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Teeth and Liquids

Drinking Water in Health and Disease

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Drinking Water in Health and Disease

By Allan Bardow and Maja Bruvo Lazovic, Copenhagen, Denmark

Drinking water may affect our health to a degree that was previously unknown to man. Thus selected compositional characteristics of drinking water could play a significant role in many common diseases. This is of global interest since a number of countries have started national scale desalination programs of drinking water. In this context the two papers mentioned below describe previously unknown effects of drinking water on health and disease.

Schrøder S, Homøe P, Wagner N, Vataire AL, Lundager Madsen HE, Bardow A. Does drinking water influence hospital-admitted sialolithiasis on an epidemiological level in Denmark? British Medical Journal [OPEN] 2015.

http://bmjopen.bmj.com/content/5/4/e007385.long

Bruvo M, Ekstrand K, Arvin E, Spliid H, Moe D, Kirkeby S, Bardow A. Optimal drinking water composition for caries control in populations. Journal of Dental Research [USA] 2008.

http://jdr.sagepub.com/content/87/4/340.abstract (see text and figures below)

Further exploration into drinking water and dental caries

In Denmark all drinking water is derived from ground water without any kind of fluoridation. Therefore, although only a small country (42,925.46 km2), major variations in the drinking water composition exist. The same goes for caries experience (DMFS), which enables strong correlations to be obtained. At the same time the socioeconomic status does not show major variations across the country and the population is relatively homogeneous nationwide. The figure below shows the national variations in caries experience (A), drinking water fluoride (B) and drinking water calcium (C).
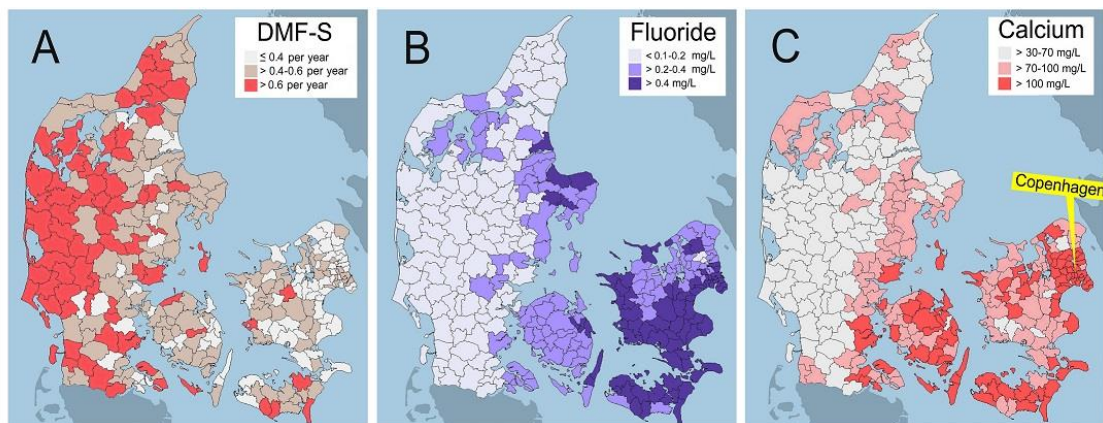

By additional iterative search and testing on the above shown data as well as additional data the explanatory power of the calcium fluoride model (presented in the paper above) on the annual number of decayed, missed and filled tooth surfaces (DMFS) among 52,057 15-year-old teenagers in 249 municipalities covering the land of Denmark could be increased to 51% (p<0.001) by adding pH, chloride and bicarbonate to the exponentially fitted model shown below:

$$DMFS/yr=exp[-0.69-(0.15*(fluoride-0.33)/0.25)-(0.09*(calcium-83.5)/25.63)-(0.04*(pH-7.69)/0.17)-(0.09*(bicarbonate-264)/94.1)+(0.07*(chloride-48)/33.0)]$$

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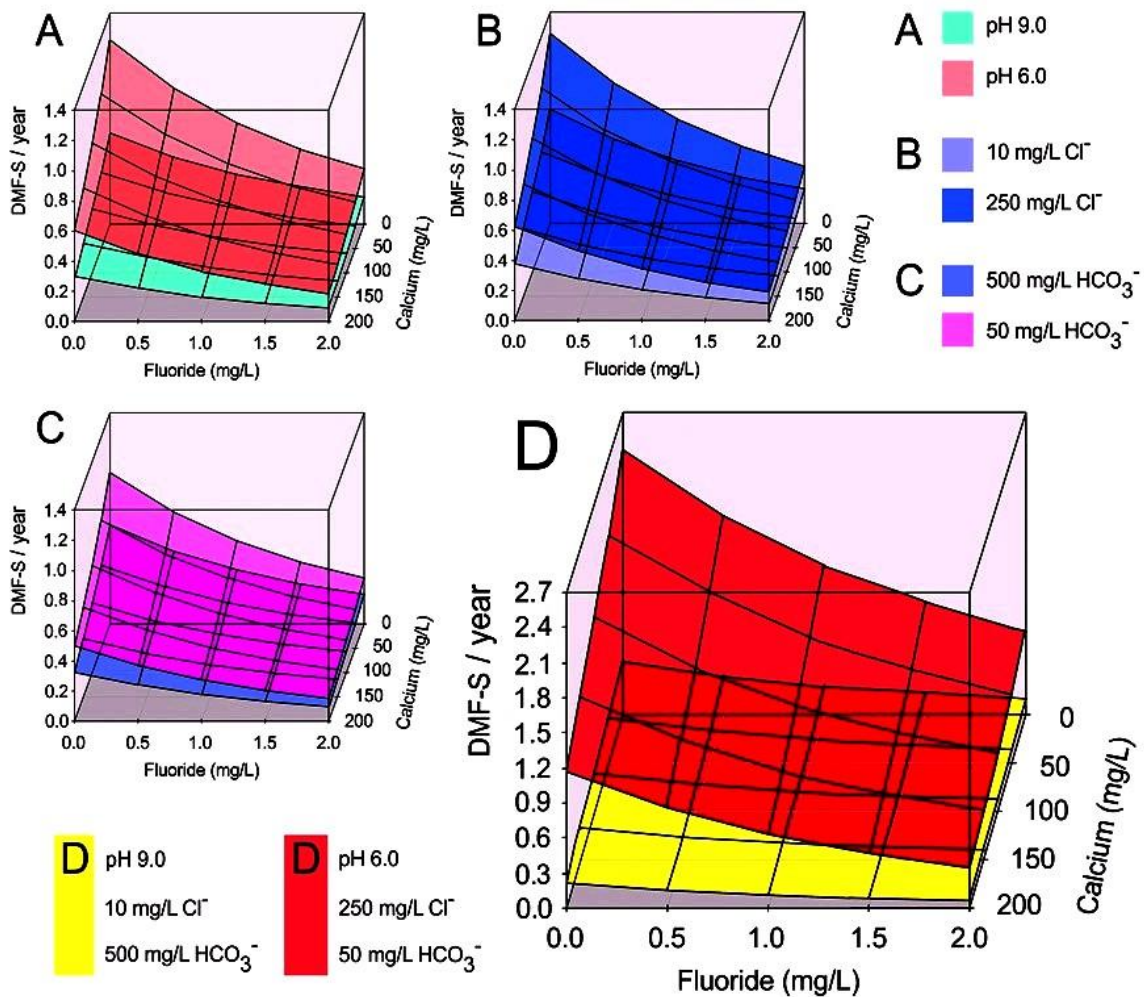
Panel A shows the effect of drinking water pH on DMFS/year as a function of drinking water calcium and fluoride, panel B the effect of drinking water chloride, panel C the effect of drinking water bicarbonate and panel D the combined effect of drinking water pH, chloride and bicarbonate on DMFS/year as a function of drinking water calcium and fluoride.

Entering average Danish drinking water values for calcium, fluoride, pH, chloride and bicarbonate into the exponentially fitted model above returned an average DMFS/year for 52,057 15-year-old teenagers in Denmark of 0.50157608 DMFS/year. Given that the caries activity normally is higher among children and teenagers compared to adults this estimated provides a fixed endpoint for 15-year-olds, however, the similar estimate for adults may be lower.

By transformation of the exponentially fitted DMFS/year function shown above the amount of fluoride (mg/L) needed to obtain a desired DMFS/year (with 51% certainty) can be determined when the 4 other parameters in this model are known or decided upon - enabling dynamic water fluoridation while maintaining a constant DMFS/year as shown in model below:

$$Fluoride=[((-0.69-(0.09*(calcium-83.5)/25.63)-(0.04*(pH-7.69)/0.17)-(0.09*(bicarbonate-264)/94.1)+(0.07*(chloride-48)/33.0)-(ln(DMFS/yr)))/0.15)*0.25]+0.33$$

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Finally we hypothesized that the combined effect of calcium and fluoride on DMFS/year mainly can be explained by the drinking water level of saturation with respect to calcium fluoride (CaF2) as shown in the figure below. Thus the degrees of saturation with respect to hydroxyapatite and calcium carbonate seemed unrelated to DMFS/year. Saturations levels with respect to fluorapatite were somewhat related, but the explanatory power on DMFS/year was much lower than for calcium fluoride:
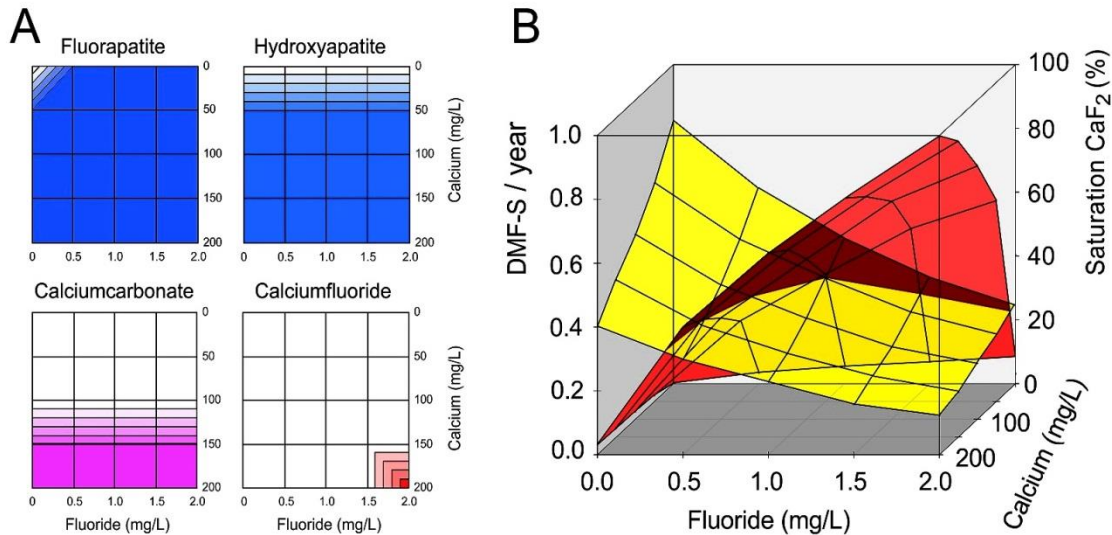
Panel A shows degrees of saturation with respect to various mineral species in drinking water as a function of calcium and fluoride and Panel B shows DMFS/year (yellow) and degree of saturation with respect to calcium fluoride (red).

Raw equations that can be used directly in: R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org/

DMFS/year=exp(-0.69-(0.15*(0.33-0.33)/0.25)-(0.09*(83.5-83.5)/25.63)-(0.04*(7.69-7.69)/0.17)-(0.09*(264-264)/94.1)+(0.07*(48-48)/33.0))

Fluoride=(((-0.69-(0.09*(83.5-83.5)/25.63)-(0.04*(7.69-7.69)/0.17)-(0.09*(264-264)/94.1)+(0.07*(48-48)/33.0)-(log(0.50157608)))/0.15)*0.25)+0.33

The raw equations were developed with average Danish drinking water values for fluoride (0.33 mg/L), calcium (83.5 mg/L), pH (7.69), bicarbonate (264 mg/L) and chloride (48 mg/L) as well as the annual increment in DMFS for 15-year-old teenagers (0.50157608). In order to apply these equations on another population all values need to be changed or decided upon accordingly to fit the nation or population in question.

Additional references

- Rygaard M, Arvin E, Bath A, Binning PJ. Designing water supplies: Optimizing drinking water composition for maximum economic benefit. Water Res 2011; 45: 3712-22.
- Rygaard M, Arvin E, Binning PJ. The valuation of water quality: effects of mixing different drinking water qualities. Water Res 2009; 43: 1207-18.