input type="checkbox"/> 1-2 år	<input type="checkbox"/> 2-5 år
<input type="checkbox"/> 5-10 år	<input type="checkbox"/> Mere end 10 år, evt. ca. antal år _____	
Evt. kommentar: _____		
_____		
<b>Hvor mange vandhaner er der i husstanden (eksklusiv udendørs haner)?</b>		
_____ stk.		
<b>Hvor mange toiletter?</b>		
_____ stk.		
<b>Hvor mange brusere?</b>		
_____ stk.		
<b>Har I egen opvaskemaskine?</b>		
<input type="checkbox"/> Ja	<input type="checkbox"/> Nej	
<b>Har I egen vaskemaskine?</b>		
<input type="checkbox"/> Ja	<input type="checkbox"/> Nej	
<b>Har I et amerikansk køleskab m. koldt vandsautomat og/eller isterningmaskine?</b>		
Amerikansk køleskab	<input type="checkbox"/> Ja	<input type="checkbox"/> Nej
Isterningmaskine	<input type="checkbox"/> Ja	<input type="checkbox"/> Nej
<b>Hvor langt er der ca. fra indgang til husstand og til køkkenhanen (bedste vurdering/lige linje)?</b>		
_____ meter		

### Oplysninger om rør og vandhane

**Er vandhanen i køkkenet forsynet med ét eller to greb?**

- ☐ 1 greb ☐ 2 greb

**Er vandhanen i køkkenet forkromet?**

- ☐ Ja ☐ Nej ☐ Ved ikke

**Har vandhanen i køkkenet påmonteret vandsparer?**

- ☐ Ja ☐ Nej ☐ Ved ikke

**Hvad er køkkenhanens fabrikat (f.eks. Grohe, Damixa, Oras...)?**

\_\_\_\_\_

**Hvor gammel er vandhanen i køkkenet?**

- ☐ < 1 år ☐ 1-2 år ☐ 2-3 år  
☐ 3-5 år ☐ Mere end 5 år, evt. ca. antal år \_\_\_\_\_

**Var din vandhane i køkkenet VA-godkendt på købstidspunktet?**

- ☐ Ja ☐ Nej ☐ Ved ikke

**Hvilke rørmaterialer er der brugt til hanerørene i køkkenet (de tynde rør der er tilsluttet vandhanen under bordet)**

- ☐ Kobber ☐ Plast ☐ Forkromet

Evt. kommentar: \_\_\_\_\_

**Hvilke rørmaterialer er der brugt til installationen fra vandmåler til hanerør? (sæt om nødvendigt flere krydser)**

- ☐ Varmforzinket (galvaniseret) stål ☐ Rustfrit stål ☐ Kobber

☐ Plast Evt. kommentar: \_\_\_\_\_

\_\_\_\_\_

**Har du yderligere oplysninger om vandinstallationen, der kunne være relevante?  
F.eks. gener såsom tilstopninger, brunt vand, dårlig smag, lange ventetider på koldt  
vand etc.**

Kommentar: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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