

Water Quality, Perception and Knowledge in China

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Poor water quality and its grave implications for health, economic and political security are especially acute in China. This thesis adds the human experience component by examining how water quality, water quality knowledge and water quality perception are related. Water quality data from 337 municipal cities and 25 counties are compared with $n = 11782$ survey respondents. Perceived severity of water pollution increases as water quality worsens, as does knowledge about water quality, and education. Water quality knowledge also improves with increased education and with worse water quality. China should complement infrastructure-based water resource management solutions with diverse, local, and inclusive policy and education in order to meet its ambitious water resource management targets.

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1 Introduction

1.1 Water Scarcity

Access to freshwater is something many people take for granted. Simply turning on the tap or buying a bottle of water makes it easy to underappreciated the immense value of clean freshwater. Water is essential for almost all aspects of modern civilization and is connected to all three pillars of sustainable development – environment, society, and the economy.

While water is a permanent resource, water that is usable and consumable by humans is not. Globally, only 2.5 percent of the Earth's water is non-saline, with most of the remaining freshwater being inaccessibly located in glaciers, ice caps or permafrost. (Shiklomanov 1993)

Water scarcity, being the scarcity of availability or access to usable freshwater resources, is a significant and increasing global issue. (UN-Water n.d.) Globally, water usage has increased at a rate of 1.7 times the rate of population increase over the past century. (F.A.O. 2014) Water stress and scarcity can be caused by increased water withdrawal, population increase, and climate, amongst others. (F.A.O. 2014) Water scarcity is three dimensional, including physical, infrastructural and institutional factors. (F.A.O. 2011b) While some regions are affected more than others, every continent is affected. Four billion people experience extreme water scarcity at least one month out of the year. (Mekonnen and Hoekstra 2016)

The implications of water scarcity cannot be understated. Global water crises stemming from water scarcity are predicted to be the largest risk globally within the next decade. (World Economic Forum 2016) Since water is vital for human existence, a lack of water can be directly or indirectly related to almost any societal indicator.

One direct impact of water scarcity can come in the form of food production. Globally, 70 percent of global renewable water resources withdrawn for human use is used for agriculture. (F.A.O. 2011b) Affected by population growth and the increased consumption of more water-intensive food due partially to economic development, it is estimated that food production must increase by 70 percent to meet demand. (F.A.O. 2011b) Another impact is health. Health can be affected by the quantity and quality of water. The impacts of dehydration, water-borne diseases, and consumption of polluted water are well documented. A third impact is economic. By 2050, some regions could see a GDP growth rate decline of up to six percent due to “losses in agriculture, health, income, and property” caused

by water scarcity. (The World Bank 2016)

1.2 In China

Water issues in China are especially prevalent. Despite being home to 21% of the global population, China only has six percent of worldwide freshwater resources. (The World Bank 2019, p. vii) On average, China's renewable freshwater resources were 2,062 cubic meters per capita in 2014, a decrease from 4,200 cubic meters in 1962 and far less than the half of the world average in those respective years. (F.A.O. 2016) China's renewable freshwater resources are also highly location dependent. For example, only 19.7 percent of total internal renewable surface water and 30 percent of groundwater resources reside in northern China. (F.A.O. 2011a) Northern China's renewable freshwater access is only 757 square meters per capita per year, far below the water scarcity limit of 1,000 square meters per capita per year. (Zhang et al. 2010)

1.3 Water Pollution

In addition to the already strained water resource problem, poor water quality caused by pollution is amplifying the problem and is causing further economic, societal and environmental problems. Roughly 80 percent of groundwater resources were found to be unsafe for human contact. (Jing 2016) Economic costs attributed to poor water quality in 2003 were over 1.16% of GDP (Wu et al. 1999), and were estimated to be 2.3% in 2007. (The World Bank 2019, 2)

Historically, and especially since the Opening Up and Reform era post-1978, the Chinese government has prioritized economic growth over environmental protection. In terms of water resource management, the government's investment strategies have prioritized large scale water infrastructure projects over environmentally-friendly pollution-control policies, due to a variety of political and non-political reasons. (Rogers and Crow-Miller 2017) Mao Zedong famously embraced the idea of the now-partially-completed South-North Water Transfer Project, one of the largest infrastructure endeavors in history, by saying "The south has plenty of water and the north lacks it, so if possible why not borrow some?" (Reuters 2009)

In addition to having the political will and prowess to pursue economic development, Chinese leadership has also at times shown a campaign-style action to mitigate environmental pollution. One such example was the

substantial air quality improvements in Beijing during the 2008 summer Olympics. (Zhang et al. 2010) However, similar outcomes regarding improved water quality have not been as positive. Analysis of water quality trends has been hampered partially due to data limitations, including public accessibility, the scope of measurement, and technological limitations including long latency periods. (Zhang et al. 2010)

Recently, further policy has been implemented to address water scarcity and pollution issues. In 2015, the State Council released an ambitious attempt to do this, colloquially known as the “Water Ten Plan,” which sets water quality-related goals to be met by 2020. (国务院. 2015) However, results so far have been mixed, with nearly half of all provinces missing their water quality targets in 2017. (Greenpeace 2017) One factor which may help this progress, and one of the goals outlined in the Water Ten plan, is the improvement of water quality sensing technology and data management.

Water pollution is a well-documented issue both in China and abroad. Improvements in both water quality and availability of water quality data in recent years. However, less attention has been paid to Chinese citizens’ knowledge about and perception of water quality. It is easily assumed that perception of water quality would be based on the real water quality – i.e., if water quality is good, then people perceive it to be good, while if water quality is bad, then people perceive it to be bad. However, this may not be the case. Divergence between perception and reality, or delays in reality driving perception could be important for policy makers in whether their resource-intensive campaign-style water quality reforms are the most effective policy tool, in regards to finance, behavior change or political support. From a political and social science perspective, perception of water quality could be more important in decision making than actual water quality. (Coughlin 1976, 206) These policy implications could easily be multifaceted, and could reveal further discrepancies between social groups and geographic regions, which could lead to decreased political effectiveness. (Larson et al. 2009)

2 Background

2.1 Environmental Policy, Knowledge and Perception

Water quality and quantity issues in China and abroad sit within the context of environmental policy, environmental education, and societies’

perception of the two. (Caldwell and others 1990) Analysis linking environmental knowledge and attitudes (perception) have existed for decades. The assumption, and common model, is that:

“increased knowledge leads to favorable attitudes towards pollution abatement which in turn lead to an action promoting environmental quality.” (Ramsey and Rickson 1976)

At the time, in the 1970s, most scholars agreed with this model, concluding that “a broad public literacy of biological and ecological concepts is at the heart of defining, reclaiming, and maintaining environmental quality,” but also concedes that the results of education are variable. (Ramsey and Rickson 1976)

Understanding the background of environmental policy, knowledge, education and perception is important in understanding how they interact in the concept of water quality in China and abroad.

2.2 Definitions

Several definitions are adapted for this thesis, and are discussed in more detail in following sections. This is important since many terms are used interchangeably in the field of environmental issues and how humans interact and perceive them. (Johnson et al. 1997) The first two are defined by (Sudarmadi et al. 2001). Environmental awareness is “the attention and concern (mindful and heedful) of individuals to environment problems.” Environmental perception is “the recognition of [an environmental issue] as a problem, based on memory and prior experience.” These two interact, as perception is “a basic determinant of awareness in that it triggers attention and concern.” (Endsley 1995) However, “perception only leads to awareness when it exceeds frequency and intensity thresholds. (Merikle, Smilek, and Eastwood 2001) In the context of environmental issues, perception refers to the state of the environment (or a specific environmental feature) as being problematic, while awareness refers to attention to the issue because of the impacts of a change in usability of the environment. (Tang, Folmer, and Xue 2013, sec. 2.1.2)

Thus, this definition of environmental perception is applied to water quality perception: water quality perception is the recognition of water quality as a problem. When reference is made to an increase in perception, it is referring to an increased intensity of the recognition that water qual-

ity issues are a problem. Further definitions and applications are made in following sections.

Environmental knowledge is as it sounds – the amount that someone knows about the environment or environmental issues. It has long been assumed that an increase in environmental knowledge can lead to changes in attitude and behavior, which in turn can influence policy. (ARCURY 1990) Thus, for this thesis, a similarly clear definition is applied for water quality: knowledge of water quality refers to the acquisition of a baseline amount of knowledge about water quality. Further definitions and applications are made in following sections.

Finally, environmental quality refers to measurement of the condition or state of the environment, based off of predetermined variables, indicators, and methodology. (Johnson et al. 1997) The authors stress that this term is irrespective of the source and cause of the condition, only that the state is compared against and relative to certain requirements and standards. For example, changes in water quality can be caused by both human-induced pollution and by naturally-occurring changes. Thus, applied to the context of water quality, the definition emerges: water quality “is a measure of the condition of water relative to” standards and requirements of humans. (Johnson et al. 1997, 587)

2.2.1 Environmental Policy

Environmental conservation has a long and global history, at times being documented as early as the seventh century, with examples afterwards often being local or anecdotal. (BBC News 2013) In the broader context of environmental appreciation or dependency, the history likely goes back to the dawn of humanity. This is evident in written and modern-day history as some indigenous cultures do not separate the environment and the society. (Armiero and Sedrez 2014, 2–3)

Much of the documented history of modern environmentalism and environmental policy comes from the United States. Preservation was one of the first policy instruments, most notably with the Yellowstone National Park Act of 1872 (“Rules and regulations of the Yellowstone national park. Department of the interior.” 1881) Water pollution was one of the first environmental issues which received federal legislation with the The Federal Water Pollution Control Act of 1948 (“The Modern Environmental Movement | American Experience | PBS” n.d.), which later became known as the Clean Water Act. (US EPA 2013)

Another related field of study is Environmental history, which “studies the mutual relationships of humans and nature through time.” (Hughes 2016, 1) This field of study, a subset of the field of history, aims to link and remind historical significance of the link between humans and nature. Environmental historians aim to “see human events within the context where they happen, and that is the entire natural environment.” (Hughes 2016, 2) This has relevance to policy makers worldwide and in China.

Despite much of the literature covering history in the United States, environmental protection can be seen as a global phenomenon in many parts of the world and throughout the 20th and 21st centuries, albeit with differing impact, scope and timeliness. The link to its global nature is highlighted in a study which finds that international organizations and communities have central importance in the diffusion of one particular type of environmental policy, the Environmental Impact Assessment, and its particular importance for less-developed countries. (Hironaka 2002)

2.2.2 Environmental Knowledge and Education

Knowledge about most topics is learned through theory (education) and practice (experience). This is no different with the environment. The term ‘Environmental Knowledge’ accounts for multiple ways of learning and acquisition. In the 1970s, authors stressed the complicated pathways from information to knowledge:

“...the acquisition of environmental knowledge involves a complicated series of processes – sensation, perception, imagery, retention, recall, reasoning, problem solving, judgment, and evaluation. It is an individual process, each person having a unique cognition of the world, but the overlap in images among individuals permits environmental communication.” (Holcomb 1977)

Environmental Education (EE) is a subset of Environmental Knowledge and is inexorably tied to environmental protection and policy. One of its main goals is “Awareness - to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.” (“Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977: Final Report - UNESCO Digital Library” n.d.) An earlier definition was presented in 1969 from the United States, and has proved reliable and accurate since:

Environmental education is aimed at producing a citizenry that is **knowledgeable** concerning the biophysical environment and its associated problems, aware of **how** to help solve these problems, and **motivated** to work towards their solution. (Stapp et al. 1969)

While there is a longer documented environmental protection movement in the United States than in China, it is important to note that Dr. Stapp wrote this definition with the perspective that only 50 years had passed since much of the United States was rural and underdeveloped. It can be argued that China shares this temporal perspective today.

Progress continued with development and deployment of EE the international level, with many landmark events in environmentalism and sustainability putting EE at their core, including The International Environmental Education Program (IIEP 1975), the World Conservation Strategy (IUCN 1980), ‘Tbilisi Plus Ten’ (1987), Our Common Future (WCED 1987), and The Earth Summit (UNCED). (Neal and Palmer 2003, p13–15)

EE also has the potential for direct and indirect positive environmental impacts. One study reviewed 105 EE studies which emphasized conservation outcomes, and found that EE programs which included and focused on ecological indicators (such as improved water quality) had outcomes with the most directness (as opposed to indirect impact categories such as community capacity building), and concluded that local aspects of regional and global problems are important for the directness of the link. (Ardoin, Bowers, and Gaillard 2020)

Several other studies have mixed results. One study examined the relationship between environmental knowledge and attitudes of fourth-graders in Germany but found no correlation between the two. (Liefländer and Bogner 2018) However, the authors noted that the lack of correlation was probably caused by measurement constraints. Another study examined high school students’ environmental knowledge and attitudes and found “significant difference in both knowledge gain and attitudes of students after exposure” where “environmental knowledge scores increased by 22%” after the completion of a 10-day environmental course, and “environmental attitudes became more environmentally favorable.” (Bradley, Waliczek, and Zajicek 1999)

2.2.3 Environmental Society (Perception)

There is an intuitive link between the state of the environment and one's perception of the environment. Environmental perception has been defined as "awareness of, or feelings about, the environment, and as the act of apprehending the environment by the senses." (Zube 1999) A more detailed definition takes into account its multi-dimensional aspects, as a "transactional process between the person and the environment." (Ittelson 1973) He offered three general conclusions:

1. It is not directly controlled by the stimulus.
2. It is linked to and indistinguishable from other aspects of psychological functioning.
3. It is relevant and appropriate to specific environmental contexts.

Ittelson continues in his theoretical framework and suggest that environments "surround the person, provide opportunities for exploration, and provide information that is received through all senses – feeling, hearing, seeing, smelling, and tasting." (Zube 1999, section. Definition) Environments provide more information than the person can apprehend, thus leaving the potential for the environment to influence in unperceivable ways. Additionally, according to Ittelson, environments have *ambiance* - a "quality, mood or atmosphere" which can relate to the social context of environmental experience, and is viewed through the lens of past experience and current perceptions. Simply put, environments affect both individuals and societal groups in ways which are not always easy to understand, and can change or be affected in the present and the past. This has an affect on policy, as information regarding how the general population feels about the environment can inform policy makers.

While studies into societies' perception of the environment often focuses on positive aspects when investigating wilderness and landscape aesthetics, studies regarding air, water and sound usually focus on negative factors. (Zube 1999, section. Air, water, and sound) These studies often focus on maximum levels of pollutants (quantitatively or qualitatively) or annoyance thresholds. Interestingly, different cultures have been found to have different threshold qualitative pollution or annoyance levels, which could be seen as a limitation of this study.

One other factor in environmental perception was the "magnitude, diversity and rapidity of environmental change." (Zube 1999, section. Ma-

major environmental changes) Studies in this domain indicate that “physical proximity to the change, magnitude and kind of change, length of time in current residence, and personal value orientations are all related to the perception of and response to the phenomenon.” (Zube 1999, section. Major environmental changes)

2.2.4 Linking

Studies have looked at some of the variables mentioned previously in relation to other demographic data. One study in 1998 “investigated differences in perception, knowledge, awareness and attitude with regard to environmental problems between educated and [non-educated] groups.” (Sudarmadi et al. 2001) They found that “subjects in the educated group had better perception, more detailed knowledge, were more aware, and had better attitudes in regard to regional and global environmental problems.”

2.2.5 In China

Despite its international perception (often correct) of poor environmental protection, China does have history of concern with environmental degradation. In terms of history, the consensus in China amongst researchers is that while the field of environmental history originated in the United States in the early 1970s, the field came to China in the 1990s, and is now studied by researchers of historical geography, social, economic and world history. (Han 2016) While a new and evolving field, the trajectory of study in this area comes from pollution issues in China, which follows trends from the emergence of this study in other countries. (Han 2016, 7)

In terms of policy, China makes “great leaps” of progress and reform every decade or so since the political reform in the early 1970s. (Xie 2020)

There is also evidence showing that environmental issues and their repercussions are deemed important by the local population. One study found that Chinese university students were more concerned about environmental risk, and deemed “environmental issues to be more harmful to health, to the environment, and to social economic development of the nation than did the American respondents. environmental issues to be more harmful to health, to the environment, and to social economic development of the nation than did the American respondents.” (Duan and Fortner 2012) Furthermore, they found that Chinese students were concerned about fresh

water shortage, and safe drinking water shortage more than other environmental concerns, and only less so than human population growth.

Finally, simple analysis of China's one-party political implementation might lead one to assume that civil society has little to no influence on environmental policy. However, this does not appear to be the case. One study found that Chinese civil society organizations (CSOs) work in similar ways to those in more liberal and democratic countries. (Teets 2018) This further places importance water quality knowledge and environmental education, since there are direct and indirect links to policy changes.

2.3 Water Quality and Perception

2.3.1 Factors in Water Quality

The WHO sets standards for drinking water quality ("Guidelines for Drinking-water Quality" 2017) , which have been applied by the Chinese government. (Qu et al. 2012; 中华人民共和国国家 2006) China applied 106 factors into its drinking water quality standards in 2011, mostly in line with the WHO's 155 factors from the same year. These are broken down into several categories, including microbial aspects, chemical aspects, radiological aspects, and acceptability aspects. For this thesis, the exact determinate of these components are not investigated, nor are the relative importance between certain indicators and perception, or knowledge. However, it should be noted that not all indicators of water quality have direct negative health implications – for the acceptability aspects (also referred to as aesthetic aspects), undesirable qualities (including taste, smell, and color) can erode public trust in otherwise healthy drinking water. ("Guidelines for Drinking-water Quality" 2017, 219)

2.3.2 Water Quality in China

China often cites its developing country status as a reason that it underperforms on environmental indicators. However, China ranks lower than other countries with similar or even lower GDP. (Wendling, Z. A. et al. 2020, X, fig. ES-1) Overall, China ranked 120th with a score of 37.3 in 2020, which was the same ranking as in 2018 but with a decreased score from 50.74.¹

¹The framework of the overall EPI score is comprehensive and weighs 32 indicators. However, the weighting of some indicators changed between 2018 and 2020, making comparison difficult. The visualization of each years breakdown can be seen in 2018 (Wendling et al. 2018, 6, fig. 2.1) and 2020 (Wendling, Z. A. et al. 2020, XI, fig. ES-2).

(Wendling, Z. A. et al. 2020, XII; Wendling et al. 2018, 15)

In 2020, China ranked 54th (6th regionally) in sanitation and drinking water, with a score of 59.4/100. (Wendling, Z. A. et al. 2020, 57) Specific rankings for sanitation and drinking water were not available for 2018. For the broader category of Environmental Health (HLT), China scored 31.72/100. (Huang and Xu 2019)

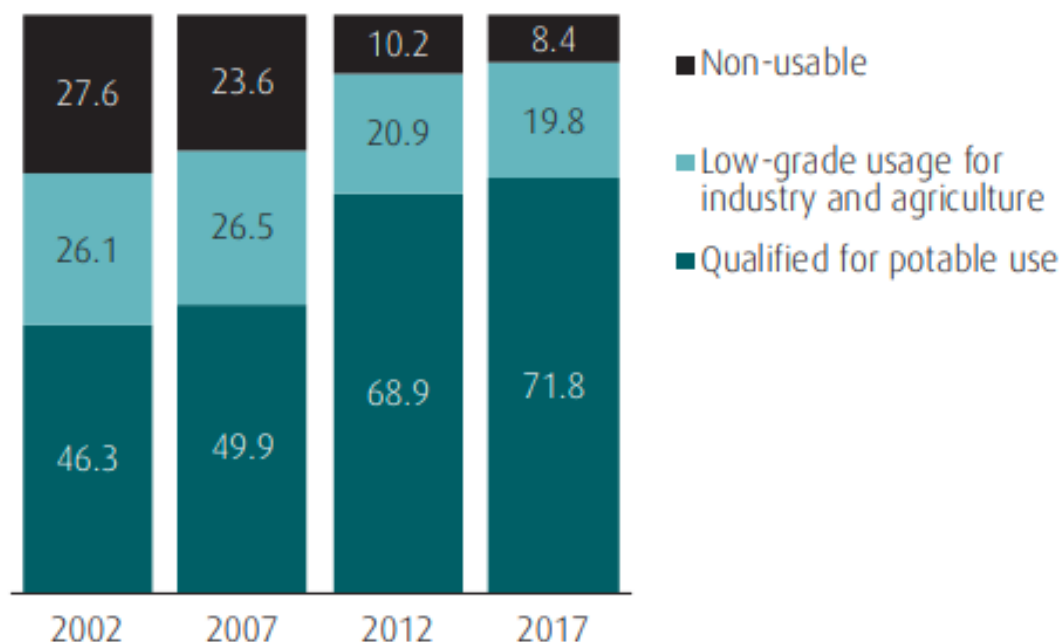
China uses a tiered categorical composite indicator, referred to as China's Water Quality Index (CWQI). ("The National Standards of the People's Republic of China" n.d.)

ClassUtilization

- I Mainly applicable to the water from sources, and the national nature reserves.
 - II Mainly applicable to first class of protected areas for centralized sources of drinking water, the protected areas for rare fishes, and the spawning fields of fishes and shrimps.
 - III Mainly applicable to second class of protected areas for centralized sources of drinking water, protected areas for the common fishes and swimming areas.
 - IV Mainly applicable to the water areas for industrial use and entertainment which is not directly touched by human bodies.
 - V Mainly applicable to the water bodies for agricultural use and landscape requirement.
-

While the state is improving, there is still progress to be made: **turn into my own graphic.** [The World Bank (2019), fig. 1.3; p. 19]

Figure 1.4 Proportion (%) by the Quality Level of Rivers, 2002, 2007, 2012, 2017



Source: Source: Data from Ministry of Ecology and Environment.

Figure 1: wbg_wq_river.png

Access to water is another factor in the population' s perception of water. China has increased its use of basic sanitation services by 28% from 2000-2017 (Organization and others 2019, 31, fig. 33) and achieved 100% safely managed drinking water access. (Organization and others 2019, 48, fig. 51)

{table} Minimum water access in China in 2000 and 2017 :name: jmp-2019-china-water-access

Year	Population	% Urban	At least basic - National	At least basic - Rural	At least basic - Urban
2000	1 283	36	80	70	98
2017	1 489	58	93	86	98

(Organization and others 2019, 89, annex. 3.1)

{table} Minimum national improved water details in China in 2000 and

2017 :name: jmp-2019-china-water-detail-national

Year	Safely Man- aged	Accessible on premises	Available when needed	Free from contamina- tion	Piped	Non- piped
2000	-	65	77	-	51	30
2017	-	92	90	-	76	18

(Organization and others 2019, 89, annex. 3.1)

{table} Minimum rural water details in China in 2000 and 2017 :name: jmp-2019-china-water-detail-rural

Year	Safely Man- aged	Accessible on premises	Available when needed	Free from contamina- tion	Piped	Non- piped
2000	-	46	65	-	31	40
2017	-	86	81	-	54	34

(Organization and others 2019, 89, annex. 3.1)

{table} Minimum urban water details in China in 2000 and 2017 :name: jmp-2019-china-water-detail-urban

Year	Safely Man- aged	Accessible on premises	Available when needed	Free from contamina- tion	Piped	Non- piped
2000	93	98	97	93	87	12
2017	92	96	96	92	92	6

(Organization and others 2019, 89, annex. 3.1)

China’ s improvement in water infrastructure has gone on for decades, with particular improvement since 1990 with an increases in municipal water supply utilities coverage from 50% in 1990 to 88% in 2005. (Browder et al. 2007, xvii) In the same report on infrastructural improvements, the authors repeatedly cite concerns for water quality and quantity issues, citing the problem originating from “outdated water treatment technology and

high levels of pollution in the raw water.” (Browder et al. 2007, 17) The report also states that “Water quality monitoring is generally poor and the data is consequently unreliable,” however this is outdated. (Browder et al. 2007, 17) The report continues that national policies, including drinking water quality, are only implemented in higher-tier cities and are often loosely enforced. (Browder et al. 2007, 30) The problem was especially evident in second tier, third tier and non-urban towns, as evident below:

{table} Urban Water Market Segments :name: wb-2005-urban-water

Market Segment	Number of Cities	Total Population (million)	Per Capita GDP (RMB)	Average Wastewater Treatment Coverage (%)	Average Water Supply Coverage (%)
Pop > 2m, GDP/cap > \$3k	21	90	35,900	61	93
0.5m < Pop < 2m, \$1.5k < GDP/cap < \$3k	331	201	19,100	38	91
Pop < 0.5m, GDP/cap < \$1.5k	310	58	7,300	21	86
Country Towns	1,636	96	N/A	11	82

(Browder et al. 2007, 31, tab. 3.1)

The report continues, noting a slight increase in average category V or V+ in Chinese rivers from 1991 - 2002. (Browder et al. 2007, 33, fig. 3.3) It also notes discrepancies between water supply, water quality and public information for residents to judge the quality themselves (i.e. perception), noting that most urban residents do not drink water directly and is first boiled, which is both a cultural tradition and response to “the uncertain quality of the water from the tap.” (Browder et al. 2007, 61)

China’ s water quality faces continued scrutiny in the 2010s. In 2011, as a part of the 12th Five Year Plan (2011-2015), China’ s central govern-

ment earmarked almost RMB 700b (roughly US\$108b) for water improvement, including water treatment and piping systems. (Hongqiao Liu 2015, section. Intro) Within this timeline, China's 'National Drinking Water Quality Standard' (GB 5749-2006)² was aimed to be implemented.² (中华人民共和国国家 2006) While improvements have been made in access to water, the quality of the water is questionable. China has historically been reluctant to release such data - the mid-2013 water quality assessment report was "classified" as of 2015 (Hongqiao Liu 2015, 4), and the state of China's soil pollution was classified as a "state secret" until 2014. (Hornby 2014) Greenpeace East Asia determined that "Fourteen provinces failed to meet their water quality improvement targets during the 12th Five-Year Plan period (2011-2015)." ("Nearly Half of Chinese Provinces Miss Water Targets, 85% of Shanghai's River Water Not Fit for Human Contact" 2017) The analysis noted that national progress was made during the first half of the 12th Five-Year Plan period, but 'flattened off' beginning in 2013.

2.3.3 Water Quality Perception

While actual water quality is clearly important, so too is perception. Many factors exist in the public's perception of water quality. While "organoleptic properties" exist, most notably flavor, others exist including "risk perception, attitudes towards water chemicals, contextual cues provided by the supply system, familiarity with specific water properties, trust in suppliers, past problems attributed to water quality and information provided by the mass media and interpersonal sources." (Miguel de França Doria 2010) Water quality perceptions are especially important when water is used for drinking or other domestic purposes, causing some to consider perceptions of water quality more important than actual water quality. (Sheat 1992) Thus, it is important for policy makers to consider not only reality of water quality, but also the public's perception. Trends indicate that water quality policy should include not only the protection of human health, but also "acceptability." ("The Bonn Charter for Safe Drinking Water" 2004, sec. 7.7)

Research into water quality perception has existed since the 1960s, but is very heterogeneous, including; different use cases of water (drinking,

²This standard was first introduced in 2007 in accordance to international water quality standards. However, since the water quality across China then was far below the new standard, it only went into full effect in July 2012.

household, agricultural, etc.); different delivery methods (piped, bottled) and different geographic and demographic localities, with most research conducted on bottled water and in developed countries. (Miguel de França Doria 2010)

One study represented research in an under-studied theme and demographic. Stakeholders' perceptions of important measures of river water quality in one region of Ghana suggest that in developing countries (or regions with lower objective water quality), faecal matter in and around rivers, and presence of plastic waste in rivers was deemed to be the most important measure, followed by the smell, clarity, color, and taste ("organoleptic properties") of the water. (Okumah, Yeboah, and Bonyah 2020, fig. 3)

Multiple factors drive perception of environmental issues. In a related issue, water scarcity, one study examined farmers' ($n = 446$) awareness and perception of water shortages in irrigation. (Tang, Folmer, and Xue 2013) They found that "age, percentage of time spent on farming and social network are the main determinants of awareness," and that "water price and drought experience are the most important explanatory variables of perception" in the Guanzhong Plain, Shaanxi Province, China. Furthermore, they found that awareness and perception strongly interact, citing literature which found that households who used less water show a higher level of awareness of water conservation. (Gregory and Leo 2003) However, these study water quantity, not water quality, so they are not necessarily analogous.

2.3.4 Linking the Components

While many studies have examined the issues discussed earlier, few have looked at the alignment of water quality perceptions and actual water quality. One such study was conducted in Newfoundland, Canada, which "investigated public perceptions of water quality and the perceived health risks and associated with the actual quality of public water supplies in the same communities." (Ochoo, Valcour, and Sarkar 2017) While they found "no association with public satisfaction level and actual water quality of the respective communities," they did show demographic disparities in water quality perception.³ Furthermore, the authors found that differ-

³The authors concluded that "Older, higher educated and high-income group respondents were more satisfied with water quality than the younger, less educated and low-income group respondents." However, they also stated that "We had little scope to explore the possible explanations, and hence further studies are required to verify the age, gender educational status and income differential about the satisfaction of public

ences in opinion existed between respondents who were supplied by the same water system. However, this is expected due to the problematic nature of public opinion. (Shepard 1909) The authors also mentioned that water quality data is publicly available, but is most likely not communicated in a way which facilitated knowledge transfer.

Another study investigated discrepancies in drinking water quality and behavior of household water treatment in Nepal. (Kunwar and Bohara 2019) They found that perception and real drinking water quality influences behavior – a deviation between the two was determined to be a primary factor in using water treatment techniques, in addition to drinking water source, income, education, and taste.

An investigation into public perception, knowledge and behavior regarding river water quality was conducted in India (Tarannum, Kansal, and Sharma 2018) They found that respondents use mostly lived experience, and not scientific methods, to shape their perception of river water quality, while risk perception was directly linked to their utilization of the river in their daily lives.

2.4 Background Conclusions

In conclusion of background terms, ideas and research, direct measurement of environmental quality is not the only variable in analyzing how the local population knows, perceives and interacts with their local and regional environment. As indicated, complicated education and knowledge pathways influence perception of water quality in addition to the standard hypothesis that direct water quality leads to perception. In order to mitigate the negative implications of water stress, a further analysis of how these terms interact is vital.

—

3 Literature Review

This research proposal looked at many publications covering a broad range of related topics, some of which are outlined below:

- (Mekonnen and Hoekstra 2016) analyzed the current situation of water scarcity worldwide and found “two-thirds of the global population (4.0 billion people) live under conditions of severe water scarcity

service like water supply.”

at least 1 month of the year,” with nearly half living in China and India alone.

- (Liu and Yang 2012) look at water sustainability in China. They conclude that while China’s recent policy efforts to alleviate water scarcity have been laudable, they are insufficient.
- (Araral and Wang 2013) look at water governance, water insecurity, and its related research. They find that a second-generation research agenda on water governance, including a focus on incentive structures and other multi-disciplinary approaches, is required.
- (Kahn, Hanjra, and Mu 2009) looks at the effects that water management has on crop production and food security in China. They conclude that water management affects many aspects of China’s development, it also affects food pricing and security globally.
- (Araral and Wang 2013) looks at the relationship between water resource management and droughts in China and find that demand-side management can be more effective in meeting the challenges imposed by increasingly-severe droughts.
- (Piao et al. 2010) looks at the impacts of climate change on water resources and agriculture in China. They recommend that further research should be conducted to further understand the impacts of climate change.
- (Bai and Imura 2001) look at sustainable urban water resource management with a case study analysis of Tianjin, China. They suggest that a holistic, systems approach to water management is key for sustainability.
- (Lu 2014) looks at the importance of full project life-cycle cost analysis in addressing water challenges, particularly with wastewater treatment facilities, concluding that there are serious inefficiencies currently.
- (Rogers and Crow-Miller 2017) take more of an overview approach in synthesizing literature regarding the politics of water in China. They find that there are serious gaps in the literature regarding hydropolitics in China.
- (Webber, Crow-Miller, and Rogers 2017) look at the infrastructure side of water resource management in China with a review of the South-North Water Transfer Project. They find that this project is emblematic of the engineering-heavy approach often taken in China and will pose serious risks to regional governance and have serious environmental impacts.

- (Jin, Andersson, and Zhang 2016) looks at air pollution control policies in China with a retrospective perspective. They break down the history of air pollution policies into three phases, and conclude, amongst other takeaways, that there's a continuously increasing demand for quantification of all aspects regarding air pollution, including air quality, source identification, atmospheric modeling, and health risk assessments. These conclusions have the potential to be analogous to future water policy.
- (Hofstedt 2010) looks at the implications of domestic and international stability stemming from China's water scarcity and the government's current plans to address it. They argue that many of the options to alleviate water scarcity (increase water pricing, remove the requirement to be self-sufficient in grain production, increased efficiency of water usage in agriculture) all have serious downsides, and can have serious negative effects on political stability domestically and internationally.
- (Ward and Loftis 1986) looks at water quality monitoring and improvements (at the time) in data collection. They argue that increased data collection itself is not enough to affect the management of water resources; data analysis and reporting are also very important, and that understanding why monitoring water quality is important in the design process of water quality monitoring itself.
- (Glasgow et al. 2004) looks at the emerging technology surrounding real-time remote monitoring (RTRM) and concludes that this technology will have a progressively-larger impact and importance for monitoring water quality.
- (Shirode et al. 2018) and (Abubaker et al. 2018) look at the emerging technology of an Internet of Things (IoT) based water quality monitoring system. They show that this kind of system can address some of the limitations of manual, lab-based water quality testing (time-consuming, costly, etc.), and their real-time monitoring capabilities offer a large potential for improved water quality monitoring.

4 Research Questions

Based on the literature review and background information, there is utility in examining relationships between water quality, knowledge, perception, and other variables. Several questions are examined, and several hypothe-

ses emerge:

Question Number	Research Question	H0 (Null Hypothesis)	H1 (Hypothesis)
R1	Is there a relationship between water quality and perception of water quality? (I.e. do perceptions and reality match)?	Worse local water quality is independent of water quality perception.	Worse local (provincial) water quality relates to an increased perception of severity of water quality issues (114d → 1).
R2	Does knowledge of water quality affect perception?	Increased knowledge is independent of perception.	An increase knowledge of water quality issues relates to an increased perception of severity.
R3	Does the level of obtained education relate to water quality knowledge?	Increased education is independent of knowledge of water quality.	Increased education relates to more knowledge about water quality.
R4	Does the level of obtained education relate perception?	Increased education is independent of an increased perception of severity.	Increased education relates to an increased perception of severity
R5	Are there differences between water quality perception, and water quality knowledge, in rural vs. urban households?	There is no significant difference between urban and rural households.	There is a significant difference in perception of severity of water quality issues between urban and rural households.

Question Number	Research Question	H0 (Null Hypothesis)	H1 (Hypothesis)
R6	Is there a relationship between water quality and knowledge of water quality?	There is no relation between water quality and water quality knowledge.	There is a relation between water quality and water quality knowledge.

4.1 Scope

The scope of this thesis is to provide a multi-variable descriptive analysis of the relations between water quality, education, perception, knowledge. Rural status is also examined in one research question, and is used as a control variable in others. Other demographic data and question responses are used to aid the analysis and discussion, but are assumed to be outside of the scope unless specifically mentioned. Further, multi-variable analysis which analyze these variables concurrently is also outside of the scope of this thesis.

5 Methodology

5.1 Data Sources

The main analysis of this thesis center around two data sets, described below.

5.1.1 Chinese General Social Survey (CGSS)

This national survey, originally launched in 2003, aims to monitor and document relationships between quality of life (in both individual and collective scope) and social structures, both in urban and rural environments. (“Home-中国综合社会调查” n.d.) One of the main benefits is its longitudinal design – however this feature is not utilized in this thesis, which will be discussed later. The survey has been conducted nearly annually since 2003, with a major redesign conducted in 2010. Thus, surveys conducted

prior to 2010 are referred to as “Cycle II” while surveys conducted in 2010 or later are referred to as “Cycle II.”

The CGSS is conducted by face-to-face interviews, which on average require 90 minutes to complete. (“Implementation-中国综合社会调查” n.d.) The survey consists of a questionnaire, which is composed of three modules (beginning in Cycle II):

Module	Frequency	Dimensions	Variables	Coverage	Comments
Core	Annual	11	152	All participants	-
Background Variables	Annual	-	71	All participants	-
Social Change Trends	Annual	-	81	All participants	-
Topic	Annual (5 year rotation)	-	-	All participants	Either one or two topic modules per year.
Additional	-	-	-	1/3 - 1/2	Coverage depends on quantity of other questions and demand

(“Questionnaires-中国综合社会调查” n.d.)

The published data is in the form of a Stata file, which consists of 11783 rows (respondents) and 871 columns (variables).

The Environmental Module (“环境(ISSP)” or “L部分” ⁴) is of particular interest in this analysis. (“调查问卷-中国综合社会调查” n.d.) It asks 25 questions and sub-questions, most of which are directly or indirectly related to the environment. There are several interesting questions which ask things related to environmental protection, importance, perception and knowledge:

The primary question regarding water quality perception was question

⁴ “How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?” which has been translated from the original Chinese question “您认为中国的江、河、湖泊的污染对环境的危害程度是?”

114d ask about the severity of harm to the environment caused by pollution of rivers and lakes.⁵ Survey participants can respond with a range from one to five, with one being “extremely harmful to the environment,” to five being “there is no harm at all.”⁶ This question is significant because it quantifies the respondents’ perception of the severity of water quality on the environment. However, this question does not directly regard the perception of drinking water quality, or the importance of drinking water quality for health or other factors.

The primary question regarding water quality knowledge was question 12409 tests respondents’ knowledge of the water quality scale used by China. The question requires respondents to state if a statement about water quality is correct, incorrect, or if they don’t know.⁷ This question is important since it tests respondents’ knowledge of the water quality scoring system used in China. However, this question does not directly test users knowledge of the underlying environmental and pollutant issues which are the basis of this water quality scale, nor does it test their knowledge or education about environmental issues or protection directly.

Many other interesting questions are present in the data set. For this thesis, several others were selected, and the values were analyzed. This discussion is presented later in this thesis.

5.1.2 Blue City Water Quality Index Ranking (WQIR)

The second data set was compiled by the author from a report from the Institute of Public & Environmental Affairs, a non-profit environmental research organization based in Beijing. (“About IPE” n.d.) The report, the Blue City Water Quality Index 2019, compiles various surface, drinking, and ground water quality data published by various government agencies and assigns a score (their proprietary Blue City Water Quality Index

⁵ “How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?” which has been translated from the original Chinese question “您认为中国的江、河、湖泊的污染对环境的危害程度是?”

⁶Extremely harmful to the environment – 1; Very harmful – 2; Some hazards – 3; Not very harmful – 4; There is no harm at all – 5; Cannot select – 8. This was translated from 对环境极其有害 – 1; 非常有害 – 2; 有些危害 – 3; 不是很有害 – 4; 完全没有危害 – 5; 无法选择 – 8

⁷The question is in a superset of knowledge about environmental knowledge, which states: “We also want to know your mastery of environmental protection knowledge. Please listen carefully to each of the following statements, and according to your solution to determine whether they are correct.” The question is: “In the domestic water pollution report, the water quality of Category V (5) is better than that of Category I (1),” which is false. This question was translated from: “国内水体污染报告中,V(5)类水质要比I(1)类水质好.”

Score (BCWQI)) and publishes the results at a sub-provincial level (second administrative level, or “admin 2”). (Jun, Sunan, and Haijin, n.d.) The methodology and conversion to the government’ s water quality score is provided. This report was chosen as the basis for this data set since it was the most comprehensive data the author could find with the closest publication date to the CGSS. The difference in time of the two data sets is discussed in the section. In the appendix of this report, the BCWQI for each second administrative level, including the city name, province, and ranking, is included. This data, in a table in the PDF report, was exported into a comma separated value (.csv) file for later analysis.

It should also be noted that the water quality score used in the WQIR data set is derived from the official Chinese water quality index system. The following table translates between the two scoring systems: (Jun, Sunan, and Haijin, n.d., 5)

IPE Score	IPE Level (EN)	IPE Level (ZH)	EQ Water
0.00 - 4.79	Excellent	优	II
4.79 - 10.28	Good	良	III
10.28 - 16.85	Moderate	一般	IV
16.85 - 24.74	Relatively Poor	较差	V
24.70 - 50.00	Poor	差	V

5.2 Analysis

Analysis for this thesis was conducted using the general-purpose computer programming language Python. To allow for accessibility, readability, and reproducibility, the primary data analysis medium was a Jupyter notebook (Kluyver et al., n.d.), a document format which allows for text and code to be read and execute in an easy-to-read format, which was hosted on GitHub, to allow for accessibility. (Rynearson 2020) This was chosen after initial data analysis was conducted in a more traditional Python file, which was less collaborative and more cumbersome.

The two main data sets were loaded into the Jupyter notebook and reviewed for initial analysis, beginning with the CGSS2010. Then, after reviewing the data, it was cleaned and processed in several ways:

5.2.1 Choosing Appropriate Questions

Demographic Questions The thesis proposal and hypothesis were created before the author reviewed the data set, and before the author was aware of the environmental module of the CGSS. While many variables were deemed interesting, several variables were initially selected for broader analysis:⁸

Code	Variable (English)	Variable (Chinese)	Importance	Analyzed?
s41	Province		Location of the individual	X
a2	Gender		Possible control	X
a3a	Birth year		Age of respondent	X
a7a	Highest level of education		Education could be linked to perception and knowledge?	X
a91	Rural / agricultural household		Possible control	X

Not all of the variables were utilized, such as income and subjective personal health, since they were outside of the scope of this thesis.

Environmental Questions The CGSS includes many demographic data on each respondent. Of which, the following were deemed important for one or more reasons:⁹

Code	Question (English)	Question (Chinese)	Response Types	Importance	Drawback	Analyzed?
11a	In your opinion, in terms of the current situation in our country, which of the following issues is the most important?					Yes

⁸Translated from Chinese into English.

⁹Translated from Chinese into English.

Code	Question (English)	Question (Chinese)	Response Types	Importance	Drawback	Analyzed?
l1b	like l1a, but 2nd most important					Yes
l6a	In your opinion, in terms of the current situation in our country, which of the following issues is the most important?					No
l6b	How serious are env. problems facing China?					No
l7a	Which is most important env. issue in China?				Response types are categorical, so differences in severity is not captured.	
l7b	Which has greatest impact on you/family?					
l8a	Knowledge of causes of environmental problems from ?l7					
l8b	Knowledge of solutions of environmental problems from ?l7					
l12a	In order to protect the environment, to what extent are you willing to pay a higher price?					
l12b	like l12a, but with higher taxes					
l12c	like l12a/b, but with willingness to lower living standards					

Code	Question (English)	Question (Chinese)	Response Types	Insight Drawn	Feedback	Analyzed?
l137	Environmental issues directly affect my daily life					
l14d	How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?					X
l15a	see question, about statements of responsibility					
b	for environmental protection (individuals/companies, government, etc.)					
l16c	In terms of solving environmental problems in your area, how do you think the local government has done in the past five years?"					
l20e	Do you often save water or reuse water specifically for environmental protection?					
l240g	In the domestic water pollution report, the water quality of Category V (5) is better than that of Category I (1)					X

As evident, these questions include questions related to the environment in general, perceptions of the local, national and global environment, water, and knowledge of water quality issues.

Many more survey questions were included in the main and additional module sections. Many of these relate to social satisfaction, political involvement, and future aspirations. Future analysis could be done with many of these questions, but were not within the scope of this analysis.

5.2.2 Important Questions

Within the previously-identified relevant variables, the following have been identified as the most relevant for the scope of this study.

Code	English	Chinese	Value Range (used)
s41	Province	省	Range, see data analysis
a2	Gender	性别	1 = male, 2 = female
a3a	Birth year	您的出生日期是什么	Birth year
a7a	Highest level of obtained education	您目前的最高教育程度是	none, 13 = master' s and above
a91	Rural / agricultural household	请问目前您或者您配偶是否为农业户口(或者户口所在地)	yes, 2 = no
l14d	“How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?” (Used to measure perception)	您认为中国的江、河、湖泊的污染对环境的危害程度	1 = not important, 5 = not important at all
l2409	“In the domestic water pollution report, the water quality of Category V (5) is better than that of Category I (1)” (Used to measure knowledge)	国内水体污染报告中, V(5)类水质要比I(1)类水质好	yes, 2 = incorrect

5.2.3 Geographic Alignment

The two data sets are of differing geographic precision. The CGSS2010 (and all CGSSII data sets) include data on the province of where the respondent resided. Based on the structure of the data, it is assumed that more precise geographic information is included, however the CGSS publishing team

chooses only to release the provincial information.

This is different than the WQIR2018 data, which is published at the sub-provincial level (admin 2). Thus, for comparative analysis, the mean water quality per province was calculated (more on this below).

Insert Admin1 and Admin 2 maps here.

5.3 Application

5.3.1 Structure of the Analysis

As previously discussed, the relationships between water quality, water quality perception, and water quality are investigated. The following table summarizes how the theory and data are linked:

Term	Definition	Data	Range	Measurement and Direction
Water quality	The measure of the condition of water relative to standards and requirements.	score (from WQIR)	6.9 - 23.6	A decrease in water quality is measured by an increase in the value of score.
Water quality perception	The recognition of water quality as a problem.	114d (from CGSS)	1 - 5	An increase in water quality perception is measured by a decrease in the value of 114d
Water quality knowledge	The acquisition of a baseline amount of knowledge about water quality.	12409 (from CGSS)	1, 2, 8	If 12409 is 1, the respondent is not knowledgeable. If 12409 is 2, the respondent is knowledgeable. If 12409 is 8, the respondent is somewhat knowledgeable.

5.3.2 Procedure

Once the data sets were loaded and reviewed for importance and quality, initial data analysis was conducted. Due to the author's limited experience with Python, multiple versions of the analysis were conducted in or-

der to gain working knowledge of Python and of the data set.

For provincial comparative analysis, the data was sorted by province s41 and grouped into visual and numerical approaches of looking for differences between provinces. Several functions were created which allowed the author, and users, to see provincial comparative analyses on any question by inputting the question code. Either quantities of responses or their mean value would be output, as well as a heatmap for quick comparison. This initial analysis helped the author validate the main variables that were analyzed, which are discussed later.

Then, the WQIR2018 data was loaded. An initial plot was created to see the distribution of water quality per sub-province, sorted by province. Histograms were added to visualize the distribution of water quality measurements and values.

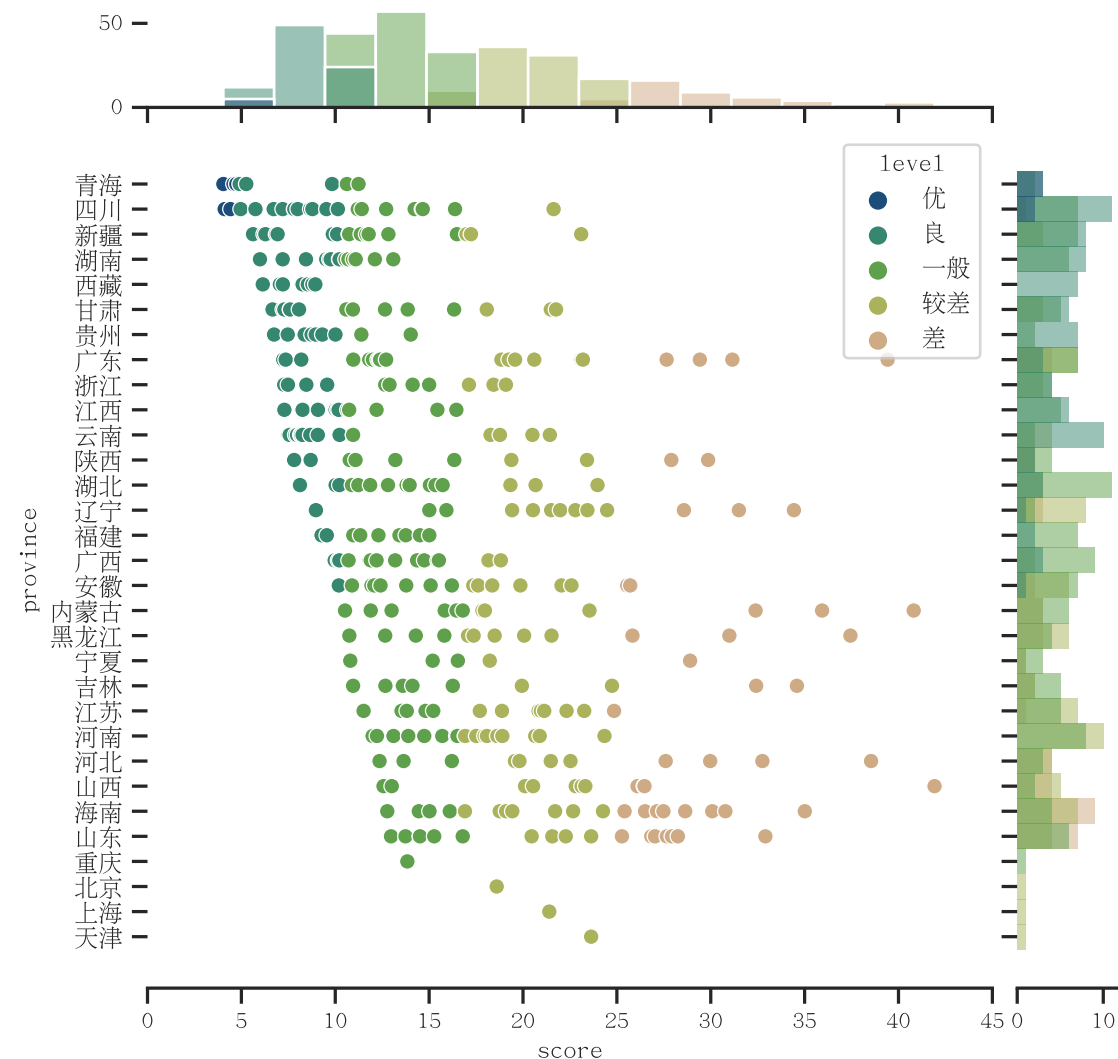


Figure 2: wqir2018.svg

From the previous steps, a subset of questions were created. Two main questions and one demographic variable were identified for further analysis: question 114d was used as the the main question to quantify perception¹⁰; 12409 was used as the main question to quantify water quality knowledge¹¹; and a7a was used to quantify education.¹² These questions are discussed more in depth in the following limitations section. Other demographic data was used to control for results of the analysis. Many other relevant and interesting questions could be investigated from the data, but they are outside of the scope of this thesis.

Next, the values of these were examined. The author spent significant effort on this stage to better understand the state of the data set, and to understand the implications of choices in cleaning this data. Several revealed to be outside of the acceptable range, such as being recorded as negative numbers not present in the valid response list. Since the origin or reason behind these values could not be determined, they were discarded. This lead to further discrepancies in the number of values per category, including per province, education, perception and knowledge. This is discussed further in the analysis section.

Once invalid values were removed, the two data sets were merged on their shared province values. This was done in two separate ways, which allowed for different analysis.

1. **On Provinces:** The mean water quality per province was added to the mean value per province of each analyzed variable. This allows for simpler data analysis, but loses some individual demographic data (gender, income, age, education, etc.).
2. **On Individuals:** The mean water quality per province was added to the individual response values. This makes the analysis slightly more complicated, but allows for comparison across the demographic data mentioned above. However, it should be noted that it runs the risk

¹⁰ “How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?” which has been translated from the original Chinese question “您认为中国的江、河、湖泊的污染对环境的危害程度是?”

¹¹The question is in a superset of knowledge about environmental knowledge, which states: “We also want to know your mastery of environmental protection knowledge. Please listen carefully to each of the following statements, and according to your solution to determine whether they are correct.” The question is: “In the domestic water pollution report, the water quality of Category V (5) is better than that of Category I (1),” which is false. This question was translated from: “国内水体污染报告中,V(5)类水质要比I(1)类水质好.”

¹² “What is your current highest education level (including those currently studying).” The values range from 1 - no education to 13 - postgraduate and above, in progressive order. This question was translated from “您目前的最高教育程度是(包括目前正在读的)”

of providing a false sense of improved precision, and the mean water quality of the province may not accurately reflect the local situation of the individual.

While the author spent substantial time on analysis using the first method, the results of this study are mostly presented using the second method as they are more robust. The author conducted a large correlation test examining the correlation between every combination of questions and demographic data. While this test provided interesting results and provided inspiration for further investigation, most of the findings were outside of the scope of this thesis.

Once the data was analyzed, the author aligned the research questions and hypothesis with the data set variables. Each research question, and each tested hypothesis, was examined for correlations between two relevant variables, and were compared against one or more variables as a control. The analysis and findings are mentioned in the analysis section.

5.4 Limitations

Several limitations exist based on the scope of both data sets, as well as limitation with some of the assumptions made by the author.

First, as discussed previously, there is misalignment between the CGSS and the WQIR data sets on two dimensions. The first is geographic. Since water quality data offered more geographic precision than the social survey responses (i.e. smaller regions), the effectiveness of comparison is reduced. This is in addition to the fact that water quality scores were originally presented as mean values per prefectural regions. This is different than the CGSS responses – while they were recorded at a more local level, geographic alignment information is only available at the provincial level. Further, the comparison between individuals and mean values per prefectural region results in the possibility that an two individuals in the same prefectural region experience different water quality, which is not possible to account for in the current methodology.

The second misaligned dimension is temporal, as the CGSS responses and water quality data differ by seven years. This is not ideal, since multiple indicators could have changed between that time. One is water quality, which has changed due to factors including the national government's initiatives, but this change has not been uniform across the country. Another indicator which could have changed is knowledge about water qual-

ity issues. Third, perception of water quality could have changed as well.

Further limitations come from the perceived findings based upon the CGSS question set. The two main questions which were analyzed, 114d and 12409, are not perfectly analogous to the conclusions the author made. 114d refers more to rivers and lakes in China, which are not necessarily the drinking water sources which are used by the respondent. Further, the severity of pollution being harmful to the environment is not necessarily the same as the respondents' perception. 12409 directly tests respondents' knowledge of water quality scales used by China, but this question, and 114d, do not necessarily test for knowledge, and perception, of the local water quality - the question refers to China in general.

— # Notes - Those who are more aware about environmental issues may be more knowledgeable about water issues (17a). - Mention that water pollution is the 2nd highest category counted for 17a and 3rd for 17b - To ask perception in a different way, I could use respondents who say water is #1 from 17a 17b instead of 114d and if the trends matching education, perception and quality are the same. - Those who think 114d is harmful probably think that water pollution is #1 for 17a and 17b

6 Analysis

6.1 Results

The following is a summary of the results of the analysis. The code and procedure can be referred to in the section.

Overall, respondents are self-report a fairly high level of concern regarding environmental issues, and a high level of awareness for environmental issues facing China.¹³

Response Value	l6a	l6b
1	I don' t care at all	Very serious
2	Less caring	More serious
3	I can' t say that I don' t care about it	Neither serious nor not serious

¹³l6a asks "Generally speaking, how much do you care about environmental issues?" and l6b asks "Based on your own judgment, on the whole, do you think the environmental problems facing China are serious?"

Response Value	l6a	l6b
4	More concerned	Not too serious
5	Very concerned	Not serious at all

For l6a and l6b ($n = 3362$) the mean response was 3.67 and 2.15 respectively, noting the structure of the data – an increase in l6a notes an increase in concern while a decrease in l6b notes an increase in awareness. The distribution of responses is the following:

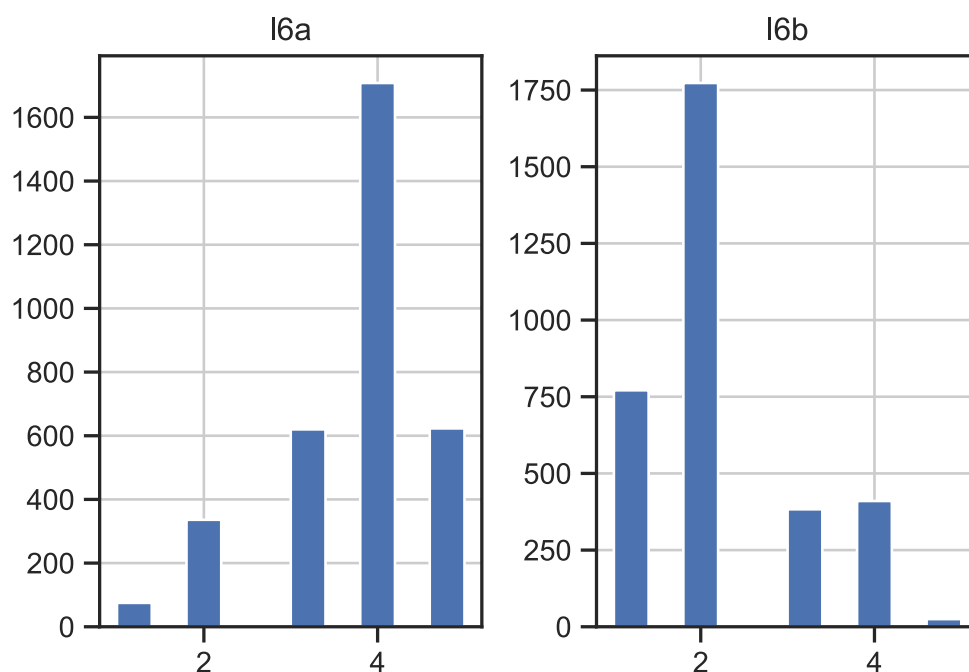


Figure 3: l6_fig1.svg

The trend is consistent across most provinces, water quality, gender, education levels, age groups, and rural classification. **Insert plots for these controls**

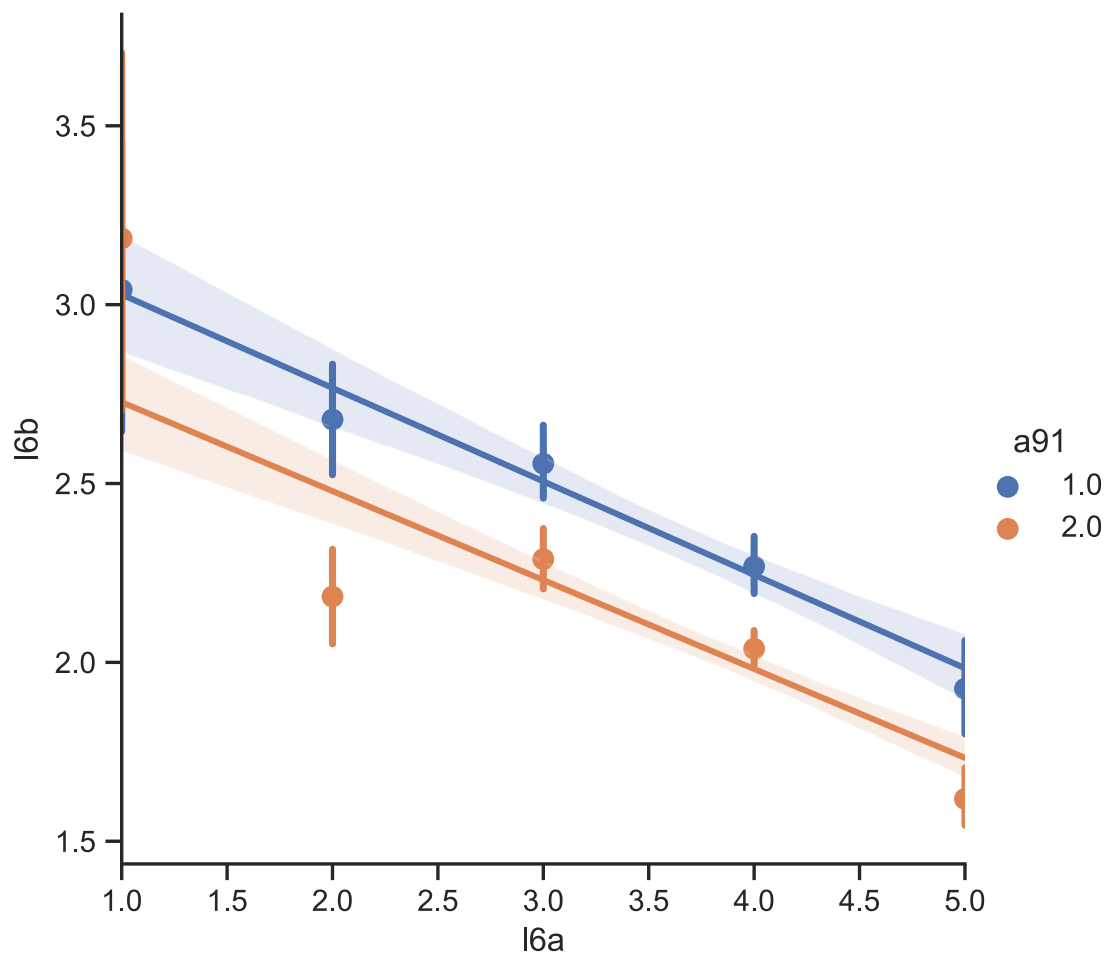


Figure 4: l6_fig2.svg

Concern of water pollution ranked high on respondents' overall environmental concerns. Respondents ranked their most ($n = 3218$) and second-most ($n = 3045$) important environmental issues in China. Water pollution was the second most common response for their most important environmental concern, behind air pollution and ahead of domestic waste disposal. Water scarcity ranked lower. For respondents' second most concern, water pollution was the third most common response, behind domestic waste disposal and ahead of fertilizer and pesticide pollution.

Code	Name
1	Air Pollution
2	Fertilizer and pesticide pollution
3	Water scarcity
4	Water pollution

Code	Name
5	Nuclear waste
6	Disposal of domestic waste
7	Climate Change
8	Genetically modified food
9	Depletion of natural resources
10	None of the above

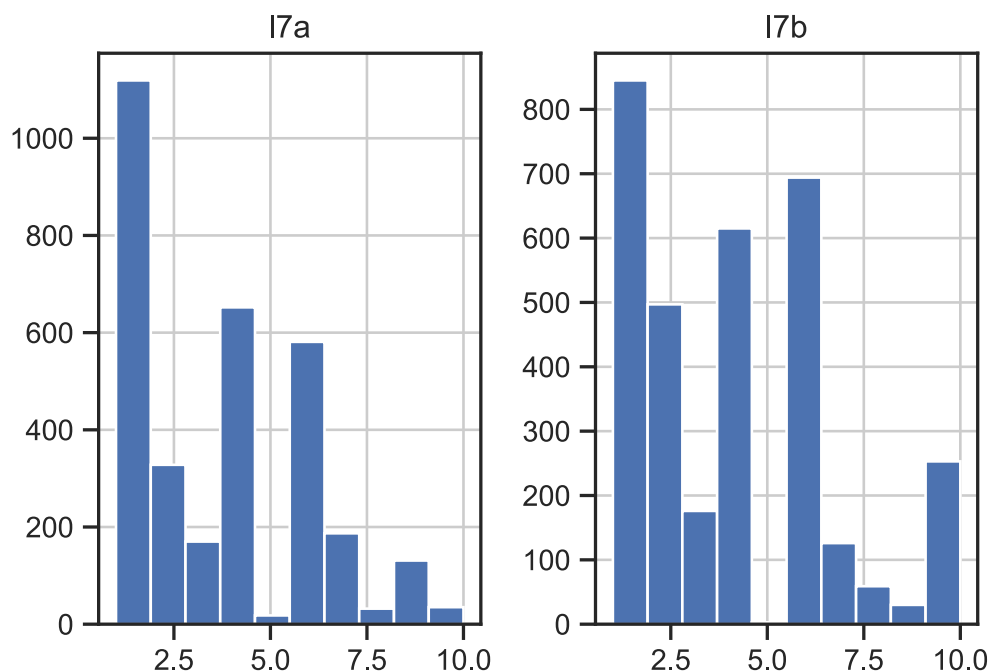


Figure 5: l7_fig1.svg

Label histogram, find a way to do this in Seaborn

For the following hypotheses, it is important to remember the question types and response ranges. As the level of perceived harm increases for 114a, the value decreases. As responses approaches 2 for 12409, the knowledge about water quality issues is assumed to increase. While this is a set of binary responses, it is calculated as a mean later in this analysis.

	114d (perception)	12409 (knowledge)
Value	How do you think the pollution of rivers, rivers and lakes in China is harmful to the environment?	In the domestic water pollution report, the water quality of Category V (5) is better than that of Category I (1)
1	Extremely harmful to the environment	Correct
2	Very harmful	Error (note: this response is correct)
3	Some hazards	-
4	Not very harmful	-
5	There is no harm at all	-

It should be noted that there are discrepancies in both the number of responses per province, per type of value (demographic variable or question response), and for the number of water quality measurements per province. Thus, conclusions from individual provinces should be taken with caution – for example, data from Tibet ($s_{41} = 25$) is especially scarce.

Insert countplot of these differences

6.1.1 Hypothesis 1: Worse local (provincial) water quality (score increases) relates to an increased perception of severity of water quality issues (114d decreases)

There is a statistically significant ($p = 4.98e-9$) correlation with a large number of responses ($n = 3253$). Thus, actual water quality is related to perception of water quality, and worse water quality relates to an increase in perception of severity. However, there is a poor regression fit (coefficient of determination $r = -0.1023$). Note that the range of water quality scores is large when respondents reply with the most-severe perception response type (114d = 5).

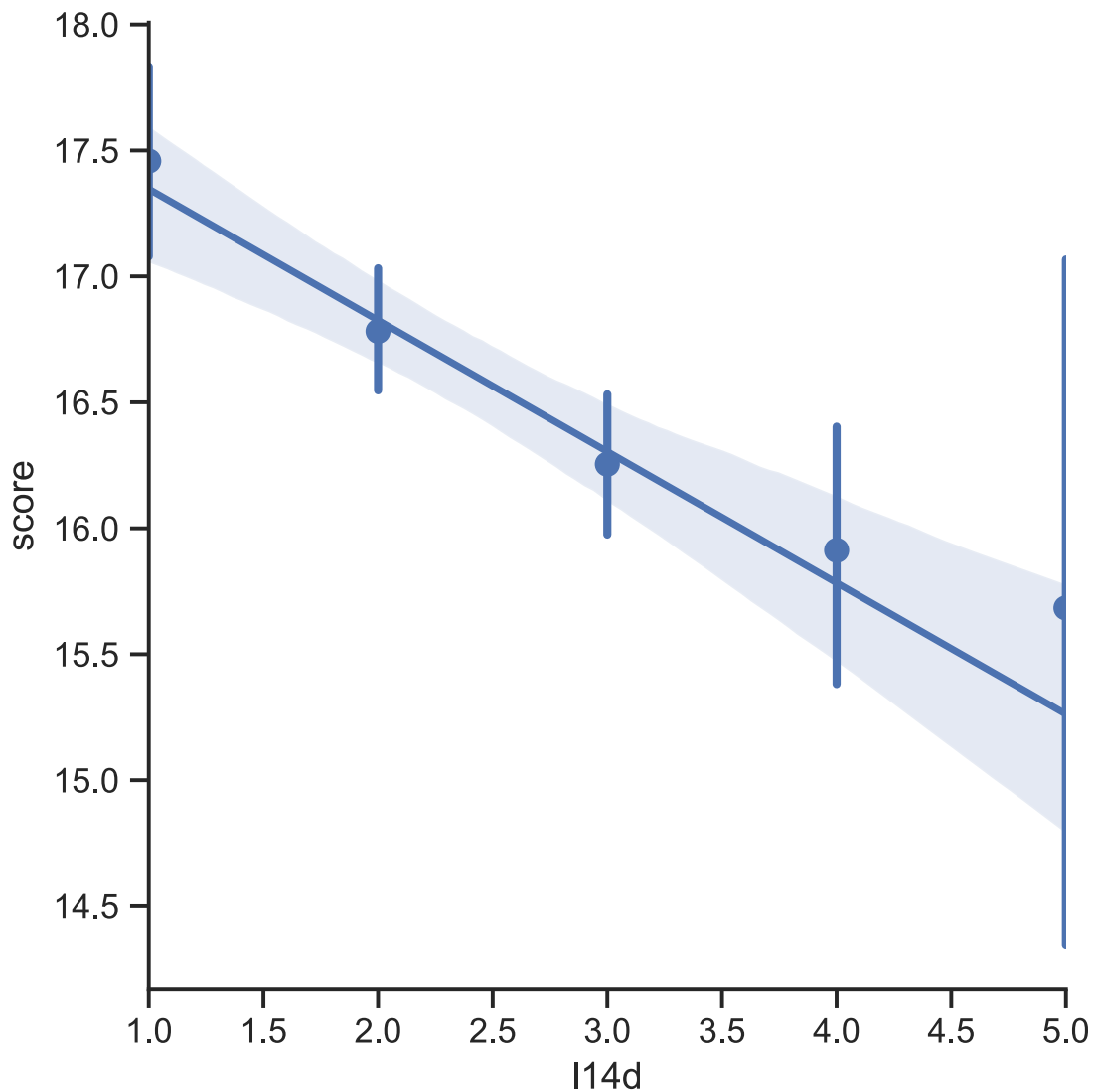


Figure 6: h1_fig2.svg

6.1.2 Hypothesis 2 - An increase knowledge of water quality issues (l2409) relates to an increased perception of severity (l14d)

There appears to be a relationship between water quality knowledge and perception from the smaller sample size ($n = 861$). Respondents who replied incorrectly (when $l2409 = 1$) ($n = 282$) have a mean perception response $l14d = 2.383$, while respondents who replied correctly (when $l2409 = 2$) ($n = 579$) have a mean perception response $l14d = 2.197$.

There is a statistically significant ($p = 8.81e-4$) correlation, however there is a poor regression fit (coefficient of determination $r = -0.1023$).

With increased water quality knowledge ($l2409 = 2$), environmental perception is increased (decreased $l14d$). However, this trend is no longer vis-

ible when factoring for rural/urban a91, education level a7a, and for other demographic question. For more conclusive results, further multi-variable statistical analysis is required.

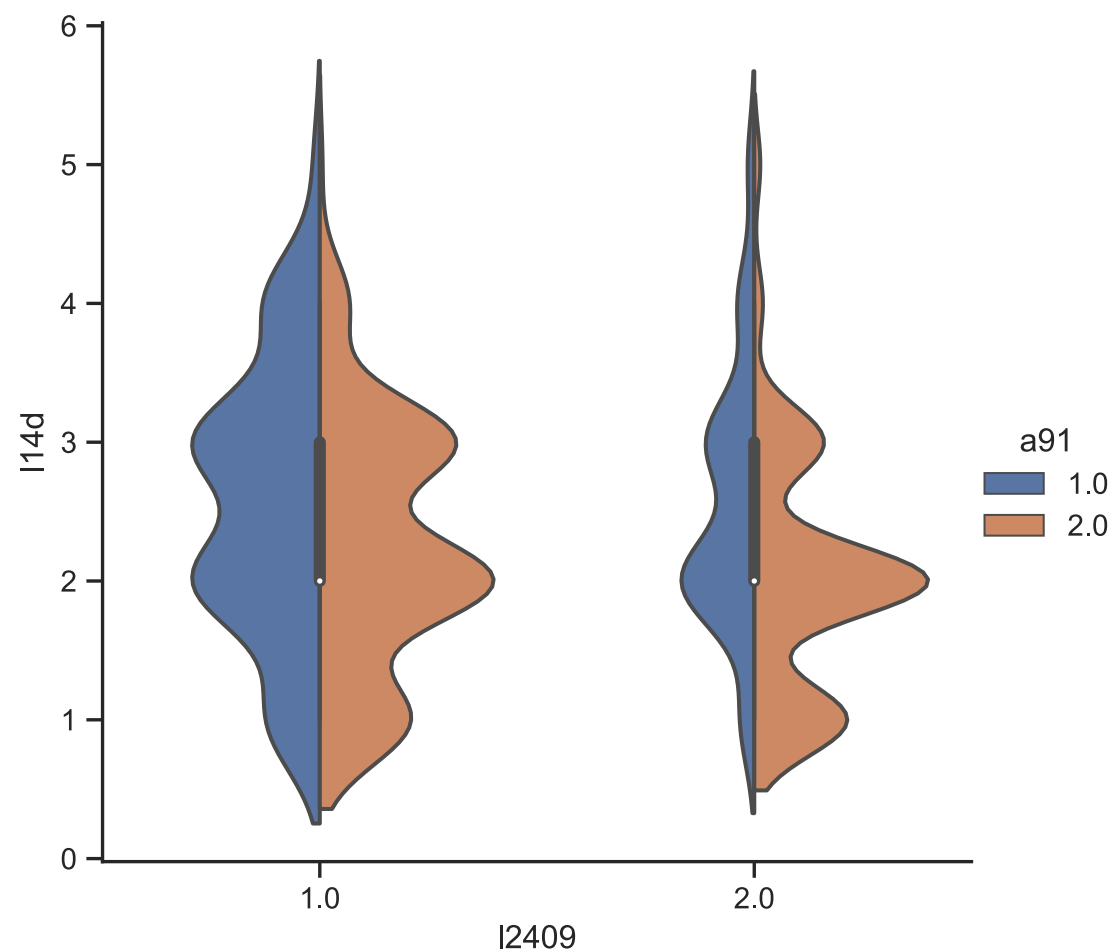


Figure 7: h2_fig.svg

6.1.3 Hypothesis 3 - Increased education (a7a) relates to more knowledge about water quality (12409)

There seems to be a relation between these two variables. Since 12409 is analyzed as a binary variable (only two responses), values from each education level are averaged to find the mean.

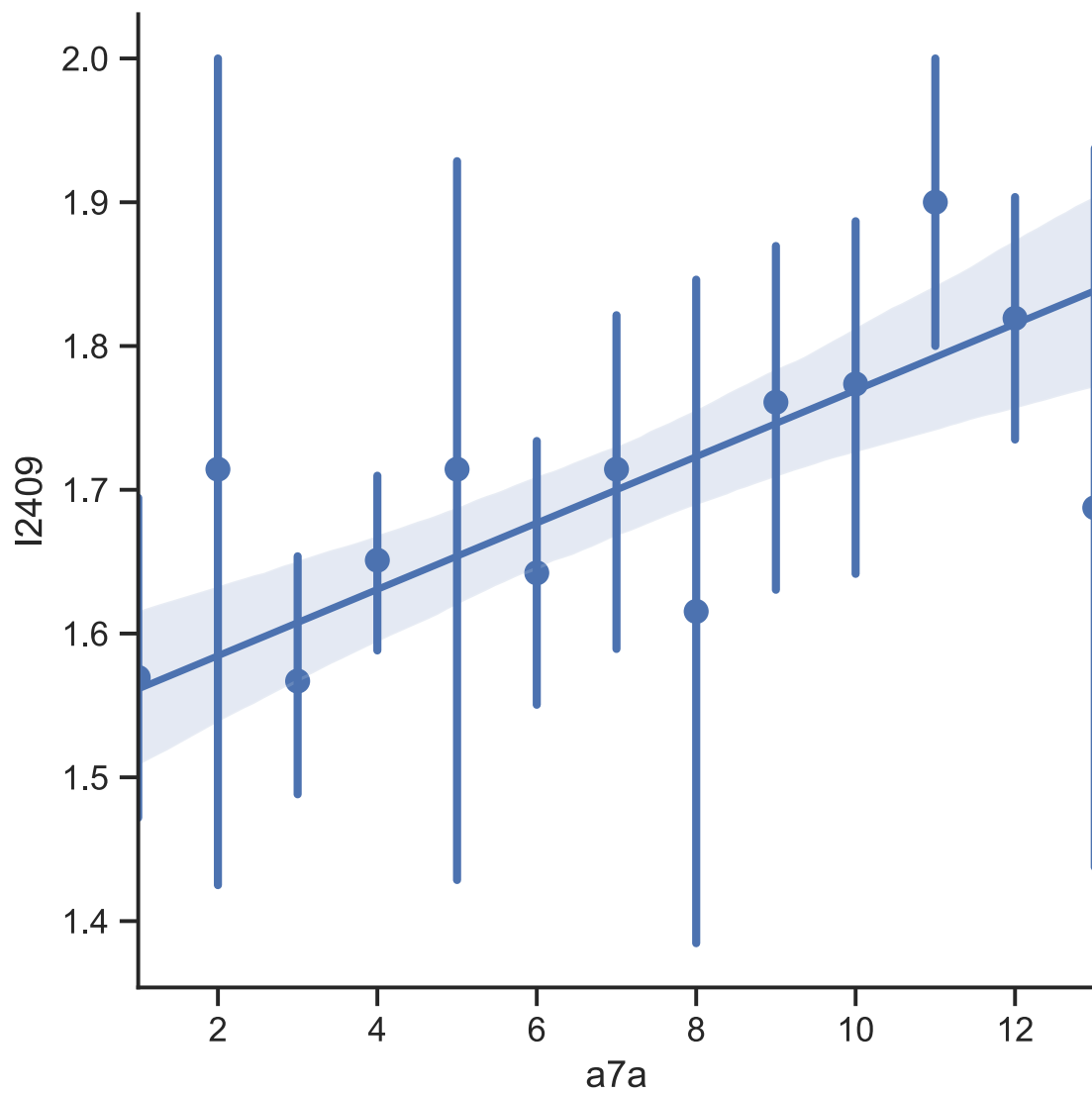


Figure 8: h3_fig1.svg

There is a statistically significant ($p = 1e-6$) correlation, however there is a poor regression fit ($r = -0.16$) with a smaller sample size $n = 881$. Further comparison with rural versus non-rural responses reveal large differences in both the typical level of education and the number of responses per rural classifier.

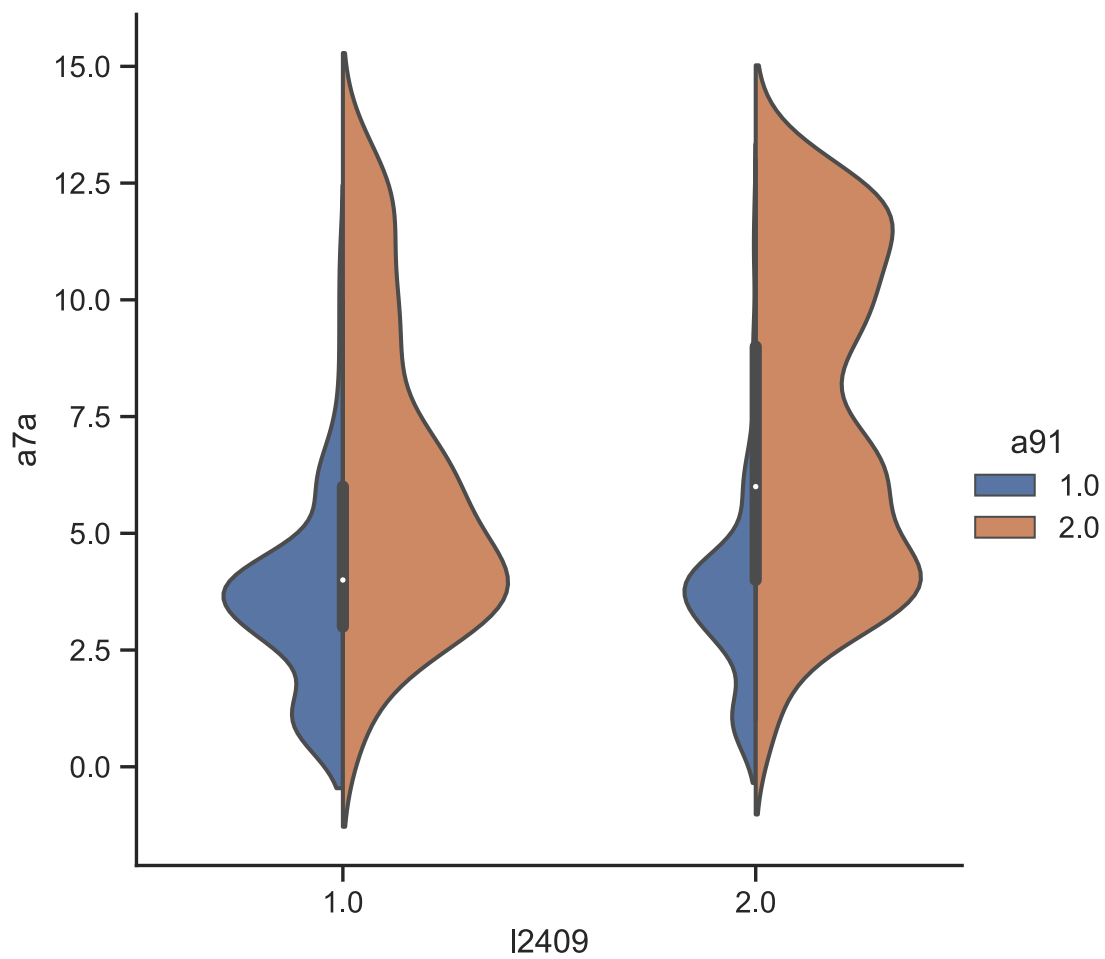


Figure 9: h3_fig2.svg

6.1.4 Hypothesis 4 - Increased education (a7a) relates to an increased perception of severity (114d):

There is a clear trend between education and perception, with a larger sample size ($n = 3252$). There is a statistically significant correlation ($p \approx 0$). There is a fairly low regression fit ($r = -0.2109$).

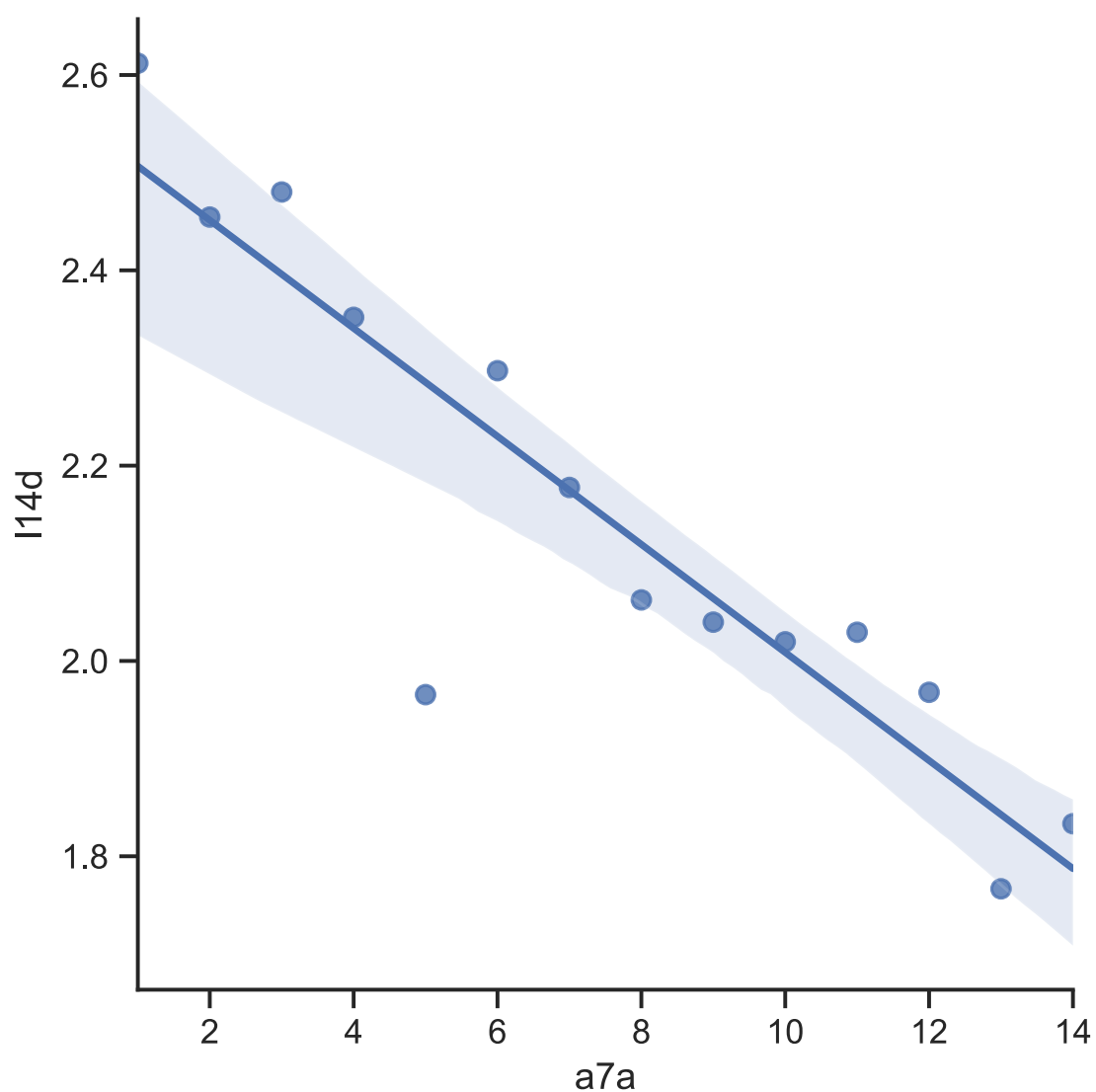


Figure 10: h4_fig1.svg

When differentiated by rural classification, an interesting trend becomes evident: non-rural households have a higher perception than rural households at each education level, however this difference decreases as education increases. Analysis into the reason behind this was not conducted.

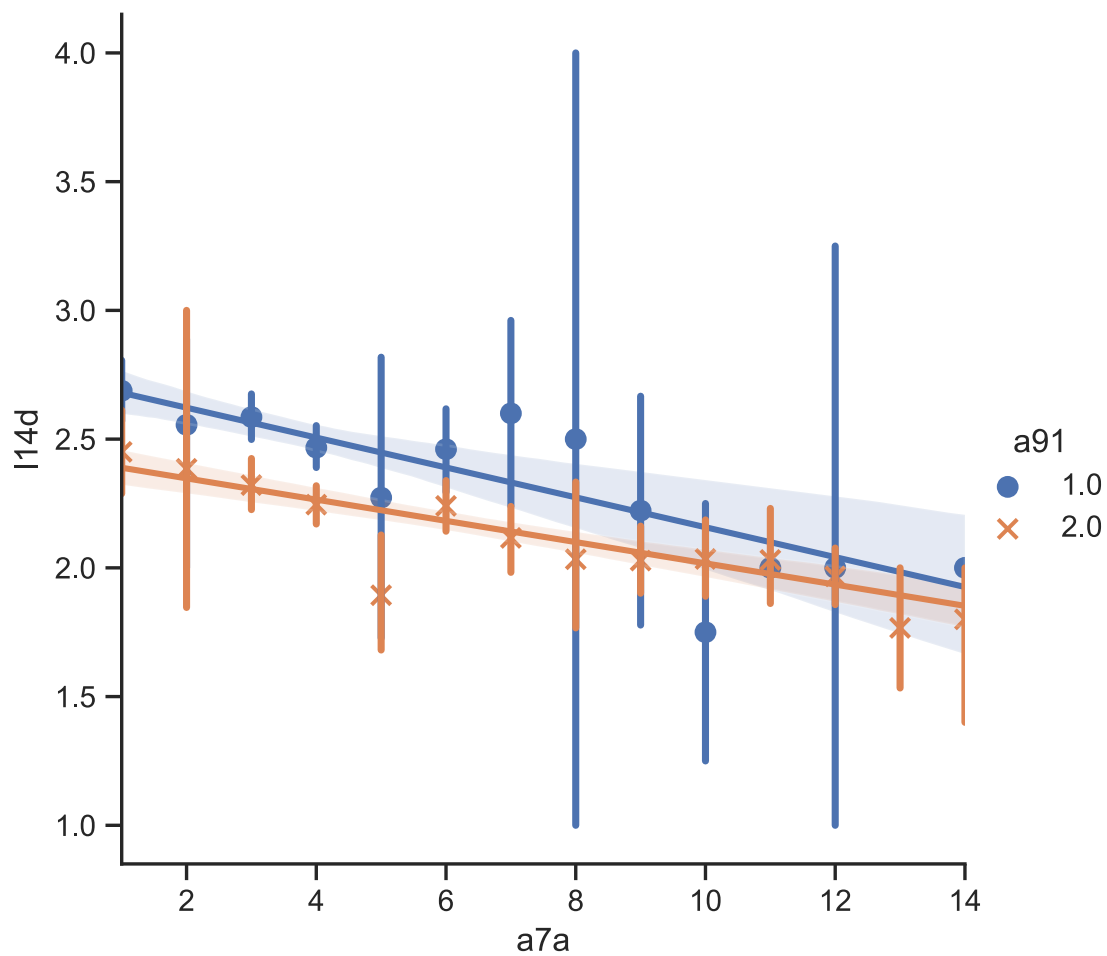


Figure 11: h4_fig2.svg

6.1.5 Hypothesis 5 - There is a significant difference in perception of severity of water quality issues (l14d) between urban and rural households (a91).

With a larger sample size ($n = 3252$), a statistically-significant difference was found ($p \approx 0$). There is a fairly low regression fit ($r = -0.2018$) The mean l14d value per rural classification was calculated. However, education levels vary significantly between rural and non-rural respondents.

Rural Classification	Number of Responses	Mean Perception (l14d)	Mean Education Level (a7a)
Rural (a91 = 1)	1257	2.536	3.48
Non-rural (a91 = 2)	1995	2.172	6.24

Rural Classification	Number of Responses	Mean Perception (l14d)	Mean Education Level (a7a)
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6.1.6 Hypothesis 6 – There is a relation between water quality and water quality knowledge.

There seems to be a small but statistically-significant difference ($p \approx 0$) between water quality knowledge levels and water quality. With a large number of responses ($n = 3628$), a decrease in knowledge relates to a decrease in water quality. With knowledgeable respondents (12409 = 2), the mean water quality was 16.85. With somewhat knowledgeable respondents (12409 = 8), the mean water quality was 16.56. Finally, with respondents with no knowledge (12409 = 1), the mean water quality was 16.20. The statistically-significant difference was not matched with any level of confidence in the fit of the model, with $r = -0.10$. It should be noted that with this hypothesis, response types equal to 8 (“can’ t answer”) were included while they were omitted previously.

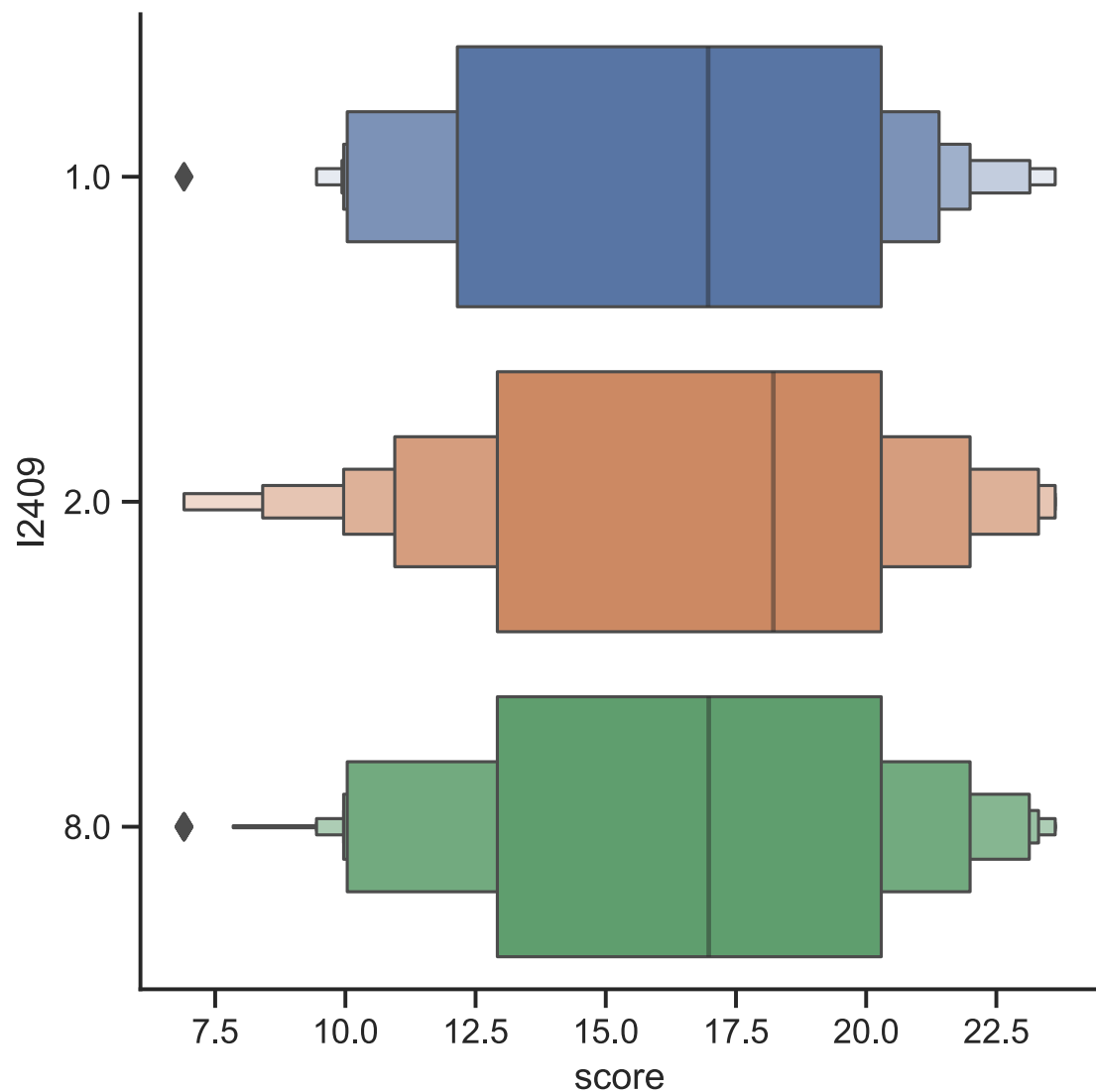


Figure 12: h6_fig1.svg

6.2 Findings

The analysis above produced interesting results. Overall, the first five hypotheses were proven correct, with the limitation that all regression analyses provide a poor fit to model these trends. The sixth hypothesis shows a statistically-significant difference, but a trend is harder to be confident about. This can be explained that there are variable(s) which are contributing to this trend which are not accounted for in the simple two-variable regression analysis. Another interpretation could be that there factors influencing these correlations which are not accounted for in the data sets analyzed for this thesis. Further analysis is required to explain the causes

of this poor fit. The limitations discussed previously, including geographic precision, differences in periods of time and applicability of the analyzed questions, should also be noted. Given more data, specifically updated CGSS results when the environmental module is included, would give the opportunity to conduct a longitudinal analysis.

7 Discussion

The discourse on water quality should have a more holistic focus which values local knowledge, subjective perspectives and increased awareness to complement the current primary focus on direct water quality.

7.1 Issues and Implications

China has made a range of commitments, and notable action, on improving the country's water quality. The government invested 717.6b RMB (US\$110.3b) to address water quality, quantity and flooding issues in 2017 alone. (The World Bank 2019, p.. vii). The priority improvement method is infrastructure development – Since the founding of the P.R.C., over 800 billion cubic meters of water storage has been constructed though over 400 thousand kilometers of river dikes and over 98000 reservoirs. (The World Bank 2019, 2) Additionally, nearly 6000 water supply projects provide rural services to more than 800 million people.

The Three Red Lines policy best states the central government's aims to address water resources issues: (The World Bank 2019, box. 1.2)

- Water quantity: By 2030, total water use must not exceed 700 billion cubic meters.
- Water use efficiency: By 2030, industries will reduce their water use per US\$1600 (RMB 10,000) of industrial added value to 40 cubic meters. In addition, by 2030, irrigation efficiency must exceed 60 percent.
- Water quality: By 2030, 95 percent of water function zones must comply with water quality standards. In addition, by 2030 all sources of drinking water will meet set standards for both rural and urban areas and all water function zones will comply with water quality standards

Progress is being made towards Sustainable Development Goals 6 – Clean Water and Sanitation. However, China still has substantial improvements

to make: for example, water stress is high and expected to increase (SDG 6.4.2), and household wastewater treatment is low (SDG 6.3.1 - 38%). (“Country (or Area) | SDG 6 Data” n.d.)

SDG 6.3 focuses on water quality:

By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. (Martin n.d.)

Another key component to China’ s water policy is its efficiency. SDG 6.4 focuses on this:

By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity. (Martin n.d.)

China is currently far from achieving this target. A recent study found that not only does China have a significant lack of resource efficiency, there are also significant discrepancies between provinces and across time frames. (Song, Wang, and Zeng 2018) This indicates the situation is local, and a homogeneous national-level solution may not be appropriate. Currently, China spends two to three times more than the average upper-middle-income country for the same economic output.¹⁴ (The World Bank 2019, 2) Furthermore, while agricultural and industrial water use has remained relatively constant in recent years, domestic use has and continues to increase.

¹⁴This is a measurement to compare how much water is used to achieve a set amount of added value in the industrial sector. “China’ s water consumption per RMB 10,000 (roughly US\$1,450) industrial added value is two to three times greater than the average upper-middle-income country (UMIC).”

Figure 1.5 Water Use Structure by Province (100 million m³), 2015

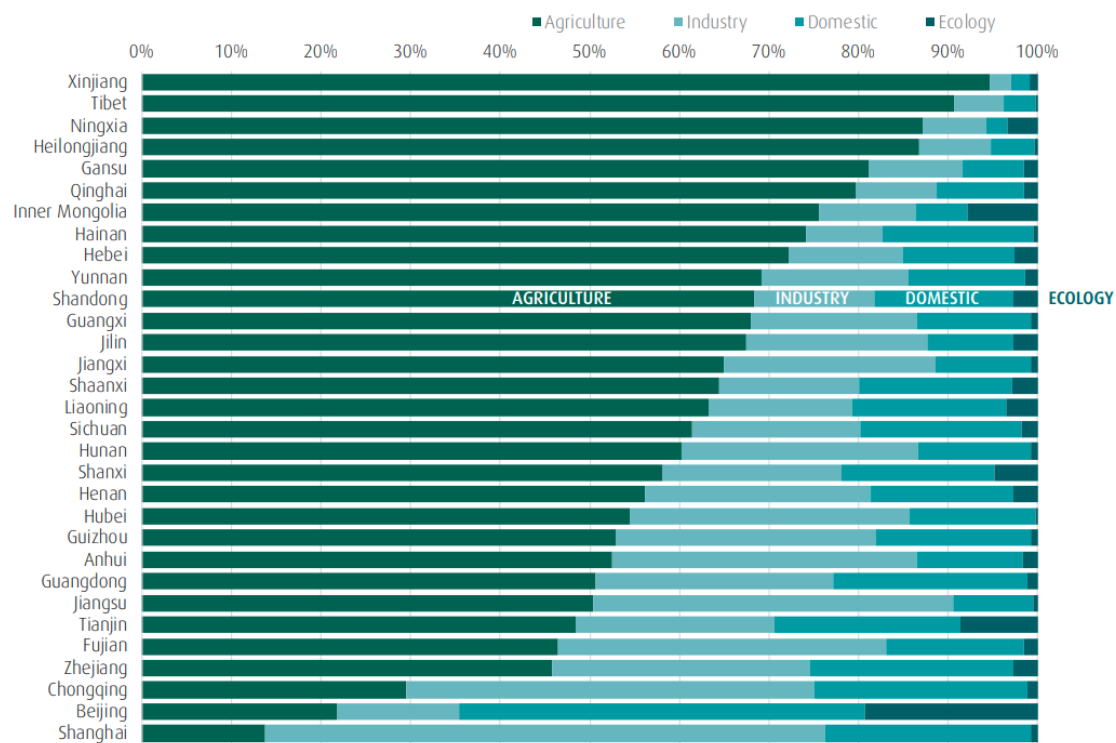


Figure 13: wq_prov_sector.png

Find data, make my own chart (The World Bank 2019, 22)

The two main driving forces for economic growth with relation to water resources are quantity and utilization. (Chen and Tang 2017) Since current technology all but prohibits increasing the overall quantity, the main method of achieving economic growth is to increase the quantity of usable water (by increasing quality) and decreasing inefficiency.

The issues highlighted above lead to increased pressure and deterioration of ecosystem services. Natural ecological systems are decreasing in size, quality, and utility to provide benefits for the society – wetlands and riverbanks are decreasing in their ability to provide flood protection, and wetlands are less able to retain water. (The World Bank 2019, 3) Furthermore, biodiversity has declined significantly. This is at direct odds with China's plan to become an 'ecological civilization,' as highlighted in their 13th Five-Year Plan (2016-2020).

Another notable policy implication is China's energy profile. Coal usage is more prevalent in the north, where water resources are less abundant. Since large quantities of water are required for fossil fuel production and use (roughly six cubic meters per ton of coal and roughly ten cubic meters per ton of oil), diminishing water resources have the potential to strain en-

ergy production. (The World Bank 2019, 3)

Many of these issues are exacerbated by policy coordination problems. While national standards have been discussed in this thesis, water resource management often is in the purview of local and provincial officials. (The World Bank 2019, 4) Water Resource Bureaus exist at all levels of administrative regions, from townships to provincial levels).

7.2 A Multi-Stakeholder, Multi-Scale Approach

This all leads to the conclusion that top-down, Beijing-lead infrastructure programs are not enough to meet many of the SDG 6 targets and indicators.

Engineering as a broader profession can be looked at through an ethical lens. Engineers, and engineering, should not be the end solution, they should be seen as a provider of a service in order to facilitate improvement through informed consent and participation. (Taft H. Broome Jr 1986) states the issue eloquently:

“[E]ngineering is always an experiment involving the public as human subjects. This new view suggests that engineering always oversteps the limits of science. Decisions are always made with insufficient information. In this view, risks taken by people who depend on engineers are not really the risks over some error of scientific principle. More important and inevitable is the risk that the engineer, confronted with a totally novel technological problem, will incorrectly intuit which precedent that worked in the past can be successfully applied this time. [...] Interestingly these new moral dimensions are not being created primarily by philosophers. They are the works of engineers themselves.”

Inclusion of local knowledge and expertise can reduce the impacts of this issue. The less-discussed SDG 6.B mentions this:

Support and strengthen the participation of local communities in improving water and sanitation management. (Martin n.d.)

While data is limited, China had low participation from users and communities for drinking water, sanitation and hygiene promotion in both rural and urban areas, and only had moderate participation for national water resources planning and management in 2017. (“Country (or Area) | SDG 6 Data” n.d.) This seems to have improved with urban and rural

drinking water, with high and moderate levels of participation in 2019, respectively.

Other sectors are also not very involved, due to poor economic policy instruments which do not properly incentivize innovative and sustainable water use. (The World Bank 2019, 7) Improvements in the pricing and accountability of water usage in both abject quantities and inter-agency knowledge sharing would improve the situation from a policy perspective.

The central government has an opportunity to increase local autonomy by playing a coordinating and supporting role. Beijing should continue to set standards and provide funding, but allow local administrators to adapt their implementation. This will have an improvement on regions with low-efficiency of water usage through cross-regional cooperation and communication. (Zhao, Sun, and Liu 2017, sec. 4) Regional governments should prioritize water protection, domestic water usage and industrial motivations, as well as coordinate to reduce discrepancies in efficiency between urban and rural areas (urban areas are usually more efficient). (Zhao, Sun, and Liu 2017, sec. 4)

(Priscoli 2004) examined public participation in water resources management, and identified five areas of concern. Additional context has been added to points of relevance by the author.

1. Ethical dimensions of water management.

Access to safely managed water and sanitation services is a human right, which provides dignity. (Assembly 2010) This includes availability, quality, accessibility, affordability and safety. (Heller 2015)

2. Water management and civic culture.

“Civic responsibility is enhanced when citizens meaningfully participate in making decisions that affect their lives.” (Priscoli 2004, 223) When water, civic culture and governance come together, knowledge transfer and empowerment occurs. While this phenomenon is not new ((Priscoli 2004) cites the fountains in the public squares of many European cities), it is being lost as technical solutions become outside of the understanding of the average resident.

3. Tension between the technical and political.

As discussed previously, technical innovation is important for improving the water quality situation in China. However, in many societies, the technical and political realms operate separately and sometimes at odds with one another. It is important for policymakers to understand some of the technology they are legislating on, as well as for technical professionals to understand the policy mechanism and context.

4. Reconciling the discontinuities between geographic and jurisdictional boundaries.

This ties in with knowledge transfer and local realities, as mentioned previously. Since participation is ultimately a locally-led phenomenon, it is important to coordinate between localities effectively.

5. Need for better and more conflict management.

As water resources become more stressed under the pressure of more demanding users, having knowledgeable and skilled professionals and effective systems to mitigate conflict is vital.

With many of these points, knowledge and education can be the facilitators of positive improvements in the causes and effects of water resources issues.

7.3 Education

In addition to policy changes, education-focused policies should be implemented to directly and indirectly improve China's water situation through knowledge and perception acquisition pathways.

First, water and environmental education should be expanded in scope and scale in China's 9-year compulsory education. A study investigated the relationship between water conservation behavior and water education in Guangzhou, China through a survey ($n = 237$) – they found that additional education will result in improved behavior regarding water conservation, through both awareness improvement and personal behavior change. (Xiong et al. 2016) At least in Guangzhou, a first-tier city with above-average economic status, the authors found that water-conservation

education was extremely rare, accounting for only 0.2–1.4% of the curriculum and included in only four compulsory courses throughout the nine-year compulsory education program. The study found that most students agreed with the premise that water conservation is necessary, but failed to change behavior to address the problem. Further, the least frequent source of water conservation knowledge sources were government activities (10%), indicating a lack of direct knowledge transfer from the current water resources management policymakers. (Xiong et al. 2016, fig. 4)

Similar conclusions could be made with regard to water quality, as it plays a role in water conservation strategies. While another study failed to link higher education levels with water resource efficiency, the authors noted that the lack of this correlation was due to the current weak state of water resource education in the Chinese education system, especially in early phases of education. (Song, Wang, and Zeng 2018, sec. 5.2) This is in contrast with the authors' findings of technological innovation's effect on water resource efficiency — this effect was significant in some but not all parts of the country, further indicating that heterogeneous strategies could prove more effective than homogeneous ones.

In regards to expanding general environmental and water resource education, specific components of water scarcity, water quality, measurement, sources and implications should all be taught. The national government has a very clear, easy-to-understand water quality index, but the thesis analysis reveals that this is not well comprehended by the general public. This should be explicitly taught with a focus on its importance — summarizing many complex indicators into one composite value which is easy to understand, compare and evaluate. Further, education water quality and its implications to many facets of life (as discussed in this thesis) should be expanded. So to should non-lecture-based education. The knowledge and implications should be localized as much as possible, with local experts, field trips, and other experiential learning techniques.

One tool should be a water information sharing platform which is accessible to both the general public and water stakeholders. (The World Bank 2019, 10) For water stakeholders, open data on water quantity, quality, pricing, and utilization can improve the overall water resources management sector. For individuals, access to information about their local, regional and national information on water quantity, quality, pricing, and utilization can improve water awareness, perception and knowledge. It also has the potential to align water quality with perceptions, which can improve political support if positive.

7.4 Conclusion

Water quality and its grave implications for human, economic and political security have been explored at length. This thesis adds the human perception component to the discussion.

The analysis highlights two categories of how water quality perception and knowledge. The first is through education, correlates positively with perception and knowledge traits. Specifically, more educated individuals perceive the impact of water quality to be greater and more harmful than less educated individuals. Also, education in general related positively with knowledge about water quality specifically. The second is though the condition of regional water quality. Perceived severity increases in areas with worse water quality. So to does knowledge about water quality.

Thus, a multifaceted policy approach should be undertaken. This should continue to make infrastructural improvements in water quality, but also make improvements in the education, societal and communication portions of water quality and water resource management. Making the general populous more aware and more engaged in the water pollution discourse can cause improvements in which infrastructure solutions alone can not. With increased trends in urban and domestic water usage, having an informed populous is key to abating water pollution, scarcity and availability issues.

Finally, more research should be undertaken which better models knowledge acquisition pathways for water quality, multivariable analysis on how the variables mentioned in this thesis interact with one another, and quantitative predictions of the impact that non-infrastructure policy would have. With such a serious threat to China and the world, all types of solutions should be considered and implemented.

China has an opportunity to transition from an under-performing water resource actor to one which leads and innovates in multisectoral policy solutions. This will not only cause improvements to various health and economic metrics, but also create a more knowledgeable, engaged, sustainable and satisfied civilization.

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