Metals and Related Substances in Drinking Water Series

Best Practice Guide on the Management of Metals in Small Water Supplies

By Matthew Bower and Dr. Colin Hayes

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Abbreviations and Acronyms

CR	Continuous Regeneration
DDS	Domestic Distribution System
DWI	Drinking Water Inspectorate (England and Wales)
DWQR	Drinking Water Quality Regulator (Scotland)
EBCT	Empty Bed Contact Time
EU	European Union
FTU	Formazin Turbidity Unit
GAC	Granular Activated Carbon
ICP	Inductively Coupled Plasma
IR	Intermittent Regeneration
MDPE	Medium Density Polyethylene
NSF	National Science Foundation (USA)
PET	Polyethylene
PoE	Point of Entry
PoU	Point of Use
RO	Reverse Osmosis
SG	Specific Gravity
UV	Ultra-violet
WHO	World Health Organisation
WRAS	Water Regulations Advisory Service (UK)
WSP	Water Safety Plan

About this Best Practice Guide

This Best Practice Guide is one of a series which derives originally from the knowledge assembled by the European research network COST Action 637, supported by a wide range of experts from 26 European countries, the US and Canada. The funding received from COST over the period December 2006 to November 2010 is duly acknowledged. The main objective of COST Action 637 was to stimulate better control of metals in drinking water and to minimise environmental and health impacts. COST is supported by the EU RTD Framework programme and is the oldest and widest European inter-governmental network for co-operation in research.

Since November 2010, the research network has continued to be active as a Specialist Group within the International Water Association, expanding from its primarily European origins to encompass a truly international membership. The aim of the group is to develop and share best practice in the management of metals and related substances in water supplies around the world.

The management of small water supplies presents a unique challenge globally, in countries at all stages of development. A combination of lack of resources, limited understanding of the risks and poor expertise means that individuals and communities may face serious health risks from these supplies. This is not only due to microbiological contamination, but also from contamination by metals, either due to natural or man-made contamination of the source water or through leaching from plumbing materials due to inadequate conditioning and corrosion inhibition and use of inappropriate materials.

This Best Practice Guide aims to share best practice and experience from around the world on a practical level. It will look at general issues relating to small supplies and ways of managing these, adopting a Water Safety Plan approach to deliver sound and lasting improvements to quality. Management techniques and treatment relating to specific metals will be covered, from a theoretical and practical perspective, to deliver a publication that will act as an authoritative guide for all those faced with the problem of ensuring the quality of a small water supply. Varied case-studies will help to illustrate issues and ways in which they have been resolved.

Foreword

Guarding the quality of small water supplies, which are frequently limited in both financial and technical resources, remains a significant challenge for most parts of the world. Although such supplies individually provide water for small numbers of people, the total number supplied is significant and represents the potential for many individuals to be affected by unwanted contaminants. While waterborne pathogens present the greatest acute risk to health, there are chemicals that can have a significant impact on health with repeated exposure.

Metals can reach drinking water from contamination of raw water or by leaching from pipes and fittings. The most widely recognised are arsenic and lead but there are other metals that can either be a threat to health or render water unacceptable for domestic use by affecting colour and, sometimes, taste. It is, therefore, important that there are frameworks for identifying and managing the risks that these contaminants present. This volume provides a timely examination of both the risks and the management approaches that are suitable for application to small supplies in many different settings.

Professor John Fawell
Cranfield University, Water Science Institute.

Executive Summary

The focus of this Best Practice Guide is the management of metals and related substances in small water supply systems. There are many definitions of the term "small water supply" but the majority serve less than 50 people. A common characteristic is weak management, lack of expertise and lack of resources. Governments and regulators around the world have become increasingly aware of the magnitude of the problems associated with small supplies; even so, a large proportion are not subject to regulation despite small water supplies being more likely to contain high concentrations of metals and metalloids, particularly arsenic, copper, iron, lead and manganese.

A drinking water safety plan is a useful tool for assessing and managing the risks associated with small water supplies. Extensive guidance on water safety planning is available from the World Health Organization and the best results come from involving a team of people with an interest in the supply. It will be beneficial for local authorities (or equivalent organisations) to coordinate and prompt water safety planning in their area, thereby making expertise available to individual supply owners. Educational processes have a major part to play in raising the awareness of small supply owners.

Some metals are of health concern whilst others cause nuisance. Metal solubility is strongly influenced by oxidative state, pH, alkalinity and natural organic matter and these factors should feature in risk assessment. Sampling methods have limitations and must be selected with care. Field testing methods are now available and can avoid the high costs associated with laboratory analysis provided they are used correctly.

Many metals in small supplies are present in the source, either naturally occurring or arising from man-made activities. Careful choice of source location and construction of infrastructure can prevent or reduce contamination. Treatment processes can introduce metals into water if inappropriate or poorly controlled. Distribution systems and plumbing materials can also contaminate a supply with metals, notably copper, iron, lead, nickel and zinc. Water conditioning, good system design and careful choice of plumbing materials are key to reducing post-treatment contamination.

The choice of treatment process is usually a compromise between performance, practicalities and cost. Point of entry and point of use systems are often used to treat small water supplies. The appropriate treatment arrangement will depend on individual circumstances. Loose media filters are often used to remove insoluble metals.

Iron is the main metal to affect small water supplies at concentrations requiring treatment. Care should be taken to ensure that oxidation of ferrous iron is substantially complete prior to filtration. Manganese

removal also relies on oxidation but can be aided with catalytic removal using manganese dioxide. Arsenic and some other metals can be removed by adsorption onto either activated alumina or ferric oxide. The ongoing maintenance of any installed treatment process is vital in ensuring its continued effective operation.

To minimise metal contamination from distribution pipework and plumbing, it is important to manage the corrosivity of the water, that is, the tendency of the water to dissolve metals. The main approach will be to keep the water's pH above 7.0 (and preferably in the range 7.5 to 8.0) using simple filters containing alkaline media. Additionally, any lead pipes should be replaced using copper or plastic.

For easy reference, a Manual of Individual Metals summarises occurrence, chemistry, health and aesthetic significance, regulatory standards and guideline values, and options for management in a catchment.

Four case studies illustrate how metals in small supplies have been tackled:

- Arsenic removal in Italy
- Iron removal in the United Kingdom
- Metals in areas of water scarcity in Africa
- Unexplained Lead Contamination of a Small Water Supply in Northern Scotland

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Chapter 1

The difficulties of managing water quality in small water supplies

1.1 WHAT ARE SMALL WATER SUPPLIES?

1.1.1 Definitions

Size is relative. This applies to most things, and water supplies are no exception. To a municipal water supplier in a large urban area, "small" may mean a water treatment plant less than 1 Ml/d. In many rural areas across the world, there are countless supplies that provide life-giving water to an individual dwelling or a small, remote community. Clearly, a small supply means different things to different people. The USEPA defines a small water supply as serving 501–3300 people, with a supply serving 500 people or less classified as very small. In other parts of the world, a water supply of 500 people would be classed as medium sized or even large. The European Drinking Water Directive legislates for supplies serving more than 50 people or supplying more than 10 cubic metres per day, unless they are involved in a commercial activity.

Such water supplies are often underfunded, poorly managed and neglected, and yet this should not be the case. Even in the developed countries of Western Europe and North America, small water supplies provide the only source of drinking water for a significant minority of the population. A figure of 10% has been estimated for the percentage of the population of the European Union reliant on small or very small water supplies (Hulsman, 2005), based on aggregated data from member states. Globally, the World Health Organisation (WHO) estimates that 884 million people (13% of the world's population) had no access to an improved water supply in 2008 (WHO/UNICEF, 2010). By far the majority of these supplies will be small ones, and most – WHO estimate 94% of this population – will live in rural areas. From similar data on small water supplies around the world it is evident that:

- estimates of the populations served carry a high degree of uncertainty;
- figures vary widely between countries;
- the issue of small, unimproved water supplies is especially acute in rural areas;
- the data on the nature and quality of these supplies is often very limited.

Clearly, in this topic area it is not helpful to rely too closely on definitions and absolute statistics. It is more useful to consider the characteristics of these supplies and the common factors which make the quality of water they supply difficult to maintain consistently to a sufficiently high standard. For the purposes of this publication, small water supplies will be considered primarily to be ones serving less than 500 people and which experience one or more of the following issues:

- minimal or limited regulation
- varying raw water in terms of quantity and quality
- very limited resources for treatment and correct distribution and storage of water
- a lack of expertise in water treatment and supply
- a low awareness of risk
- a lack of robust monitoring and safeguards

With the very smallest water supplies – those serving just a few people – the problems above are often intensified and treatment options more limited. This guide will aim to specifically address the difficulties encountered by these supplies.

1.1.2 What does a small water supply look like?

Sources of raw water for consumption are varied, and most are scaleable, so that a river abstraction could supply a single property or a small town. Similarly, groundwater sources can supply large populations via wellfields containing many boreholes or consist of a single well in someone's garden. Typical sources of water for small supplies include the following:

- Streams
- Lakes or ponds
- Springs
- Wells
- Boreholes
- Temporary sources such as bowser or tanker

There are also a number of management scenarios for small supplies and, more than anything else, it is probably these that define the health risk presented by the supply. A supply serving a handful of people that is owned, managed and operated by a large municipality or utility company is ultimately far less likely to experience the same quality issues at the point of use as those encountered by a supply of the same size that is managed by individuals or a community. This publication is very much aimed at the latter scenario, although the technical challenges described may also affect the former.

Some examples of relevant management scenarios are described below:

Individual responsibility supplies

These supplies are very small and supply a single property or family dwelling. The user of the supply has sole responsibility for the operation and maintenance of the supply, whether the implications of this are fully understood and accepted or not. These supplies are often described in legislation as private wells and may be subject to minimal or no regulation and state or municipal involvement. Water quality monitoring will often be at the discretion of the user, and where there is a lack of interest, awareness of the risks or resources it is highly likely that no monitoring will take place. Where it does take place, the dataset collected is unlikely to be of a sufficient size to provide a representative picture of the quality of the water supplied. Although outside the scope of this publication, the microbiological situation illustrates this point effectively – a single sample taken on one day that is free from faecal indicator bacteria provides no guarantee that the supply is free from contamination on the remaining 364 days of the year. Provided the water appears clean, the assumption may be made that it is safe for drinking.