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THE PUBLIC HEALTH EFFECTS OF ABANDONED COAL MINE WORKINGS ON RESIDENTS IN SOUTH WELLINGTON, NANAIMO

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Abstract

The direct public health effects of organic compounds and metals associated with drinking water are unclear, especially as only a small fraction of the daily intake of elements reaches the human body[1]*. However, surveys by the Environmental Protection Agency (EPA) have "confirmed the presence of several organic petroleum and solvent types of compounds in drinking water effected by mine operations"*[2]*. Among these pollutants are "suspect carcinogens"*[3]*.*

Previous studies have shown that in coal mining areas, the quality of groundwater decreases with depth. There is an extensive network of abandoned coal mines in South Wellington, and several domestic wells have been drilled directly into these mines or coal seams. In August 2002 the Ministry of Water Land and Air Protection calculated the quality of well water in the Cassidy observation well in Nanaimo. In this analytical report, substances in the well such as sulphur and iron were shown at levels exceeding the recommended drinking water quality guidelines.

I am currently researching the potential positive and negative impacts of abandoned coal mine workings on the health of residents in South Wellington, Nanaimo. This project will compare the health of two groups, a study group drinking well water, and a control group drinking the city's mains water. The major objective of the data analysis will be to determine which specific illnesses are more common in the study area and in the control area.

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[1] National Research Council (1980). Trace-Element Geochemistry of Coal Resource Development. Washington, National Academy Press, 34.

[2] ibid

[3] ibid

reaches the human body.[4] However, surveys by the Environmental Protection Agency (EPA) have "confirmed the presence of several organic petroleum and solvent types of compounds in drinking water effected by mine operations".[5] Among these pollutants are "suspect carcinogens".[6] One such area lies in a rural area south of Nanaimo, on Vancouver Island.

Previous studies have shown that in coal mining areas, the quality of groundwater decreases with depth. There is an extensive network of abandoned coal mines in South Wellington, and several domestic wells have been drilled directly into these mines or coal seams. In August 2002 the Ministry of Water Land and Air Protection calculated the quality of well water in the Cassidy Observation well in Nanaimo. In this analytical report, substances in the well such as sulphur and iron were shown at levels exceeding the recommended water quality guidelines.

Groundwater flowing through abandoned coal mines often has depressed pH levels and elevated hydrogen sulphide, iron, aluminium and nitrates.[7] Such water is also typically high in copper, zinc, mercury, and lead.[8] Many of these levels exceed the recommended water quality guidelines put forth by the Ministry of Water, Land and Air Protection (WLAP).

Water can be toxic if it contains elevated iron (WLAP 1998). According to Health Canada, at levels above the standard for drinking water quality of 0.3 mg/L, iron may be associated with the development of neoplasms. Studies have also shown that elevated nitrate are correlated with the development of Sudden Infant Death Syndrome[9] and high levels of aluminium have been associated with several forms of dementia, including Alzheimer's disease.[10] The health effects of many other elements however, are unclear. There have been few studies for example, on the impacts of hydrogen sulphide in drinking water yet hydrogen sulphide is commonly found in the groundwater near coal mines.[11] This gas is known to cause detrimental respiratory illness in humans.[12] However, the systemic effects of ingesting hydrogen sulphide are obscure, and studies correlating hydrogen sulphide to health have been restricted to lab animals.[13]

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[4] National Research Council (1980). *Trace-Element Geochemistry of Coal Resource Development*. Washington, National Academy Press, 34.
[5] ibid
[6] ibid
[7] Bickford G (2003). Personal Interview. Victoria.
[8] Meadows A. and A. Carpenter (1997). Acid Mine Drainage and Groundwater Pollution, *Groundwater Pollution Primer* <http://www.cee.vt.edu.>.
[9] George M., et al (2001). Incidence and Geographical Distribution of Sudden Infant Death Syndrome in Relation to Content of Nitrate in Drinking Water and Groundwater Levels, *European Journal of Clinical Investigation*, 31, pp.1083-1094.
[10] Foster H (2002). Why the Preeminent Risk factor in Alzheimer's disease cannot be Genetic, *Medical Hypotheses*, 59 (1), pp. 57-61.
[11] Bickford (2003).
[12] Agency for Toxic Substances and Disease Registry (1998). *The Toxicological Profile for Hydrogen Sulphide*, U.S. Department of Health and Human Services.
[13] ibid

South Wellington is a large, rural area South of the city of Nanaimo. It is located within the Regional Electoral District Area "Nanaimo A", and in the year of 2001 had 1,955 families and a population of 6,420.[14] The city of Nanaimo and most surrounding areas receive water from the Nanaimo Lakes and the Nanaimo River. [15]Approximately 20km from the city boundary, water is transported from the South Fork dam and Jump Creek Reservoir, to the village south of Extension and the city of Nanaimo via two parallel pipelines.[16] However, the main pipeline does not service South Wellington, an area south of the City of Nanaimo. This area relies entirely on wells for domestic water purposes.

Most such domestic wells in South Wellington have been drilled at depths ranging from 50.0 ft. to 200.0 ft.[17] The lithology of each well differs, however this information may be accessed through the WLAP well database. Since there are three coal seams in the South Wellington area, some wells have been drilled directly into the abandoned coal mines or coal seams.

The Nanaimo Coalfield was a major coal producer between 1852 and 1968.[18] Within the Nanaimo Coalfield are three major seams; the Wellington, Newcastle and Douglas. The Hudson's Bay Company developed the Douglas, the uppermost mineable seam.[19] The Douglas mines included those referred to as the Black Track Mines, which had seams averaging over 5` thick.[20] Included in the Black Track Mines in South Wellington are; the Alexander slope, South Wellington no.5 slope and South Wellington no.10 slope. South Wellington no.10 slope was one of the prime mines within the Douglas seam, producing 2.7 million tonnes between 1937 and 1952.[21] These three mines are those most likely to have a significant impact on groundwater in South Wellington.

Located near Extension road, the Alexander Slope was opened in 1884.[22] It closed in 1901 after filling with water, and reopened in 1930.[23] Problems relating to spontaneous combustion caused it to close for a second time in 1935.[24] According to the Ministry of Energy and Mines in Nanaimo, this specific mine had 'lots of problems with water'.[25]

South Wellington no.5 slope is located to the north of Becks Lake. This mine opened in 1917, and displayed extreme variations in coal thickness.[26] With the development of fuel oil and spontaneous combustion within the shafts, the mine closed in 1935.[27]

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[14] Census Canada (2001).
[15] City of Nanaimo (2001). *Greater Nanaimo Water District.* <http://www.city.nanaimo.bc.ca>.
[16] ibid
[17] Ministry of Water, Land and Air Protection (2003). Well Database. Government of British Columbia. <http://www.wlapwww.gov.bc.ca>.
[18] Davis J. (1986). *Coal in British Columbia.* Victoria: Ministry of Energy, Mines and Petroleum Resources.
[19] Gardner S. (1999). *Coal Resources and Coal Mining on Vancouver Island.* Campbell River: Gardner Exploration Consultants.
[20] ibid
[21] Davis J. (1986).
[22] Murray K. (1986). *Coalbed Methane Project.* Vancouver Island Gas Company, Ltd.
[23] ibid
[24] ibid
[25] ibid
[26] ibid

In 1937 South Wellington slope no.10 opened to the south of the no.5 slope.[28] Although mostly low-quality coal, seams in this modern mine ranged from 8`-20` thick in diameter.[29] This mine remained open from 1937 until 1952m, when explosions and ventilation problems prompted its closure.[30]

There is relatively little knowledge about the post-mining of coal and its effects on groundwater. However, it is generally understood that the influence of mine site abandonment has adverse effects on the quality of groundwater. Due to mining induced fracturing of bedrock, abandoned coal mines have the ability to cause the loss of overlying perched aquifers.[31] A study by Epps (1978) reports that in coal mine regions, groundwater supplies are susceptible to pollution from percolation. With great porosity and permeability, abandoned coal mines become aquifers in themselves. Moreover, it is suspected that a portion of the residential wells in South Wellington draw water straight from the mines.[32]

With degrading effects on groundwater, abandoned mines significantly affect the general public through the discharge of non-point source pollution.[33] Well water becomes highly susceptible to Acid Mine Drainage (AMD) with the flow of water through abandoned coal mines. AMD is referred to as "drainage flowing from or caused by surface mining, deep mining or coal refuse piles that is typically highly acidic with elevated levels of dissolved metals."[34]

AMD typically occurs whenever groundwater moves or leaks into the mine. While in operation, groundwater is constantly being pumped from the coal mines to prevent flooding of the work area. When mine operations cease however, so does the pumping of water. With the absence of the underground pump the groundwater will naturally begin to rise, dissolving iron oxides, sulphates and proton acidity, all of which are products of pyrite oxidation.[35]

The water may become contaminated with coal and mineral matter and with the soluble oxidation products of pyrite in coal.[36] When iron sulphide minerals and pyrite (which is found naturally in the seams of coal) are exposed to air and water, ferrous sulphate and sulphuric acid are produced.[37] Sulphur is present in coal as partly organic and inorganic compounds, and upon combustion sulphur is converted into sulphur dioxide.[38] This gas is highly soluble in water, and creates a highly acidic environment. The groundwater system is then adversely effected, as "sulphuric acid dissolves heavy metals, such as lead, zinc, copper, and mercury".[39]

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[27] ibid
[28] ibid
[29] ibid
[30] ibid
[31] Bickford (2003)
[32] ibid
[33] Meadows A. and A. Carpenter (1997).
[34] ibid
[35] Sherwood J. and P. Younger (1997). Modelling Groundwater Rebound after Coalfield Closure, *Groundwater in the Urban Environment*, (1), pp.165-170.
[36] Soliman M. et al. (1998). *Environmental Hydrology*. New York: Lewis Publishers.
[37] National Research Council (1980).
[38] Commission on En ergy and the Environment. (1981). *Coal and the Environment*. London.
[39] Meadows A. and A. Carpenter (1997).

Previous studies have shown that in coal mining areas, the quality of groundwater decreases with depth. In Alberta, numerous substances have adversely effected the quality of groundwater near coal mines.[40] Nitrate, iron, fluoride, sulphide, sodium and alkalinity levels all exceeded the recommended daily guidelines for drinking water.[41] A study of the Estevan valley aquifer in Saskatchewan also showed incongruously high levels of iron. In 1961, iron levels in this aquifer were measured at 2.1 mg/L.[42] According to this study; these levels were seen to indicate potential problems, as they are well above the drinking water standard for iron, which have been set by WLAP at 0.3mg/L.[43]

In analytical reports of observation wells, WLAP annually calculates the quality and quantity of well water throughout the province of British Columbia. Of the three observation wells located in Nanaimo, the Cassidy well (well #228) is the nearest to South Wellington. The analytical report for August 2002 shows that this particular well is high in both iron and sulphur. The iron content is an astonishingly 6.79 mg/L, which greatly exceeds the recommended allowable dose of iron in drinking water, which is 0.3 mg/L. The sulphur content is also very high at 1.2 mg/L. According to WLAP, the recommended intake of sulphide (the chemical compound containing sulphur) is 50ug/L, which is a mere .05 mg/L. The detectable sulphide, in addition to high iron and manganese, may suggest an anoxic (depleted dissolved oxygen) groundwater condition.[44] If anoxic conditions are present, they are likely to be caused by coal shale or by AMD.[45] If the source of elevated iron and sulphide is caused by AMD, one would also expect to find elevated aluminium, manganese, sulphate, decreased alkalinity (elevated acidity), low pH and an elevation of other heavy metals.[46]

Iron is the fourth most common element in the earth's crust, and the most abundant heavy metal.[47] With respect to abandoned coal mines, the occurrence of iron levels increase with AMD.[48] It is surprising then that, as previously mentioned, the observation well in Cassidy, near South Wellington has an exceptionally high iron content of 6.79 mg/L, while the drinking water quality guideline for iron is 0.3mg/L.[49]The ingestion of large quantities of iron can have significant adverse effects on human health and may contribute to the development of Haemochromatosis.[50] This condition occurs when "normal regulatory mechanisms do not operate effectively, leading to tissue damage as a result of the accumulation of iron".[51]

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[40] Barrie W.B. and C.H. Carr. (1988). *Water use in the Coal Mining Industry and its Influences on Ground Water in Western Canada.* Ottawa: National Hydrology Research Institute.
[41] ibid
[42] ibid
[43] ibid
[44] Macfarlane D. (2003) Personal Interview. Victoria
[45] ibid
[46] ibid
[47] Health Canada. (1996). *Guidelines for Canadian Drinking Water Quality*. Ottawa: Canada Communication Group.
[48] ibid
[49] Ministry of Water, Land and Air Protection (2003). *Analytical Report*. Government of British Columbia, WLAP Analytical Services.
[50] Health Canada. (1996).
[51] ibid

Moreover, when the iron concentration exceeds 0.3 mg/L, individuals are shown to be at greater risk of developing neoplasms.[52]

Sulphur also occurs at higher than recommended levels in the Cassidy observation well. Sulphates, a combination of oxygen and sulphur, are naturally occurring minerals that dissolve over time and are released into groundwater.[53] The build-up of sulphate has a laxative effect on humans and can cause severe dehydration, which is of particular concern in infants.[54] Sulphur reducing bacteria thrive in oxygen deficient environments such as wells and use excess sulphur as an energy source. These bacteria produce large quantities of hydrogen sulphide.[55]

Formed through the decomposition of organic matter, hydrogen sulphide is flammable and poisonous.[56] Although it largely effects the respiratory system, its presence "inhibits the enzyme that allows cells to use oxygen during energy metabolism."[57] Through drinking water and oral ingestion, sulphides have been reported to cause nausea, headache, vomiting, epigastric pain, and irritation to mucous membranes.[58] The Registry of Toxic Effects of Chemical Substances reported that after intravenously administering 6 mg/L of sulphide to male and female rabbits, five of the six animals died within less than two minutes.[59] In a reproduction study using lab rats, hydrogen sulphide was found to be embryotoxic and to have adverse effects on reproduction functioning.[60]

The analytical report of the Cassidy observation well did not include an analysis of nitrate. However, Robert Finkelman of the U.S. Geological Survey has found high water nitrate levels that were linked to coal deposits in Balkans.[61] Kidney failure, which has taken the lives of over 100,000 villagers, has been linked to toxic wells sunk into shallow coal deposits.[62] Interestingly, high levels of nitrate have been found in well water samples from numerous wells in the West Coast of British Columbia.[63] Such nitrates are formed by the breakdown of organic matter, and under certain circumstances may accumulate in the environment.[64] According to one study, there has also been a deterioration of the health of individuals in areas of Bulgaria where wells had "exceptionally high levels of nitrates".[65] In the human body nitrates are converted into nitrites, which may be fatal at excessive levels.[66] This is especially true in infants where

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[52] ibid
[53] Varner (2003). *Drinking Water: Sulphates and Hydrogen Sulfide.* <http://www.ianr.unl.edu/pubs/water>.
[54] ibid
[55] ibid
[56] ibid
[57] Office of Environmental Health Assessments. *Hydrogen Sulphide.* <http://www.doh.wa.ehp>.
[58] Health Canada (1987). *Guidelines for Canadian Drinking Water Quality-Supporting Documents: Sulphide (as H2S).* <http://www.hc-sc.gc.ca>.
[59] ibid
[60] ibid
[61] Hecht J. (2001). Wells of Misery, *New Scientist,* 172 (2317), pp.16.
[62] ibid
[63] Ministry of Health (2000). *Nitrate Contamination in Well Water.* Government of British Columbia. <http://www.healthplanning.gov.bc.ca>.
[64] Harte J. et al. (1991). *Toxics A-Z: A Guide to Everyday Pollution Hazards.* Berkley: University of California Press.
[65] Hecht J. (2001).
[66] Harte J. et al. (1991)

metohemoglobinemia occurs when excessive nitrites cause the blood to loose its ability to transfer oxygen.[67] Sudden Infant Death Syndrome (SIDS) mortality, for example, positively correlated with high concentrations of nitrate in drinking water.[68] Furthermore, when nitrites react with food in the gastrointestinal tract, they can form potent carcinogens known as nitrosamines, linked to cancer.[69]

Although aluminium levels in the Cassidy observation well are not particularly high, this element can be found abundantly in groundwater, especially in the presence of AMD.[70] Aluminium has severe impacts on human health.[71] Evidence suggests that areas most harmful to human health are those in which drinking water contains little calcium and magnesium but elevated levels of aluminium.[72] Aluminium has adverse effects on the nervous system and is responsible for various dementia disorders.[73] Exposed to high levels of aluminium in dialysis fluid machines, kidney patients develop dialysis encephalopathy, which is characteristic of speech and behavioural changes, tremors, convulsions and psychosis.[74] Other diseases of the nervous system that have also been associated with aluminium include Parkinson's disease, amyotrophic lateral sclerosis and Alzheimer's disease.[75]

Without baseline studies and monitoring programs the effects of mining clearly deteriorate the hydrological system. Methods can be used to reduce and remove harmful elements from groundwater. Limestone and its derivatives are most frequently used for neutralizing acid mine water.[76] However, the limestone will only remove certain trace elements and those solubilities sensitive to pH, such as aluminium and iron.[77] Other ions such as calcium, magnesium and sulphate are less dependent on pH, and may actually increase with limestone neutralization.[78] The only solution offered by the Ministry of Health for excess nitrate is to "consider developing a new well in a different location".[79] Reverse osmosis is the most reliable way of removing most contaminants from drinking water, but this process is extremely costly, and in the case of private wells would be at the expense of the residents.[80]

Research on the correlation between abandoned coal mines and the effects of the quality of groundwater on health are limited.[81] The Ministry of Energy and Mines has had its budget reduced and, as a result its branch in Nanaimo has been closed. Although the Ministry of Health

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[67] ibid
[68] George M. et al. (2001).
[69] Harte J. et al. (1991).
[70] Macfarlane D. (2003)
[71] Health Canada (2003). *Aluminium in Drinking Water and Human Health*. <http://www.hc-sc.gc.ca>.
[72] Foster (2002).
[73] Health Canada (2003).
[74] ibid
[75] ibid
[76] Soliman M, et al. (1998).
[77] National Research Council (1980).
[78] ibid
[79] Ministry of Health. (1995). *Health Protection and Safety: Safe Water Supply Vital to your Health*. British Columbia: Government of British Columbia.
[80] ibid
[81] National Research Council (1980).

has been involved in studies relating to polluted groundwater and residential health in South Wellington, research has been limited and often unfinished as a result of inadequate funding.

Historical pollution is becoming increasingly recognized as a threat to public health. Economic constraints appear to be one of the main barriers to progress in this area of research.[82] When the Britannia copper mines closed, the public was left to deal with the aftermath. For years residents of Britannia were exposed to highly acidic waters and soil.[83] One resident even exclaimed that he needed to purchase new footwear each year as, 'the soles of [his] boots would be eaten away by the ground'.[84] For this community however, the cost of environmental clean up was a financial barrier they felt did not belong to them. With little funding put into research and clean up, the community seemingly ignored their environmental quandary.

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[83] National Film Board of Canada (2000). *Britannia a company town.* Montreal: Screen Siren Pictures, Inc.
[84] ibid

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