Water and Wastewater Practitioner Series: KIWA Report

Scaling Propensity of Water: New Predictive Parameters

M.J.C. van Raalte-Drewes, H. Brink,
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SUMMARY

New parameters were developed that enable to predict and analyse in a quick and simple way the occurrence of calcium carbonate precipitation (scaling) during heating of drinking water. The commonly used parameter to predict the occurrence of calcium carbonate precipitation, e.g. the Saturation Index determined at 10^{o}C (SI_{10}), turned out not to cover the problems appearing in practice.

To perform a good analysis of the factors influencing calcium carbonate precipitation in water heating equipment, four parameters need to be determined:

- the $CCPP_{90}$ (Calcium Carbonate Precipitation Potential at 90^{o}C);
- the SI_{90} (Saturation Index at 90^{o}C);
- the NI (Nucleation Index);
- the MCCP (Measured Calcium Carbonate Precipitation).

The $CCPP_{90}$ and SI_{90} describe together the hydrodynamic driven force for the calcium carbonate precipitation reaction. The nucleation index indicates in which rate the calcium carbonate precipitation is accelerated by nuclei present in the water. Finally, the MCCP refers to a measurement under practical conditions, whereby the calcium carbonate accumulation is measured.

In this report the link between values of the parameters and practical problems to appear is determined. In addition some practical examples on the use of the parameters are described.

The research indicates that no excessive calcium carbonate precipitation in water heating equipment occurs when the water type complies with the following recommendations:

$CCPP_{90}$	<	0.6 mmol/L
SI_{90}	<	1.0
NI	<	0.85
MCCP	<	0.2 mmol/L

Serious problems regarding calcium carbonate precipitation will be found in water types where the following values are exceeded:

$CCPP_{90}$	>	1.2 mmol/L
MCCP	>	0.6 mmol/L

A decisive answer regarding the magnitude of calcium carbonate precipitation during water heating can be obtained by performing an MCCP-measurement. There is a clear relation found between the results of the scaling measurement (MCCP) and the occurrence of calcium carbonate precipitation in practice. When MCCP is smaller than 0.2 mmol/L, no calcium carbonate precipitation is usually found. Moderate problems with calcium carbonate precipitation were experienced when MCCP values were between 0.2 and 0.6 mmol/L while values exceeding 0.6 mmol/L led almost always to serious problems.

When no measurements of MCCP are available, the $CCPP_{90}$ can be used to predict the seriousness of calcium carbonate precipitation. When $CCPP_{90}$ is smaller than 0.6 mmol/L no problems with precipitation appear. Between 0.6 and 1.2 moderate problems can be faced, while by values higher than 1.2, excessive calcium carbonate precipitation usually occurs.

The saturation index at 90°C (SI_{90}) and the nucleation index (NI) seem to be too less distinctive for Dutch water types. It turned out however, that calcium carbonate precipitation is enhanced by higher values of nucleation index (higher than ca. 0.85), what can occur after softening of water in pellet reactors.

It turned out after application of the new determination methods that the new parameters are suitable to predict calcium carbonate precipitation in household water heating equipment and to analyse it further. The scaling measurement (determination of MCCP) seems to be the most appropriate to estimate the seriousness of the problems associated with calcium carbonate precipitation. Prediction of the magnitude of calcium carbonate precipitation can be done using the $CCPP_{90}$ parameter. To optimise the conditioning and filtration processes, the nucleation index should be considered.

1

New parameters to determine the scaling potential of water

In the period between 1989 and 1996 new determination methods were developed enabling to predict and analyse relatively quickly and simple the occurrence of calcium carbonate precipitation during heating of drinking water. The reason for the development of these measurement methods was that there were inexplicable problems with calcium carbonate precipitation. These appeared in the end of the 80's after introduction of softening and deacidification. In addition it turned out that the commonly used parameter to predict calcium carbonate precipitation, the saturation index SI calculated by 10^{o}C, was not sufficient (Van Eekhout et al., 1991). Within the Netherlands' Water Works Joint Research Program, a project was started focussed on the development of better prediction methods.

In the research it turned out that four parameters need to be considered to perform a good analysis of calcium carbonate precipitation (Van Eekhout et al., 1991):

- the $CCPP_{90}$ (Calcium Carbonate Precipitation Potential at 90^{o}C);
- the SI_{90} (Saturation Index at 90^{o}C);
- the NI (Nucleation Index);
- the MCCP (Measured Calcium Carbonate Precipitation).

The $CCPP_{90}$ and SI_{90} together describe the hydrodynamic driven force for the calcium carbonate precipitation reaction. The nucleation index indicates in which rate the calcium carbonate precipitation is accelerated by nuclei present in the water. Finally, the MCCP refers to a measurement under practical conditions, whereby depth of calcium carbonate accumulation is measured.

For each of these four parameters calculation procedures, computer programs as well as measurement set-ups are proposed. It regards:

- the computer program CCPP90 to calculate the $CCPP_{90}$ and the SI_{90};
- the set-up to for the determination of the Nucleation Index;
- the measurement of MCCP.

More information on these parameters can be found in various manuals (Kiwa reports SWS 95.505, SWE 95.014 and SWE 97.012).

At the end of the research it is stated by which results of the measurement methods excessive calcium carbonate scaling may occur. In this report the results are reported.

In chapter 2 the relation between the results of the new determination methods and practical experiences are given. Based on this, recommended values are defined for the results of these methods. Chapter 3 shows some examples of the use of the measurement methods. These applications give the base for earlier defined recommended limit values. A systematic approach for the efficient implementation of new determination methods is included in chapter 4. Finally the conclusions of this research are given in chapter 5.

2

Recommendations to prevent scaling

2.1 Approach to establish new recommendations

To define limits for the results of the new determination methods a relation with practical experiences is established. This should enable prevention against problems with calcium carbonate precipitation during heating of water.

As first it was attempted to collect quantitative data regarding maintenance of water heating equipment. The link between these maintenance data and the measured parameters could result in a statistical relation. However, it turned out during the performance of the experiment that insufficient quantitative data about maintenance of water heating equipment were available for a statistical analysis.

Therefore it was decided not to formulate statistical relations, but to define empirical limiting values. For some supplementary drinking water supply areas it was decided whether the problems with calcium carbonate precipitation in water heating equipment were known. The following data were used in the latter case: qualitative information about maintenance of water heating equipment (when available), qualitative information about maintenance of water heating equipment made available by lessors and information from complains registration system of the involved Drinking Water Companies.

Finally the calcium carbonate precipitation capacity was determined using the four new parameters for 27 water types. These water types were first divided into three groups: water types causing evidently calcium carbonate precipitation in water heating equipment, water types which are known by Drinking Water Company to lead from time to time to complains related to calcium carbonate precipitation and finally water types causing no problems with calcium carbonate precipitation. By comparison of the results of new determination methods for these three water types, the limiting values were determined.

It was important for this research to investigate very different water types. It regards for instance drinking water produced from ground water, bank filtrate water and surface water. In addition a large geographical spreading was considered leading to a representative picture for the Dutch situation.

2.2 Relation between results of determination methods and practical experience

For drinking water originating from different locations in The Netherlands where no softening process is applied, the results of the measurements are given in Table 2.1. The locations are divided into three groups:

- locations where calcium carbonate precipitation in water heating equipment is evident;
- locations where it is known by Drinking Water Companies that calcium carbonate precipitation in water heating equipment occurs from time to time;
- locations where no complains are registered about calcium carbonate precipitation.

Table 2.1 Results of new determination methods: calcium carbonate precipitation parameters of drinking water samples taken at the pump stations at various locations in The Netherlands.

Pump station	$CCPP_{90}$ mmol/L	SI_{90} (-)	NI (-)	MCCP (mmol/L)	Boilers % of cleaned units
Problems with calcium carbonate precipitation					
1	0.93	1.09	0.61	0.59	
2	1.63	1.24	0.62	1.01	10.9
3	1.86	1.17	0.72	0.70	12.5
4	1.18	1.21	0.76	0.63	6.4
Moderate problems with calcium carbonate precipitation					
5	0.61	1.00	0.65	0.23	
6	0.83	0.96	0.60	0.16	
7	0.98	1.17	0.57	0.22	3.5
8	1.00	1.03	0.67	0.45	
9	1.08	1.12	0.62	0.50	5.5
10	1.09	1.24	0.53	0.37	
11	1.11	1.14	0.55	0.51	
12	1.11	1.08	0.87	0.28	
13	0.80	1.04	0.63	0.33	
No problems with calcium carbonate precipitation					
14	0.34	0.85	0.68	0.04	<5
15	0.37	1.09	0.45	0.01	
16	0.38	0.67	0.54	0.01	0.9
17	0.63	0.25	0.52	0.01	1.6
18	0.63	0.98	<0.47	0.08	<2
19	0.69	0.98	0.50	0.01	<2
20	0.13	0.52	0.73	0.00	
21	0.17	0.58	0.69	0.07	

The comparison of the calcium carbonate precipitation parameters from the three groups leads to the following ranges (Table 2.2).

Table 2.2 Ranges of calcium carbonate precipitation parameters in the three different groups

	$CCPP_{90}$ (mmol/L)	SI_{90} (-)	NI (-)	MCCP (mmol/L)
Excessive calcium carbonate precipitation	0.9-1.9	1.1-1.2	0.6-0.8	0.6-1.0
Moderate calcium carbonate precipitation	0.6-1.1	1.0-1.2	0.5-0.9	0.2-0.5
No problems with calcium carbonate precipitation	0.1-0.7	0.3-1.1	<0.5-0.7	0.0-0.1

An analysis of the tables lead to the conclusion that no problems in water heating equipment related to calcium carbonate precipitation will be experienced when the values of parameters are:

$CCPP_{90}$ < 0.6 mmol/L
SI_{90} < 1.0
MCCP < 0.2 mmol/L

On the other hand the serious problems may occur when the values amount at:

$CCPP_{90}$ > 1.2 mmol/L
MCCP > 0.6 mmol/L

Almost all water types are characterised by a SI_{90} from a rather narrow range of 1.0 and 1.2. It seems that the SI_{90} is too less distinctive for Dutch drinking water. By SI_{90} lower than 1.0 no problems with calcium carbonate precipitation were encountered.

Further, the division into these groups does not seem to be distinctive regarding the measured nucleation index. In all these three groups almost exclusively low values of nucleation index were found. Only for one location the value of 0.7 was exceeded. It seems that by NI lower than approximately 0.75 and 0.85 no enhancement of calcium carbonate precipitation occurs.

The Nucleation Index is generally significantly higher for water softened in pellet reactors. The calcium carbonate precipitation parameters of drinking water softened in pellet reactors are given in table 2.3.

Table 2.3 Results of new determination methods: calcium carbonate precipitation parameters of drinking water from pump station from various locations in The Netherlands subjected to softening in pellet reactors.

Pump station	$CCPP_{90}$ (mmol/L)	SI_{90} (-)	NI (-)	MCCP (mmol/L)
		Problems with calcium carbonate precipitation		
Moderate problems with calcium carbonate precipitation				
22	0.62	1.11	1.49	0.24
23	0.70	1.19	0.99	0.23
24	0.74	1.20	1.05	0.11
25	0.30	0.77	0.87	0.14
No problems with calcium carbonate precipitation				
26	0.80	1.24	0.83	0.14
27	0.29	0.91	0.75	n.d.

n.d. not determined

Table 2.3 shows that the higher values of NI are found in water after softening in pellet reactors. Further it turns out that in some cases complains about calcium carbonate precipitation are periodically registered. It mainly appears by water types characterised by high nucleation index, or in another words in water types rich in nuclei accelerating the calcium carbonate precipitation. By the values of NI lower than 0.85 no complains were registered.

The enhancement of the calcium carbonate precipitation at higher values of nucleation index is also visible in two measurements shown in Table 2.4. It considers the same water supply area. The first sample was taken just after the pump station, the second in the supply area.

Table 2.4 Calcium carbonate precipitation parameters for drinking water in the supply area G.1.

	$CCPP_{90}$ (mmol/L)	SI_{90} (-)	NI (-)	MCCP (mmol/L)
Drinking water directly after pump station	0.62	1.11	1.49	0.24
Drinking water from supply area	0.59	1.11	0.73	0.15

The chemical composition of the water was almost identical, which can be seen in comparable values of the $CCPP_{90}$ and SI_{90}. The nucleation index of water directly after the pump station is however higher than the nucleation capacity in the supply area. Also, in the MCCP measurement in the sample after the pump station, more precipitated calcium was found. It seems that calcium carbonate precipitation is accelerated at a nucleation index of approximately 1.5.

2.3 Recommendations

Excessive calcium carbonate precipitation in water heating equipment does not occur in types of water complying with the following limit values for the new parameters of calcium carbonate precipitation capacity:

$CCPP_{90}$ < 0.6 mmol/L
SI_{90} < 1.0
NI < 0.85
MCCP < 0.2 mmol/L

To be sure that the water does not cause any excessive calcium carbonate precipitation in domestic water heating equipment, it is recommended to condition water in question in such a way that the parameter limits are fulfilled. Exceeding of one of these limit values will however not always lead to problems with calcium carbonate precipitation. It is further analysed in chapter 4.

3

Examples of applications

3.1 Determination of the benefits and necessity of water treatment/conditioning

A study was performed to determine the necessity and the benefits of water conditioning (softening, deacification) for all existing and future water intakes belonging to the Drinking Water Company Limburg, The Netherlands. For all water types the $CCPP_{90}$ was determined based on water quality data delivered by Water Laboratories. In addition, the maintenance of water heating equipment within the considered water supply area was surveyed. The Electricity Enterprise delivered data regarding maintenance state of electric(al) boilers. The results are given in Figure 3.1

The comparison of both schemes in Figure 3.1 shows large similarities. For all water supply areas where the $CCPP_{90}$ is lower than 0.6 mmol/L, the percentage of decalcified boilers is lower than 5%; for the pump stations with $CCPP_{90}$ higher than 0.6 mmol/L the percentage of boilers yearly decalcified was higher than 5%.

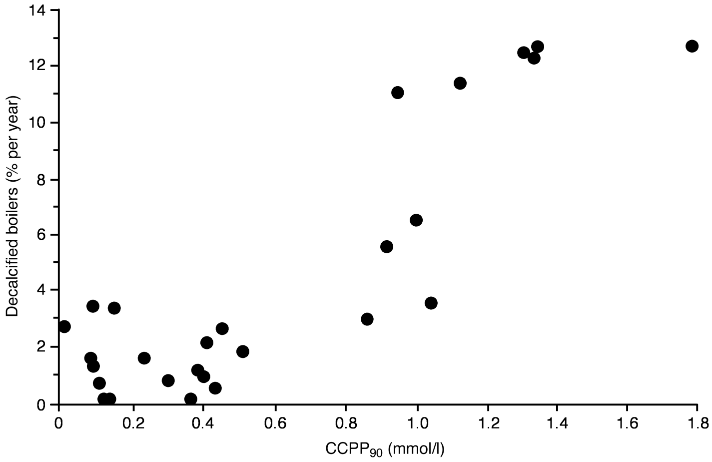

Figure 3.1. The percentage of the boilers needed to be yearly decalcified and the $CCPP_{90}$ in the water supply areas in Limburg, The Netherlands.

In Figure 3.2 the results are presented in another way: the percentage of boilers decalcified per year per water supply area is presented against the $CCPP_{90}$ of the drinking water distributed in the water supply area. Each point in this figure represents one drinking water supply area.

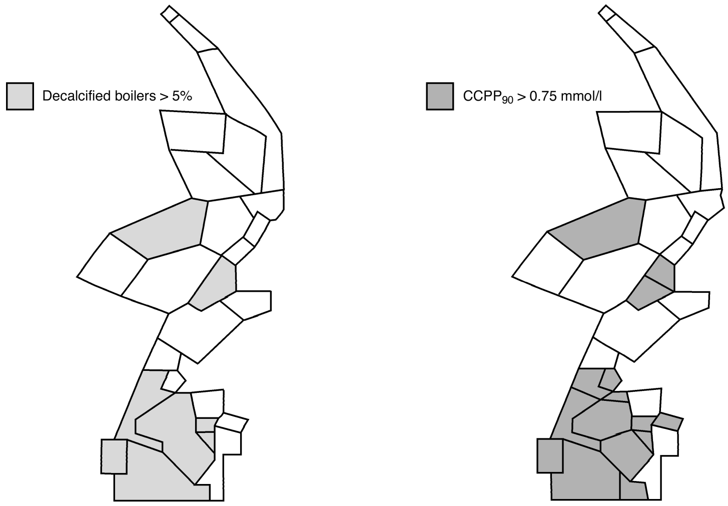

Figure 3.2 The percentage of boilers yearly decalcified versus the $CCPP_{90}$ of the drinking water in the water supply area.

This figure shows that in the areas where the $CCPP_{90}$ is lower than 0.6 mmol/L less than 5% of the electrical boilers was decalcified. By water types characterised by $CCPP_{90}$ higher than 0.6 mmol/L a decrease in maintenance of water heating equipment can be expected when the $CCPP_{90}$ will be decreased as a result of conditioning to a value lower than 0.6 mmol/L.

3.2 Answering complaints of users about calcium carbonate precipitation

A Drinking Water Company received for a longer period of time complains of consumers regarding white particles in the water. As a result of those complains research was started, focussed on the causes of the phenomenon ‘white particles’. Within the research the occurrence of excessive calcium carbonate precipitation in water heating equipment was found as a possible reason. To determine in which rate the distributed drinking water causes calcium carbonate precipitation, the new determination methods were implemented for samples originating from a pump station and four locations in the supply area (Figure 3.3). The results are summarised in Table 3.1.

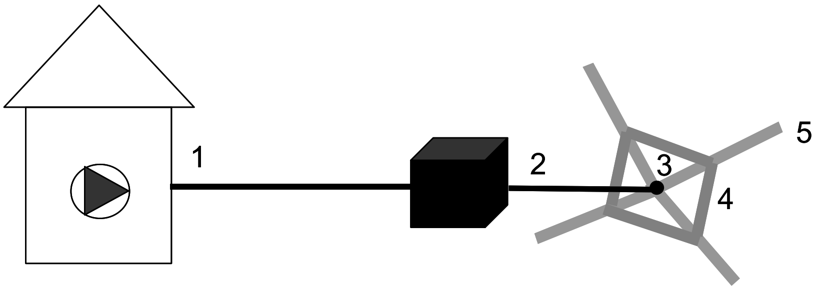

Figure 3.3 Schematical presentation of considered locations

Table 3.1. Calcium carbonate precipitation parameters for drinking water sampled just after pump station and at locations of water supply area.

	$CCPP_{90}$ (mmol/L)	SI_{90} (-)	NI (-)	MCCP (mmol/L)
1 just after pump station	0.17	0.58	0.69	0.07
2 after transport main (cement)	0.14	0.55	0.83	0.09
3 after distribution system (cement)	0.17	0.61	0.68	0.05
4 embranchment of distribution net: begin A-C line	0.20	0.70	0.67	0.05
5 embranchment of distribution net: end A-C line	0.20	0.74	0.74	0.14

The calcium carbonate precipitation propensity of the drinking water (all: $CCPP_{90}$, SI_{90}, NI and MCCP) is for almost all locations low. Based on these results it was concluded that the occurrence of ‘white particles’ did not result from excessive calcium carbonate precipitation in water heating equipment. It was later confirmed that the white calcium particles were not formed in the water heating equipment.

It is remarkable in the measurement results that a higher magnitude of calcium carbonate precipitation after heating was observed in water remaining for a longer period in contact with cement piping. It regards hereby the embranchment of the distribution net. Adjustment of water composition (conditioning) can decrease leaching of hydroxyl ions from cement pipes, and consequently preventing an increase of the calcium carbonate precipitation capacity. It is also expected that decrease of the retention time of water in the cement pipes will result in a lower calcium carbonate precipitation after heating of water.

It turned out in this research that implementation of the new determination methods, and especially the MCCP measurement, are very suitable to quantify the problem signalised by users complains.

3.3 Optimisation of conditioning processes

Already at the beginning of the 1980s it was known that during softening of water using pellet-softening, micro-crystals of calcium carbonate can be formed (Van Ammers, 1982, Graveland, 1987). It was assumed then that micro-crystals were formed when caustic soda was used as softening agent, but now it is known that micro-crystals are formed also when using milk of lime. The reason for the formation of micro-crystals of calcium carbonate during the softening process is local (high) over-saturation with calcium carbonate (spontaneous formation of nuclei) and the erosion of splinters during collisions of softening granules (Van Eekhout et al., 1991, De Blois et al., 1991). Micro-crystals of calcium carbonate in the water accelerate the calcium carbonate precipitation.

Taking into account the spontaneous formation of micro-crystals caused by local high over-saturation of calcium carbonate, it is expected that micro-crystals can be also formed in other places causing or accelerating calcium carbonate precipitation. For instance dosage of caustic soda to correct pH of water can be one of the reasons. Micro-crystals can also be formed during distribution of water, for instance by leaching of calcium hydroxide from cement-containing materials. There are however no experiences that the formation of micro-crystals under mentioned circumstances led to problems with calcium carbonate precipitation in heating water units.

Measurement of the nucleation index allows the determination of how far calcium carbonate precipitation is enhanced by the presence of nuclei in water.

The amount of micro-crystals formed during softening of water depends on the design and the operation of the pellet reactors. In the research performed by KIWA in co-operation with diverse Drinking Water Company, it turned out that the following factors are important:

- construction of the bottom in the softening reactor (Van Eekeren et al., 1992);
- water upflow velocity in the reactor;
- depth of softening (Dirken et al., 1995).

It was confirmed by research that an increase of the up-flow velocity in the pellet reactor leads to an increase of the formation of micro-crystals.

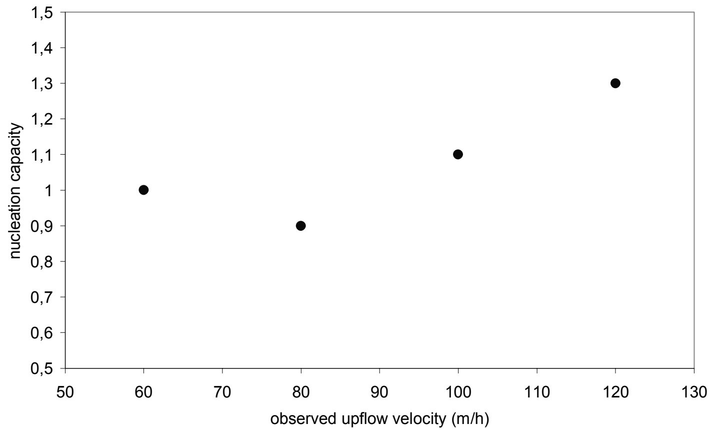

Figure 3.4 The nucleation capacity of the reactor effluent as function of the up-flow velocity in the pilot plant reactor (softening using caustic soda) on the pump station Katwijk, The Netherlands.

Because a significant fraction of the micro-crystals formed in the pellet reactor is removed in the following filtration step, the measurement of the nucleation capacity can be also applied to evaluate the efficiency of the filtration.

When micro-crystals are not efficiently retained during filtration, increase of the calcium carbonate precipitation can result.

The implementation of the determination of the nucleation capacity on several points in the purification process on the pump station Scheveningen, The Netherlands reflects the sense of the measurement method to evaluate the filtration steps (Figure 3.5). This refers to instantaneous exposure.

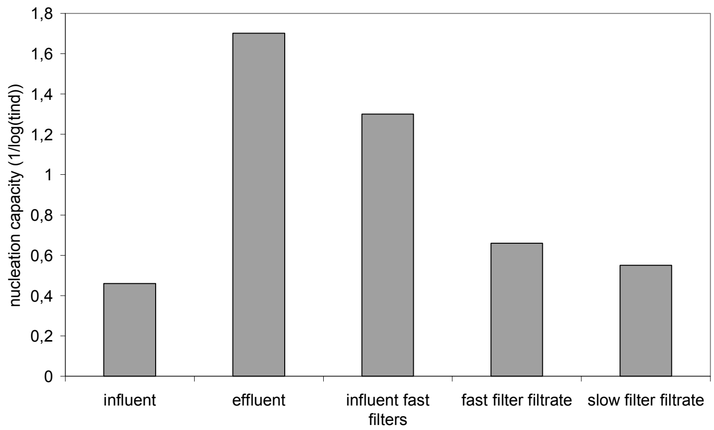

Figure 3.5 The nucleation capacity of the water on different points in water purification process on the pump station Scheveningen, The Netherlands (softening with milk of lime).

The figure shows that during the softening process micro-crystals are formed. The amount of micro-crystals is first lowered by mixing with un-softened water and after that by fast filtration. In the filtrate the nucleation index is however even higher than in the influent; single layer rapid sand filters show still some breakthrough of micro-crystals.

4

How to use the new scaling prediction methods

4.1 Implementation to prevent client complaints

Establish the scaling measurement and determine MCCP:

- when MCCP < 0.2 it is hardly to be expected that complaints are caused by occurrence of calcium carbonate precipitation during water heating. The following action: search further for the reasons of complaints;
- when MCCP > 0.2: complaints can result from calcium carbonate precipitation during heating. Action follows: search for the reason for the occurrence of calcium carbonate precipitation by implementing of new determination methods:
  - o $CCPP_{90}$ > 0.6 mmol/L: the chemical composition of water may lead to calcium carbonate precipitation during water heating. Implementation of water conditioning is usually efficient to decrease the calcium carbonate precipitation capacity.
  - o $CCPP_{90}$ < 0.6 mmol/L: the chemical water composition does not lead directly to enhancement of calcium carbonate precipitation. Implement now the measurement of index capacity:
    - ▪ NI > 0.85: there are nuclei present in the water enhancing calcium carbonate precipitation. The calcium carbonate precipitation capacity can be decreased by optimisation of the purification process.
    - ▪ NI < 0.85: no indication for nuclei in the water. The reason for the relatively large magnitude of calcium carbonate precipitation is not known.

The schematic representation of this systematic procedure is given in Figure 4.1.

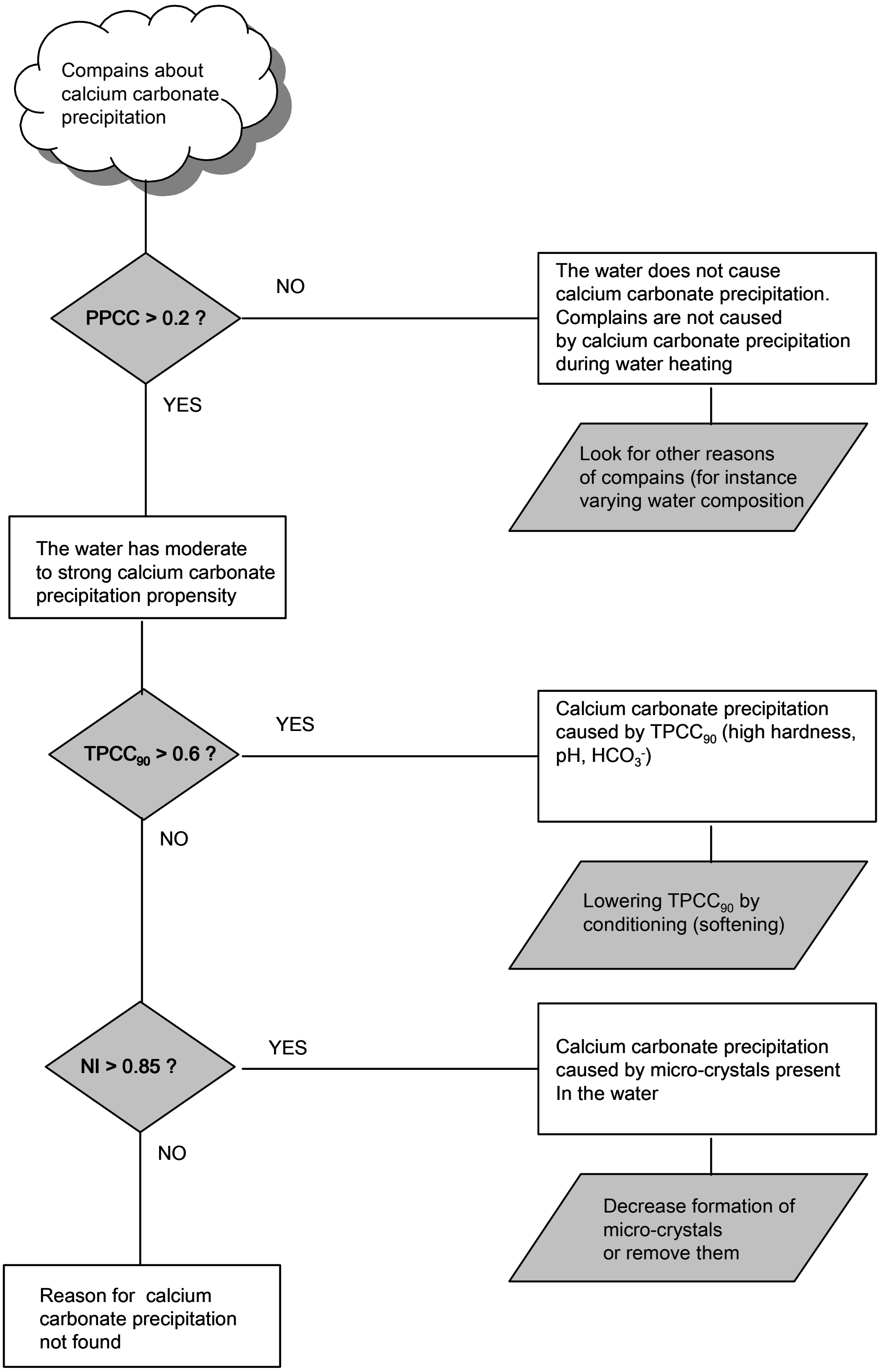

Figure 4.1. Implementation of measurement methods to solve the complains regarding calcium carbonate precipitation

4.2 Implementation to determine the benefits and necessity of conditioning

Calculate the $CCPP_{90}$ to determine the magnitude of benefit by conditioning for calcium carbonate precipitation:

- the $CCPP_{90}$ > 1.2 mmol/L: a lot of calcium carbonate precipitation will occur after water heating in the water supply area resulting in intensive maintenance of water heating equipment and relatively high costs. Introduction of conditioning (softening) will decrease this effect;
- the CCPP90 lies between 0.6 and 1.2 mmol/L: in the water supply area the calcium carbonate precipitation will occur during water heating although not in extreme rate. Conditioning will decrease this effect;
- the CCPP90 < 0.6 mmol/L: problem with calcium carbonate precipitation will not arise in the water supply area. Conditioning will not improve here anything.

Figure 4.2 presents schematically the above-described procedure.

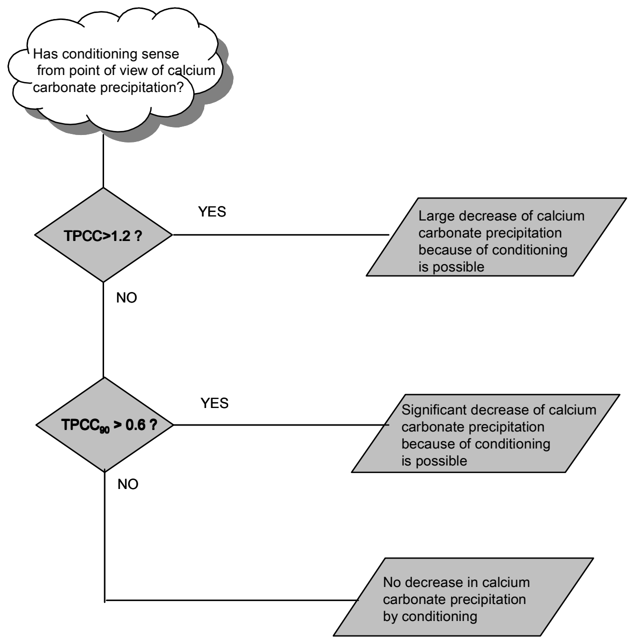

Figure 4.2. Implementation of measurement methods to determine the sense and necessity of water conditioning

4.3 Implementation to optimise conditioning and filtration processes

Conditioning processes

Implement the measurement of the nucleation index to evaluate changes in process settings during conditioning processes (for instance adjustment of surface velocity during softening, change in caustic solution dosage for pH correction). Better process setting should result in decrease of nucleation capacity. During softening this will lead, among others, in a decrease of the loading to the filters following softening process.

Filtration processes

Implement the measurement of nucleation capacity on diverse points in the purification scheme and determine the rate of nuclei occurrence in the water, the rate of their formation and removal respectively.
Control, using the scaling measurement, whether the distributed drinking water after optimisation of purification has indeed a lower calcium carbonate precipitation capacity.

Figure 4.3 presents schematically the implementation of the measurement methods.

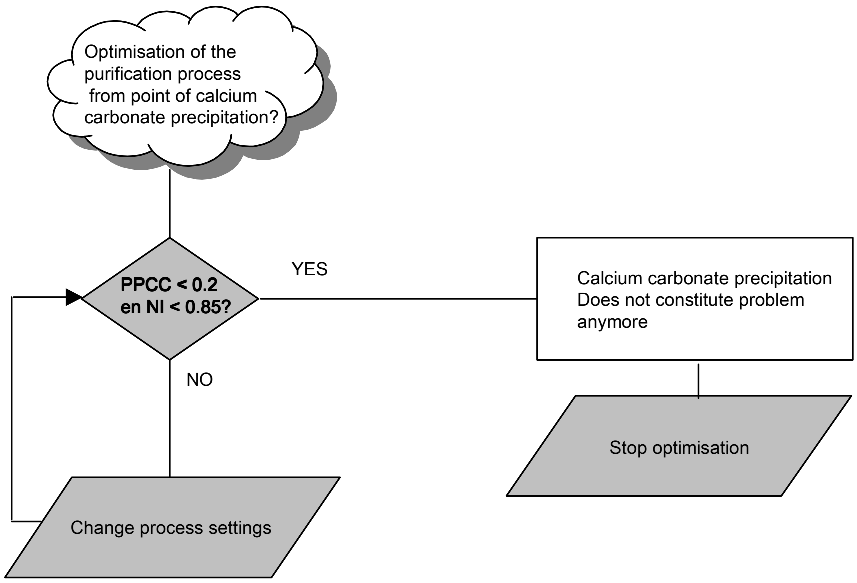

Figure 4.3. Implementation of measurement methods to optimise the purification processes

5

Conclusions

Recommendations for the water composition to prevent problems with calcium carbonate precipitation

- Excessive calcium carbonate precipitation in water heating equipment is not found in water sorts complying with the following limit values for the new parameters related to calcium carbonate precipitation:

$CCPP_{90}$	<	0.6 mmol/L
SI_{90}	<	1.0
NI	<	0.85
MCCP	<	0.2 mmol/L

  To be sure that considered water does not enhance excessive calcium carbonate precipitation in domestic water heating equipment, it is recommended to condition the water until these limit values are reached.

Risks by exceeding the limit values

- Serious problems with calcium carbonate precipitation were found at all water sorts where the following values were exceeded:

$CCPP_{90}$	>	1.2 mmol/L
MCCP	>	0.6 mmol/L

- When exceeding one of the mentioned limit values, there is a risk of excessive calcium carbonate precipitation. Exception can be gained by performing the MCCP measurement. There is a clear relation found between the results of the scaling measurement (MCCP) and the occurrence of calcium carbonate precipitation in practice. With MCCP lower than 0.2 mmol/L no calcium carbonate precipitation was observed, by values between 0.2 and 0.6 mmol/L moderate problems with calcium carbonate precipitation were experienced, and the values exceeding 0.6 mmol/L led almost always to serious problems. When no measurements of MCCP are available, the $CCPP_{90}$ can be used to predict the magnitude of the calcium carbonate precipitation. By values of $CCPP_{90}$ lower than 0.6 mmol/L problems with calcium carbonate precipitation do not occur, between 0.6 and 1.2 moderate problems can be concluded, while, by values higher than 1.2 excessive calcium carbonate precipitation prevails.

- The saturation index at 90 °C (SI_{90}) does not vary too much for Dutch water types. Almost all water types were characterised by a SI_{90} in the range between 1.0 and 1.2. A value for the SI_{90} higher than 1.0 does not implicate acute problems with calcium carbonate precipitation.
- The nucleation index NI, obtained from measurement of nucleation capacity, seems not to be very distinguished. It is found, however, that in water sorts that were softened in crystallisation reactors, high NI values could be found, enhancing calcium carbonate precipitation. By NI values lower than 0.85 there was no enhancement of calcium carbonate precipitation. There are, however, some measurements of higher values, whereby an enhancement of calcium carbonate precipitation occurred.

Possibilities to use new parameters

- The new parameters to estimate calcium carbonate precipitation capacity are suitable to predict and analyse the problems experienced with calcium carbonate precipitation in domestic water heating equipment.

  Predictions of the magnitude of calcium carbonate precipitation can be attained using the parameter $CCPP_{90}$. To optimise conditioning and filtration processes, the nucleation index is important. To evaluate the magnitude of the problem by complains about calcium carbonate precipitation, the scaling measurement (MCCP) is suitable.

Literature

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