STATS/CSE 780
Assignment 1

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Introduction

Asbestos was a common construction material prior to the 1990s that was later found to be linked to diseases such as lung cancer and asbestosis (Government of Canada, 2023). Although it was banned in 2018, asbestos is still prevalent in many old buildings and actively used in the military, nuclear, and chlor-alkali industries in Canada (Government of Canada, 2018). This report examines yearly asbestos waste trends and identifies key sectors that provinces can target to further reduce the toxin from the environment.

Methods

To begin the study, disposal data was downloaded from the Open Government Portal (Environment and Climate Change Canada, 2022) and filtered to asbestos waste only. While the original data had 17 variables, only the year, province, North American Industry Classification System (NAICS) code, and quantity of waste were important for the analyses.

To enhance the data, NAICS sector names and population estimates from Statistics Canada (2022, 2023) were joined to the data set. NAICS sector names were scraped from the Statistics Canada website (2023) and mapped to the first two digits of the NAICS code in the data set. By adding sector names, waste trends could be analyzed at a high-level for each province. Population estimates (Statistics Canada, 2022) were also joined to the data. This ensures that the analyses accounts for differences in waste quantities attributed to the population size of provinces.

Finally, three line graphs were created to examine waste quantities across the country, by province, and by sector. Quantities were converted to kilograms to standardize measurement methods and divided by population size before being plotted. All transformations and analyses were done using R and the last plot was made with Shiny (R Core Team, 2023a, 2023b).

Results

Figure 1 illustrates yearly quantities of asbestos waste in kilograms across Canada. Based on the plot, the trends in waste could be viewed in three sections. The first section is the 1990s, where asbestos waste was relatively stable every year at about 0.05 kg of waste per capita. The second section encompasses the early 2000s to mid 2010s, where asbestos waste increased by approximately

0.02 kg per capita annually. The last section is the mid 2010s to the latest available year, 2021, where there appears to be an average decrease of about 0.02 kg per capita yearly.

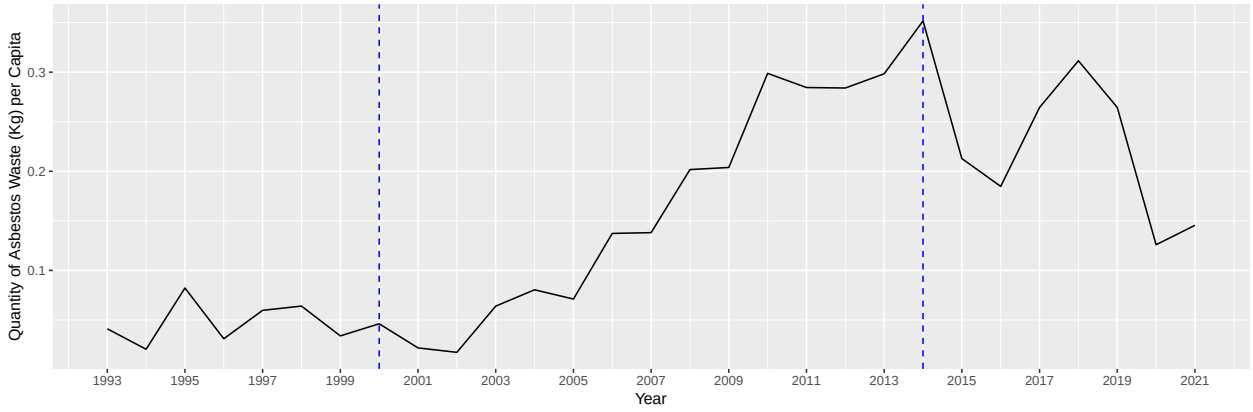

Figure 1: Annual asbestos waste across Canada can divided into 3 trends

While this shows annual asbestos waste quantities across Canada, each province has its own unique trend as shown in Figure 2 below. Alberta and Manitoba followed a similar pattern as the country, where asbestos waste increased for a period of time and decreased subsequently. Both provinces managed to have a yearly asbestos waste level of about 0.08 kg per capita since 2015. Quebec and Ontario, on the other hand, have a continually increasing trend. Quebec's asbestos waste increased by an average of 0.04 kg per capita yearly since 2002. Ontario has a generally increasing trend as well, but may have began to decline in 2017. Not enough data is available to confirm this. The remaining provinces have a relatively stable and low trend of about 0.12 kg of yearly asbestos waste per capita.

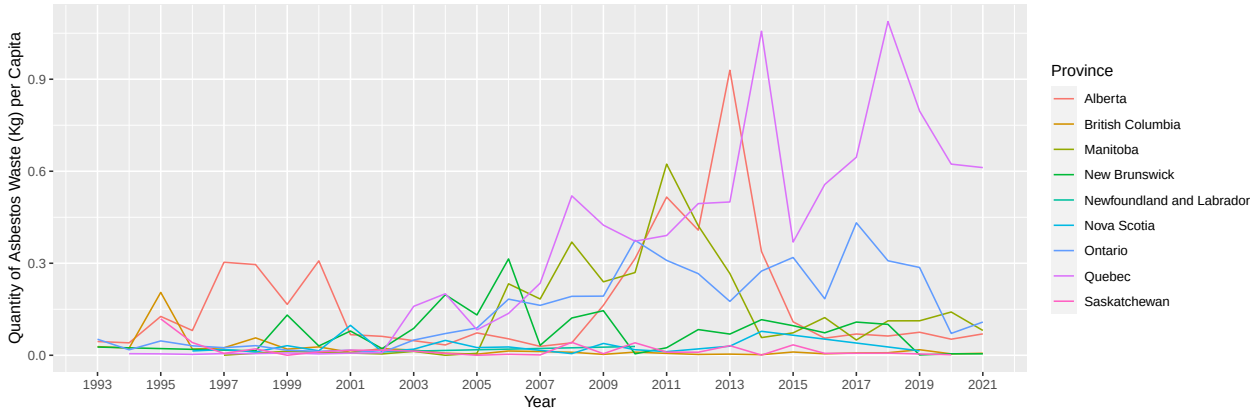

Figure 2: Asbestos waste by year and province

Provincial trends in asbestos waste are linked to different sectors as shown in the following Shiny

app: *https://1b5hyx-pao0zhu0vivian0-hsu.shinyapps.io/shiny/*. The two main sectors that have large impacts on provincial trends are the "Administrative and support, waste management and remediation services" and "Manufacturing" sectors.

Discussion

Overall, this study shows that asbestos waste is generally decreasing in Canada, although trends between provinces vary. The sectors involved with administrative and support, waste management, remediation services, and manufacturing are key drivers of provincial trends.

When interpreting the results, it is important to note that Prince Edward Island, Yukon, Northwest Territories, and Nunavut were missing from the data set (Environment and Climate Change Canada, 2022). Since zeros in the data indicate that a substance is being tracked but has no waste (Inventory, 2023), these provinces and territories are most likely not tracking asbestos as there were no rows for them in the data (Environment and Climate Change Canada, 2022). As such, they were excluded from the study. To improve similar studies in the future and promote equal well-being across Canada, tracking asbestos in these provinces and territories is suggested.

From the available data, a few recommendations can be made to reduce asbestos waste. At a federal level, funding and efforts should be focused on Quebec and Ontario since these provinces continue to have increasing waste trends. It may be useful to learn how Alberta and Manitoba managed to decrease and maintain their asbestos waste quantities, and apply similar practices to other provinces. At a provincial level, investigation into the sectors that drive asbestos waste is recommended. Understanding how these sectors are producing the waste and why waste levels are increasing could help eliminate asbestos within provinces.

This leads to one final note, increased levels of asbestos waste could indicate both negative and positive aspects about the environment. Asbestos waste is negative if the industries that are permitted to use asbestos (Government of Canada, 2018) are producing, using, and disposing of it frequently. On the other hand, it can also be positive if the waste is coming from the removal of old asbestos deposits and guidelines for proper removal are followed (Government of Canada, 2023). It is highly recommended to investigate the sources of asbestos waste prior to any action and by doing so, an effective solution can be made to reduce the toxin and create a healthier environment for all Canadians.

Supplementary material

Report Code

```
# ----- LOAD PACKAGES AND DATA ----- #

library(tidyverse)
library(ggplot2)
library(stringi)

disposalFile <- "NPRI-INRP_DisposalsEliminations_1993-present.csv"
naicsCodesFile <- "https://www23.statcan.gc.ca/imdb/p3VD.pl?Function=getVD&TVD=1369825"
popFile <- "17100009.csv"

disposalDataRaw <- read_csv(file=disposalFile, locale=locale(encoding="latin1"))
naicsCodesRaw <- read_lines(naicsCodesFile)
popDataRaw <- read_csv(file=popFile)



# ----- DATA CLEANSING ----- #

# --- Step 1: Create 2-digit NAICS code lookup table --- #
# Pull 2-digit NAICS codes / code ranges and their descriptions from the website.
naicsCodes <- data.frame(x=naicsCodesRaw) %>%
  filter(grepl("<th id=", x)) %>%
  mutate("Sector Code (2-digit NAICS Code)" = str_match(x, "CPV=\\s*(.*?)\\s*&")[,2],
         "Sector Name" = str_match(x, '"wb-inv">\\s*(.*?)\\s*</span>')[,2]) %>%
  select(`Sector Code (2-digit NAICS Code)`, `Sector Name`)
naicsCodes$`Sector Name` <- stri_replace_all_regex(naicsCodes$`Sector Name`,
                                                   pattern =
                                                     c("&#40;", "&#41;", "&#44;"),
                                                   replacement = c("(", ")", ","),
```

```
                                                    vectorize = FALSE)

# Break code ranges down to their own rows
codeRangesOnly <- naicsCodes %>%
  filter(str_length(`Sector Code (2-digit NAICS Code)`)>2) %>%
  mutate(repStart = as.integer(str_match(`Sector Code (2-digit NAICS Code)`,
                                         "([0-9]{2})[-]([0-9]{2})")[,2]),
         repEnd = as.integer(str_match(`Sector Code (2-digit NAICS Code)`,
                                       "([0-9]{2})[-]([0-9]{2})")[,3])
  ) %>%
  group_by(`Sector Name`) %>%
  group_modify(~ tibble("Sector Code (2-digit NAICS Code)" =
                          seq(.$repStart, .$repEnd))) %>%
  ungroup()

# Replace rows with code ranges with the broken down rows
naicsCodes <- rbind(naicsCodes, codeRangesOnly) %>%
  filter(str_length(`Sector Code (2-digit NAICS Code)`)==2)

# --- Step 2: Create mapping of province codes to names --- #
provMap <- tibble("Province Code" = c("AB","BC","MB","NB","NL","NS","NT",
                                      "NU","ON","PE","QC","SK","YT"),
                  "Province Name" = c("Alberta","British Columbia","Manitoba",
                                      "New Brunswick","Newfoundland and Labrador",
                                      "Nova Scotia","Northwest Territories",
                                      "Nunavut","Ontario","Prince Edward Island",
                                      "Quebec","Saskatchewan","Yukon"))

# --- Step 3: Get population data for each province --- #
popData <- popDataRaw %>%
  mutate("Population Year" = as.numeric(substr(`REF_DATE`, 1, 4)),
```

```
        "Population Month" = substr(`REF_DATE`, 6, 7)) %>%
  filter(`Population Month` == "01",
         `GEO` != "Canada") %>%
  select(`Population Year`,`Population Month`,`GEO`,`VALUE`)

# --- Step 4: Filter disposal data for asbestos and join extra data --- #
disposalData <- disposalDataRaw %>%
  filter(grepl("asbestos",
               `Substance Name (English) / Nom de substance (Anglais)`,
               ignore.case = TRUE)) %>%
  mutate("Quantity (Kg)" = if_else(`Units / Unités` == "tonnes",
                                   `Quantity / Quantité`*1000,
                                   `Quantity / Quantité`),
         "Sector Code (2-digit NAICS Code)" = substr(`NAICS / Code_SCIAN`, 1, 2)) %>%
  left_join(naicsCodes,
            by = c("Sector Code (2-digit NAICS Code)" =
                     "Sector Code (2-digit NAICS Code)")) %>%
  left_join(provMap,
            by = c("PROVINCE" = "Province Code")) %>%
  left_join(popData,
            by = c("Province Name" = "GEO",
                   "Reporting_Year / Année" = "Population Year")) %>%
  group_by(`Reporting_Year / Année`,
           `Province Name`,
           `Sector Code (2-digit NAICS Code)`,
           `Sector Name`,
           `VALUE`) %>%
  summarize("Quantity (Kg)" = sum(`Quantity (Kg)`)) %>%
  ungroup() %>%
  rename("Year" = `Reporting_Year / Année`,
         "Province" = `Province Name`,
```

```
          "Population" = `VALUE`)


# ----- SAVE DATA FOR SHINY ----- #

save(disposalData, file="shiny/disposalData.RData")


# ----- DATA AGGREGATION FOR GRAPHS ----- #

# --- Step 1: Data for country-level line graph --- #
# Aggregate data
disposalData_countryFig <- disposalData %>%
  group_by(`Year`) %>%
  summarize("Quantity of Asbestos Waste (Kg) per Capita" =
              sum(`Quantity (Kg)`)/sum(`Population`))

# Stats for in-text description
mean_1990s <- disposalData_countryFig %>%
  filter(`Year` <= 2000) %>%
  select(`Quantity of Asbestos Waste (Kg) per Capita`) %>%
  sapply(mean)
slope_early2000sToMid2010s <- lm(`Quantity of Asbestos Waste (Kg) per Capita` ~ `Year`,
                                 data=disposalData_countryFig %>%
                                   filter(`Year` >= 2000,`Year` <= 2014))$coeff[[2]]
slope_mid2010sToPresent <- lm(`Quantity of Asbestos Waste (Kg) per Capita` ~ `Year`,
                              data=disposalData_countryFig %>%
                                filter(`Year` >= 2014))$coeff[[2]]

# --- Step 2: Data for province-level line graph --- #
# Aggregate data
```

```r
disposalData_provinceFig <- disposalData %>%
  group_by(`Year`,`Province`) %>%
  summarize("Quantity of Asbestos Waste (Kg) per Capita" =
              sum(`Quantity (Kg)`)/sum(`Population`))

# Stats for in-text description
mean_AB_MB <- disposalData_provinceFig %>%
  ungroup() %>%
  filter(`Province` == c("Alberta", "Manitoba"),
         `Year` >= 2015) %>%
  select(`Quantity of Asbestos Waste (Kg) per Capita`) %>%
  sapply(mean)
slope_QC <- lm(`Quantity of Asbestos Waste (Kg) per Capita` ~ `Year`,
               data=disposalData_provinceFig %>%
                 ungroup() %>%
                 filter(`Province` == "Quebec",
                        `Year` >= 2002))$coeff[[2]]
mean_other <- disposalData_provinceFig %>%
  ungroup() %>%
  filter(`Province` != c("Alberta", "Manitoba", "Quebec", "Ontario")) %>%
  select(`Quantity of Asbestos Waste (Kg) per Capita`) %>%
  sapply(mean)


# ----- PLOT COUNTRY-LEVEL LINE GRAPH ----- #

disposalData_countryFig %>%
  ggplot(aes(x=`Year`,
             y=`Quantity of Asbestos Waste (Kg) per Capita`)) +
  geom_line() +
  geom_vline(xintercept=2000, linetype="dashed", color = "blue") +
```

```
  geom_vline(xintercept=2014, linetype="dashed", color = "blue") +
  scale_x_continuous(breaks = round(seq(min(disposalData_countryFig$`Year`),
                                        max(disposalData_countryFig$`Year`),
                                        by = 2),
                                    1))

# ----- PLOT PROVINCE-LEVEL LINE GRAPH ----- #

disposalData_provinceFig %>%
  ggplot(aes(x=`Year`,
             y=`Quantity of Asbestos Waste (Kg) per Capita`,
             color=`Province`)) +
  geom_line() +
  scale_x_continuous(breaks = round(seq(min(disposalData_provinceFig$`Year`),
                                        max(disposalData_provinceFig$`Year`),
                                        by = 2),
                                    1))
```

Shiny App Code

```
library(shiny)
library(tidyverse)
library(ggplot2)
library(stringi)


# ----- DATA PRE-PROCESSING ----- #

# Load disposal data
load("disposalData.RData")
```

```r
# Drop down options
provinceOptions <- disposalData %>%
  select(`Province`) %>%
  distinct(`Province`) %>%
  pull()


# ----- APP UI ----- #
ui <- fluidPage(

    # Application title
    titlePanel("Yearly Asbestos Waste by Province and Sector"),

    # Sidebar with a slider input for number of bins
    sidebarLayout(
        sidebarPanel(
            selectInput(inputId = "province",
                        label = "Province",
                        choices = provinceOptions
            )
        ),

        # Show a plot of the generated distribution
        mainPanel(
           plotOutput("lineGraph")
        )
    )
)


# ----- SERVER LOGIC ----- #
```

```r
server <- function(input, output) {

  output$lineGraph <- renderPlot({

    # Filter waste data by user's province selection
    disposalData_line <- disposalData %>%
      filter(`Province` == input$province) %>%
      group_by(`Year`, `Sector Name`) %>%
      summarize("Quantity of Asbestos Waste (Kg) per Capita" =
                  sum(`Quantity (Kg)`)/sum(`Population`))

    # Plot line graph that show waste by year and sector for the selected province
    disposalData_line %>%
      ggplot(aes(x=`Year`,
                 y=`Quantity of Asbestos Waste (Kg) per Capita`,
                 color=`Sector Name`)) +
      geom_line() +
      scale_x_continuous(breaks = round(seq(min(disposalData_line$`Year`),
                                            max(disposalData_line$`Year`), by = 4),1))
  })
}


# ----- RUN APP ----- #
shinyApp(ui = ui, server = server)
```

References

Environment and Climate Change Canada. (2022). *Bulk data files for all years – releases, disposals, transfers and facility locations*. Government of Canada. https://doi.org/10.18164/774eeb0c-a069-4674-a9f7-82f4adf54369

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Inventory, N. P. R. (2023). *Using and interpreting data from the national pollutant release inventory*. Government of Canada. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/using-interpreting-data.html

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Statistics Canada. (2022). *Population estimates, quarterly*. Government of Canada. https://open.canada.ca/data/en/dataset/ec690886-687d-4d59-9b1b-51311435d344

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