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Review Article

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Drinking Water and Public Health Risk

Carina Harkin

Independent Researcher, Carahealth, Ireland

***Corresponding author**
Carina Harkin BHSc. Nat. BHSc. Hom.BHSc. Acu. Cert IV TAE. MPH (pend), Independent Researcher, Carahealth Galway Ireland, MPH student UCC, College Rd, University College, Cork, Ireland. E-mail: info@carahealth.com

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Abstract

Drinking water is a social determinant to disease, a powerful determinant of health and also promotes socioeconomic development, yet public health is failing to protect the public with poor drinking water quality posing a threat to public health. Major sources of ground and surface contamination are landfill and human sewerage. Irish Water has consecutively failed to meet safety standards for bromate, nickel, nitrite, copper, pesticides, arsenic, fluoride, lead, trihalomethanes (THM). Regardless of where public opinion lies in relation to the addition of hexafluorosilicic acid to drinking water as a public health measure, it is found in Irish drinking water in illegal and unsafe amounts hence by definition poses a risk to public health. The EU Drinking Water Directive does not contain standards for microplastics. Existing drinking water treatment and wastewater treatment processes are inadequate at removing persistent toxic substances (PTS) from water. Bottled water can contain endocrine disrupting chemicals (EDCs), heavy metals, pesticides, persistent toxic substances and even gastrointestinal microbes. The following review article refers to Irish drinking public drinking water supplies however the issues reflect those of many first-world countries.

Background

Drinking Water and Public Health Risk

Drinking water is a social determinant to disease, a powerful determinant of health and also promotes socioeconomic development yet public health is failing to protect the public with poor drinking water quality the greatest threat to public health. Drinking both tap water and water from plastic bottles poses a health risk [1].

Water quality relates to Essential Public Health Operations (EPHO) 2, one of the World Health Organisation's (WHO) 10 Essential Public Health Operations; Identifying and controlling health hazards, and questions 7 and 8 in the Health 2020 Assessment Checklist [2, 3]. In relation to leadership/governance for health and empowerment of the public, both are inadequately actioned. Regarding the 5 action areas for health promotion, policy exists, however is not adequately enforced [4]. The public is not empowered nor adequately warned, it is difficult to find information on each contaminant and remedial action is expensive and complicated.

Whilst this article is about Irish drinking water and more specifically Galway, the issues surrounding the risk to human health from contamination of persistent organic pollutants (POPs) also known as persistent toxic substances (PTS) in drinking water apply globally. Existing drinking water treatment and wastewater treatment processes are inadequate at removing POPs from drinking water and future challenges to protect public health from drinking water contaminants exist [5, 6].

Up to one third of Ireland's drinking water is supplied by groundwater, with some public water supplies in certain areas of the country coming entirely from groundwater. Many counties In Ireland rely on surface water. Two thirds of Group Water Schemes use wells and springs. Some rural areas are not served by Public or Group Water Schemes, hence groundwater is the only source of supply. More than 100,000 private wells and springs are in use in Ireland [7].

Main sources of ground and surface contamination

Landfill

The landfilling and dumping of POPs and other persistent hazardous compounds, such as polychlorinated biphenyls (PCBs), hexachlorocyclohaxane (HCH), polybrominated diphenylether (PBDEs) or perfluorooctane sulfonic acid (PFOS) have significant adverse environmental and public health consequences. POPs threaten our drinking water, our food supply and ecosystem. Climate change brings an increased risk of POPs leaching from landfills due to our groundwater supply [8].

Human sewage

Faecal bacteria were detected at 43% of Irish groundwater monitoring sites in 2017 (up from 42% in 2016), with farming pollution found to be the main reason for the deterioration of water quality in Ireland [9]. A University College Cork (UCC) draft paper discussing pollution in Irish lakes and eutrophication (abnormal plant growth due to excessive nutrients from runoff entering lakes) describes human sewage as the primary source of pollution [10]. The residual sludge from 29% of Irish treated sewage are spread on agricultural land. Sewage sludge may contain, gastrointestinal microbes including Salmonella spp., Listeria monocytogenes, Campylobacter coli and jejuni, Escherichia coli and microbes causing hepatitis, intestinal flukes and tapeworms [10,11]. Sludge pollution contains heavy metals

such as lead, cadmium and mercury, posing serious environmental and health hazards [12]. Agricultural wastes including phosphate fertilisers, untreated animal waste, slurry and silage effluent, also contribute. Irish rivers have 5 times the concentration of phosphate fertilisers necessary to cause eutrophication which can result in additional exposure concerns caused by biotoxins [10].

Failures of Irish Water

The River Basin Management Plan submitted to European Commission was 2 years late [13]. Irish Water have consecutively failed year after year to meet safety standards for bromate, nickel, nitrite, copper, pesticides, arsenic, fluoride, lead and trihalomethanes (THM), with 1.3 million people drinking unsafe water [14-16]. Notwithstanding the benefits of the addition of the chemical hexafluorosilicic acid (fluoride) to our water as a public health measure, fluoride is in our water in unsafe and illegal amounts hence by definition, poses a risk to public health. In 2018 the Environmental Protection Authority (EPA) took 12 legal actions (16 already taken) against Irish Water in relation to 44 areas of untreated sewage discharge [17]. The European Union (EU) commission took Ireland to the EU court of Justice over the continued THM contamination across the country and failure to notify customers [18]. The EU Drinking Water Directive does not contain standards for plastics hence they are not testing for microplastics [19].

Water treatment must produce water that is;

- Palatable
- Free from pathogens and toxic chemicals
- Free from turbidity or suspend solids
- Free from turbidity and suspended solids
- Aesthetically acceptable
- Colourless and odourless
- Reasonably soft
- Non-corrosive
- Meets legislated limits

Who's Responsible?

Regional Management of Safe Drinking Water

The UNECE-WHO/Europe Protocol on Water and Health 1992

The Protocol on Water and Health/Convention on Protection and Use of Transboundary Watercourses and International Lakes aims to protect health by better water management and reducing water-related disease [20, 21]. Health standards are documented in the WHO Guidelines Drinking Water Quality [22].

EU Directives that Cover Safe Drinking Water

The European Communities (Drinking Water) Regulations, 2000 (S.I. 439 of 2000) and the EU (Drinking Water) Regulations (S.I 122 of 2014) monitor water quality, protection of health and penalise offending authorities. The EU directive provides consumers with adequate, timely and appropriate information [19, 23].

Monitors (Potential danger factors not outlined must also be considered);

- Microbiological parameters: Escherichia coli (No mention of cryptosporidium)
- Chemical parameters: Including lead other heavy metals and THMs
- Radioactivity: Measures tritium

48 parameters in total are measured. These parameters do not include radon, microplastics or drug resistant bacteria.

National Level Management of Safe Drinking Water

The River Basement Management Plan is a legal requirement under the Water Framework Directive (WFD), to be submitted to the EU. This plan outlines [24, 25];

- The approach Ireland will take to protect our waters up to 2021.
- More effective delivery structures put in place to build foundations/momentum for long-term improvements to water quality.
- New governance structure to bring together policy, technical and implementation actors, and public and representative organisations to ensure coordinated delivery of measures.
- New Local Authority Waters and Communities Office set up as legal requirement of EU Water Framework Directive established in February 2016 [26].

Irish Water

Irish Water (IW) is responsible for production, distribution and monitoring and published a 25-year plan for the future of water services [27]. The Environmental Protection Agency (EPA) produces an annual Public Supply Drinking Water Report providing an overview of water quality based on results reported by IW, local authorities and on EPA/Local Authority enforcement activities. The Remedial Action List 2018 Report found elevated THMs and recommended an upgrade to the Ballinasloe water treatment plant [28].

As previously mentioned, successive EPA reports have concluded that IW has consecutively failed to meet safety standards for bromate, nickel, nitrite, copper, pesticides, arsenic, fluoride, lead and trihalomethanes (THM), (14-16) thus by definition posing a public health risk.

Health Service Executive

The Health Service Executive (HSE) protects public health, advocates safe drinking water and aims to ensure a timely response to events. Under EU (Drinking Water) Regulations 2014 (S.I. No. 122 of 2014) the HSE must be consulted whenever drinking water poses a potential danger to health [19]. IW and local authorities prepare remedial actions with agreement from the HSE.

HSE National Drinking Water Group develops guidance for staff and public on number issues;

- Cryptosporidium
- Lead
- Pesticides
- Trihalomethanes
- Private well water and nitrates

Local Level

Local Authority Waters and Communities Office

To coordinate the work of local authorities and engage local communities and promote public participation [26].

Fóram Uisce
For stakeholders, community groups and sectoral representatives [30].

Galway City Council
Galway City Council (GCC) is responsible to maintain the mains system and ensure the quality of drinking water in Galway city. Drinking water quality is covered by EU Drinking Water regulations 2014 (19). Each year Drinking Water Monitor results are published (15). These results utilise independent analysis of water samples by Public Analysts Lab, the Microbiological Lab and University College Hospital Galway (UCHG). If drinking water is considered dangerous GCC must restrict water supply and alert public.

Specific Contaminants

Lead
Irish Water drafted Irish Water Lead in Drinking Water Mitigation Plan (LDWMP) to provide a framework of mitigation measures to reduce lead from pipe work dissolving into water [31].

Options are;
- Do-nothing option
- Do something

Do something options include;
- Remedial works to replace lead pipes/fittings
- Orthophosphate treatment (phosphoric acid builds internal lining inside lead pipes)
- pH correction to reduce potential for lead to dissolve

IW's Is there Lead in my Drinking Water? is a basic information website with no information on prevalence or mitigation strategies [32].

Trihalomethanes
Long term exposure to trihalomethanes (THMs) is linked to cancer [33]. THMs are limited by the EU Drinking Water directive, WHO guidelines and the EPA [34, 35]. The Irish government told the EU Commission that 412,000 people are listed on the EPA remedial action list [36]. Four water supplies in Galway exceeded THM levels, with THM readings being in the range of 200-400 mgs per litre, or 4.5 times the legal limit [37, 38]. The EPA fined IW €6,000 for delay in work to mitigate THMs.

Cryptosporidium and Escherichia coli
Boil water notices are common place in Ireland with some Irish areas having been on a boiled water notice for over six years [39]. The EPA issued a boiled water notice to 23,055 people nationwide due to Escherichia coli (E-coli) and Cryptosporidium contamination [40]. The Cryptosporidium outbreak in Galway cost €19 million with 120,000 people forced to boil water [41]. In November 2019, a boil water notice was issued by the HSE, IW and Fingal County Council to 650,000 people for areas of Dublin, Meath and Kildare affected by the Leixlip Water Treatment Plant [42]. Only recently, another boil water notice was issued for 9,500 people in the east Cork area to people affected by the Whitegate Regional Water Supply Scheme [43]. Both Cryptosporidium and Giardia are extremely hardy and chlorine resistance exists [44]. Cryptosporidium and Giardia oocysts (eggs) are effectively removed by UV treatment or filtration using a charcoal filter [45].

Radon
Radon is a naturally occurring radioactive water soluble gas. Radon from tap water is released into the indoor air and contributes to radon already present. Bathrooms and showers are a risk if the ventilation is poor and water contains high radon levels. As in their report the EPA monitor tritium but not radon [15]. Long-term exposure to radon is associated with an increased risk of lung cancer. CT screening is not indicated (46). Galway has the highest number of homes with unsafe radon levels translating to more than 2,500 chest X-rays annually [47]. Residents can check if their home is in a high radon area on the Radiological Protection Institute of Ireland (RPII) website. Radon tests from the EPA cost €79 [48]. The EPA website on radiation does not mention radiation in water nor provide an application form for radon in drinking water [49]. If radon levels exceed 500 Bq/l remediation should be undertaken [50]. The National Radon Control Strategy is a registration scheme for radon testing and remediation services [51].

New Threats

Superbugs
Antibiotic resistant E-coli has been found in the drinking water of France, a high income country [52].

Risks from water borne disease [53]
Wastewaters may contain a broad range of pathogenic microorganisms, including Escherichia coli, Campylobacter, Cryptosporidium, Salmonella spp. and pathogenic viruses [54]. The wide application of chlorine disinfectant for drinking water treatment has led to the appearance of chlorine-resistant bacteria [55].

Plastic
A study by the EPA and Galway Mayo Institute of Technology (GMIT) found microplastic passes through the public water supply filtration system [56]. 83% of samples of tap water worldwide including Ireland tested positive for microplastic. In 2016 Irish (Cork, Dublin, Offaly) tap water was found to contain excessive levels of microplastic [57]. The EU Drinking Water Directive does not contain standards for plastics [19].

Health risks associated with drinking bottled water
Plastic water bottles are made from polyethylene terephthalate (PET recycling code 1). This symbol is normally also found in soft drinks. PET does not contain bisphenol A (BPA) or polyethylene terephthalate but recent reports suggest that endocrine disruptors may leach into the contents of bottles made from PET [58]. Studies have also found that antimony, a toxic phthalate 'plasticiser' used to make plastics flexible, leaches from PET bottles placed in heat for prolonged periods. Antimony is an endocrine disrupting chemical (EDC) [59]. Some reusable plastic drinking water bottles are made from polycarbonate (recycling code 7). Polycarbonate is made of BPA [60]. Investigations show in some cases, even BPA-free PET containers might leach oestrogen-like chemicals [61].

Heavy metals
Regulations exist regarding the presence of contaminants in bottled water. Requirements include testing, reporting, and notification to regulate the presence of heavy metals in bottled natural spring water sold in California for example. Whilst tough regulations exist, safe parameters are still breached. A study looking at the presence of heavy metals in bottled natural spring water in the US found that

silver, arsenic, barium, beryllium, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, antimony, selenium, thallium, vanadium, and zinc were detected. No concentrations of these heavy metals were above either federal or California maximum contaminant levels however arsenic concentrations exceeded California public health goals in all six sources. Beryllium, mercury and thallium were not detected. The study concluded that California notification requirements for bottled water contaminants need to be improved [62].

Arsenic in Irish bottled water

In August 2019 all bottled water brands produced by the Irish company Celtic Pure were recalled by the HSE Food Safety Authority of Ireland (FSAI) due to the presence of the arsenic. Still, sparking and fruit water brands were all affected. The arsenic contamination affected dozens of brands of bottled water. Lidl, Aldi, Dunnes Stores and smaller supermarkets including Spar, Mace, Londis and Applegreen were instructed to remove water from the shelf [63].

Gastrointestinal microbes

Whilst generally considered that bottled water is free from microbes and safe to drink, several studies have reported that bottled water does not always meet safety standards. In Ireland according to the FSAI report Microbiological Safety of Bottled Water, 2.5% (19/748) of samples of bottled water were categorised as unsatisfactory, breaching limits of E-coli, enterococci, coliforms and Pseudomonas aeruginosa, therefore posing a risk to public health [64].

Pesticides

High levels of pesticides including organochloride compounds (lindane, Dichlorodiphenyltrichloroethane (DDT), and endosulfan) and organophosphorus compounds (malathion and chlorpyrifos) have been reported in the bottled water samples collected from Indian cities [65]. Bottled water samples from Poland, Spain, Kuwait and Mexico City have been found to contain pesticides, volatile organic compounds (VOCs), perfluorinated carbon compounds (PFCs) and carbonyl compounds [66].

Calls to action

- Public sector leadership and political, social and economic forces must unite for quality drinking water.
- EPHO 2 and EPHO 4 must be actioned and enforced to protect the public.
- Alternatives to chlorination (UV irradiation and membrane processes) must be sought due to disinfection by-products and chlorine resistant protozoa [67]. Denmark and Luxembourg do not use chlorine to disinfect water [68].
- European Communities (Drinking Water) Regulations, 2000 (S.I. 439 of 2000) must be expanded to include testing for microplastic, cryptosporidium and radon.

A Central Irish Drinking Water Safety Portal that;

- Lists all contaminants not within legal parameters.
- Lists health impacts of each contaminant.
- Allows people to check if their property or workplace is affected.
- Lists mitigation strategies being undertaking by authorities.
- Suggests and funds solutions for the public including end point in- line or gravity fed charcoal water filtration systems.

Water purification

Point-of-use water filters units that use NSF/WRc certified ceramic candles that use microfiltration remove;

- **Waterborne Disease:** Cryptosporidium and E-coli etc are parasites typically above 2µm (microns) and are removed by the ceramic outer shell (0.7µm) [45].

- **Chemicals:** Chlorine, fluoride, pesticides, THM's, phenols, petrochemicals, etc [69].

- **Suspended Solids and Heavy Metals:** Microplastics > 0.7µm, lead, copper, mercury, cadmium, chromium, aluminium, nickel, etc [70- 76].

Conclusions

Even though drinking water is an Essential Public Health Operations (EPHO), a powerful a social determinant to disease, a determinant to health, and promotes socioeconomic development, poor drinking water quality continues to pose a threat to public health. Drinking both tap water and water from plastic bottles presents a health risk. Public sector leadership and political, social and economic forces need unite for quality drinking water. Public discourse and mass protest is needed to demand that EPHO 2 and EPHO 4 be actioned and enforced to protect the public. Alternatives to chlorination such as UV irradiation and membrane processes must be sought. The European Communities (Drinking Water) Regulations, 2000 (S.I. 439 of 2000) must be expanded to include testing for microplastic, cryptosporidium and radon. Until remedial action is taken to update existing drinking water treatment plants to remove toxic substances from drinking water, point-of-use water filters at the consumer tap should be recommended and supplied by the state to protect public health and improve global health outcomes.

Abbreviations

Bisphenol A (BPA)
Dichlorodiphenyltrichloroethane (DDT)
Escherichia coli (E-coli)
Environmental Protection Authority (EPA)
Endocrine disrupting chemicals (EDCs)
Essential Public Health Operations (EPHO)
European Union (EU)
Food Safety Authority of Ireland (FSAI)
Galway May Institute of Technology (GMIT)
Health Service Executive (HSE)
Irish Water (IW)
Perfluorinated carbon compounds (PFCs)
Persistent organic pollutants (POPs)
Persistent toxic substances (PTS)
Polyethylene terephthalate (PET)
Polychlorinated biphenyls (PCBs)
Hexachlorocyclohaxane (HCH)
Lead in Drinking Water Mitigation Plan (LDWMP)
Polybrominated diphenylether (PBDE)
Perfluorooctane sulfonic acid (PFOS)
Trihalomethanes (THM)
University College Hospital Galway (UCHG)
Volatile organic compounds (VOCs)
Water Framework Directive (WFD)
World Health Organisation (WHO)

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