Institution: Teesside University		
Unit of Assessment: 3		
Title of case study: Shaping regional, national, and international oral health policy and practice: from bench to community.		
Period when the underpinning research was undertaken: 2008-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Vida Zohoori (Zohouri)	Professor in Oral Public Health and Nutrition	May 2007 to Present
Narges Omid	Post-doctoral Research Associate	April 2013 to October 2016
Period when the claimed impact occurred: August 2013 – 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Research at Teesside University on fluoride intake, retention and monitoring has reformed World Health Organisation (WHO) policy and led to changes in water and milk fluoridation schemes in the UK and Ireland. Specifically, the research has reshaped the WHO technical guidelines for the effective surveillance of fluoride exposure, underpinned Food Safety Authority of Ireland (FSAI) recommendations on dietary fluoride, and informed a UK regional authority's decision to introduce a fluoridated-milk scheme in local primary schools (Blackpool Council).

2. Underpinning research (indicative maximum 500 words)

According to the WHO, 60-90% of school children are affected by tooth decay in industrialised countries. Topical use of fluorides has been recognised as the key reason for the decline in the prevalence of dental caries (tooth decay) worldwide. At low levels, fluoride reduces tooth decay, but high levels can damage developing tooth enamel in young children (fluorosis). It is, therefore, important that fluoride exposure is known, and that health authorities are made aware of exposure before the introduction of any fluoridation programmes for caries prevention. The WHO recommends that fluoride supplementation programmes should be monitored prior to, and after, implementation to ensure that ingestion of fluoride from all sources by the children involved is at the appropriate level. Research undertaken at Teesside University on the intake, retention and monitoring of fluoride has elucidated key issues in fluoride measurement and total fluoride exposure, leading to new developments in experimental models, fluoride databases and monitoring plans to better understand fluoride intake and retention.

From 2009-2010, Zohoori collaborated with the Institute of Nutrition and Food Technology (University of Chile), Antioquia University (Colombia), and Newcastle University (UK) to develop models based on available data to estimate total daily fluoride intake from daily urinary fluoride excretion, and, therefore, to predict the risk of fluorosis development. The researchers assumed a fluoride absorption of 90%. Reliably estimating intake from retention data requires a strong relationship between predictor and outcome, and detailed knowledge of the fraction of fluoride consumed that is retained. The analyses revealed strong positive linear relationships between both intake and excretion and intake and retention, with different slopes for children and adults. Interestingly, beyond thresholds for total daily fluoride intake of 0.5mg/day for children and 2mg/day for adults, fractional fluoride retention remained reasonably constant at 55% and 36% of total intake, respectively. Neutral fluoride balances (fractional fluoride retention = 0) were predicted when the total daily intake was around 0.07mg/day for children and 0.8mg/day for adults, or approximately 0.01mg per kg body weight per day, irrespective of age. These results permitted acceptable population-level estimates of total daily fluoride intake from recorded daily urinary fluoride excretion, enabling predictions of the risk of fluorosis [3.1].

From 2003 to 2010, Zohoori collaborated with nine fluoride research centres on a US NIH-NIDCR (National Institute of Dental and Craniofacial Research) funded project to develop and evaluate key standardised techniques for determining the fluoride content of biological and non-biological samples and, therefore, the accurate quantification of an individual's fluoride exposure [3.2]. Since 2008, Zohoori led and co-led a series of Organix Foundation and Borrow Foundation funded projects in which the fluoride content of >750 commercially available foods and drinks were measured. In 2015, this work resulted in the publication of a unique fluoride database, which was revised and updated in 2019 [3.3, 3.4].

In 2008, and as part of a Borrow Foundation funded project, Zohoori co-led a study that was commissioned by the UK National Fluoridated Milk Advisory Group to assess the appropriateness of the fluoride dose in milk. For many years, and in many countries, fluoride has been added to milk as a public health measure for caries control. In the UK, milk fluoridation is used in school-based programmes for children who reside in low fluoridated water areas and who are at high risk of caries. The original concentration of fluoride in milk was 0.5mg in a 189-ml carton. Zohoori's research indicated that both the existing fluoride concentrations of 0.5mg and the intervention project concentration of 0.9mg in a 189-ml milk carton may be too low to achieve the WHO recommended urinary fluoride excretions concomitant with optimal fluoride exposure for children > 6y [3.5]. Consequently, Zohoori determined that UK schemes should review their current monitoring milk fluoridation programme.

3. References to the research (indicative maximum of six references)

[3.1] Villa A, Anabalon M, Zohouri V, et al. 2010. Relationships between fluoride intake, urinary fluoride excretion and fluoride retention in children and adults: an analysis of available data. Caries Research. 44, 60-8. https://doi.org/10.1159/000279325. Cited 47 times (Web of Science). Selected as an output for REF2014 (95.5% 2* and above).

[3.2] Martínez-Mier EA, Cury JA, Heilman JR, Katz BP, Levy SM, Li Y, Maguire A, Margineda J, O'Mullane D, Phantumvanit P, Soto-Rojas AE, Stookey GK, Villa A, Wefel JS, Whelton H, Whitford GM, Zero DT, Zhang W, Zohoori V. 2011. Development of Gold Standard Ion-Selective Electrode-Based Methods for Fluoride Analysis. Caries Research. 45, 3-12. https://doi.org/10.1159/000321657. Cited 72 times (Web of Science). Selected as an output for REF2014 (95.5% 2* and above).

The research was underpinned by a National Institute of Dental and Craniofacial Research. grid.419633.a. IR21DE014716 -01. Development of Gold Standard Methods for Fluoride Analysis. Principal Investigator: Martinez-Mier, EA (Indiana University-Purdue University at Indianapolis). 2003-2010. Co-Investigator: Zohoori. GPB305,000.

[3.3] Zohoori FV and Maguire A. 2016. Development of a database of the fluoride content of selected drinks and foods in the UK. Caries Research. 50, 331-336. https://doi.org/10.1159/000445981. Cited 14 times (Web of Science).

This research was underpinned by a series of grants:

The Organix Foundation. grid.419913.7. Principal Investigator: Zohoori. Assessment of fluoride intake, excretion and retention of infants in the UK. 2013-2016. GBP45,000.

The Organix Foundation. grid.419913.7. Principal Investigator: Zohoori. Assessment of fluoride intake of infants in the UK. 2009-2010. GBP43,670. Partner University: Newcastle University.

The Organix Foundation. grid.419913.7. Principal Investigator: Zohoori. Fluoride contents of baby foods in the UK. 2008. GBP25,530. Partner University: Newcastle University.

The Borrow Foundation. grid.490753.c. Principal Investigator: Zohoori. Assessment of dietary fluoride intake using two dietary methods. 2008. GBP9,580.

The Borrow Foundation. grid.490753.c. Co-Investigator: Zohoori. Fluoride Research II. 2011-2015. GBP97,198.

[3.4] Zohoori, FV, Maguire, A. 2015. Database of the Fluoride (F) content of Selected Drinks and Foods in the UK and Ireland. Newcastle University and Teesside University. Revised 2019. Available at:

https://research.tees.ac.uk/ws/portalfiles/portal/16162254/Fluoride_Database_UK_and_Ireland_food_and_drink_December_2019_.pdf.

This research was underpinned by the grants listed under [3.3]. The dataset has now been digitised and is available via Mendeley Data: Zohoori, FV, Maguire, A. 2021. A Database of the Fluoride Content of Selected Drinks and Foods in the UK and Republic of Ireland. Mendeley Data. V1. http://dx.doi.org/10.17632/v3gphvp7cs.1

[3.5] Maguire A, Walls R, Steen N, Teasdale L, Landes D, Omid N, Moynihan P, Zohoori FV. 2013. Urinary fluoride excretion in 6- to 7-year olds ingesting milk containing 0.5 or 0.9 mg fluoride. Caries Research. 47, 291-298. https://doi.org/10.1159/000346549. Cited 3 times (Web of Science). Selected as an output for REF2014 (95.5% 2* and above).

4. Details of the impact (indicative maximum 750 words)

Information on total fluoride intake is essential when planning effective community-based fluoridation programmes for the prevention of dental caries and/ or dental fluorosis. In 1999, the WHO published the document: Monitoring of Renal Fluoride Excretion in Community Preventive Programmes on Oral Health, as a key resource for the WHO Global Oral Health Programme. In 2011, a WHO technical working group meeting took place in Geneva to review this guidance. As a direct result of Zohoori's research into fluoride intake and excretion, she was invited to this meeting as an international expert to change the technical guidelines and recommendations to enable countries to plan effective surveillance systems for community prevention programmes using fluoride. The technical guideline Basic Methods for Assessment of Renal Fluoride Excretion in Community Prevention Programmes for Oral Health was published in 2014 [5.1]. This technical guideline was based extensively on Zohoori's research (she was acknowledged directly on page 5) and was written to help 'countries to plan effective surveillance of fluoride exposure' and to 'stimulate oral health personnel and public health administrators to use a systematic approach to managing and analysing data obtained from different levels of fluoride exposure'. Tables 5.3-5.5 of the guideline contain standards of urinary fluoride excretion in 24h urine collections associated with low fluoride exposure and for the range of "optimal" exposure. These standards are calculated from the experimental model that was developed by Zohoori in [3.1]. As a result, policy makers and public health authorities could more readily assess and/or monitor fluoride exposure at community levels. This guidance has been downloaded 5,101 times since 2016, with most downloads coming from the USA, India, China, UK, and Indonesia [5.2].

The recommendations of the WHO technical guideline [5.1] have had continued relevance for the incorporation of fluoride-based interventions into programmes designed to reduce early childhood caries (ECC). For example, the guideline [5.1] that draws heavily on Zohoori's research has subsequently been used to inform the 2019 WHO implementation manual Ending Childhood Dental Carries [5.3]. This manual is intended to underpin decisions made by policy-makers about ECC interventions, as well as for chief dental officers, ministry of health focal points, and public health administrators in 'the development and implementation of plans for ECC prevention and control, using the primary health-care approach'. It was stated that the manual 'may also be used in training activities to help primary care teams understand ECC as a public health problem; recognize the essential risk factors for ECC, especially lack of exclusive breastfeeding, consumption of free sugars, and inadequate exposure to fluoride in prevention of dental caries; identify opportunities for intervention against ECC and its causes'. In particular, the manual directly draws on the research of Zohoori that underpinned the guideline, stating that 'the population exposure to fluoride should be measured before programme implementation. An adequate surveillance system through periodic urinary fluoride monitoring in the child population should be considered' [5.3]. The implementation manual has been downloaded 22,558 times since publication with top downloads from USA, Brazil, Mexico, Hong Kong, and Peru [5.2].

The findings of this research also feature in a WHO information document for decision makers, Exposure to inadequate or excess fluoride: A major public health concern [5.4]. The document has been downloaded 4,356 times since publication [5.2]. This document makes clear recommendations based on Zohoori's research in the technical report [5.1]: 'to provide guidance on the need to control population exposures to fluoride and establish the important balance between caries prevention and protection against adverse effects, community health

programmes can estimate total exposure by measuring renal fluoride excretion and compare these measurements with established optimal levels using methods published by the WHO [Zohoori's research in 5.1] to undertake community measurement programmes'.

A fluoride database containing information on the fluoride content of commonly consumed food and drink items is a pre-requisite for the assessment of dietary fluoride intake at individual and/or community levels. The Republic of Ireland is the only European country with mandatory national legislation requiring artificial fluoridation of drinking water. The principal function of the Food Standards Authority Ireland (FSAI) is to protect consumers and raise compliance through partnership, science, and food law enforcement. The FSAI is a statutory, independent, and science-based body dedicated to protecting public health and consumer interests in the area of food safety and hygiene, which includes dietary intake of fluoride. As a result of Zohoori's research on fluoride concentration data [3.3, 3.4], she made a significant contribution to the analysis component of a total diet study for the FSAI between 2014–2016 [5.5, 5.6]. For the Chief Specialist in Chemical Safety at FSAI, Zohoori provided 'extensive input into the planning and subsequent execution of the analytical work required under the project. Prof. Zohoori is a renowned expert in fluoride analysis and, given her research on this topic, has advised the authority of numerous aspects in preparation of the analytical work. She subsequently took charge of the project, including sample analysis, followed by data generation and interpretation. She authored three project reports on fluoride analysis of Irish foods and beverages and provided intellectual input into queries arising during and after the study' [5.5]. The study report enabled the FSAI to evaluate possible risks, if any, to the health of Irish children and adults. According to Chief Executive Officer at the FSAI: 'This report serves to provide independent and impartial information on the exposure to fluoride through the Irish diet. It is an important piece of research which also takes into account naturally occurring levels of fluoride in food and beverages we consume in our diets in Ireland…This study reaffirms the FSAI's and its Scientific Committee's view that exposure to fluoride from the diet for all population groups in Ireland is not of concern' [5.7]. The findings of the study were shared with the Irish Expert Body on Fluorides and Health, which operate under the aegis of the Department for Health.

Since only 10% of the UK population receive fluoridated water, a school milk fluoridation scheme was introduced in 1993 as a public health measure for caries control in non-fluoridated socially deprived areas. In 2008, Zohoori co-led a study, commissioned by the UK National Fluoridated Milk Advisory Group, to assess the appropriateness of the fluoride dose in milk. As a result of this initiative and her research, Blackpool Council contacted Zohoori in 2015 to develop a protocol to carry out a urinary fluoride excretion monitoring project to assess fluoride exposure of school children before making any decision on introducing fluoridated-milk schemes in the primary schools in Blackpool. Based on the findings of the monitoring exercise, Blackpool Council's Executive approved a proposal on the 18th Jan 2016 to introduce fluoridated milk to over 8000 school children in 37 primary schools in Blackpool as an acceptable measure of delivery of fluoride to school children [5.8, 5.9, 5.10]. The scheme is now in operation with over 70% of the milk ordered by Blackpool schools being fluoridated [5.8]. There has been an improvement in dental health of children during the scheme. The Director of Public Health for Blackpool Council said: 'The average number of decayed, missing or filled teeth for 5-year-old children in Blackpool was 1.83 in 2014/15, which was significantly higher than the rate of 0.84 for England. This reduced to 1.15 in 2018/19, which was similar to the rate of 0.80 for England' [5.8].

The British Society of Dental Hygiene and Therapy (BSDHT) have subsequently referenced the initiative as best practice, with the President of the BSDHT saying: 'It is great that the local council has recognised that something needs to be done to address this huge problem and taken positive action. Other areas with similar levels of oral health problems have already introduced such schemes and this is an opportunity to show other councils that with a small, inexpensive change huge benefits can be had' [5.9].

Overall, research on fluoride intake and measurement by Zohoori at Teesside University has had a significant impact on oral health policy at regional, national, and international levels. This work has led to changes in practice in the UK and supported the continuation of fluoridation schemes in Ireland.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] Technical Guideline (pdf). World Health Organization. 2014. Basic Methods for Assessment of Renal Fluoride Excretion in Community Prevention Programmes for Oral Health. The technical expertise of VZ is acknowledged on page 5. Available at: https://apps.who.int/iris/bitstream/handle/10665/112662/9789241548700_eng.pdf?sequence=1&isAllowed=y

[5.2] Collated download statistics (pdf) for documents listed in the WHO Institutional Repository for Information Sharing (IRIS). Statistics collated on 20 October 2020.

[5.3] Implementation Manual (pdf). World Health Organization. 2019. Ending childhood dental caries: WHO implementation manual. Available at https://www.who.int/publications/i/item/ending-childhood-dental-caries-who-implementation-manual.

[5.4] Information Document (pdf). World Health Organization. 2019. Exposure to inadequate or excess fluoride: A major public health concern. Available at: https://apps.who.int/iris/bitstream/handle/10665/329484/WHO-CED-PHE-EPE-19.4.5-eng.pdf?ua=1

[5.5] Signed Letter (pdf). Testimonial from the Chief Specialist in Chemical Safety at Food Standards Authority (pdf). Received on 12 February 2021.

[5.6] Diet Study (pdf). Food Safety Authority of Ireland. 2018. Total Diet Study 2014–2016: Assessment of dietary exposure to fluoride in adults and children in Ireland. Report of the Scientific Committee of the Food Safety Authority of Ireland. https://www.fsai.ie/publications/fluoride_study_2014-2016/

[5.7] Web Press Release (pdf and live link). FSAI Website - Total Diet Study, 20 April 2018. Available at: https://www.fsai.ie/news_centre/tds_fluoride_30042018.html

[5.8] Signed Letter (pdf). Testimonial from Director of Public Health, Blackpool Council. Received on 16 December 2020.

[5.9] News Item (pdf and link). Fluoridated milk approved for Blackpool children. 2016. BDJ Team. 3, 16044. https://doi.org/10.1038/bdjteam.2016.44.

[5.10] Minutes (pdf) for Blackpool Council Executing Meeting on Milk Fluoridation Scheme. 18 January 2016. Available at: https://democracy.blackpool.gov.uk/documents/s11531/EX5%20Flouridated%20Milk.pdf