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A REVIEW OF CURRENT SITUATION AND PROBLEMS OF WATER RESOURCES IN SHANGHAI

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Abstract: Water resource is a vital asset that supports survival of both plants and animals. Shanghai city is located on the east tip of Yangtze River Delta and halfway along China's eastern coastline is said to receive relatively high amount of rainfall therefore recharging both its surface and ground water sources. However due to increased consumption levels this resource has become scarce and Shanghai is one of six cities in the world facing severe water shortages, which poses a threat to the city's residents, agricultural output, energy production, and economic productivity. Apart from water scarcity some of the water sources are highly polluted from the industrial agricultural and domestic effluents containing contaminants like; chemical oxygen demanding agents, ammonia, oils and total dissolved oxygen making the cost of treating the water to meet the accepted level standard expensive. To solve the various issues that Shanghai is facing today the municipal government should modify the various policies, laws and regulations governing the water sector that are in place. Technology is another aspect that can be used to improve the water situations in shanghai since future projections show that shanghai will be faced with high water scarcity levels. The residents are left spending a lot of money to pay for the water bills since the cost is directly charged to the end consumer that is the customer. Despite the challenges most people have access to clean piped water. The quantity might not be as it was years back, but at least the taps are not dry.

Index Terms: water resources, surface water, ground water, water scarcity, water quality, waste water, clean water.

INTRODUCTION

Water resources occupy a special place among other natural resources and is the most widely distributed substance on our planet. This precious resource is available in different forms that is liquid, solid and gases its available everywhere and plays a vital role in both the environment and human life. Of most importance is the Freshwater which accounts for only 2.5% of the Earth's water, and most of it is frozen in glaciers and ice caps[1][2]. The remaining unfrozen freshwater is mainly found as groundwater, with only a small fraction present above ground or in the air. The remaining 97.5% making up for the saline water[3].Whereas the total quantity of water on earth remains constant, its quality changes in both time and space. The problem of water quality causes a great strain on water supply systems, especially in cities along river courses[4][5]. Water resources on the other hand refer to water that is suitable for use, all the waters of the hydrosphere that is, the water of rivers, lakes, canals, reservoirs, and seas and ocean, soil moisture, the water of mountain and polar glaciers and the water vapor of in the atmosphere[6].

According to the UN It is estimated that around a billion people today, that is one in every seven people on earth, don't have access to safe drinking water. Over the years water use has grown at over twice the rate of population increase. By 2025, an estimated 1.8 billion people will be living in areas hit by water Scarcity [7][8][9][10] And, two in every three persons on this planet will be living in regions classified as water-stressed regions. Water-stressed countries are regions with fewer than 1,700 m3 of water per person per year [8]. Most countries in the Middle East and North Africa can be classified as having absolute water scarcity today[1]. These countries will be joined by Pakistan, South Africa, and large parts of India and China by the year 2025[10][11]. This means that they will not have sufficient water resources to meet reasonable water needs for domestic, industrial, agricultural and environmental purposes

Shanghai is located on the east tip of Yangtze River Delta and halfway along China's eastern coastline. It borders the estuary of Yangtze River to the north, Jiangsu and Zhejiang Provinces to the west and Hangzhou Bay to the south the north and south latitudes are 31'14' and 121'29' respectively[12]. Shanghai locates at north subtropical monsoon area with a mild and wet climate and distinct seasons; the precipitation rate is high compared to the other parts of china as the annual average precipitation is around 1096.4mm[13]. The average annual temperatures are 15.4°C and four seasons that's long summer and winter and short springs and autumn[14]. Majority of Shanghai's land area is flat, apart from a few hills in the southwest corner, due to its location on the alluvial plain of the Yangtze's river delta. It is estimated that there are around 23878 water ways in shanghai with a total length of 21, 646.3 km and that is why it is called the city of many of rivers. The Yangtze River which is the longest river in Asia and the third-longest in the world has some part of its delta within shanghai [15]. Apart from the rivers the city is also very close to the sea and there are a number of lakes like Tai lake which is the largest fresh water lake in the Yangtze delta. Water resources in shanghai are increasingly becoming polluted from both point and nonpoint sources due to agriculture, urbanization, and industry which contribute to organic, inorganic and aesthetic pollution of water.

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The city abounds with water resources but its usable fresh water is very limited. The total amount of fresh water stands at 11.88 billion cubic meters which is only 20 percent of the city's surface water. Shanghai's per capita water availability is 1,049 cubic meters, 40 percent of the country's average and 10 percent of the world's average[16]. Most of the rivers are highly polluted; this has resulted to various campaigns to improve the river water quality. An example is the Suzhou creek which flows from nearby Taihu Lake for 53 kilometers through Shanghai before entering the Huangpu River near the historic Bund district at the heart of the city. The Huangpu River is Shanghai's main water source with water from the Yangtze River and groundwater supplementing it. Groundwater accounts for the smallest percentage of water use: less than 1% of Shanghai's total annual water consumption Most of this water is used by industry and the industry to residential ratio of groundwater usage is (19:1) and mainly during the summer; In winter, groundwater is not extracted so as to allow for recharge [17].

China is home to some of the largest rivers in the world though it's facing huge ecological challenges and one of them is the looming water crisis across the country. More than half of China's 50,000 rivers that existed at the beginning of the 20th century have disappeared [18][19][20][21]. The ministry of water resources in 2014 released a report that indicated that more than 400 cities in the country shortfall of water, some 110 of which are facing serious scarcity. Over 70 percent of the country's lakes and rivers are polluted and this according to government reports with nearly half suspected to contain water unfit for human contact or consumption[22][23]. The current water use in China is estimated at 600 billion m3, of which the known groundwater abstraction constitutes 110 billion m3, although the 2010 Groundwater Action Plan indicates the actual abstraction to be up to 150 billion m3[24][25]. China has over 20 percent of the world population, but contains only seven percent of its fresh water[26]. While most of the parts in china have high amounts of water resources that are the south part where Guangdong City is located, others are considered scarce especially in the northern part of china which is dry. To change the current water situation and prepare for the future crisis there are various projects that are underway like a scheme to build over 2,500 kilometers of canals to carry trillions of gallons of water from the wet south to the arid north[27]. It's ultimately expected to be the biggest construction project in history and to cost at least 60 billion dollars

Research has shown that Shanghai water sources are of better quality than inland areas of China and it is acknowledged that nearly 14 percent of the city's sewage is discharged into rivers which serve as Shanghai's water sources without being treated[28]. According to the first water census carried out between 2010 and 2012 in shanghai it showed that only three percent of the water in the city's rivers and lakes was sufficient quality to be used as water resources for residents[16]. The poor quality of the rest of Shanghai's water resources is attributed to discharges by local Shanghai factories. A report issued by the Nature Conservancy in 2016 stated that 73 percent of the water catchment areas that supply surface water, which we depend on for daily consumption, to Shanghai and 29 other major Chinese cities were affected by medium to high pollution levels. In an interview in mid-2016, the director of Shanghai Environmental Protection Bureau, stated that 56 percent of the city's waterways were rated in 2015 as lower than Grade V, the lowest acceptable water quality level based on Chinese national water standard. In 2016 the local government announced its plans to clean up all its Grade 6 severely contaminated rivers by the end of 2017, and all Grade 5 heavily polluted rivers by 2020.

The city is classified as high quality water shortage area, which result from unreasonable water pricing, improper water resources management, Population growth, economic development and urbanization. Water pollution poses an alarming threat to shanghai drinking water. The highest percent of the shanghai population draws its drinking water primarily from shallow wells and freshwater lakes, but most of these water sources are seriously contaminated with bacterial concentrations exceeding hygienic water quality standards[15]. Hence not meeting state drinking water quality standards. The Water resources users use water at a lower price in the city, thus causing the waste of water resources and seriously leading to water pollution, which seriously affect the sustainable use of the water resources and the sustainable economic and social development in Shanghai. Meanwhile, the price of tap water and water conservancy engineering water supply also not consider the value of water resources itself which go against the effective use and conservation of water resources[29]. From the macro perspective, the lack of comprehensive assessment indicators of water resources in the current system of National Accounts of Shanghai results that the local administrative institutions do not pay enough attention to rational development and utilization of water resources, thus causing declining water quality and having a greater negative impact on the environment as well as on the sustainable economic growth of Shanghai.

According to United Nations, Shanghai is one of six cities in the world facing severe water shortages, which poses a threat to the city's residents, agricultural output, energy production, and economic productivity. Primary risks exacerbated by climate change are salt-water intrusions and eutrophication, which affect the quantity and quality of water supply[30]. Cities like Jakarta and Tokyo which are most populous like Shanghai are also facing water crisis as the nation's demand continues to surpass the supply. Currently clean water supply in Jakarta totals to 18.7 m3 per second and it is predicted that in 2025 demand for clean water will reach 41.3 m3/second as the population of Jakarta is estimated to grow to 14.6 million people from 9.6 million currently[31][32][33]. The Projected increase in precipitation and sea level rise, in combination with Shanghai's location (Yangtze mega-delta and Huangpu River), naturally low elevation, flat topography and ground subsidence, is expected to exacerbate flooding[15], causing salt-water intrusion to the water supply. Salt-water intrusions

into the water supply from the Yangtze mega-delta is attributed to rising sea level and will affect 20% of Shanghai's total water supply[34]. Projected temperature increase is expected to cause a rise in surface water temperature, exacerbating incidents of eutrophication, reducing adequate water supply. The map indicates the provinces water situation in china. It is a clear indication that shanghai is one of the china's affected city by the water crisis.

Figure 1. Water situation across the country

Source: Leong, E. (1 et al.). Water Situation in China.

As a result, increasing water demands, overuse and systemic inefficiencies, combined with persistent pollution of major water resources have resulted in depleted supplies of both ground and surface water, with devastating consequences. If current trends continue, the strain on shanghai water resources will be extraordinary, potentially threatening economic development and social stability.

Sources of water in shanghai

Shanghai makes use of its surface, underground water resources and transit water resources, ground water accounts for less than one percent of the water supplied to the city with the rest being provided by the surface water sources. In areas where the surface water is not able to meet the demand people and industries operating in these particular areas are forced to harvest the ground water. This trend has however led to the ground water resources being in a threat due to overutilization. Figure 2 shows the status of water Shanghai water resource quantity in the year 2005.

Ground water

The water table along Shanghai's coast is shallow at about 80 to 120 cm below the surface [35][36]. The source of most of the ground is precipitation that falls directly on the area or infiltration of the surface water. The average annual precipitation is very high some ground water is derived locally by induced infiltration from lakes and streams into water bearing deposits. Water occurs under water-table and arte- Sian conditions both in the unconsolidated deposits of Pleistocene and Recent age and in the consolidated bedrock which is Precambrian to Devonian and Triassic in age[35][37]. After reaching the water table the water moves from the areas of high gradient to the areas of low gradient. Therefore the general pattern of the movement of ground water in bed rock is from the areas of recharge in uplands to the areas of discharge in the lower

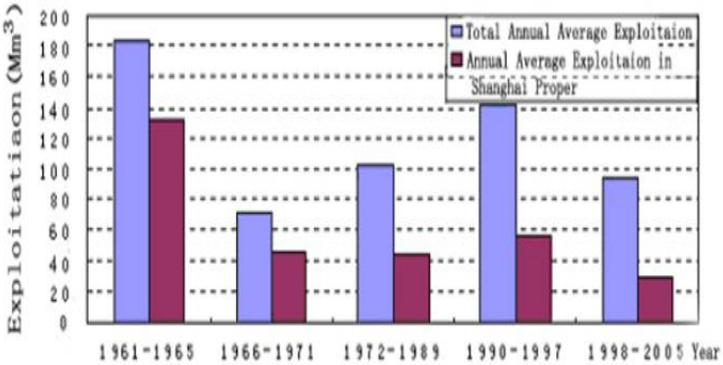
Figure 2. Water quantity from various sources.

Items		years on average	wet year (p=20%)	normal year(p=50%)	dry year (p=75%)	Things dry years(p=95%)
Local water resources quantity	surface runoff	24.15	33.6	22.01	14.97	7.80
	allowable groundwater withdrawal	1.42	1.42	1.42	1.42	1.42
	total	25.57	-	-	-	-
Transit water quantity	Taihulake basin water	106.60	132.10	104.90	84.80	58.70
	Yangtze River transit water	9335.00	10570.00	9188.00	8232.00	7078.00
	total	9441.60	-	-	-	-

Unit: $10^8 m^3$ Data Source: Shanghai water resources bulletin 2005

hillsides and the bottom of the valleys. The figure below shows the trend of ground water exploitation in shanghai.

Figure 3. Ground water extraction trends in shanghai from 1961-2005.



Source W.M.G.E. L.Alley,Ground Water.Academic Press, 2009.

The ground water resource use has been gaining an upward trend since the 19960s with a small decline the 2000s due to measures that were put in place by the Chinese government to counter overexploitation. Most of the ground water harvested is mainly used for agriculture. However extracting the underground water to substitute the river water is expensive since most of it is either polluted by the industrial discharges or the water is saline due to the closeness to the sea. Seawater intrusion is very serious due to the high concentrations of chlorine ion in GROUNDWATER [38]. The water is also highly contaminated with heavy metals, nitrate, sulfate and total dissolved solid and other pollutants. When the water has all these elements its usually difficult and expensive to treat it to be fit for human consumption and growth of crops, since these pollutants bioaccumalate in the crops and when these crops are consumed by the human beings they end up causing adverse effects.

Surface water

Shanghai, as a result of its humid climate and low relief, is abundantly supplied with surface water resources. They include streams, rivers, lakes, reservoirs, and wetlands. The term stream is used here to represent all flowing surface water, from brooks to large rivers. According to Shanghai water resources bulletin, the surface runoff water of Shanghai is 2.201 billion m3 at 50% guarantee rate. Because surface waters are on the land surface, they are easily developed for use and provide the highest percentage of water used in shanghai. As stated earlier it is estimated that there are around 23878 water ways in shanghai with a total length of 21, 646.3 km[18]some of the surface water sources in shanghai include the following.

Yangtze River

The Yangtze River is the longest river in China, running 6,300 kilometers (3915 miles). It is also the third longest river in the world. Its basin, extending for some 2,000 miles from west to east and for more than 600 miles from north to south, drains a huge area in South China[39]. The Yangtze water network covers about 1,800,000 square km, accounting for 18.8% of the land area in China[40]. The river stretches across nine provinces from western China's Qinghai-Tibet Plateau to the East China Sea.

The downstream of Yangtze is the main river section and it's located between Jiujiang and Shanghai. The River is also referred to us Chuan River because most parts flows through Sichuan Province. The famous three gorges dam is located along the Yangtze River, with many lakes scattered along its course. The Yangtze carries more water than any other river in China and contributes the highest amount of water in shanghai. The fertile soils along the river enables production of grains like rice which account for about 70% of the production made in the country[39][41]. Figure four shows the Yangtze River.

Three out of four major drinking water sources in Shanghai get their water from Yangtze River, the Qingcaosha Reservoir, the Chenghang Reservoir and Xisha Reservoir in the southwestern part of Chongming County

Figure 4. Yangtze River network.

Source:https://www.travelchinaguide.com/images/map/yangtze-river/water-system.jpg

Taihu Lake

It is the third large freshwater lake in china and it lies in the Yangtze Delta plain in Wuxi, China. The lake belongs to Jiangsu and the southern shore forms its border with Zhejiang. Taihu which means Great Lake, is a large shallow eutrophic lake, with a depth of 2 meters, area of 2338 km2, and a volume of 4.4 billion m3[18][42]. The water volume varies from season to season and this reflects on the amount of water supplied to shanghai by the lake since the supply volume as varies with the lake volume.

Suzhou River

Suzhou River is the largest branch of the Huangpu River. It stems from East Tai Lake and runs eastward for 125 kms from Guajingkou in Jiangsu Province to the Huangpu River in Shanghai, passing through Suzhou and the counties of Quing-

pu and Jianding. It is a narrow, shallow tidal river with an average width of 40-60m (130m at the estuary)[42]. The average discharge rate is 10-25 cubic meters per second. Although the Suzhou River is heavily polluted by industrial wastewater and sewage, it is an important waterway in Shanghai as it runs for 17 Kms through Shanghai's downtown.

Water use and price in shanghai

It is important to understand the level and pattern of water use in various sectors across the regions for any measures being put into effect. Economic and climatic variables have significantly affected the water demand in shanghai. Water policies have increasingly addressed demand management, which means development of water conservation and management programs to influence water demand. Demand driven measures include adoption of water saving technologies and appliances, awareness raising and economic instruments such as price and tax.

The character of water as a scarce good and the need to efficiently price its consumption has gained increasing recognition. According to china post an article published in 2006 they stated that the city used nearly 3 billion cubic meters of tap water in 2005, an increase of 4.8 percent year on year[29], with the peak daily demand approaching 10 million cubic meters. The water demand in various development sectors is increasing with the increase in population and demand for commodities.

In Agricultural sector water is used for irrigation, pesticide and fertilizer applications, crop cooling for example, light irrigation, and frost control. In shanghai to supply the largest city in the world with enough food a lot of agricultural activities take place in both the green houses and the open fields. Yangtze River belt is very fertile and provides water for agriculture to the nearby communities[42]. When agricultural water is used effectively and safely, production and crop yield are positively affected. A decrease in applied water can cause production and yield to decrease. Management strategies are the most important way to improve agricultural water use and maintain optimal production and yield. The key is to implement management strategies that improve water use efficiency without decreasing yield.

Manufacturing and other industries use water during the production process for either creating their products or cooling equipment used in creating their products. Industrial water is used for fabricating, processing, washing, diluting, cooling, or transporting a product. Water is also used by smelting facilities, petroleum refineries, and industries producing chemical products, food, and paper products[43][3]. Large amounts of water are used mostly to produce food, paper, and chemicals. improving in water use efficiencies is the primary factor for reducing industrial water use, coupled by economic structure adjustment that includes moving from conventional heavy industries towards high-tech and knowledge based industries something that is happening in shanghai. The main driving incentives are the pressing need for upgrading of the industrial structure, more stringent environmental laws and regulations, as well as cutting down the costs for potential resources or environmental crisis. The actual water use per production value has declined rapidly, thanks to the economic structure shift and an improvement in water use efficiencies.

Shanghai being the most populous city in the world needs a lot of water for domestic uses thanks to its many water ways the city is able to get water for the population living within the city. Domestic use here refers to the water used for urban households, urban public sector, rural households and livestock. The water consumption for urban households has increased substantially with improvements in the standard of living. The migration from rural to urban areas contributes partly to the increase. The rural domestic consumption has also increased but not considerably. The regional disparity in domestic water use is apparent. The average annual domestic water use is about 107 m3/capita in Shanghai[29].

In Shanghai the most current water quota was issued in 2001 and doesn't satisfy current conditions and requirements for water saving to the residents. The city closely monitors heavy water-using industries, such as power generation, metallurgy and chemical companies, which consume more than 20,000 cubic meters of water a month[44]. More recycling is required. Shanghai use nearly 3 billion cubic meters of tap water per year, with the peak daily demand approaching 10 million cubic meters[18].

Shanghai has set three price brackets for residential users. A household that consumes 220 cubic meters of water or less a year pays around 3.45 Yuan per cubic meter. Households whose annual water consumption falls between 220 and 300 cubic meters will pay 4.83 Yuan per cubic meter, while those consuming more than 300 cubic meters a year will pay 5.83 Yuan per cubic meter[45][46][47]. The water prices are high due to the high cost of treating the water from the source point the services rendered to ensure that the water gets to the end consumer.

The water quality and sources of pollution in Shanghai

According to an investigative report by the Shanghai Water Affairs Bureau in 2016, it indicated that only about 3.4 percent of the surface water in Shanghai was rated better than Level 3 on average, 23.7 percent was around Level 4, 20 percent reached Level 5, while 52.9 percent was even worse off the scale. Figure five below shows the five main categories that are used to categorize water quality in china.

Only Levels 1 to 3 are considered drinkable after treatment. Level 1 is considered to be very well and requires only simple treatment; Level 2 is slightly polluted but still drinkable with treatment. Level 3 is usually for swimming pools and fish farming, needing careful treatment to become drinkable. The forth level is for industrial use and artificial scenery, no human contact. Level 5 is for agriculture. Anything above level 5 is considered not suitable for any use.

Figure 5.Environmental quality standards for surface water (GB3838-2002)

Grade	
I	Unpolluted
II	Have to be treated first, but is safe for rare and valuable water species
III	Have to be treated first, but is safe for aquafarm and suitable for human use.
IV	Only suitable for industrial production and recreational activities and in some cases no direct contact with the human body.
V	Only suitable for agriculture and landscape design.
V+	Not suitable for any use.

Source: Leong, E. (1 et al.). Water Situation in China.

The growing economic development and increase in population has resulted in serious problems of surface and ground water pollution due to large amount of untreated waste water being discharged into the rivers and other water courses. The location of shanghai; that's at the lower reaches of Taihu Lake and the Yangtze River puts it in a very passive position, therefore it receives pollution from thousands of towns and farms in the upper reaches. Authorities in Shanghai say over half of 2,500 lakes and rivers near the city are heavily polluted[15][42].

According to the first water census conducted in Shanghai in the years 2010 and 2012, 53% of water was said to be below the worst grade of five levels, and only 3% of local surface water was clean enough for fish farms or household use[18]. The surface water pollution in Shanghai is characterized of organic type of pollution. The main polluting contaminants are COD (cr), COD (MN), NH3, oils and total phosphorus. Based on the monitoring data of 2000 water pollution is still serious and the city cannot meet the relevant water quality standard required[34].

It is widely known that some factories discharge chemical waste without treatment into water bodies and excessive use of fertilizer and chemical use in agricultural zones can find its way into the water supplies[1][48][49]. This is a serious problem for health which hasn't been given very much attention. Recently, the Chinese government has been in the middle of a five year plan to deliver safe drinking water to all of shanghai. The focus is to build a 92,300 kilometers of pipelines and thousands of treatment plants[45].

The most famous incident about the quality of water in shanghai is the Suzhou creek water pollution [43]. The creek suffered pollution from industrial and domestic waste water, oil spills from the boats that used to transport goods and material s from the nearby industries and human waste that made it stink. The creek's water failed to meet even the country's lowest water quality standards, and more alarmingly, had become a public health hazard because of the risks of spreading cholera, typhoid, dysentery, and other diseases. The city's children and the poor were most vulnerable as they lived and played near the creek.

Despite efforts Shanghai has made throughout the years such as closing and relocating polluting factories and industries as well as excavating polluted river sediment in Suzhou Creek, which used to be lined with factories that deposited poorly treated or not treated waste water, the general water quality in Shanghai is quite poor[21]. However the situation has greatly changed since 2000s due to the construction of waste water treatment plants and solid water collection wharves. The measures improved the environment of large areas of Shanghai by not only improving sanitation services but also by providing greater access to parks and green spaces along the riverbanks. Major water pollutants in shanghai are Dissolved Oxygen, Volatile Phenols, BOD, lead, copper, petroleum products, cadmium, arsenic and many others[23].

Recommendations

To ensure that the current situation is stopped and avoid more serious issues to arise in the future the shanghai government should come up with various measures. Some of the things that they can put into consideration are the following.

Involving all the stake holders while making urban water plans is essential the process starts by forming a Learning Alliance in which all stakeholders of the urban water sector are represented. The Learning Alliance members jointly define a vision, which is a qualitative picture of the desired future for the water system. The vision is subsequently made operational through the formulation of objectives and sustainability indicators.

Assessment tools can be used to score the indicators. After the objectives have been agreed, it is necessary to consider the external factors that are not controlled by urban water managers, but that are nevertheless very important for urban water management, such as climate change, population growth, and customer preferences.

Waste water should be considered as a resource by using the available current technologies. The system should maximize the benefits from the waste water. Therefore biogas, energy and nutrients are reclaimed from the waste water, after the resource recovery The water can also undergo proper treatment to ensure that all the toxic substances are eliminated and at the end support urban agriculture as well as be used for some industrial purposes.

The city receives high rains and storm water collection systems should be in place. The water should be harvested as a water supply and infiltrated or retained to support aquifers water ways and vegetation. This water can be further treated and used for urban landscape vegetation ,irrigate fields, wash down vehicles, flush toilets, fight fire, and so on, to reduce the reliance on rivers.

Water prices should reflect the cost of developing and delivering water supplies. The municipal government should come up with different tariffs that account for water quality. This will control ground water and surface water use patterns. Tariffs, taxes, and subsidies can be used to distribute benefits fair-

ly without diminishing the productivity of water resources. But if tariffs are set too low so they favor poor users and then cannot support effective operations and maintenance, the system may inadvertently contribute to greater inequality the pricing instruments can be designed so users pay more for higher levels of consumption or quality.

The city should come up with rules and regulations that address urban water systems. Water resources and services laws should provide a comprehensive framework. The framework should be applicable to all utilities both public and private.

Conclusion

Many factors have attributed to scarcity and pollution in shanghai both natural causes and manmade causes which make up the highest percentage. Several factors and measures should be put in place and proper follow up done to improve the current situation. Heavy reliance on the water resources should be reduced to reduce the extraction levels. The Shanghai municipal government should mandate in house recycling and reuse of water for all manufacturing facilities to reduce cases pf industrial heavy reliance on water. The government should provide a timeline for upgrading and consider monetary incentives, such as grants or tax credits, to aid the process. This approach is expected to increase water availability for residential usage and for agriculture industry by reducing competition with developed industry. In addition, this will reduce the industry sector's reliance on an unstable water supply and increase its resiliency to water shortages in case of an emergency.

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