Potassium– Background Document
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Introduction

Potassium is an essential element in humans, and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for water softening in place of, or mixed with, sodium chloride so potassium ions would exchange with calcium and magnesium ions. Possible replacement or partial replacement of sodium salts with potassium salts for conditioning desalinated water has been suggested. The latter seems to be an unlikely development at this stage in view of the cost difference. The move to using potassium is driven by concerns over the total dietary intake of sodium, particularly in developed countries of the West where there are concerns regarding the high intake of salt from processed foods. On the other hand, there are also concerns that some diets may be low in potassium. This is not a concern for the general population, however, increased exposure to potassium could result in significant health effects in people with kidney disease or other conditions, such as heart disease, coronary artery disease, hypertension, diabetes, and/or who are taking medications that interfere with normal body potassium handling.

Exposure to Potassium

Potassium is an essential element and is present in all animal and plant tissues. The primary source of potassium for the general population is the diet since potassium is found in all foods and particularly vegetables and fruits. Some food additives are also potassium salts, e.g. potassium iodide. Some individuals require potassium supplements, which are given under medical supervision; others take potassium supplements without supervision, although this is not recommended.

Potassium permanganate may also be used in the drinking water treatment process. Resulting levels of potassium in drinking water are relatively low when compared to levels resulting from water softeners using potassium chloride. Where potassium permanganate is used in water treatment concentrations of added potassium can be up to a maximum of 10 mg/litre but it would normally be less than this.

Although concentrations of potassium normally found in drinking water are generally low and do not pose health concerns, the high solubility of potassium chloride and its use in treatment devices such as water softeners can lead to significantly increased exposure. In the UK a survey carried out for the Regional Heart Study (WRc 1987) found a mean concentration of 2.5 mg potassium/litre with an upper 90 percentile of 5.2 mg/litre. Data from Canada indicate that average concentrations in treated and raw drinking water in different areas vary between <1-8 mg/litre. However, concentrations ranged up to 51 mg/litre in Saskatchewan, which is the largest production area for potassium chloride in Canada (Health Canada, 2008).

When used, potassium-based (usually mixed potassium and sodium) water softeners remove minerals such as calcium and magnesium ions from hard water, replacing them with potassium and sodium ions, rather than sodium ions alone. The intake of potassium from the consumption of drinking water treated with a water softener using potassium chloride will vary depending on the level of hardness in the source water. Assuming that a 100% potassium chloride regenerated water softener releases 14 mg K^+/litre in water with a hardness of 17 mg $CaCO_3$/litre, the amount of potassium released in 1 litre of drinking water can be calculated for different hardness levels. Table 1 shows that a water softener using potassium chloride can add significantly to the intake of potassium when compared to the amount that would be typically consumed in drinking water, even when the water treated had water hardness levels generally considered to be acceptable (Health Canada, 2008). With a hardness of 100 mg/litre the concentration would be 82 mg/litre, 200 mg/litre would be 164 mg/litre and 500 mg/litre would be 411 mg/litre.

Table 1: Intake of potassium as a result of water softener use, by hardness level

Drinking water hardness (mg $CaCO_3$/litre)	**K^+ concentration (mg/litre)**	**Intake[c] (mg/kg bw/day)**
Treated tap water	8.0[a]	0.27
100 (acceptable)[b]	82	2.7
200 (poor)[b]	164	5.5
500 (unacceptable)[b]	411	13.7

[a] Average K^+ concentration in drinking water, based on the average potassium concentration in the Canadian province with the highest measured K^+ concentrations
[b] Based on Health Canada's drinking water quality guideline for hardness
[c] Assuming consumption of 2 litres of water per day by a 60-kg adult

Essential Intakes

As indicated above, potassium is an essential element for human nutrition and requirements are generally measured in grams per day. Potassium and sodium maintain the normal osmotic pressure in cells. It is a cofactor for many enzymes and required for the secretion of insulin, creatinine phosphorylation, carbohydrate metabolism and protein synthesis.

Excessive loss of salts, such as through severe diarrhoea or intense and prolonged sweating, can result in a sufficient loss of potassium to result in hypokalaemia. This can cause a range of effects, including cardiac arrhythmia, muscle weakness, nausea and vomiting and low muscle tone in the gut. Longer term hypokalaemia is believed to cause a predisposition to hypertension (UK EVM 2003).

Table 2: Dietary Reference Intake values (as Adequate Intake) derived by IOM (2004)

Age group	**Dietary Reference Intake (g/day)**

Infants	0-6 months	0.4
	7-12 months	0.7
Children	1-3 years	3.0
	4-8 years	3.8
Males	9-13 years	4.5[a]
	14->70 years	4.7[a]
Females	9-13 years	4.5[a]
	14->70 years	4.7[a]
Pregnancy	n/a	4.7[a]
Lactation	n/a	5.1[a]

[a] UK guidelines for adults – 3.7 g/day with no requirement for additional intake in pregnancy and lactation; n/a = not applicable

The adequate intake for adults (19–>70 years of age) is 4.7 g/day (67 mg/kg bw/day for a 70 kg adult) and is based on potassium's effect of countering salt (sodium chloride) sensitivity in African Americans, as well as epidemiological evidence linking higher levels of potassium intake with decreased risk of bone loss and kidney stones.

Interactions with other elements

It is known that the balance between sodium and potassium intake is very important, since excess sodium intake can result in depletion of potassium levels. In magnesium deficiency there is a failure to retain potassium in sufficient quantities and an excess intake of potassium can interfere with magnesium uptake.

Effects of high potassium intake

Adverse health effects due to potassium consumption from drinking water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting (Gosselin *et al*. 1984). Case studies of toxicity resulting from high doses of salt substitutes have described chest tightness, nausea and vomiting, diarrhoea, hyperkalaemia, shortness of breath and heart failure. For example, a fatality resulted from hyperkalaemia and resultant asystole after ingestion of 21 g of salt substitute (approximately 11 g potassium (Restuccio 1992). A 2 month old boy died after being given three doses of 1.5 g potassium chloride with breast milk over one and a half days (Wetli and Davis 1978).

Potassium toxicity has been studied in relation to the use of high doses of salt substitutes. The symptoms described have been chest tightness, nausea and vomiting, diarrhoea, hyperkalaemia, shortness of breath and heart failure. However, the data are not considered adequate to derive an Upper Limit for intake. This is compounded by a number of high risk groups considered below. However, it is considered by the UK expert group on vitamins and minerals that for normal individuals, ingestion of supplements of up to 3700 mg K^+/day is likely to be without overt effects, although tablets may lead to some minor gastrointestinal mucosal erosion. This conclusion was based on studies by Grimm *et al.* (1988, 1990) and McMahon *et al*. (1982, 1984).

High risk groups

Adverse effects due to higher than normal potassium plasma concentrations (hyperkalaemia) may occur in certain segments of the population when consuming drinking water with unusually high levels of potassium arising from the use of ion exchange treatment with particularly hard water, or accidental release of very high concentrations. Individuals most at risk are primarily those in which excretion of potassium ions might be reduced or compromised, including those with kidney disease or renal insufficiency, older individuals who have reduced physiological reserve in their renal function, as well as individuals with other conditions (heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, and existing kyperkalaemia) and/or individuals who are taking medication(s) that interfere with normal potassium-dependent functions in the body. In addition, infants may also be more vulnerable due to a limited renal reserve and immature kidney function.

Kidney disease is not thought to be able to seriously affect potassium homeostasis until the kidney has reached less than 40% of normal function. This can be many thousands of individuals and is likely to increase with ageing populations. In Canada, it is estimated that approximately 44,000 individuals have stage 4 (15-30% of kidney function) and stage 5 (<15% of kidney function) kidney disease (Stigant et al. 2003) and are at greater risk of developing hyperkalemia under certain conditions, including potassium supplementation (KCl-based water softener) and/or the consumption of certain medications.

Medication that can interfere with potassium homeostasis

A number of medications can cause hyperkalaemia when administered to individuals with kidney disease or diseases that affect potassium homeostasis. These drugs can be divided into two categories: those that interfere with the cellular mechanisms that regulate potassium uptake, and those that interfere with renal potassium excretion. The first category includes non-selective beta blockers, used in the treatment of hypertension, heart disease, coronary artery disease and fluid-retaining syndromes. The second category includes the following classes of drugs: potassium sparing diuretics (hypertension, heart disease, kidney and liver disease); nonsteroidal anti-inflammatory drugs (NSAIDs)(pain treatment); angiotensin-converting enzyme (ACE) inhibitors (heart disease, coronary artery disease, hypertension, diabetes, kidney disease); angiotensin II receptor blockers (heart disease, hypertension); trimethorprim (HIV treatment); cyclosporin (immunosuppressive drug) and aldosterone inhibitors (heart disease, hypertension, birth control)(Perazella and Mahnensmith 1997; Perazella 2000; CCS 2003; CHS 2005).

Currently it is recommended that groups at risk should not take any potassium supplementation except under close medical supervision.

Adverse effects may also occur when potassium plasma concentrations are lower (hypokalaemia) than the normal range (3.5-5.0 mmol/litre). Both hyperkalaemia and hypokalaemeia result from disruptions in transcellular homeostasis or in the renal regulation of potassium excretion (Gennari 2002).

Discussion

Currently there is no evidence that potassium levels in municipally-treated drinking water, even water treated with potassium permanganate, are likely to pose any risk for the health of consumers. It is not considered necessary to establish a health-based guideline value for potassium in drinking-water.

Although potassium may cause some health effects in susceptible individuals, potassium intake from drinking water is well below the level at which adverse health effects may occur. Health concerns would be related to the consumption of drinking water treated by potassium-based water treatment (principally potassium chloride for regeneration of ion exchange water softeners), affecting only individuals with kidney dysfunction or taking medications that interfere with normal potassium-dependent functions in the body. It is recommended that susceptible individuals avoid the consumption of water (for drinking or cooking) treated by water softeners using potassium chloride or take appropriate medical advice.

In cases where a significant amount of potassium is added to water through the use of a water softener, the recommended strategy is to limit the addition of potassium to water that will be ingested or to avoid ingesting such water. This can be done by having a proportion of the water bypass the softener altogether. Although technologies are available to remove potassium, they are generally more expensive and redundant when combined with the softening treatment.

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