Author: Shihan Zhang

Email: Zhangshihan0924@126.com

Faculty of Land and Food Systems

University of British Columbia

# LWS 548 Major Project

August 2022

*Master of Land and Water Systems*

---

**Urbanization Associated with Heavy Metal Pollution**

**A Review of Threats to Drinking Water Source Quality of Changchun City, in NE China.**

**Executive Summary**

Changchun is a typical city that experienced significant urbanization constructions in the past decades. With the continuous economic development, the expansion of the city, and the improvement of people's living standards, the heavy metals pollution of drinking water resources in Changchun will rapidly increase. Drinking water is an essential and fundamental requirement for supporting human living. However, heavy metal acclamation in the drinking water resources can affect the drinking water quality and threaten Changchun residents. Comparing the data of Xinlicheng reservoir and Shitoukoumen reservoir indicates the urbanization affected by heavy metals pollution from point and nonpoint sources. The second Songhua river also suffers the heavy metals pollutants from urban sewage and industrial wastewater. In addition, the heavy metal sediment in the Second Songhua river might also come from the sediment transport from other cities through the river basin. This paper lacks primary data to support the evidence, which might result from the reliance on secondary data sources. This study is limited to the published literature on the topics of interest outlined earlier. Therefore, the Changchun government needs particular policies to address the problem of heavy metal pollution while simultaneously balancing the rise of urbanization and environmental harm.

**Table of Contents**

Introduction ………………………………………………………………………………… 5

Objectives …………………………………………………………………………………… 8

Methods ……………………………………………………………………………………... 9

Study Site Description

1. Drinking water resource and Supply Boundary ………………………………………...10
2. Songhua River ……………………………………………………………………… 12
3. Second Songhua River ……………………………………………………………. 13
4. XinliCheng Reservoir ……………………………………………………………. 14
5. Shitoukoumen Resvior ………………………………………………………………… 15
6. Jingyuetan Reservoir ……………………………………………………………………16
7. Climate and Geography of Changchun
    a. Climate ………………………………………………………………………. 17
    b. Geography …………………………………………………………………… 17

Literature Review

1. Heavy metal sources in urban environments …………………………………………. 18

2. Transport pathways of heavy metals from urban environments
    a. Stormwater Runoff ……………………………………………………… 20
    b. Air ……………………………………………………………………….. 21
    c. Soil ……………………………………………………………………….. 22

3. Fate of heavy metals in river environments

    a. Accumulation in bed sediments, re-suspension of sediments ……… 24

b. Bioaccumulation ……………………………………………………..……25
c. Biomagnification through food web ………………………………... 25

4. Exposure to human

a. Drinking contaminated water ………………………………………. 26
b. Eating fish ……………………………………………………………..  27

6. Heavy Metal Assessment for Changchun water supplies

Water Quality (Heavy Metals) Assessment

a. Xinlicheng & Shitoukoumen Reservoir ………………………  29
b. Second Songhua river ……………………………………... 31

Result

a. Development history of Changchun …………………………….35
b. Data Analysis……………………………………………………36

7. Heavy Metal Pollution Mitigation Review

Opportunities for Changchun and the Second Songhua River ……………… 38

8. Conclusions ……………………………………………………………………... 41

9. Recommendations……………………………………………………………. 42

10. References …………………………………………………………………….. 44

11. Appendix………………………………………………………………………….54

## Introduction

Drinking water has been the primary requirement for human development in the past hundred years. Since the industrial revolution, heavy metal pollution from industry and transport activities in the urban environment has become an increasing concern in many cities worldwide (Peng et al., 2016). In many places of the world, heavy metal concentrations in drinking water are higher than international standards and have adverse effects on human health through differences in contamination (Fernandez-Luqueno et al., 2013). Heavy metal sources, transport mechanisms, and environmental fate vary depending on the type and chemical form of the metal, land use activities, and characteristics of the receiving environment (Peng et al., 2016). The economy and population have proliferated in the past four decades, leading to increased rates of land-use change due to urbanization and other phenomena (OECD, 2012; Huang et al., 2015). Rapid urbanization has resulted in the extraction, processing, utilization, and disposal of heavy metals into the environment, especially water and sediments from point and nonpoint source pollutants.

Commonly identified heavy metals worth concern in drinking water resources include lead, iron, cadmium, copper, zinc, and chromium (Mohod & Dhote, 2013). Long-term exposure to these metals through sewage in drinking water can cause physical, muscular, and neurological degeneration, resulting in Alzheimer's disease, Parkinson's disease, muscular dystrophy, multiple sclerosis, and other diseases such as cancer (Mohod & Dhote, 2013). Lead is also one of the most prevalent heavy metals of concern found in drinking water, and when concentrations exceed the acceptable limit, it causes metabolic poisoning and enzyme inhibition (Mohod & Dhote, 2013).

China is one of the world's largest industrialized countries, and there is much evidence that heavy metal impacts human health and the environment. Drinking water supplies from source water and groundwater are vulnerable to heavy metal pollution and associated environmental degradation and are typically managed using costly treatment investments (Akpor & Muchie, 2010). In the Northeast China Plain, Changchun is a representative city suffering from pollution due to urbanization and industrialization.

Heavy metal pollution in the Second Songhua River poses a risk to Changchun's drinking water supply (Mohod & Dhote, 2013; Guan et al., 2018). Previous studies have investigated heavy metal pollution by degraded soils (Yang et al., 2012) and other environmental problems (Jiayin et al., 2020). In the past 20 years, the Changchun government had paid more attention to improving the local economy and urban design, focusing less on management for drinking water protection (citation needed). As a result, in recent years, Changchun's drinking water resources are impaired by heavy metal pollution; the Changchun government started recognizing the impacts of heavy metal and working on improving water quality.

In order to ensure the safety of drinking water, the Changchun government is now paying more attention to water source protection. For example, they advised to remove Fe and Mn from water prior to use (Adeyeye et al., 2020). The government's drinking water quality management focuses primarily on chemical and biochemical treatment in the water supply stations to filter or precipitate heavy metals (Ding et al., 2018). However, the investment in treatment is insufficient because it does not address broader environmental degradation. According to Kirschner et al.'s research, the level of heavy mental in Xinlicheng and Shitoukoumen reservoirs' sediments might be higher than the Canadian heavy metals sediment standard (2005). The Second Songhua river, which provides 55% of drinking water for Changchun residents, is still facing a massive challenge of heavy metal pollutants (Kirschner et al., 2005). However, the Second Songhua river pollution is not only the Changchun government responsible for due to the Second Songhua river's flow through different cities, and the transfer program is started in Jilin City. The long-term heavy metal pollution in drinking water resources will harm human health, environmental conditions and sustainable urban development (Mohod & Dhote, 2013). Therefore, the Changchun government needs to pay more attention to solving the heavy metals pollution in the drinking water resource for watershed management.

Alternative approaches for maintaining drinking water source quality exist, and they are well-established, supported by scientific evidence, and have been adopted in many parts of the world (Jiayin et al., 2020). An integrated watershed management is a watershed-based approach that is the basis for investigation in this paper to address Changchun's drinking water source pollution. By conducting an assessment at a watershed scale, one can measure water quality effects at a particular site through regular monitoring and identify potential stressors throughout the watershed (contributing area). This can inform alternative management solutions implemented upstream at the sources of pollution. An appropriate source water protection strategy can help communities be more resilient to the risk of water contamination, which may be exacerbated by future climate change and urban growth (Howard et al., 2016).

**Objectives:**

This paper presents a case study of a heavy metal assessment on the drinking water sources of Changchun and provides recommendations for alternative strategies to address pollution for water resources managers and decision makers.

**Objective 1:** To present a comprehensive review of heavy metal pollution in watersheds, including surface water, sediments, and groundwater.

**Objective 2:** To assess the historical and current status of Changchun's drinking water sources, focusing on heavy metals, based on a literature review.

**Objective 3:** To identify known and potential stressors in the contributing drinking water sources (Xinlicheng, Shitoukoumen, Jingyuetan reservoirs and Second Songhua River) to heavy metal pollution.

**Objective 4:** To present alternative pollution management strategies in Changchun's drinking water supplies. Furthermore, provide recommendations for future data monitoring and research needs for integrated watershed management in the Second Songhua River Basin and three reservoirs.

## Methods

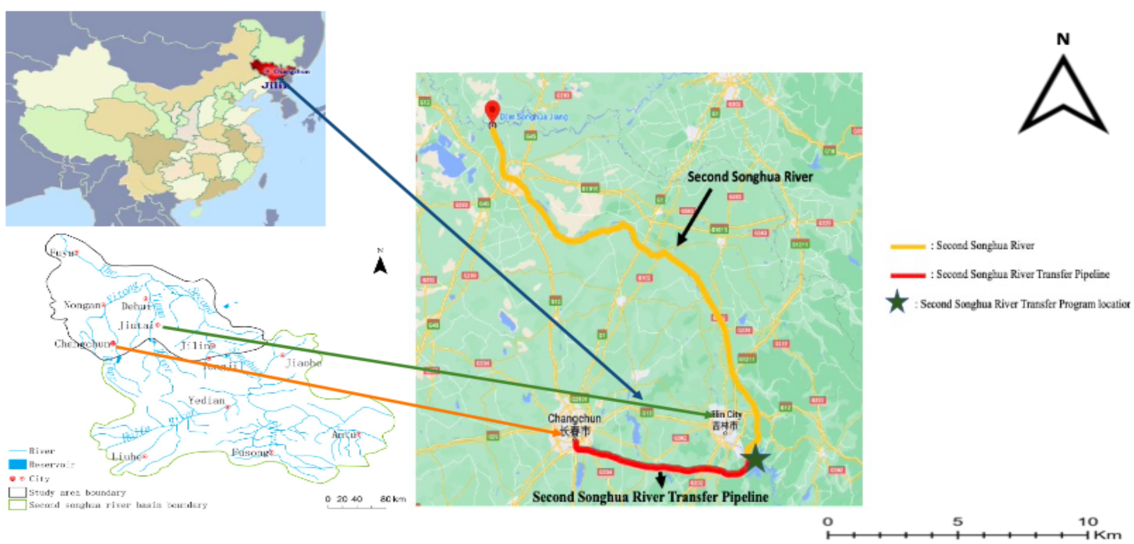
A comprehensive literature review of heavy metal pollution in watersheds, including surface water, sediments, and groundwater, was conducted.

Available data and information for the case study area (including Changchun city, the Songhua Basin, and the Second Songhua River) were compiled and synthesized. Original research, technical reports, journal articles, and case studies were reviewed and analyzed based on the following: heavy metals – Lead, iron, cadmium, copper, zinc, chromium; contaminant source, transport, fate, and exposure risks. Due to China's existing data privacy policies, the data were drawn from published literature and reports. Further discussion on this is addressed in Objective 4. Published results were synthesized into an assessment of heavy metal pollution and environmental effects and their association with watershed stressors. The presented assessment supports a discussion of alternative strategies to address heavy metal pollution in Changchun's drinking water sources. This discussion is guided by a literature review of the following principles: pollution prevention, precautionary principle, source water protection, and integrated watershed management (Environment and Climate Change Canada, 2019; Heathcote, 2009).

## Study Sites Description

### Drinking Water Resource and Supply Boundary

The second Songhua River drinking water transfer program is about 263 kilometres and accounts for approximately 55 % of the water supply for Changchun residents (Kirschner et al., 2005). The Second Songhua river does not locate in the Changchun' main city area, but the transferring water from the Second Songhua River project connected the water supply and demand relationship between the Second Songhua River in Jilin city and Changchun (Kirschner et al., 2005). Figure 1 indicates the transfer relationship between the Second Songhua River to Changchun and tells more information about the watershed boundary of the Second Songhua River. The Second Songhua River's flow through multiple cities in figure 1 might cause heavy metals sediment transport from different cities to Jilin and affect the drinking water quality of Changchun. The yellow line is the discharge of the Second Songhua River, and the red line is the Second Songhua River drinking water supply transferring program.




(Wang et al., 2016)

**Figure 1**: *The Second Songhua River Water Transfer Program and the Second Songhua River Watershed Boundary*

Drinking water resources from three reservoirs mostly come from groundwater and precipitation. Furthermore, about 45% of the city of Changchun's water supply is provided by groundwater (Zhang, 1993). Figure 2 shows three reservoir locations and relationships for Changchun City. Water from the Shitoukoumen, Jingyuetan, and Xinlicheng reservoirs, which are situated in the east and south of the city, provide the majority of Changchun City's drinking water supply (Zhang, 1993).

The water from the Second Songhua River transferring program will save part of the water in three resviors as emergency or reserving water for future use (Kirschner et al., 2005). Moreover, it could help to improve the water amount of three reservoirs due to the drought seasons(Zhang, 1993). The other part of the water will be directly sent to water stations, after water treatment will transport to the drinking water pipelines. Therefore, Shitoukoumen, Jingyuetan, and Xinlicheng reservoirs are connected with the Second Songhua river transferring program pipeline (Kirschner et al., 2005).

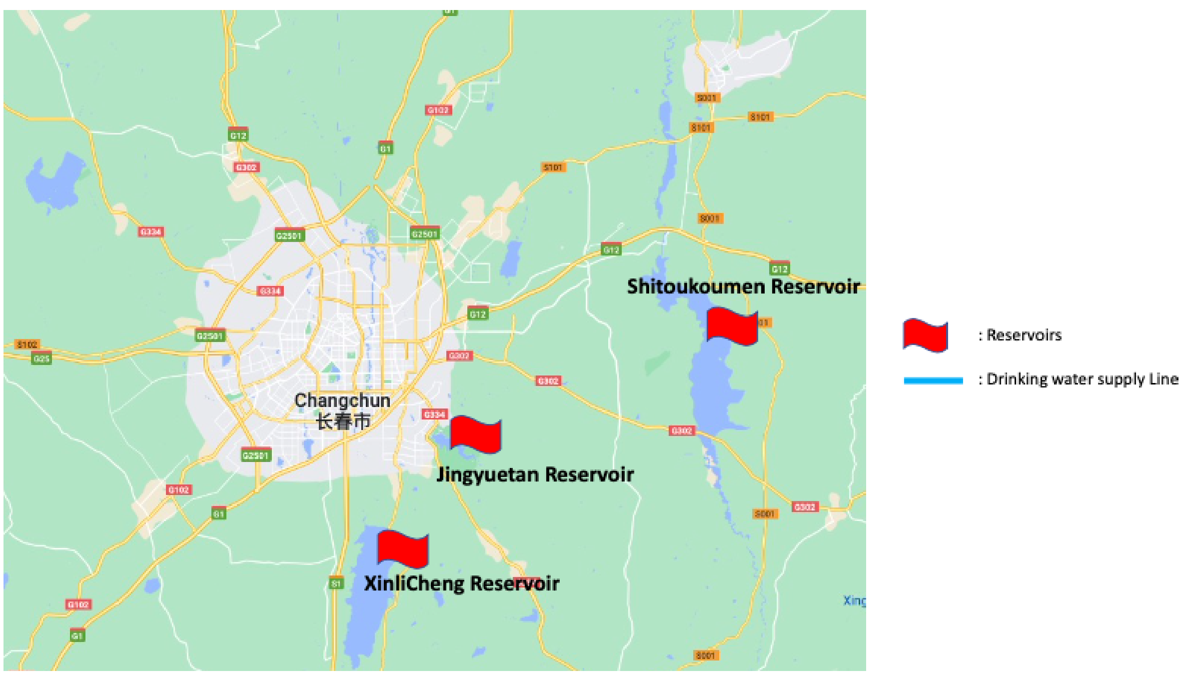



**Figure 2:** *Shitoukoumen, Jingyuetan, and Xinlicheng Reservoirs Drinking Water Supply Line*

**Songhua River**

Changchun City locates in the Songhua River Basin, one of China's largest basins (Yang, 2009). The Songhua River Basin situates in China's far northeast (119° 52′ – 132° 31′ E and 41° 42′ – 51° 38′ N) (Wang et al.,  2016). It has a total land area of 556,800 km2, making it one of China's seven main river basins (Wang et al., 2016). The Songhua River Basin's height ranges from 50 to 2700 m above sea level (Wang et al., 2016). The Lower Songhua River travels 939 kilometers northeast before meeting the Amur River, with a mild slope and large river channel carrying the combined flow from the Nenjiang and Second Songhua Rivers (Wang et al., 2016). The Nenjiang River Basin (NRB), in the west, the Upper Songhua River Basin (USRB), also known as the Second Songhua River, and the Lower Songhua River Basin, in the northeast, together make up the Songhua River Basin (SRB) (Wang et al., 2016).

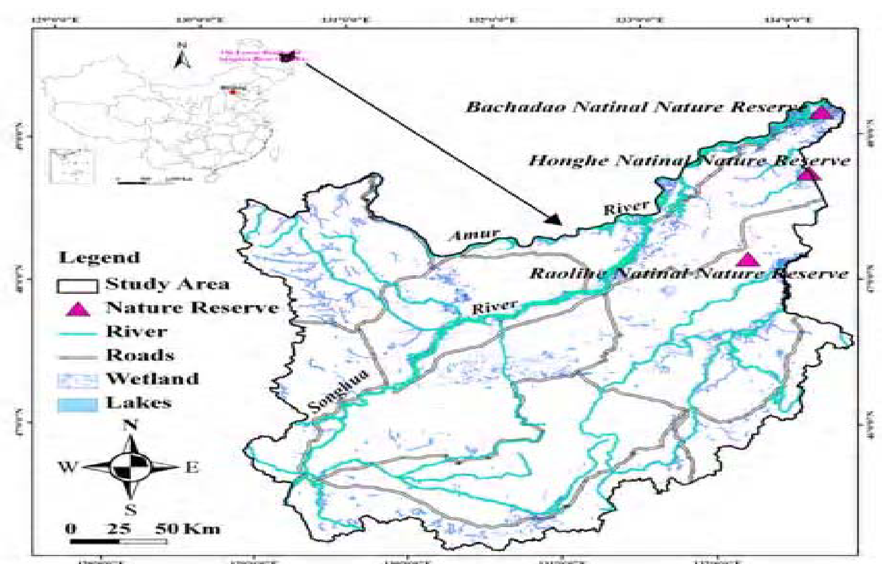



**Figure 3**: *Songhua River Distribution* (Lin et al,. 2018)

**Second Songhua River**

This assessment focuses on the Second Songhua River. The Second Songhua River is a tributary channel from the Songhua River, located in Jilin province (Li et al., 2014). The Second Songhua River rises in Changbai Mountain's Tianchi Lake and flows 958 kilometers from southeast to northwest, draining an area of 73,400 kilometers (Wang et al., 2016). One of the most significant rivers in northeastern China is the Second Songhua River (Lin et al., 2008). The river is approximately 958 kilometers long overall (Li et al., 2014). The Second Songhua River has a basin of 73.4 103 km2, and its tributaries provide an average annual discharge of 14.8 km3 (Li et al., 2014). Near Songyuan city, the Second Songhua River and the Nen River converge to form the Songhua River (Lin et al., 2008). The Second  Songhua River flows east from this point to join the Heilong River at the border between China and Russia (Lin et al., 2008). The primary supply of drinking water for the cities of Changchun and Jilin is the Second Songhua River (Zhang et al., 2016).

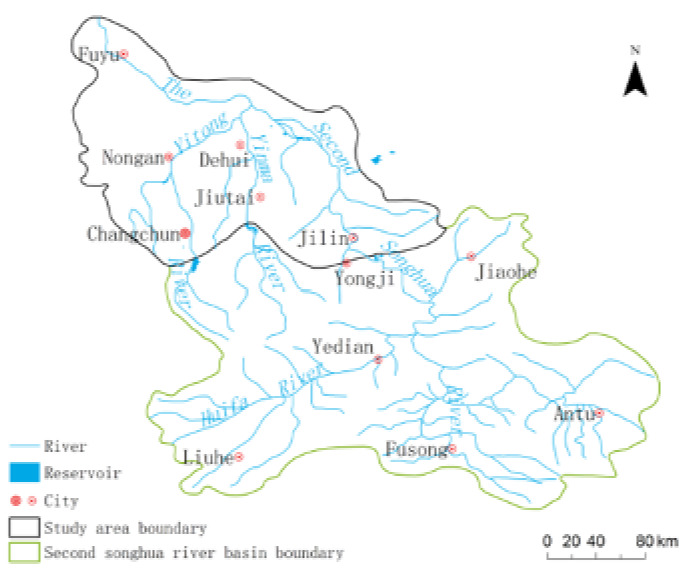



**Figure 4**: *Second Songhua River Distribution* (Wang et al., 2016

**Reservoirs:**

**Xinlicheng Reservoir:**

The Xinlicheng Reservoir is situated on the Yitong River, a tributary of the Yinma River in the Songhua River Basin, 20 kilometres south of Changchun City, Jilin Province (Li et al., 2022). The reservoir is 592 million square meters (Li et al., 2022). Xingli reservoir can hold 273 million square meters, while the intermediate flood control reservoir can hold 3,200 million square meters (Li et al., 2022). It is a sizable reservoir with multiple uses, such as downstream flood management, waterlogging prevention, power generation, and fish farming, is used to supply water to Changchun's industrial and domestic sectors (Li et al., 2022).

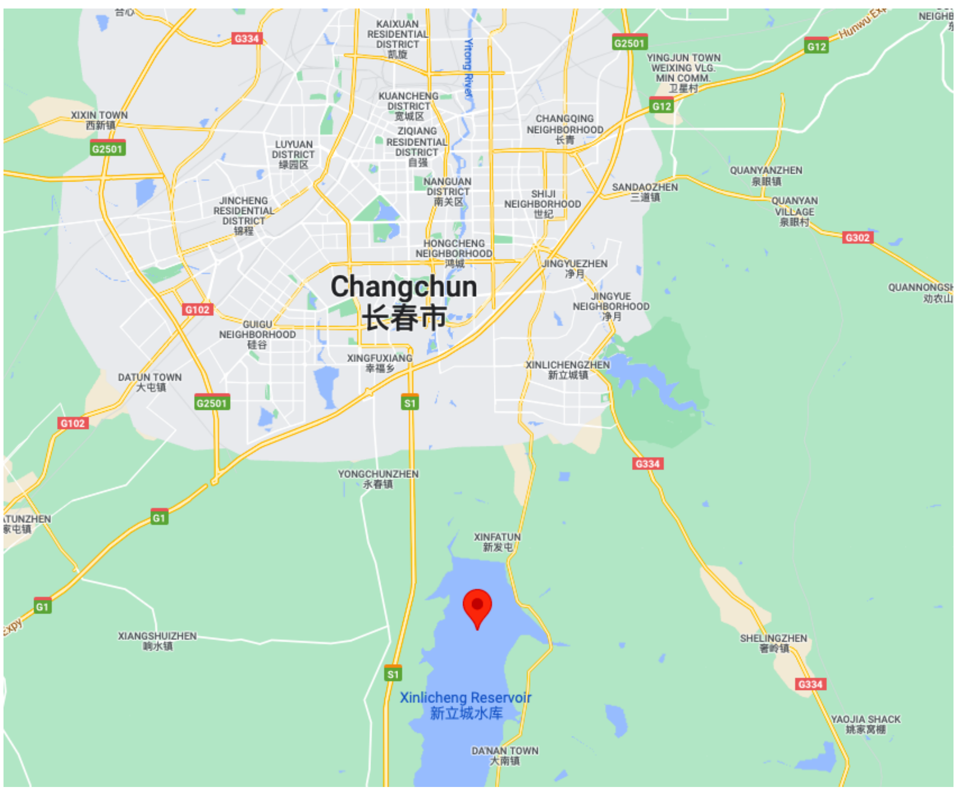



**Figure 5**: *Xinlicheng Reservoirs*

**Shitoukoumen Reservoir:**

The Shitoukoumen reservoir is situated in the Jilin Province's middle sections of the Yinma River (Zhang et al., 2019). The reservoir's construction location is 500 meters southwest of Shitoukoumen Village in Jiutai District, Xiyingchengzi Township, Changchun City (Zhang et al., 2019). Shitoukoumen reservoir is 57.3 kilometers away from Changchun. The location is at 43° 58'n and 125° 45'e. The reservoir's primary construction goals are flood management and waterlogging prevention, urban water supply, agriculture irrigation, fish farming, and electricity production (Zhang et al., 2019).


**Figure 6**: *Shitoukoumen Reservoirs*

**Jingyuetan Reservoir:**

Jingyuetan reservoir locates in the Jingyuetan national park. The Jingyuetan reservoir is near Changchun's movie wonderland, southeast of Changchun, and 18 kilometers from the city center (Qiu et al., 2015). It covers an area of wetlands of about 5.3 square kilometers. According to records, jingyuetan was built in 1934 to supply water to Changchun and has also been used as an emergency water source in recent years (Qiu et al., 2015).


**Figure 7**: *Jingyuetan Reservoirs*

## Climate and Geography of Changchun

### Geography

Changchun is in the center of the Northeast China Plain. The municipality situates between latitudes 43° 05′ and 45° 15′ N and 124° 18′ and 127° 02' E (Yang et al., 2012). Changchun municipality has a total area of 20,571 km2, including 2,583 km2 of metro regions and 159 km2 of the city proper (Yang et al., 2012). Within its administrative zone, the city locates at a moderate elevation, ranging from 250 to 350 meters (Yang et al., 2012). A tiny tract of low mountains with the Laodaodong Mountain, which rises to a height of 711 meters, as its highest point, can be found to the city's east (Yang et al., 2012). There are 222 rivers and lakes in Changchun prefecture. Yitong River, a tiny Songhua River tributary, traverses the city's central part (Yang et al., 2012).

### Climate

Changchun has a humid continental climate with four distinct seasons (Zhao et al., 2019). Due to the impact of the Siberian anticyclone, winters are long from November to March, cold, windy, and dry, with a mean temperature of 14.7 °C (5.5 °F) in January (Zhao et al., 2019). Although they are relatively short transitional seasons, spring and fall are typically dry and windy (Zhao et al., 2019). Due to the East Asian monsoon, summers are hot and muggy with a predominant southeasterly wind. July has an average temperature of 23.2 °C (Zhao et al., 2019). Winter snowfall is often infrequent, while June to August sees the heaviest concentration of annual rainfall (Zhao et al., 2019). An average year will have about 2,617 hours of sunshine and a frost-free period of 140 to 150 days, with monthly percent potential sunshine ranging from 47 percent in July to 66 percent in January and February. Extreme temperatures have been recorded from 33.0 °C to 35.7 °C (Zhao et al., 2019).

**Heavy Metal Sources in Urban Environments (Point and Nonpoint Sources)**

Point source pollution is easier to control as substantial reductions in the discharge of pollutants into water bodies have been realized over the past few decades (Taebi & Droste, 2004). Contrary to point source pollution, nonpoint source pollution is an aggregate of small contaminant inputs released from many sources spatially distributed through a watershed (Taebi & Droste, 2004). In Changchun, heavy metal pollution comes from point and nonpoint sources. Both sources come from urban areas, and part of the pollution is from the countryside, which is emission from the urban area. Industrialization pushes heavy metals pollution toward a serious issue.

A heavy industrial base in China was also developed in this basin on the East side of Changchun, with industries including widely dispersed machine, chemical, power and manufacturing, metallurgical, grain processing, and cement production (Guan et al., 2018). The significant population and industrialization growth leads to heavy metal sources from different types of point and nonpoint source pollution. Furthermore, big industries will transfer the wastewater to three Reservoirs after treatment. However, the treatment of heavy metal stander is not able to be found by the public. Furthermore, small industries might directly emit the wastewater to the outside of industries.

Figure 8 indicates the point source pollution transfer to three reservoirs from FAW company, the biggest heavy metals producer in Changchun. Four lines transfer the wastewater to the reservoir. The blue line is the special one that emits the treated wastewater to the Yitong River. Yitong River is in the center of Changchun and feeds most small lakes and wild organisms (Zhao et al., 2021). The government published the wastewater policy for the industries that need completed treatment and access to the standard of treatment water. Then the treated wastewater will be discharged to three reservoirs. There is no evidence that all the heavy metals will remove from the treatment process and non-impact on the watershed system or organism health.

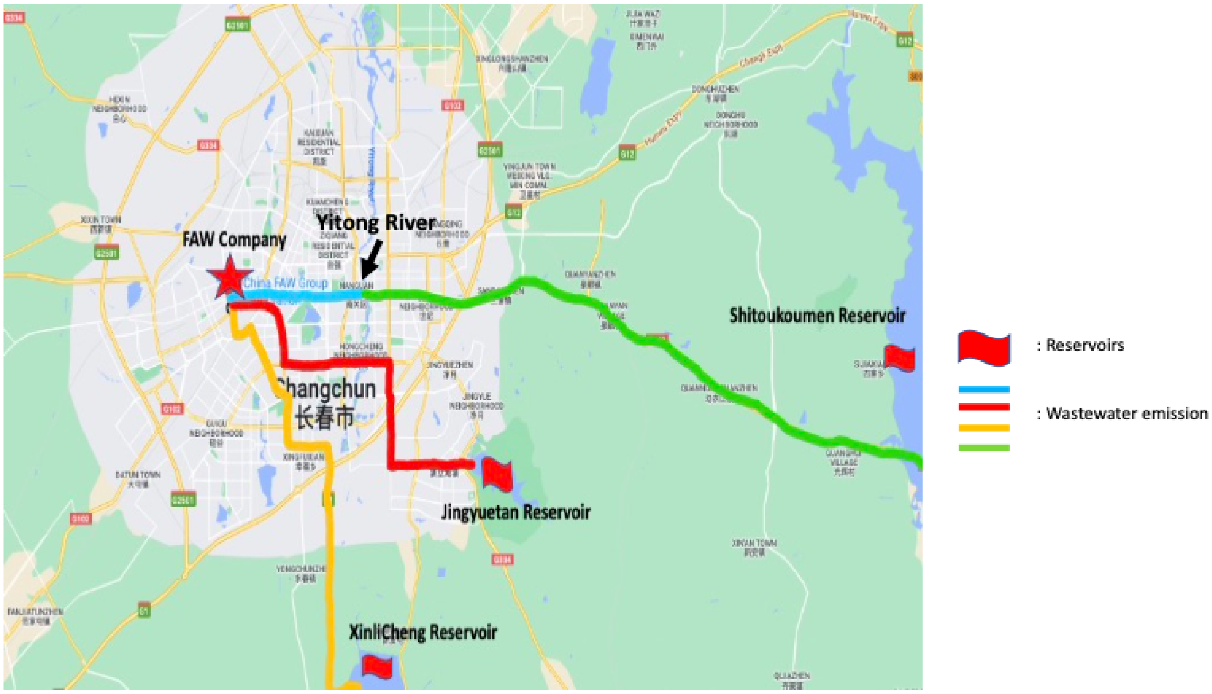



**Figure 8** : *The Point Source Pollution Transfer to Three Reservoirs from FAW Company*

According to Lin et al.'s research, the significant discharge of raw chemical industrial waste in Jilin in the 1960s and 1970s caused the Upper Songhua River to experience severe mercury pollution (2007). The sediments nonetheless experienced moderate to severe mercury pollution even during the 1970s, although mercury concentration in the sediments dramatically decreased (Lin et al., 2007). Consequently, the second Songhua River water quality has substantially declined recently, making it the second Songhua fluvial system's most contaminated watershed (Guan et al., 2018).

Furthermore, human sewage and activities, such as automobile emissions, small industrial discharges in central urban areas, and other infrastructure construction activities in Changchun also increase the heavy metals pollutants (Yang et al., 2012). Therefore, heavy metals from human behaviors will flow into the surrounding soil and the urban watershed, which is connected with the Second Songhua river basin. And then, the pollution will transport to the Second Songhua river region or accumulate into the soil due to heavy falls and polluting groundwater.

**Transport Pathways of Heavy Metals from Urban Environments**

Human behaviors and industries emit heavy metal pollutants in Changchun. These heavy metals pollutants might have different transport pathways to urban watersheds, soil and groundwater. For instance, heavy metals are absorbed and transported by soil sediment and storm runoff. The transportation of the heavy metal possibly causes a secondary pollution source (Tang et al., 2014). Urban transportation patterns and land use features are closely correlated with the occurrence of heavy metal transport (Duong & Lee, 2011).

**Stormwater Runoff**

Stormwater runoff is one of the crucial transporters carrying a variety of heavy metal contaminants to receiving water bodies and soil sediment in urban areas (Liu et al., 2018). The rapid population and economic growth might increase the stormwater runoff transportation in Changchun. Stormwater runoff from heavy metal sources is mostly from daily human consumption; it can be actual products, such as runoff from roofs, tire wear, food, or activities, such as big businesses and car washes in the urban area (Pang et al., 2008). Households, drainage systems, commercial establishments, pipe sediments delivered in sewage water, atmospheric deposition, traffic, construction materials, and pipe sediment transported in stormwater were the different types of heavy metals in Changchun‘s urban area (Pang et al., 2008). That might cause the principal repository or sink for heavy metals, and other contaminants in cities are urban soil, a crucial component of the urban heavy metal pollutants (Yang et al., 2012). These points or nonpoint pollution will flow into the groundwater or watershed from urban areas due to heavy rainfall. The heavy rainfall will send the heavy metal sediment from the soil to the groundwater or urban watershed. Both groundwater or urban and rural watersheds are drinking water resources for Changchun. In addition, compared to residential areas, wash-off from road surfaces, industrial, and commercial areas tend to produce larger quantities of heavy metals in stormwater runoff in Changchun (Lu et al., 2012). The heavy metals from stormwater runoff might be hard to find and solve in the short term. That will potentially threaten human health and environmental degradation for Changchun residents.

**Air**

Heavy metal pollutants could also transfer in different phases, such as the atmospheric and ground phases in the urban area. Both daily sewage and industrial waste could be the resource of atmospheric phase transport. Pollutants from the atmospheric and ground phases are essential contributors to heavy metal accumulation in urban stormwater (Lu et al., 2018). Pollutants produced in urban areas can first gather in the air before being carried via atmospheric deposition to ground surfaces (Wang et al., 2016). Both dry and moist deposition can take place in the atmosphere. While a wet or bulk deposition is proportional to rainfall depth, dry atmospheric deposition of heavy metals positively correlates to previous dry days (Lu et al., 2018). The findings also demonstrate that various sources, such as non-exhaust emissions, exhaust emissions, and re-suspension of previously deposited heavy metals, contribute to the atmospheric deposition of heavy metals (Lu et al., 2018).

Furthermore, heavy-duty traffic volume is a significant source of the buildup of heavy metals on road surfaces (Lu et al., 2018). These pollution sources will potentially transfer to the atmosphere during the rainy season or wet deposition (Lu et al., 2018). In this context, there is a connection between the atmospheric and ground phases and, thus, the significance of atmospheric heavy metals as a cause of stormwater contamination (Lu et al., 2018).

**Soil**

As mentioned before, the part of the heavy metals transferred from stormwater runoff and atmospheric phase could accumulate into soil. In this context, the transferred heavy metal could cause soil erosion, sedimentation, leaching groundwater, and lateral stream flow.

A spatial study discovered that places with extremely high metal concentrations were typically found in industrial and residential neighborhoods, by the side of the road, and in densely populated commercial districts in Changchun (Li et al., 2001). Additionally, the concentration of heavy metals decreases with depth and increasing distance from the road. In addition, major soil components like Mn, Al2O3, CaO, Fe2O3, MgO, SiO2, K2O, and NaO were also examined (Chen et al., 2005). Numerous heavy metals, including Cu, Pb, Hg, As, Cd, and Zn, were in high concentrations in Changchun's soils (Chen et al., 2005). While the mean concentrations of K2O, MgO, Na2O, and SiO2 were comparable to the mean concentrations in soils from Jilin Province, the mean metal concentrations were significantly higher than the background values of topsoil in the Changchun region (Chen et al., 2005). They were also higher than the mean concentrations in soils from Jilin Province (Chen et al., 2005). These heavy metals might cause soil degradation in Changchun. Heavy metals can change the soil pH value, disrupt important microbial activities and reduce soil microorganism activity and population (Yan et al., 2018). These factors will affect plant growth and decrease the nutrient ability of the soil.

Groundwater and stream waterways can contaminate heavy metals seeping through the earth (Kumar et al., 2013). Water from precipitation or snowmelt can pick up trace amounts of dissolved heavy metals as it seeps into polluted soil (Kumar et al., 2013). The contaminated water subsequently percolates through the groundwater and into the drainage basin of the area (Aryal et al., 2006). Heavy metals accumulated in the soil might also leach to the groundwater due to heavy rainfall, vegetation, and water transportation (Aryal et al., 2006). Furthermore, it might transfer into the streams from the groundwater because the groundwater might be connected with local streams (Aryal et al., 2006). The controllable flooding and natural disasters might also cause heavy metals to transfer to the stream or the groundwater (Aryal et al., 2006). For a long time, the heavy metals from soil sediment will affect aquatic environments and health in the Second Songhua river.

**Fate of Heavy Metals in River Environments**

Heavy metals in municipal sewage, industrial effluents, and urban runoff are among the harmful compounds of particular importance (Jain et al., 2008). Most of the wastewater with heavy metals in the East of Changchun will become a direct pollution emitter to the watershed, especially for the Second Songhua River or Reservoirs, the discharge basin of the Second Songhua River. However, the government of Changchun has published some strategies to mitigate the pollution. Heavy metals pollution is less focused on because the economic support industries like vehicle industries provide most of the heavy metals into the watershed. Otherwise, stormwater runoff will also leach and transport the heavy metals from urban sewage to the river environments.

Different watersheds will contaminate heavy metal sediment due to land use and human behaviours. For example, in the Songhua River Basin, the distribution of total heavy metal concentrations changed significantly in the sequence Zn > Cr > Pb > Cu > Ni > As > Hg > Cd (Guan et al., 2018).

After heavy metals transfer from Changchun urban areas or industries to the river environment. Heavy metals will primarily be absorbed by lake sediments, while they can also be supplied to the water above them (Jain et al., 2008). The discharge of heavy metals from sediments into the water below creates secondary contamination and may seriously harm the aquatic system's natural state (Jain et al., 2008).

**Accumulation in Bed Sediments, Re-suspension of Sediments**

Heavy metals of low solubility are easily absorbed and accumulated in sediments ( Ma et al., 2013). Some heavy metals cannot readily dissolve in water, so they typically bind to suspended particles and settle as sediment (Algül & Beyhan, 2020). Therefore, sediments in river beds or lake bottoms frequently serve as a significant reservoir for pollutants released into water bodies (Vandecasteele et al., 2004). Under certain circumstances, heavy metals adsorbing in sediments can desorb back into the water above, resulting in secondary pollution and perhaps harmful consequences on species (Algül & Beyhan, 2020).

The heavy metal pollutants accumulated in watersheds might also cause negative impacts on the watershed from chemical, biochemical and physical properties. To be specific, the chemistry of the aquatic system changes will cause specific biochemical processes to take place and organic complexing agents to enter the system. That will lead to pH changes, the redox conditions change, or the salinity rises, and contaminated sediments can act as non-point sources of heavy metals to the water column (Jain et al., 2008). These factors might affect Changchun's development in different ways. However,  further details will be separated into different parts to discuss, and a detailed explanation will be indicated in the data analysis.

**Bioaccumulation**

In the Long term, heavy metals emitted from Changchun to the Second Songhua River and Reservoirs could potentially harm food webs ( Xiao et al., 2012). Bioaccumulation is generally the buildup of pollutants in living organisms, including heavy metals or pesticides (Heikens et al., 2001). Since they take in toxins from the water surrounding them quicker than the abililty that their bodies can eliminate, aquatic organisms are frequently prone to bioaccumulation (Heikens et al., 2001). Additionally, physicochemical and biological factors, including pH, temperature, hardness, exposure time, exposure length, species eating patterns, and habitat complexity, may contribute to the accumulation of heavy metals in fish organs (Ahmed et al., 2019). Humans can also become bioaccumulative, affected by toxins in our food, air, or water, or by ingesting infected aquatic species. Because heavy metals do not biodegrade, they can linger in our bodies for a very long time (Heikens et al., 2001).

Microorganisms are consumed by insects, fish, and people who stay at the top of the food web (Malik et al., 2010). In the food chain, bioaccumulation starts with the smallest bacteria and ends with people (Malik et al., 2010). In some cases, heavy metals can even infiltrate the cells of microorganisms like phytoplankton in oceans and bond to their surfaces (Malik et al., 2010). Heavy metals can interact with substances generated by the microbe to digest food and undergo chemical changes once they enter the cell (Malik et al., 2010).

**Biomagnification through Food Web**

For a long time, biomagnification might have happened after bioaccumulation in the Second Songhua River and Yimma Basion. Biomagnification is the process through which the concentration of heavy metals rises in the food chain. Due to their limited solubility in water, heavy metals typically bind to suspended particles before settling as silt (Jain et al., 2008). Thus, heavy metals can enter the food chain in an aquatic environment and become available for biota accumulation (Jain et al., 2008). Fish are a good indicator of pollution since they can store heavy metals in their tissues and are at the top of the food chain and a significant food source for humans (Jain et al., 2008). In light of the effects-heavy metal contamination from sediments may have on aquatic life and human health, assessment of this pollution is crucial (Jain et al., 2008). That might have affected the health of Changchun residents.

**Exposure to Human**

Besides the different strategies impacting the Changchun surrounding aquatic system environment, residents in Changchun will be exposed to heavy metal pollution directly and indirectly from groundwater or stormwater runoff transportation.

**Drinking Contaminated Water**

Drinking contaminated water will cause the worst direct impact on human health from heavy metal pollutants. As discussed, the point source pollution is from industries, and nonpoint source pollution is from human daily sewage and behaviours. The Changchun government pushed the policy for all the point source pollution and required industries to ensure water treatment before discharging to the three reservoirs. However, the research indicated that the leading technology for heavy metals wastewater treatment only could replace 90 % of the heavy metal (Barakat et al., 2011). That means 10 % of the heavy metals will still be transferred to drinking water resources from three reservoirs or the Second Songhua river. The insufficient heavy metals treatment will lead residents to drink contaminated water directly, negatively affecting human health in the long term.

Furthermore, the nonpoint pollution from urban areas will be a considerable challenge for drinking water resources. When point pollution emits after treatment, nonpoint pollutions directly flow to the soil or watershed and then leaches to drinking water resources because of the connection between groundwater and drinking water resource. In this case, the heavy metal pollution will be more easily accumulated in human bodies and harm human health because there is a non-technical treatment process to reduce the toxicity of heavy metals. Unsafe levels of pollutants in drinking water can negatively impact the brain, reproductive system, and chronic disorders like cancer (Rehman et al., 2018).

**Eating Fish**

When people drink contaminated water, they could be directly affected by heavy metal pollutants. However, eating contaminated fish impacts humans indirectly. Bioaccumulation will occur in the long-term in environments polluted by heavy metals. Individuals stay in the top position of the food web and eat other animals that might also be affected by heavy metal pollutants. Heavy metal toxicity accumulated from eating fish can harm or impair the operation of the brain and central nervous system, decrease energy levels, harm the liver, lungs, kidneys, bones, and other essential organs, and also harm the blood's composition (Isangedighi, 2019). Long-term exposure may gradually worsen physical, muscular, and neurological conditions such as multiple sclerosis, Alzheimer's disease, Parkinson's disease, and muscular dystrophy. It is typical to experience allergies, and prolonged exposure to specific metals or their compounds may even result in cancer (Isangedighi, 2019). When it does, heavy metal poisoning is a chemically necessary condition. If ignored or improperly managed, toxicology can cause severe sickness, a decline in quality of life, and death (Isangedighi, 2019).

According to the research, most fish consumed in Changchun is produced by three reservoirs (Liu et al., 2008 ). That means Changchun residents face enormous challenges of bioaccumulation or biomagnification through the food web, and residents will suffer the most severe risk of heavy metal bioaccumulation.

**Heavy Metal Assessment of Changchun's Drinking Water Supplies**

The heavy metal assessment is based on published data and literature; however, data might be limited in the study area. Previous research primarily focused on the Second Songhua River, the Shitoukoumen, and the Xinlicheng reservoirs. Jingyuetan reservoir lacks data from the literature review, so this paper will only focus on the Xinlicheng and  Shitoukoumen Reservoir. Climate and environmental effects will be discussed with each water source.

The heavy metals' concentrations focus on the elements of Zn, Cu, Pb, Cr, and Cd because the World Health Organizations list these heavy metals as Major Public Health Concern in the drinking water resources (Jamshaid et al., 2018). The Changchun industries also produce these heavy metals. Mn will also be considered as a heavy metal pollutant because Mn has been reported to have affected the drinking water quality and caused drinking water to be light brown in Changchun in the past five years.

The data analysis of Xinlichang, Shitoukoumen Reservoirs, and Second Songhua river has higher uncertain errors due to the limitation of data and literature. The literature used for three drinking water resources did not measure in the same year. The data of Xinlicheng, Shitoukoumen reservoirs, and Second Songhua River have different measured periods. Xinlicheng reservoir was measured in 2017, Shitoukoumen reservoir was measured in 2020, and Second Songhue river was measured in 2008. The Changchun and Jilin governments might improve heavy metal management and mitigate the heavy metals sediment from 2008 to 2022.

**Xinlicheng & Shitoukoumen Reservoir** :

Table 1 indicates the Environmental Protection Agency's (EPA) heavy metal Guidelines for Sediments (Onjefu et al., 2016) and the heavy metal data from Xinlicheng and Shitoukoumen Reservoir. Compared to the EPA standard and the two reservoirs' heavy metals concentrations, in Shitoukoumen Reservoir, all the other heavy metals' concentrations measures are lower than the polluted standard of EPA sediment concentration, expected Cr. However, all the heavy metal concentration measures exceed the not polluted range and are toward the moderately polluted range in the Xinlicheng reservoir. The measure of Mn is more than two times higher than the heavy polluted minimum level, but Cd is in the not polluted range of Xinlicheng reservoir. In addition, compared to the heavy metals concentration of Shitoukoumen reservoir and Xinlicheng reservoir, Shitoukoumen reservoir sediments are lower than in Xinlicheng reservoir.

The heavy metal pollution in Shitoukoumen Reservoir is mainly from the industries because Shitoukoumen Reservoir is 57.5 kilometres from Changchun. The long distance from the city significantly reduces nonpoint pollution from daily urban competitions. In addition, strong industry sources, particularly Shitoukoumen Reservoir and its higher tributaries, may have a more substantial potential influence on the toxic metals Cd, Ni, Pb, and Zn, endangering the safety of the drinking water supply (Adeyeye et al., 2020). Therefore, the concentration of heavy metals in Shitoukoumen reservoir is lower than in Xinlicheng reservoir due to fewer urban nonpoint pollution emissions.

Furthermore, the sediment of Xinlicheng reservoir might be affected by environmental and geographical conditions. The Xinlicheng reservoir's regular geometric features and unique terrain facilitate high rates of siltation and bed sediment accumulation, with a relatively shallow water depth of approximately 10 meters (Zhu et al., 2017). The sediments are prone to resuspension and settling close to the dam. Pulsed suspended solids polluted with heavy metals may build event layers close to the dam because the Xinlicheng reservoir has a short and direct path for floods and wastewater transport lines to reach the dam (Zhu et al., 2017). The Xinlicheng Reservoir likely has substantial siltation potential and fluctuating metal distributions, expected to result from flood episodes brought on by heavy precipitation and industrial wastewater (Zhu et al., 2017). This could cause the buildup of home and industrial sewage in Changchun City that was channeled into the Xinlicheng reservoir, and then the rest of the wastewater from home might follow by storm runoff (Zhu et al., 2017).

Otherwise, the temperature and the climate might influence heavy metals' discharge in the aquatic environment. According to the research, metal release rates are faster at higher temperatures (30–35°C) than at lower ones (Li et al., 2013). The release rates of heavy metals at the same temperature went in the following order: Zn > Cu > Pb > Cr > Cd (Li et al., 2013). However, the highest average temperature in Changchun in July is 23.2 °C. Changchun has a moderate and balanced humidity for the year even though extreme temperatures have been recorded from 33°C to 37 °C (Zhao et al., 2019). Therefore, the climatic impact could be negligible for Shitoukoumen and Xinlicheng reservoirs.

| Heavy Metals(Mg/kg) | Not polluted | Moderately polluted | Heavy pollutes | Xinlicheng Reservoir (2017) | Shitoukoumen Reservoir (2020) |
|---|---|---|---|---|---|
| Cr | <25 | 25-75 | >75 | 108.2 | 46.6 |
| Cu | <25 | <6 | >6 | 41.6 | 23.8 |
| Zn | <90 | 90 - 200 | >200 | 112.7 | 52.23 |
| Mn | <300 | 300-500 | >500 | 1211.7 | NONE |
| Pb | <40 | 40 -60 | > 60 | 47.9 | 32.38 |
| Cd | —----- | <6 | >6 | 1.7 | 0.29 |

**Table 1**: *Environmental Protection Agency (EPA) heavy metal Guidelines for Sediments (Onjefu et al., 2016) and Xinlicheng, Shitoukoumen Reservoir Data (Zhu et al. 2017;Adeyeye et al., 2020).*

**Second Songhua River:**

The Second Songhua River is one of the drinking water resources for Changchun residents, providing nearly 55 % of the drinking water. The heavy metal pollution in the Shitoukoumen, Jingyuetan, and Xinlicheng reservoirs sediment will transfer to the Second Songhua River through the inflow and outflow water streams of the basin (Pintilie et al., 2007). The second Songhua River is also one of the largest rivers in Jilin province so it will receive heavy metals from other basins in different cities through the soil sediment or stream flow.

On the other hand, the Second Songhua River has been polluted by industries that produce heavy metals. As mentioned, in the 1960s and 1970s, Jilin City's chemical industry discharged a significant volume of raw or primary effluent into the Second Songhua River, which led to significant mercury pollution (Lin et al., 2008). Furthermore, the Second Songhua river also has the largest petrochemical company in Jilin Province, Jilin Petrochemical Company, PetroChina Co. Ltd., based in the industrial metropolis of Changchun City. The petrochemical industry is one of the primary heavy metal contamination sources that cause heavy metals to accumulate in aquatic environments through atmospheric deposition, precipitation, and wastewater to the Second Songhua River. (Bai et al., 2012).

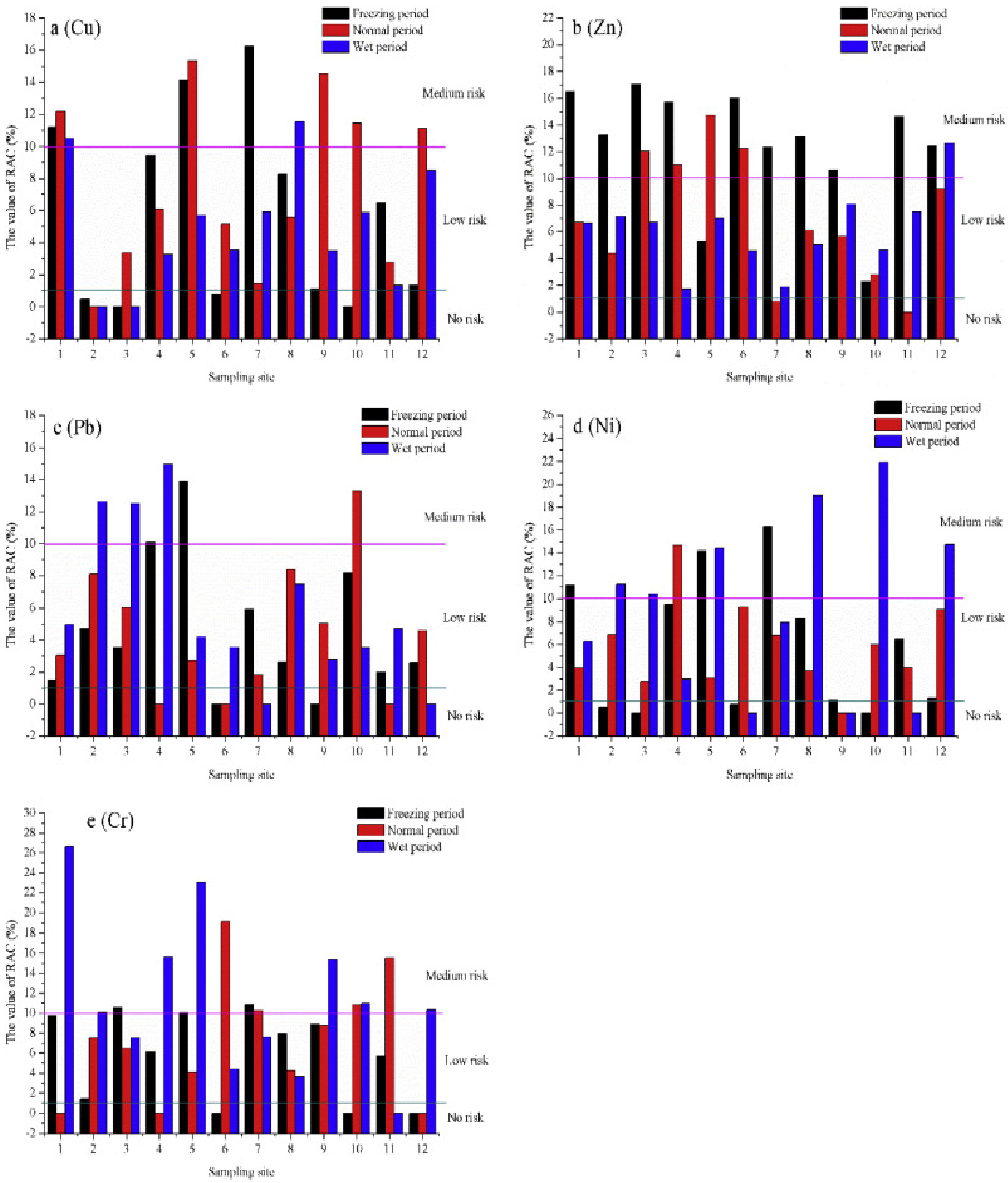
The Second Songhua River flows through different cities, climatic conditions will account for the heavy metals' concentration in different periods. Furthermore, the Second Songhua River is a naturalized watershed with less pollution and will freeze in the wintertime. Therefore, heavy metal concentration measures in different periods (wet, regular and frozen) under different climatic conditions, complicating pollution dynamics.

In the freezing period, the total heavy metal concentrations ranged from 289.43 to 507.89 mg/kg, with a mean value of 346.34 mg/kg; in the average period, they ranged from 123.98 to 372.63 mg/kg, with a mean value of 221.48 mg/kg; and in the wet period, they ranged from 151.73 to 342.84 mg/kg, with a mean value of 247.03 mg/kg. The freezing phase had the highest overall concentration of heavy metals.

Moreover, to evaluate the ecological risks of heavy metals in sediments, taking into account bioavailability and mobility, a risk assessment code (RAC) based on the percentage of total heavy metals in the acid-soluble fraction is utilized in figure 9 (Singh et al., 2005). Specifically, figure 9 indicates different heavy metals in 12 different sample locations in the Second Songhua river in three periods (Wet, regular, and frozen), which provide the drinking water resource for Changchun residents. The graph shows the concentration of Cu is the highest in the frozen period, 16 % of RAC, and accessed the medium risk level. However, the average of Cu concentration is only 4.96% and has the lowest risk. The concentration of Zn is higher than Cu in the frozen period is nearly 18 %, with an average of 12.45%, and also higher than the medium risk level. Compared Zn to Cr, the highest concentration of Cr is in the normal period, about 27 %, and the average value of Cr is 11.27 %. To decrease the order of average value for heavy metals Zn (8.58%),> Cr (8.16%) > Ni (6.2%) > Cu (6.05%) > Pb (4.98%), demonstrating that the environmental dangers associated with Zn and Cr were higher because they were more bioavailable and mobile than other metals. Furthermore, there is the average value of heavy metals all in the lower ecological risk range (Lin et al., 2008).

Pb and Ni also have the highest concentration for three periods analyzed in the standard period. The highest value of Pb is about 15 %, with an average of 4.42%, and the highest value of Ni is 23%, with an average of 6.2%. Pb, Ni and Cr accessed the medium risk level most often in the wet and frozen periods. Cu and Zn accessed the medium risk level mainly in the frozen and regular periods. The total heavy metal concentrations in the freezing period ranged from 289.43 to 507.89 mg/kg, with a mean value of 346.34 mg/kg. In the regular period, they ranged from 123.98 to 372.63 mg/kg, with a mean value of 221.48 mg/kg; in the wet period, they ranged from 151.73 to 342.84 mg/kg, with a mean value of 247.03 mg/kg.

Due to the climatic conditions, the freezing phase had the highest concentration of heavy metals. This value was around 1.5 times greater than regular wet periods (Lin et al., 2008). The significant inputs of nonpoint pollution sources into the aquatic environment, such as melting snow and large air particles transporting heavy metals from heating activities, were blamed for the greatest heavy metal concentration discovered during the freezing period (Lin et al., 2008). The nonpoint source also comes from daily sewage leachings and snowmelt runoff transported to power plants, car deterioration and exhaust emissions, household garbage from agriculture, petrochemical sector, power plants, car deterioration and exhaust emissions, and household garbage (Lin et al., 2008). In the petrochemical industry, heavy metal pollution is from point pollution sources of heavy metals. The heavy metals from the petrochemical and chemistry industry will accumulate into the soil and become sediments. In the wintertime, snow will melt into soil and transfer the heavy metal sediments from groundwater and runoff to the Second Songhua River.




(Lin et al., 2008)

**Figure 9**: *Concentrations of Heavy Metals in Sediment for 12 Sample Locations in the Second Songhua River*

**Results:**

**Development History of Changchun**

Northeastern China's Jilin Province is home to the sizable city of Changchun, which has a population of 3.68 million. The ten counties that comprise the research region have a combined population of around 7.534 million (Changchun Bureau of Statistics, 2017). Changchun is a city that is both industrial and agricultural. The region includes Yushu and Nong'an counties, China's top two grain-producing counties (Er, 2015). Changchun is also an important center for automobile industries as it is home to the China First Automobile Works (FAW) Group Corporation's and Changchun Passenger Car Works' most extensive production facilities.

Looking back to the development history of Changchun, we can see that in nearly half a century, the urban population (almost 3 million people) had increased nearly three times, and the metropolitan construction area had expanded by roughly half (Yue et al., 2015). The population and industrialization development cause severe heavy metal pollution in the Second Songhua River. Historically, Changchun city's raw or primary industrial effluent was frequently dumped into the river, which led to the river's significant mercury pollution in the 1960s and 1970s (Lin et al., 2008). It is well known that in November 2005, the Jilin Chemical Co. river spilled an estimated 100 tonnes of poisonous materials made up of a mixture of nitrobenzene, aniline, and benzene (Lin et al., 2008).

In addition, mercury pollutants from the 1960s to 1970s caused the Second Songhua River to suffer enormous challenges in mercury removal management. Results showed that mercury content in the sediments has the highest value of 1.27 mg kg-1 at Jilin City of the Second Songhua River, the drinking water resource point for Changchun residents (Lin et al., 2007). Additionally, the mercury concentration in the sediments at the effluent discharge site declined from 16.8 mg kg/year in 1974 to 0.09 mg kg/year in 2015 (Lin et al., 2007). The deeper layers in the sedimentary sections of the river had higher quantities of mercury than the surface sediments indicating that more significant levels of mercury were discharged in the past and were subsequently buried through time by less polluted sediments (Lin et al., 2007). However, compared to the Environmental protection agency (EPA) heavy metal Guidelines for Sediments

(Onjefu et al., 2016), mercury concentration still needs to decrease through management scenarios.

Therefore, industrial and municipal effluent significantly impact the Second Songhua River's water quality (Wang et al., 2016). This watershed discharges roughly 645 million tonnes of wastewater annually, of which 44% comes from the city of Jilin (Wang et al., 2016). Water quality deterioration in three Reservoirs is particularly bad because total nitrogen, phosphorus, and ammonia nitrogen levels exceed the standard; the river's length, where water quality is below Grade V levels, makes up 42.9% of its total length (Wang et al., 2016). Municipal and industrial sewage has had a significant negative impact on the Changchun drinking water resource.

**Further Analysis:**

Overall, the data analysis of Xinlichang and Shitoukoumen Reservoirs reflected that nonpoint pollution from urban areas provided more heavy metal sources to the reservoir and affected drinking water quality. Compared the concentrations of heavy metals in Xinlichang to Shitoukoumen Reservoirs, Xinlichang Reservoir has a higher heavy metal concentration and a shorter distance from Changchun City than Shitoukoumen Reservoirs. The heavy metals sediment concentration in Shitoukoumen reservoir is not in the polluted range. However, the heavy metals sediment concentration of Xinlicheng reservoirs tends to be moderately polluted. The climate does not affect heavy metal transport in the Changchun area due to its low humidity (Wang et al., 2019). The environmental conditions lead Xinlichang Reservoir easily absorb heavy metals in the sediment. The rapid social-economic and demographic population pushes heavy metal pollutants differently. The rapid population growth led to urban areas expanding three times in Changchun, causing the nonpoint source to be closer than the drinking water resource. In this context, it could prove that nonpoint sources from urbanization will affect the drinking water quality.

In addition, industries will discharge treated wastewater to three reservoirs, the drinking water resources. Although the drinking water will be treated before being provided to residents, this research indicated that water treatment only could replace 90% of the heavy metals (Barakat et al., 2011). The rest of the heavy metals will dissolve or sediment in the watershed, affecting human health in the long term. Industries are the economic support for Changchun's future development, so there are fewer chances to reduce the production rate of industries. Therefore, the Changchun government needs to publish more efficient management strategies to solve the nonpoint and point pollution from industries and urban consumption. The heavy metals pollution in Changchun is affected by climatic, environmental, socioeconomic and demographic factors from urbanization development.

On the other hand, the Second Songhua River is the most extensive drinking water resource for Changchun residents, and urban and nonpoint heavy metal pollutants have also threatened it, especially mercury pollution, since the 1960s until now (Lin et al., 2008). The dataset of the Second Songhua River indicates that the climate affected the heavy metals pollution due to the frozen period in winter through melting snow transport. The heavy metals pollutants in the winter mostly come from nonpoint sources in the urban area. The point pollution is mainly from the petrochemical industry and chemical industries. The heavy metal from the petrochemical industry will accumulate in the soil and be transported to the Second Songhua river through storm runoff and snow melt (Lin et al., 2008). It also shows that climatic, socioeconomic, and demographic urbanization factors accelerated the heavy metal pollutants in drinking water in Changchun.

Overall, the data resource analysis for Shitoukoumen, Xinlincheng reservoirs, and the Second Songhua river shows that urbanization increased heavy metals pollution and threatened the drinking water quality of Changchun. The pollution comes from point and nonpoint pollution sources in these three locations. The Second Songhua river might suffer the heavy metals pollution from different cities' transport through the Second Songhua river basin.

**Heavy Metal Pollution Mitigation Review - Opportunities for Changchun and the Second Songhua River**

The nonpoint and point heavy metals pollutants are multitudinous to impact the drinking water quality for Changchun residents. The heavy metal concentration in the sediment of Xilicheng and the Second Songhua River has the potential to affect human health through heavy metal accumulation. The point pollution source from industries routinely emits the treated wastewater into the reservoirs and Second Songhua River. Non-removal of heavy metals from industrial wastewater will directly accumulate in the reservoir's sediment or dissolve in the water. On the other hand, the nonpoint pollution from urban areas might also accumulate heavy metals in soil sediment and watershed. Then, transport to the drinking water resource due to flooding or stormwater runoff.

The Changchun government could consider using integrated watershed management strategies to mitigate heavy metals pollution. Integrated watershed management (IWM) is managing human activities and natural sources on a watershed basis while considering local community interests and challenges, including the effects of growth and climate change. Integrated watershed management offers a holistic, systems-based approach to managing the lands that contribute to drinking water supply sources rather than focusing primarily on end-of-pipe treatment as a fix (Heathcote, 2009).

From the previous discussion, Changchun's heavy metals pollution comes from various reasons. The pollution could be controlled using improved technologies or migration of wastewater emissions. However, the nonpoint pollution source cannot be controlled through management strategies. Changchun is a city with production and commercial activities supporting basic economics. Integrated watershed management will include the integral components of the water resource, such as the ecosystem, a natural resource, and social and economic (Heathcote, 2009). Using integrated management methods helps reduce the investment cost for managing heavy metals pollution and reduces the economic damage to industries. Integrated watershed management could help to balance the future sustainable development, economic growth, and natural environment protection for Changchun. An integrated watershed management strategy can also help communities be more resilient to the risk of water contamination which may be exacerbated by future climate change and urban growth. In addition, integrated watershed management could also protect the Second Songhua River wetland environment and wildlife by controlling and considering whole heavy metals sources.

The nonpoint pollution in urban areas might be more challenging to control than point sources because different sewage and activities in Changchun produce pollution. In this case, integrated watershed management could help to reduce nonpoint pollution due to the overall deployment of watershed management. That could help reduce the residents' pollution and increase their awareness of pollution issues.

At the same time, the Changchun government might need to improve the wastewater treatment for industries to reduce the heavy metal residual in treated wastewater. Furthermore, the Changchun government must improve the treated wastewater emission issues and avoid recycling the treated wastewater through the drinking water resource or urban watershed. That will increase the risk of heavy metal pollution and the difficulty of heavy metal removal. Therefore, the Changchun government might need to find other solutions to emissions and reusing the industries' wastewater. For instance, the wastewater could be reused by industries after treatment, which could help reduce heavy metal emissions.

Compared to traditional heavy metals pollution management strategies in Changchun and the Second Songhua River, integrated watershed management solves more than one serious pollutant in various locations. Although the traditional strategies can solve specific pollution issues efficiently in certain locations, they do not consider the different environmental influences or further development. Integrated watershed management could also help improve the sustainable development of water resources in Changchun and the Second Songhua River, such as water scarcity challenges in the future through climate changes and urbanization development.

The Changchun government might also need to establish routine pollution monitoring and assessment in addition to integrated watershed management. The monitoring and evaluation must be done at a watershed scale, such as even airshed, groundwater recharge area - contributing source area for the drinking water source, in addition to taking these approaches and offering potential solutions to pollution problems for affected communities (National Research Council, 1999). It is hard to identify the fountainhead of nonpoint heavy metal pollution sources. The nonpoint pollution will be collected together and then transferred to the watershed. The monitoring and assessment could help the Changchun government find the conditions and accumulation trends of nonpoint heavy metals pollution affecting drinking water quality in different locations and areas. That could help target and improve integrated watershed management strategies in Changchun's most polluted (nonpoint heavy metals) regions and the Second Songhua River.

The study involves several limitations and delimitations. The first limitation relates to the data timeline - the entire study period is at least 20 years, but the past data might not be valid to be used in the framework. The study is based solely on secondary data as no primary data will be collected for the analysis. The lack of preliminary data might cause uncertainty in result analysis because, during the research period, the Changchun government might have improved management strategies and decreased the heavy metals concentrations. In addition, due to the reliance on secondary data sources, this study is limited to the published literature available for the topics of interest outlined earlier. Further research could focus on the specific data monitoring and assessment of drinking water quality or the heavy metals contained in the drinking water, which could be directly measured from faucets in Changchun.

In addition, the study will not investigate the cause of Changchun's industrialization rate and management strategies changing factors due to the COVID- 19 and the limited amount of information. COVID- 19 highly affected the sediment concentration because most industries are suspended during this particular period. After COVID-19, the Changchun government needed to pay more attention to heavy metal assessment and monitoring. This will show if the data is accurate or has been affected by other factors.

**Conclusion:**

In conclusion, this paper evaluates the heavy metal contamination in Changchun's drinking water supplies. The quality of Changchun's drinking water is significantly impacted by the heavy metal brought on by urbanization. The review of heavy metal pollution in watersheds and the historical and current condition of Changchun's drinking water sources indicate the city's heavy metal pollution levels through identifying existing and potential stresses in the contributing drinking water source regions for the Second Songhua River, Xinlicheng, Shitoukoumen, and Jingyuetan reservoirs. Heavy metal impairs drinking water quality while enhancing urban areas plagued by point and nonpoint sources of pollution. The Changchun government must put more effort into reducing pollution and heavy metal sediment in the drinking water supply. The Changchun government must have specialized techniques such as integrated watershed management or routine pollution assessment and monitoring to address the heavy metals pollution challenges and balance simultaneous urbanization expansion and environmental degradation.

**Recommendations:**

The project aims to find how urbanization affects the concentration of heavy metals in drinking water and establish a framework to determine the tread between drinking water, heavy metal contamination, and urban development. The project's results could help improve Changchun's future urban plans and development. Furthermore, the study indicates the mechanism of urbanization's influence on drinking water heavy metals contamination. Climatic, environmental, Socioeconomic, and demographic impacts analysis will help develop sustainable water supply through water management strategies. In addition, climatic and environmental indicators analysis could help reduce pollution emissions in Changchun.

**References** :

Abrahams, P. W. (2002). Soils: their implications to human health. *Science of the Total Environment*, *291*(1-3), 1-32.

Adeyeye, O., Xiao, C., Zhang, Z., & Liang, X. (2020). State, source and triggering mechanism of iron and manganese pollution in groundwater of Changchun, Northeastern China. *Environmental Monitoring and Assessment*, *192*(10), 1-15.

Ahmed, A. S., Sultana, S., Habib, A., Ullah, H., Musa, N., Hossain, M. B., ... & Sarker, M. S. I. (2019). Bioaccumulation of heavy metals in some commercially important fishes from a tropical river estuary suggests higher potential health risk in children than adults. *Plos one*, *14*(10),

Akpor, O. B., & Muchie, M. (2010). Remediation of heavy metals in drinking water and wastewater treatment systems: processes and applications. *International Journal of Physical Sciences*, *5*(12), 1807-1817.

Algül, F., & Beyhan, M. (2020). Concentrations and sources of heavy metals in shallow sediments in Lake Bafa, Turkey. *Scientific reports*, *10*(1), 1-12.

Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals—concepts and applications, *Chemosphere*, *91*(7), 869-881.

Aryal, R. K., Murakami, M., Furumai, H., Nakajima, F., & Jinadasa, H. K. P. K. (2006). Prolonged deposition of heavy metals in infiltration facilities and its possible threat to groundwater contamination.*Water Science and Technology*, *54*(6-7), 205-212.

Bai, J., Xiao, R., Zhang, K., & Gao, H. (2012). Arsenic and heavy metal pollution in wetland soils from tidal freshwater and salt marshes before and after the flow-sediment regulation regime in the Yellow River Delta, China. *Journal of Hydrology*, *450*, 244-253.

Barnes, K. B., Morgan, J., & Roberge, M. (2001). Impervious surfaces and the quality of natural and environments. *Baltimore: Department of Geography and Environmental Planning, Towson University*.

Barakat, M. A. (2011). New trends in removing heavy metals from industrial wastewater. *Arabian journal of chemistry*, *4*(4), 361-377.

Beckers, V., Poelmans, L., Van Rompaey, A., & Dendoncker, N. (2020). The impact of urbanization on agricultural dynamics: A case study in Belgium. *Journal of Land Use Science*, *15*(5), 626-643.

Calmano, W., Ahlf, W., & Förstner, U. (1990). Exchange of heavy metals between sediment components and water. In *Metal speciation in the environment* (pp. 503-522). Springer, Berlin, Heidelberg.

Charlesworth, S., Everett, M., McCarthy, R., Ordonez, A., & De Miguel, E. (2003). A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry, West Midlands, UK. *Environment international*, *29*(5), 563-573.

Canada Health. (2009, March 9). *Government of Canada*. Canada.ca. Retrieved July 30, 2022, from https://www.canada.ca/en/health-canada/services/publications/healthy-living /guidelines-canadian-drinking-water-quality-guideline-technical-document-mercury.html

Chen, T. B., Zheng, Y. M., Lei, M., Huang, Z. C., Wu, H. T., Chen, H., ... & Tian, Q. Z. (2005). Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. *Chemosphere*, *60*(4), 542-551.

Changchun Bureau of Statistics (2017). *Changchun statistical year book*. Chinese Statistics Press, pp 61–64.

Davydova, S. (2005). Heavy metals as toxicants in big cities. *Microchemical Journal*, *79*(1-2), 133-136.

Dach, J., & Starmans, D. (2005). Heavy metals balance in Polish and Dutch agronomy: Actual state and previsions for the future. *Agriculture, Ecosystems & Environment*, *107*(4), 309-316.

Deng, X. (2020). Influence of water body area on water quality in the southern Jiangsu Plain, eastern China. *Journal of Cleaner Production*, *254*, 120136.

Dey, S. (2014). Fluvial hydrodynamics, geoplanet: earth and planetary sciences.

Ding, M., Li, J., Liu, X., Li, H., Zhang, R., & Ma, J. (2018). Exploring links between water quality and E.coli o157: H7 survival potential in well waters from a rural area of southern changchun city, china. *Journal of Water and Health*, *16*(2), 300-310.

Duong, T. T., & Lee, B. K. (2011). Determining contamination level of heavy metals in road dust from busy traffic areas with different characteristics. *Journal of environmental management*, *92*(3), 554-562.

Environment and Climate Change Canada. (2019, July 4). *Government of Canada*. Canada.ca QRetrieved July 21, 2022, from https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/guide-to-understanding/chapter-3.html

Er Y. 2015 *The List of Major Grain Producing Counties. List of National Production County* http://www.huanqiumil.com/a/144028849145015.html (accessed 26 July 2016) (in Chinese)

Fallah Shorshani, M., Bonhomme, C., Petrucci, G., André, M., & Seigneur, C. (2014). Road traffic impact on urban water quality: a step towards integrated traffic, air and stormwater modelling. *Environmental Science and Pollution Research*, *21*(8), 5297-5310.

Franco-Uría, A., López-Mateo, C., Roca, E., & Fernández-Marcos, M. L. (2009). Source identification of heavy metals in pastureland by multivariate analysis in NW Spain *Journal of hazardous materials*, *165*(1-3), 1008-1015.

Fernandez-Luqueno, F., Lopez-Valdez, F., Gamero-Melo, P., Luna-Suarez, S., Aguilera-Gonzalez, E. N., Martínez, A. I., ... & Pérez-Velázquez, I. R. (2013). Heavy metal pollution in drinking water-a global risk for human health: A review. *African Journal of Environmental Science and Technology*, *7*(7), 567-584.

Fu, Xiao, Yuan Shen, Rencai Dong, Hongbing Deng, and Gang Wu. "Analysis of urbanization based on center-of-gravity movement and characteristics in Songhua River basin of China and its southern source sub-basin between 1990 and 2010." *Chinese Geographical Science* 26, no. 1 (2016): 117- 128.

Gambrell, R. P., Khalid, R. A., Collard, V. R., Reddy, C. N., & Patrick Jr, W. H. (1976). Effect of pH and redox potential on heavy metal chemistry in sediment-water systems affecting toxic metal bioavailability.

Gill, L. W., Ring, P., Casey, B., Higgins, N. M., & Johnston, P. M. (2017). Long term heavy metal removal by a constructed wetland treating rainfall runoff from a motorway. *Science of the Total Environment*, *601*, 32-44.

Guan, J., Wang, J., Pan, H., Yang, C., Qu, J., Lu, N., & Yuan, X. (2018). Heavy metals in Yinma River sediment in a major Phaeozems zone, Northeast China: Distribution, chemical fraction, contamination assessment and source apportionment. *Scientific reports*, *8*(1), 1-11.

Guo, X., Zuo, R., Meng, L., Wang, J., Teng, Y., Liu, X., & Chen, M. (2018). Seasonal and spatial variability of anthropogenic and natural factors influencing groundwater quality based on source apportionment. *International Journal of Environmental Research and Public Health, 15*, 279.

Hamadoun, B., Tang, J., & Lin, N. F. (2004). Groundwater quality and contamination index mapping in Changchun City, China. *Chinese Geographical Science*, *14*(1), 63-70.

Heathcote, I. W. (2009). *Integrated watershed management: principles and practice*. John Wiley & Sons.

Heikens, A., Peijnenburg, W. J. G. M., & Hendriks, A. J. (2001). Bioaccumulation of heavy metals in terrestrial invertebrates. *Environmental Pollution*, *113*(3), 385-393.

Howard, G., Calow, R., Macdonald, A., & Bartram, J. (2016). Climate change and water and sanitation: likely impacts and emerging trends for action. *Annu. Rev. Environ. Resour*, *41*(1), 253-276.

Hongyi, N. I. U., Wenjing, D., Qunhe, W. U., & Xingeng, C. H. E. N. (2009). Potential toxic risk of heavy metals from sediment of the Pearl River in South China. *Journal of Environmental Sciences*,*21*(8), 1053-1058.

Huang, C., Zhang, M., Zou, J., Zhu, A. X., Chen, X., Mi, Y., ... & Li, Y. (2015). Changes in land use, climate and the environment during a period of rapid economic development in Jiangsu Province, China. *Science of the Total Environment*, *536*, 173-181.

Hussain, M., & Imitiyaz, I. (2018). Urbanization concepts, dimensions and factors. *Int J Recent Sci Res*, *9*(1), 23513-23523.

Hvitved-Jacobsen, T., Vollertsen, J., & Nielsen, A. H. (2010). *Urban and highway stormwater pollution: concepts and engineering*. CRC press

Isangedighi, I. A., & David, G. S. (2019). Heavy metals contamination in fish: effects on human health. *Journal of Aquatic Science and Marine Biology*, *2*(4), 7-12.

Jamshaid, M., Khan, A. A., Ahmed, K., & Saleem, M. (2018). Heavy metal in drinking water its effect on human health and its treatment techniques-a review. *Int. J. Biosci*, *12*(4), 223-240.

Jain, C. K., Gupta, H., & Chakrapani, G. J. (2008). Enrichment and fractionation of heavy metals in bed sediments of River Narmada, India. *Environmental monitoring and assessment*, *141*(1), 35-47.

Jiayin, G., Mingfei, Z., Zhaoguang, H., & Wei, S. (2020). Influence of expressway construction on the ecological environment and the corresponding treatment measures: A case study of changyu (changchun-fuyu lalin river) expressway, china. *Nature Environment and Pollution Technology*, *19*(3), 1195-1201.

Kadlec, R. H., & Wallace, S. (2008). *Treatment wetlands*. CRC press.

Kirschner, L. A., & Grandy, E. B. (2005). The Songhua River spill: China's pollution crisis. *Nat. Resources & Env't*, *20*, 66.

Kumar, M., Furumai, H., Kurisu, F., & Kasuga, I. (2013). Tracing source and distribution of heavy metals in road dust, soil and soakaway sediment through speciation and isotopic fingerprinting.*Geoderma*, *211*, 8-17.

Lin, C., He, M., Zhou, Y., Guo, W., & Yang, Z. (2008). Distribution and contamination assessment of heavy metals in sediment of the Second Songhua River, China. *Environmental monitoring and assessment*, *137*(1), 329-342.

Li, Z., Wang, Q., & Luo, Y. (2006). Exposure of the urban population to mercury in Changchun city, Northeast China. *Environmental Geochemistry and Health*, *28*(1), 61-66.

Li, F., Zhang, G., & Xu, Y. J. (2014). Spatiotemporal variability of climate and streamflow in the Songhua River Basin, northeast China. *Journal of Hydrology*, *514*, 53-64.

Liu D. (2008) *Changchun is a City with a Severe Shortage of Water*. http://enews.xwh.cn/html/200805/12/content_103799.htm (accessed 6 May 2016) (in Chinese).

Li, X., Poon, C. S., & Liu, P. S. (2001). Heavy metal contamination of urban soils and street dusts in Hong Kong. *Applied geochemistry*, *16*(11-12), 1361-1368.

Lin, Chunye, Mengchang He, Yuxiang Zhou, Lijuan Hu, Wei Guo, Xiangchun Quan, and Zhifeng Yang. "Mercury contamination and dynamics in the sediment of the Second Songhua River, China." *Soil and Sediment Contamination: An International Journal* 16, no. 4 (2007): 397-411.

Liu, L., Dong, J., & Geng, Z. (2009). Investigation of Clonorchis sinensis infection in freshwater fish in the Changchun City integrated market. *Zhongguo Bingyuan Shengwuxue Zazhi/Journal of Pathogen Biology*, *4*(6).

Li, H., Shi, A., Li, M., & Zhang, X. (2013). Effect of pH, temperature, dissolved oxygen, and flow rate of overlying water on heavy metals release from storm sewer sediments. *Journal of Chemistry*, *2013*.

Lin, C., He, M., Zhou, Y., Guo, W., & Yang, Z. (2008). Distribution and contamination assessment of heavy metals in sediment of the Second Songhua River, China. *Environmental monitoring and assessment*, *137*(1), 329-342.

Lu, A., Wang, J., Qin, X., Wang, K., Han, P., & Zhang, S. (2012). Multivariate and geostatistical analyses of the spatial distribution and origin of heavy metals in the agricultural soils in Shunyi, Beijing, China. *Science of the total environment*, *425*, 66-74.

Liu, L., Dong, J., & Geng, Z. (2009). Investigation of Clonorchis sinensis infection in freshwater fish in the Changchun City integrated market. *Zhongguo Bingyuan Shengwuxue Zazhi/Journal of Pathogen Biology*, *4*(6).

Lu, Y., Zhang, P., Li, W., Liu, J., Shang, X., Cheng, Y., & Li, Y. (2022). Comparison of gut microbial communities, free amino acids or fatty acids contents in the muscle of wild Aristichthys nobilis from Xinlicheng reservoir and Chagan lake. *BMC microbiology*, *22*(1), 1-12.

Ma, Z., Chen, K., Yuan, Z., Bi, J., & Huang, L. (2013). Ecological risk assessment of heavy metals in surface sediments of six major Chinese freshwater lakes. *Journal of environmental quality*, *42*(2), 341-350.

Malik, N., Biswas, A. K., Qureshi, T. A., Borana, K., & Virha, R. (2010). Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. *Environmental monitoring and assessment*, *160*(1), 267-276.

Mattison, D. R., & Gardner, H. (2012). Working Group: Allen H. Gates, Alain Leonard, Mariann Wide, Kari Hemminki, JHJ Copius Peereboom-Stegeman. *Reproductive and Developmental Toxicity of Metals*, 42.

Meng, X. X., & Li, S. Z. (1995). Study on background value of soil environment of the Jilin Province. *Beijing: Science*.

Möller, A., Müller, H. W., Abdullah, A., Abdelgawad, G., & Utermann, J. (2005). Urban soil pollution in Damascus, Syria: concentrations and patterns of heavy metals in the soils of the Damascus Ghouta. *Geoderma*, *124*(1-2), 63-71.

Mohod, C. V., & Dhote, J. (2013). Review of heavy metals in drinking water and their effect on human health. *International Journal of Innovative Research in Science, Engineering and Technology*, *2*(7), 2992-2996.

National Research Council. (1999). *New strategies for America's watersheds*. National Academies Press.

OECD, E. O. (2012). Medium and long-term scenarios for global growth and imbalances. *Volume*, *1*, 191-224.

Onjefu, S. A., Kgabi, N. A., & Taole, S. H. (2016). Heavy metal seasonal distribution in shore sediment samples along the coastline of Erongo Region, western Namibia. *European Journal of Scientific Research*, *139*(1), 49-63.

Peng, C., Cai, Y., Wang, T., Xiao, R., & Chen, W. (2016). Regional probabilistic risk assessment of heavy metals in different environmental media and land uses: An urbanization-affected drinking water supply area. *Scientific Reports*, *6*(1), 1-9.

Peng, J. F., Song, Y. H., Yuan, P., Cui, X. Y., & Qiu, G. L. (2009). The remediation of heavy metals contaminated sediment.*Journal of hazardous materials*, *161*(2-3), 633-640.

Pintilie, S., Brânză, L., Bețianu, C., Pavel, L. V., Ungureanu, F., & Gavrilescu, M. (2007). MODELLING AND SIMULATION OF HEAVY METALS TRANSPORT IN WATER AND SEDIMENTS. *Environmental Engineering & Management Journal (EEMJ)*, *6*(2).

Pourabadehei, M., & Mulligan, C. N. (2016). Effect of the resuspension technique on distribution of the heavy metals in sediment and suspended particulate matter. *Chemosphere*, *153*, 58-67.

Prasad, M. N. V. (2003). Phytoremediation of metal-polluted ecosystems: hype for commercialization. *Russian Journal of Plant Physiology*, *50*(5), 686-701

Qiu, L., Cui, P., Lv, L. S., & Sun, S. J. (2015, July). Evaluation of changchun Jingyuetan national scenic spot ecosystem services, China. In *International Conference on Chemical, Material and Food Engineering* (pp. 865-867). Atlantis Press.

Quisenberry, S. S., Trahan, G. B., Heagler, A. M., McManus, B., & Robinson, J. F. (1992). Effect of water management as a control strategy for rice water weevil (Coleoptera: Curculionidae). *Journal of economic entomology*, *85*(3), 1007-1014.

Rehman, K., Fatima, F., Waheed, I., & Akash, M. S. H. (2018). Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of cellular biochemistry*, *119*(1), 157-184.

Singh, K. P., Mohan, D., Singh, V. K., & Malik, A. (2005). Studies on distribution and fractionation of heavy metals in Gomti river sediments—a tributary of the Ganges, India. *Journal of hydrology*, *312*(1-4), 14-27.

Sparks, D. L. (1995). Environmental soil chemistry. San Diego: Academic.

Sun, Q., Sun, Z., Xing, W., Hao, G., Li, X., Du, J., ... & Li, X. (2021). Ecological health risk assessment of heavy metals in farmland soil of Changchun New Area. *Pol J Environ Stud*, *30*(6), 1-13.

Sun, C., Zhang, Z., Cao, H., Xu, M., & Xu, L. (2019). Concentrations, speciation, and ecological risk of heavy metals in the sediment of the Songhua River in an urban area with petrochemical industries. *Chemosphere*, *219*, 538-545.

Sun, X., Fan, D., Liu, M., Liao, H., Zheng, S., & Tian, Y. (2020). Budget and fate of sedimentary trace metals in the Eastern China marginal seas. *Water Research*, *187*, 116439.

Tang, W., Shan, B., Zhang, H., Zhang, W., Zhao, Y., Ding, Y., ... & Zhu, X. (2014). Heavy metal contamination in the surface sediments of representative limnetic ecosystems in eastern China. *Scientific reports*, *4*(1), 1-7.

Taebi, A., & Droste, R. L. (2004). Pollution loads in urban runoff and sanitary wastewater. *Science of the total Environment*, *327*(1-3), 175-184.

Vandecasteele, B., Quataert, P., Vos, B. D., & Tack, F. M. (2004). Assessment of the pollution status of alluvial plains: a case study for the dredged sediment-derived soils along the Leie river. *Archives of environmental contamination and toxicology*, *47*(1), 14-22.

Wang, J., Xie, X., & Fang, C. (2019). Temporal and spatial distribution characteristics of atmospheric particulate matter (PM10 and PM2. 5) in changchun and analysis of its influencing factors. *Atmosphere*, *10*(11), 651

Wang, L., Ye, X., & Du, X. (2016). Suitability evaluation of river bank filtration along the Second Songhua River, China. *Water*, *8*(5), 176.

Wang, Y., Wang, P., Bai, Y., Tian, Z., Li, J., Shao, X., ... & Li, B. L. (2016). Assessment of surface water quality via multivariate statistical techniques: a case study of the Songhua River Harbin region, China. *Journal of hydro-environment research*, *7*(1), 30-40.

Wang, Q., Liu, M., Li, Y., Liu, Y., Li, S., & Ge, R. (2016). Dry and wet deposition of polycyclic aromatic hydrocarbons and comparison with typical media in urban system of Shanghai, China. *Atmospheric Environment*, *144*, 175-181.

Wu, G., Kang, H., Zhang, X., Shao, H., Chu, L., & Ruan, C. (2010). A critical review on the bio-removal of hazardous heavy metals from contaminated soils: issues, progress, eco-environmental concerns and opportunities. *Journal of hazardous materials*, *174*(1-3), 1-8.

Xiao, R., Bai, J., Gao, H., Wang, J., Huang, L., & Liu, P. (2012). Distribution and contamination assessment of heavy metals in water and soils from the college town in the Pearl River Delta, China. *CLEAN–Soil, Air, Water*, *40*(10), 1167-1173.

Yang, Z., Lu, W., Long, Y., Bao, X., & Yang, Q. (2012). Assessment of heavy metals contamination in urban topsoil from Changchun City, China. *Journal of Geochemical Exploration*, *108*(1), 27-38.

Yang, L. I., Linyu, X. U., & Shun, L. I. (2009). Water quality analysis of the Songhua River Basin using multivariate techniques. *Journal of water resource and protection*, *2009*.

Yan, X., Liu, M., Zhong, J., Guo, J., & Wu, W. (2018). How human activities affect heavy metal contamination of soil and sediment in a long-term reclaimed area of the Liaohe River Delta, North China. *Sustainability*, *10*(2), 338.

Yang, Y., Li, S., Gao, Y., Chen, Y., & Zhan, A. (2019). Environment-driven geographical distribution of bacterial communities and identification of indicator taxa in Songhua River. *Ecological Indicators*, *101*, 62-70.

YUE, C., CUI, Y. L., RAO, R., & DONG, X. (2015). Evaluation on water resources carrying capacity of Changchun-Jilin Region. *Journal of Groundwater Science and Engineering*.

Zhang, B., Song, X., Zhang, Y., Ma, Y., Tang, C., Yang, L., & Wang, Z. L. (2016). The interaction between surface water and groundwater and its effect on water quality in the Second Songhua River basin, northeast China. *Journal of Earth System Science*,*125*(7), 1495-1507.

ZHANG Li-hua, 1993. A preliminary discussion of the present situation on pollution of groundwater in Changchun City and its tendency [J]. Journal of Jilin Geoloo', 12(4): 75-8t. (in Chinese)

Zhao, Q., Yang, X., Liu, H., Hu, Y., He, M., Huang, B., ... & Zhang, X. (2019). Effects of climate factors on hemorrhagic fever with renal syndrome in Changchun, 2013 to 2017. *Medicine*, *98*(9).

Zhang, Y., Zhang, H., Zhang, Z., Liu, C., Sun, C., Zhang, W., & Marhaba, T. (2018). pH effect on heavy metal release from a polluted sediment. *Journal of Chemistry*, *2018*.

ZHANG Li-hua, 1993. A preliminary discussion of the present situation on pollution of groundwater in Changchun City and its tendency [J]. Journal of Jilin Geoloo', 12(4): 75-8t. (in Chinese)

Zhang, Z., Xiao, C., Adeyeye, O., Yang, W., & Liang, X. (2020). Source and mobilization mechanism of iron, manganese and arsenic in groundwater of Shuangliao city, Northeast China. *Water, 12*, 534.

Zhang, B., Song, X., Zhang, Y., Han, D., Tang, C., Yu, Y., & Ma, Y. (2012). Hydrochemical characteristics and water quality assessment of surface and groundwater in Songnen plain, Northeast China. *Water Research,* *46*, 2737–2748.

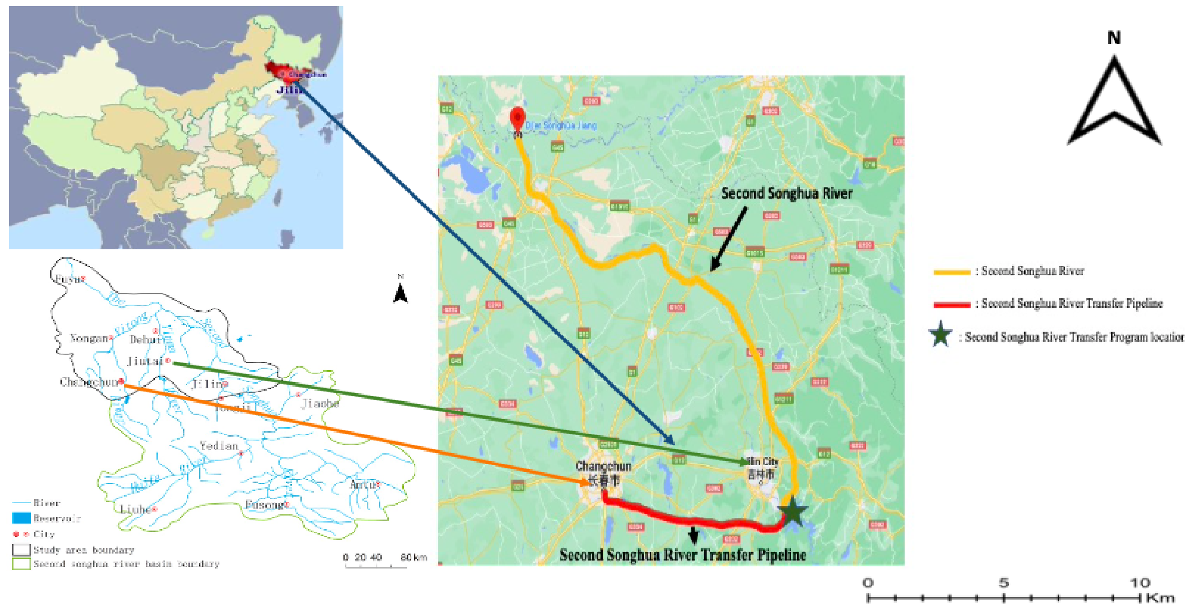
Zhao, H., Li, X., Wang, X., & Tian, D. (2010). Grain size distribution of road-deposited sediment and its contribution to heavy metal pollution in urban runoff in Beijing, China. *Journal of Hazardous Materials*, *183*(1-3), 203-210.

Zhao, K., Fu, H., Wang, Q., & Lu, H. (2021). Determination of Water Quality Characteristics and Nutrient Exchange Flux at the Sediment—Water Interface of the Yitong River in Changchun City, China. *Water*, *13*(24), 3555.

Zhang, L., Lu, W., Hou, G., Gao, H., Liu, H., & Zheng, Y. (2019). Coupled analysis on land use, landscape pattern and nonpoint source pollution loads in Shitoukoumen Reservoir watershed, China. *Sustainable Cities and Society*, *51*, 101788

Zhu, L., Liu, J., Xu, S., & Xie, Z. (2017). Deposition behavior, risk assessment and source identification of heavy metals in reservoir sediments of Northeast China. *Ecotoxicology and environmental safety*, *142*, 454-463.

APPENDIX:




(Wang et al., 2016)

Figure 1: Second songhua River water transfer Program and Second Songhua River watershed boundary

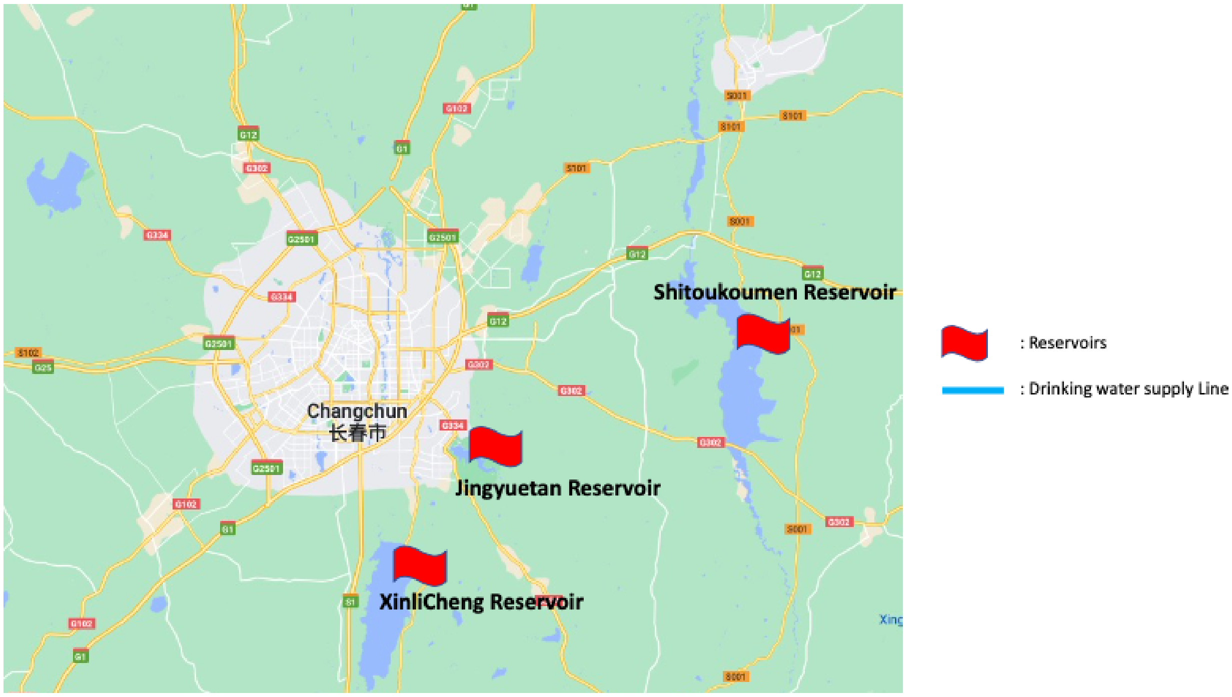



Figure 2: Shitoukoumen, Jingyuetan, and Xinlicheng reservoirs drinking water supply line

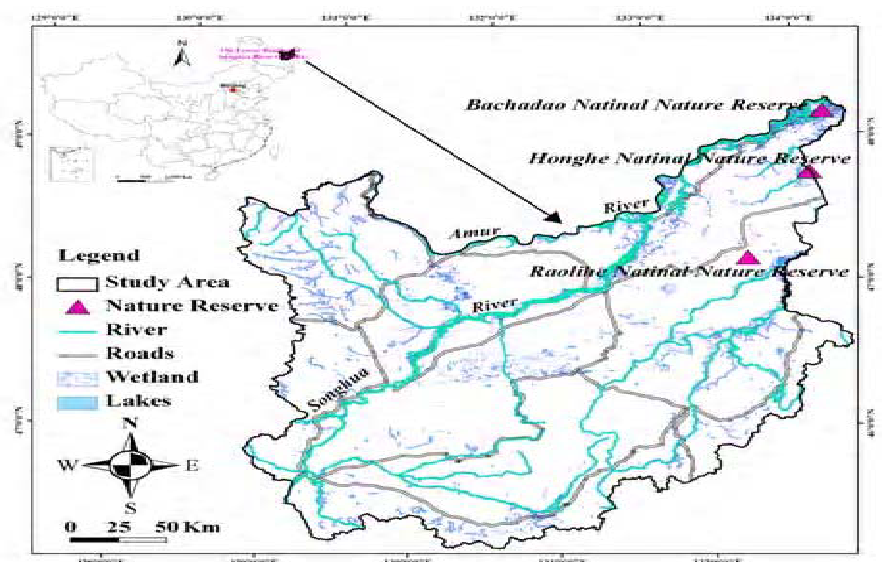



Figure 3: Songhua River distribution (Lin et al,. 2018)

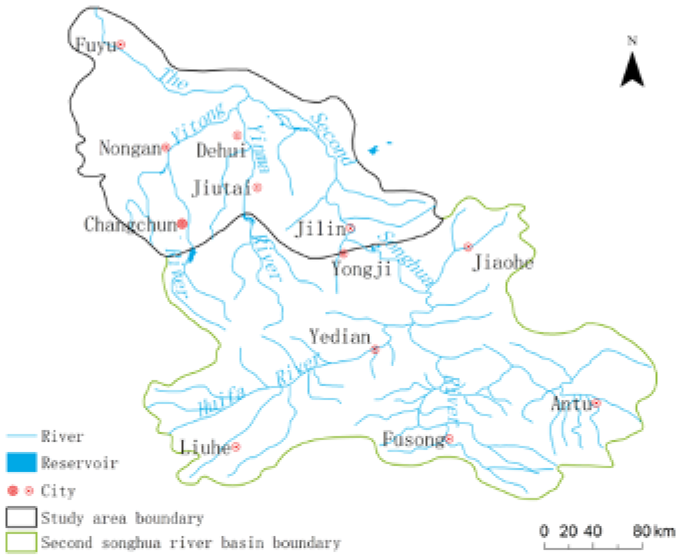



Figure 4: Second Songhua River distribution (Wang et al., 2016)


Figure 5: Xinlicheng reservoirs


Figure 6: Shitoukoumen reservoirs


Figure 7: Jingyuetan reservoirs

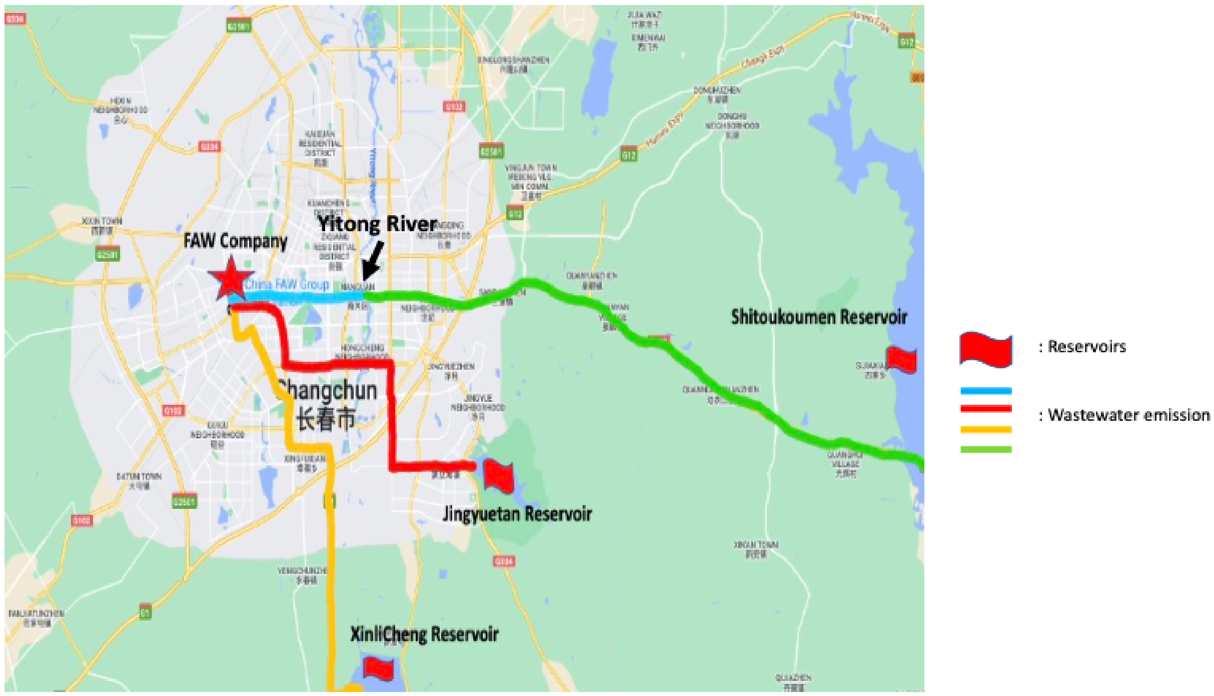
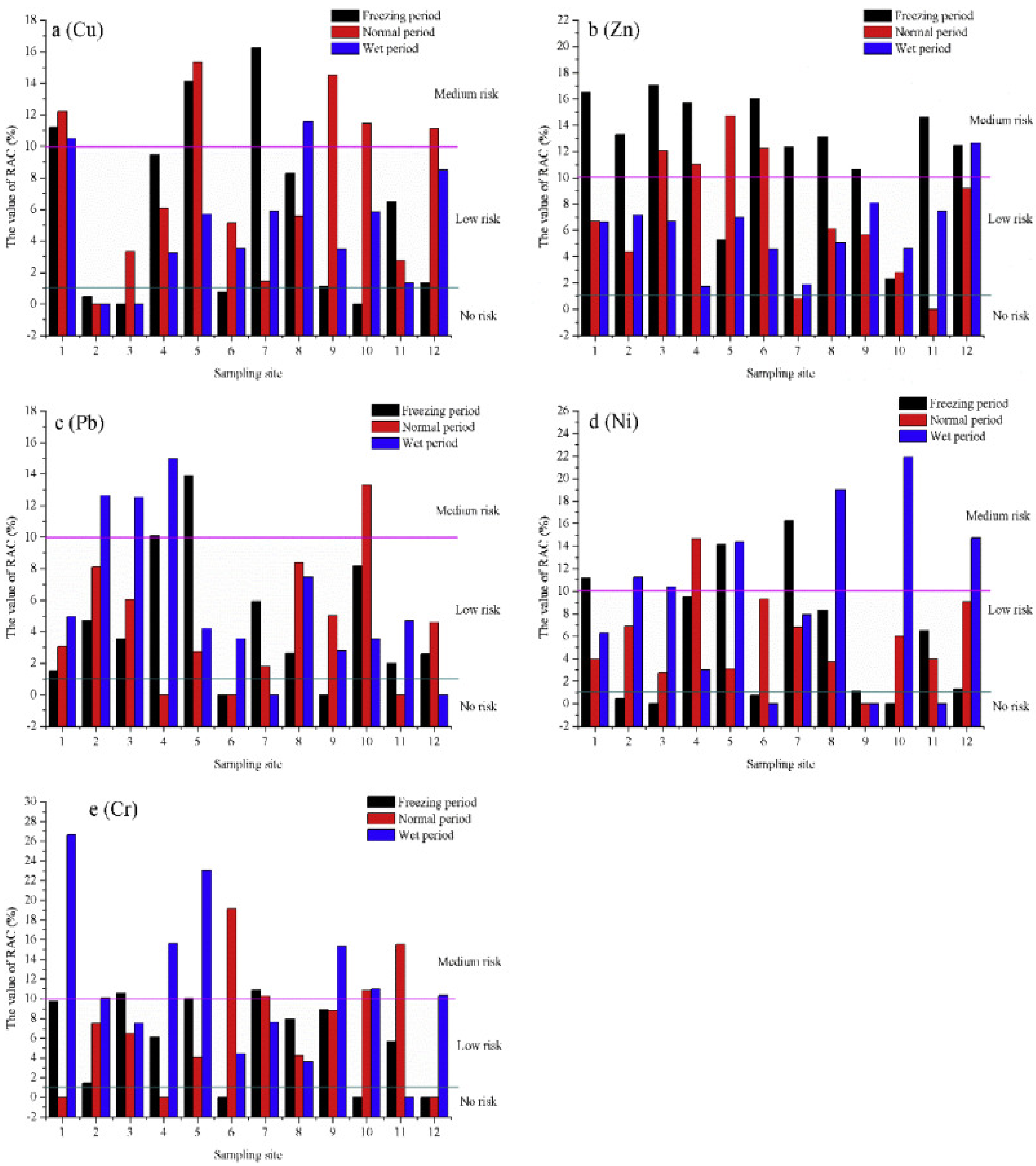



Figure 8 : the point source pollution transfer to three reservoirs from FAW company

| Heavy Metals(Mg/kg) | Not polluted | Moderately polluted | Heavy pollutes | Xinlicheng Reservoir | Shitoukoumen Reservoir |
|---|---|---|---|---|---|
| Cr | <25 | 25-75 | >75 | 108.2 | 46.6 |
| Cu | <25 | <6 | >6 | 41.6 | 23.8 |
| Zn | <90 | 90 - 200 | >200 | 112.7 | 52.23 |
| Mn | <300 | 300-500 | >500 | 1211.7 | NONE |
| Pb | <40 | 40 -60 | > 60 | 47.9 | 32.38 |
| Cd | —----- | <6 | >6 | 1.7 | 0.29 |

Table 1: indicates Environmental protection agency (EPA) heavy metal Guidelines for Sediments (Onjefu et al., 2016) and Xinlicheng, Shitoukoumen Reservoir data (Zhu et al. 2017;Adeyeye et al., 2020).




(Lin et al., 2008)

Figure 9: Indicates Concentrations of heavy metals in sediment for 12 sample locations in Second Songhua River .