Physiological Impact of Nitrate Intake from Non-disinfected Drinking Well Water

Dr Mina Sadeq

Scientia

PHYSIOLOGICAL IMPACT OF NITRATE INTAKE FROM NON-DISINFECTED DRINKING WELL WATER

Prolonged exposure to nitrate from contaminated water affects the transport of oxygen in blood. Nitrate can react with haemoglobin, oxidising it into methaemoglobin, which is unable to carry oxygen. High methaemoglobin levels among infants result in a medical condition known as methaemoglobinemia or blue baby syndrome. **Dr Mina Sadeq** and her team from the National Institute of Hygiene in Morocco, conducted two studies to investigate the combined effects of nitrate and bacteria on the development of methaemoglobinaemia in infants and young children.

The Sources of Nitrate Contamination in Ground Waters

Hundreds of millions of people use water from unprotected wells and springs around the world. These sources of groundwater can be contaminated with nitrogen fertilisers, agricultural runoffs, animal manure and sewage. The organic and inorganic compounds present in the contaminants can directly or indirectly sustain bacterial life forms. For example, nitrate, an undesirable fertiliser residue in the food chain, can support the growth and proliferation of bacteria that thrive by metabolising it to produce nitrite.

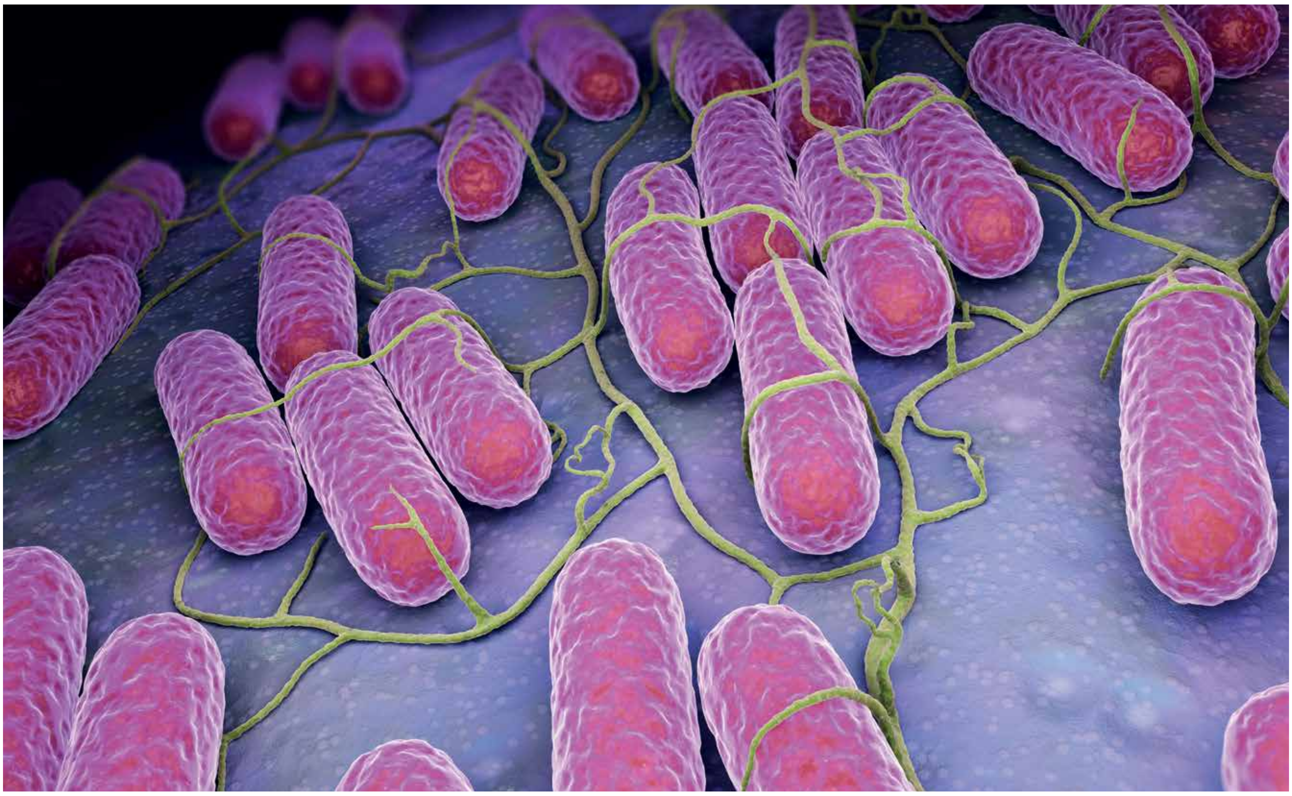
Dr Mina Sadeq, from the National Institute of Hygiene in Morocco, has long been involved in a research project that aims to establish the physiological impact of nitrate intake among populations that are exposed to high levels of the contaminant. Dr Sadeq and her team conducted two studies in Morocco to collect data on the methaemoglobin levels in the blood of young children exposed to nitrate in well water. They aimed to ascertain if the effect of nitrate exposure on methaemoglobin levels was similar among those who disinfect water to kill bacteria and those who do not.

How Nitrate Affects the Transport of Oxygen in the Blood

A high intake of nitrate and its consequent reduction to nitrite, causes the formation of methaemoglobin, a derivative of haemoglobin that cannot bind to oxygen. Methaemoglobin contains a highly oxidised form of iron (Fe^{3+}) instead of the typical ferrous form (Fe^{2+}), which is usually present in haemoglobin. The levels of methaemoglobin in the body should not exceed 2% of the total haemoglobin.

Once that threshold is crossed, a number of symptoms can develop, such as dizziness, fatigue and blue discolouration of skin and lips, a condition known as cyanosis and generally observed at methemoglobin

levels higher than 10%. Cyanosis is usually a sign of an underlying disease called methaemoglobinemia. Below this level, methaemoglobinemia is generally not a noticeable disease. As methaemoglobin levels increase, symptoms continue to get more serious. These can include confusion, seizures, and rapid heart rate. In the worst cases, high levels of methaemoglobin can tragically lead to coma and death.



Illustraton of Salmonella.

From previous research, it was well known that nitrate from drinking water can reduce the blood's ability to transport oxygen to the infant's body by increasing the methaemoglobin levels, a medical condition known as infant methaemoglobinaemia or blue baby syndrome. However, less was known about nitrate-induced methaemoglobinaemia in young children. Furthermore, it was not clear whether it is nitrate, bacteria, or the presence of both that increases methaemoglobin level in the blood, as no previous study had investigated this.

Establishing the Impact of Chronic Nitrate Exposure

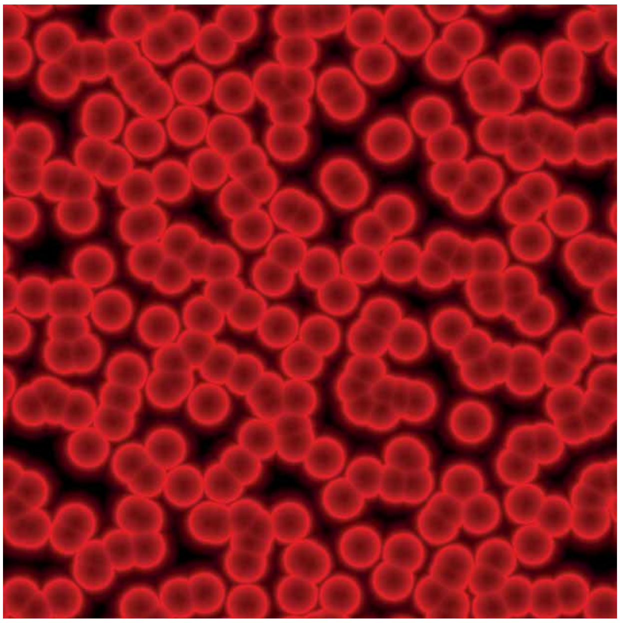
Dr Sadeq and her team were interested in determining whether a possible nitrate effect could be chronic, that is, proportional to the time of exposure to nitrate. For this reason, children who had not been born or had not grown up in the area were excluded from the study. In order to undertake a fair investigation, many variables had to be controlled. The children in the study were aged between 1 and 7 years of age, and were recruited from two adjacent areas in Salé in Morocco, and which had similar air quality, only differing in the quality of the drinking water available. A study physician was employed to screen for taken medications, use of herbs, and household chemicals that could affect the blood level of methaemoglobin.

Nitrate exposure was assessed through a preliminary interview, a detailed questionnaire and the analysis of samples of water from either the exposed area or the unexposed municipal water supply. More than 50% of the participants were aged between 1 and 5 years. The study findings confirmed that the level of nitrate ions present in well-waters had an effect on the concentration of methaemoglobin in the blood. The findings also suggested that the length of exposure to nitrate in the water might increase the likelihood of developing methaemoglobinaemia in older children as compared to their younger counterparts, with no apparent differences observed relating to gender.

Role of Micro-organisms in the Oxidation of Haemoglobin

As well-waters in rural areas may be contaminated with both nitrate as a consequence of agricultural activities, and microorganisms, Dr Sadeq and her team wondered whether water disinfection with chlorine might be a factor that contributes, in addition to nitrate exposure, to the development of methaemoglobinemia in young children. The research team published a second study, in which they investigated not only the effect of nitrate, but of other factors related to potential bacterial water contamination.

Typically, bacteria process organic matters by first decomposing them to give ammonia, which is then oxidised to nitrite and nitrate. The study showed that when chlorine was used to disinfect well-waters, the effect of both low and high nitrate concentrations on the likelihood of developing methaemoglobinaemia were similar. However, in the absence of chlorination, higher levels of nitrate correlated with blood sample concentrations of



methaemoglobin that were 5 times higher than those observed within the cohort that was exposed to lower levels of nitrate. A plausible explanation is that, in the absence of disinfectant, some microorganisms, including E. coli and Salmonella, are capable of reducing the chemically unreactive nitrate ion to nitrite ion, which can, in turn, react with haemoglobin and produce methaemoglobin.

Potential causes of methaemoglobinaemia other than drinking water nitrate were not identified in either of the two studies.

The air quality, the socio-economic status indicators (housing and living conditions, and family income), the frequented food markets, and the quality of health care provided by the two available health centres all were similar for both high and low exposed participants. These findings confirmed that the effect of nitrate on the development of methaemoglobinaemia was manifested only in the presence of waterborne microorganisms.

Concluding Remarks

Dr Sadeq and her collaborators reported that children drinking well-water with high nitrate levels have a higher risk of developing methaemoglobinemia, a condition where haemoglobin is oxidised to methaemoglobin, severely affecting the amount of oxygen that the blood is able to transport. The team observed that this 'nitrate effect' was chronic, meaning that the levels of methaemoglobin in young children increased with the period of exposure to nitrate in drinking well waters. In the absence of disinfection with chorine, increased methaemoglobin levels were about 5 times higher in children who were exposed to high nitrate water levels than in children in the low nitrate level group.

Given the long-term consequences of lack of oxygen associated with methaemoglobinemia, the relationship between waterborne microorganisms, nitrate exposure via drinking water and increased methemoglobin level in childhood needs to be further explored.

Meet the researcher

Dr Mina Sadeq
National Institute of Hygiene
Unit of Environmental Epidemiology
Rabat
Morocco

Dr Mina Sadeq received her PhD in Environmental Epidemiology from Ibn Tofail University in Morocco (with a Fulbright joint supervision from the Hubert Department of Global Health at Emory University, USA). After completing her doctoral studies, Dr Sadeq was appointed to the Unit of Environmental Epidemiology in Morocco. Her interests include the investigation of the effect of environmental factors on various health issues such as tuberculosis, asthma, and the effects of lead poisoning on children. Dr Sadeq has authored several peer-reviewed publications and is an Editor of the *Environmental and Water Sciences, Public Health & Territorial Intelligence Journal* (Public Health section). She is also a member of the International Society of Global Health (ISoGH) in the UK.

CONTACT

E: mina.sadeq@gmail.com

KEY COLLABORATORS

Larbi Idrissi, National Institute of Hygiene, Morocco
Christine L Moe, Rollins School of Public Health at Emory University, USA
Rajaa El Aouad, National Institute of Hygiene, Morocco
El Bachir Ben Abbou, National Institute of Hygiene, Morocco
Fatima Benammi, National Institute of Hygiene, Morocco
Naima Nouari, National Institute of Hygiene, Morocco
Benaissa Attrassi, Faculty of Science, Ibn Tofail University, Morocco
Imad Cherkaoui, Regional Observatory of Epidemiology of Rabat-Salé-Zaer, Morocco
Mohamed Lakranbi, Directorate of Epidemiology and Disease Control, Morocco
Redouane Aboukal, Faculty of Medicine & Pharmacy, Mohammed V University, Morocco

FUNDING

This work was supported by WHO-EMRO (Project TSA 04/6). The views and opinions expressed in this article are those of the authors and do not necessarily reflect the view of WHO-EMRO.

FURTHER READING

M Sadeq, CL Moe, B Attarassi, I Cherkaoui, R El Aouad, L Idrissi, Drinking water nitrate and prevalence of methemoglobinemia among infants and children aged 1–7 years in Moroccan areas, International Journal of Hygiene and Environmental Health, 2008, 211, 546–554.

M Sadeq, R Abouqal, B Attarassi, M Lakranbi, R El Aouad, L Idrissi, Does exposure to nitrate in drinking Water contribute anything the effect of water chlorination on children methemoglobin levels? Journal of Environmental Protection, 2012, 3(2), 169–176.