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Faculty of Tropical AgriSciences

Proposal of proper technologies for water purification in Phnom Penh, Cambodia

MASTER'S THESIS

Prague 2021

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Declaration

I hereby declare that I have done this thesis entitled Proposal of proper technologies for water purification in Phnom Penh, Cambodia independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 01/08/2021

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Ponloeu Chhour

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Abstract

The intention of the research is to propose water purification technology, which is effective and efficiency for the reduction of pollution in water to fit with WHO and Cambodia clean water standard. The specific objective of this research is to identify the compounds in water sources of Phnom Penh Cambodia and evaluate their influence on the community and the environment. The data was collected from lake, river and tap water. The data was then compared with the past PPWSA report. The result illustrated that there is coliform which effect the water quality and as well certain arsenic level leaking out to the environment from the underground water to the river. Therefore, the study proposes the adaptation of new technology such as activated carbon, ion exchange, ferrate treatment and reverse osmosis for future water purify in Phnom Penh, Cambodia. Furthermore, the adaptation of new technology could help Phnom Penh reduce physical, chemical, and biological hazard in the future as water is the most important sources for both human being and developing of the country.

Keywords: water purification technologies, pollution, Phnom Penh, Cambodia, reverse osmosis, ferrate treatment, activated carbon, ion exchange.

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List of abbreviations

ADB	Asian Development Bank
AFD	Agence Francaise De Developpement
AOAC	Association of Official Analytical Chemists
As	Arsenic
BBC	British Broadcasting Corporation
℃	Degree Celsius
Cd	Cadmium
CDC	Central for Disease Control and Prevention
CO_2	Carbon Dioxide
Cr	Chromium
Cu	Copper
EPA	United States Environmental Protection Agency
FAO	Food and Agriculture Organization
GAC	Granular Activated Carbon
GDP	Gross Domestic Product
ODC	Open Development Cambodia
HDPE	High Density Polyethylene
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Program
Km	Kilometer
mg/l	Milligram per liter
MLMUPC	Ministry of Land Management, Urban Planning and Construction

MOWRAM	Ministry of Water Resources and Meteorology
NCDD	National Committee for Sub-National Democratic Development
Ni	Nickel
NIS	National Institute of Statistics of Cambodia
NTU	Nephelometric Turbidity Unit
PAC	Powder Activated Carbon
Pb	Lead
PPCH	Phnom Penh City Hall
PPWSA	Phnom Penh Water Supply Authority
RGC	Royal Government Cambodia
Tl	Thallium
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
UNTAC	United Nations Transitional Authority in Cambodia
V	Vanadium
VOC	Volatile Organic Compound
WB	World Bank
WHO	World Health Organization
WTP	Water Treatment Plant
Zn	Zinc
µg/l	Microgram per liter

1 Introduction

The lack of access to clean water and water pollution are two fierce challenges in developing countries, especially in those urban cities which are growing rapidly. Not only these problems cause one of the foremost risk factors for illness, diseases and death, but they also hinder the development of economy and productivity.

In the developing countries, scarcity of clean water is common due to the limited access to it and the poor infrastructure. Cambodia is one of the developing nations in South-East Asia with the capital city of Phnom Penh. This country is still facing such challenges in several parts of the country despite the fact that it is rich in fresh inland water. The geography of Cambodia is quite blessing in terms of natural resources and fresh water. The central plain includes 75 percent of the land area and hold between 10 to 30 meters above sea level. The central plain is drained by the Tonle Sap river, the Mekong river, the Bassac river and many smaller tributaries. The Great Lake, the Tonle Sap lake is the main feature of the central plain. The lake has a surface area of around 8,155 km^2 and can store water at around 15.9 billion m^3. It is started as the largest single freshwater storage and source of inland freshwater. The central plain itself is bounded by sandstone mountain range in the north where the border with Thailand is formed, by granite mountains in the south and southwest, and a basaltic highland in the northeast of the country. However, it is seen that in some areas of the country, people still need to transport water in a traditional way. In other words, water is taken from wells, rivers, lakes, or rain then it is cleaned by certain methods such as boiling for instance. Such difficulty occurs because of the lack of infrastructure and necessary distribution systems all over the country.

The capital city of Cambodia is rapidly growing as the number of people incoming to the city is increasing due to job finding and commerce. Since the area is basically expanding, the water distribution infrastructure is found to be insufficient to sustain such growth in number of populations. The government of Cambodia is now facing the lack of clean water not only in the rural areas but in the suburbs around the capital.

This study aims to tackle this challenge and to identify the main sources of water in Cambodia as well as to assess and evaluate the quality of water and the infrastructure. It also focuses on the contemporary water treatment and purification methods used in Cambodia and especially in the capital city of Phnom Penh.

The research is inspired by the challenge itself that the country is facing because the author believes that the access to clean water is the fundamental priority that any government in developing countries need to focus on. It is very delightful to investigate on this matter in order to identify the setbacks in the water infrastructure and the water treatment methods in placed. This paper also seeks to answer the research question:

How to improve water purification technologies in Phnom Penh?

This diploma thesis contains three main parts: theoretical and practical part along with the results. The theoretical section introduces the basic background of Cambodia including climate, geography and the hydrology and water situation in the country. It also mainly involves the geography of the capital city in question, water sources, water distribution systems as well as the water treatment plants in the city.

Moreover, to answer the research question above, the practical part consists of the methodology used in the paper, data collection process and data analysis such as water testing and test comparisons. Both primary and secondary data analysis are used as the methodology. This section also elaborates on the water treatment process in current practice as well as the water treatment technologies. Furthermore, the author further explains certain other technologies namely the Ferrate technology, the ion exchange technology and the reverse osmosis technology. Last but not least, the results along with the discussion are to be presented after the practical part in order to fulfill the goal of this diploma thesis.

2 Background of The Kingdom of Cambodia

2.1 Basic Information

Cambodia or officially known as The Kingdom of Cambodia, receiving independent from France in 1953 (Kiernan 2010), is located in Indochina peninsula in Southeast Asia. Cambodia is bordered by Vietnam to the east, Lao PDR to the north and Thailand in the northwest with Phnom Penh as the capital. This country occupies an area of 181,035 km² with the population of 16.25 million (WB 2018). Most of the country's population are Theravada Buddhism (95%) (Sovechea 2018) and the rest are Christian, Muslims, animists, Jews, Baha's and Cao Dai adherents. Cambodia has its own language known as Khmer. Since 1985, Cambodia have just one Prime Ministry known as Hun Sen (BBC 2014). Cambodia is a war survival country, surviving from two decade of civil war (1970s and 1980s) and a decade of unstable politic and internal conflict between the states (1990s) (Chandler 2008). In 1993, the very first Royal Government of Cambodia was established with the help of UNTAC (Frost 1994).

2.2 Geography

In geographically point of view, Cambodia landscape is dominated by many characteristic geographical features including the central plains, the Mekong River and the Tonle Sap Lake (Tyner 2008).

The central plains cover approximately 75 percent of Cambodia's area. Around the plains there are highland forests which include the Elephant range, Cardamon and Dangrek mountain range along with the Chhlong highland and Rattanakiri plateau that merge with Vietnam's central highland (Smedley 2016). In the Cardamon mountain range, there exists the highest peak of Cambodia Phnom Aoral 1831m) (Grismer et al. 2007). The Elephant range has an elevation of 1079m (Rundel et al. 2003) and Dangrek mountains at the north of the country have elevations of an average of 500m with the highest peak reaching 700m (Shewan et al. 2020).

The Mekong River is one of the largest rivers in Asia and the largest in Southeast Asia and known as the 12th largest river in the world. Its origin rests in mainland China, and it flows through Myanmar, Thailand, Laos PDR before reaching Cambodia and continue to Vietnam before it flows into the sea (Sok et al. 2020). The Mekong River comes across the capital of Cambodia (Phnom Penh) and over there intersects Bassac river in the south and Tonle Sap River to the northwest.

The Tonle Sap is a combination of lake and river system. Tonle Sap is well known as the largest freshwater reservoir in Southeast Asia (Uk et al. 2018). It was named as UNESCO biosphere in 1997 because of its valuable ecological location (Mitchell 2005). The most unique thing that Tonle Sap has is that the change of direction of the current direction twice a year, it flows south to the sea in the raining season and flows back from south back to the lake during dry season. During the monsoon season, the Mekong River rise and bring water in to Tonle Sap and enlarge it four time its normal size, then when the dry season come, the water from Tonle Sap flow back into the Mekong (Kummu et al. 2014). The Tonle Sap is well known in Cambodia as an excellent source of freshwater fish.

2.3 Climate in Cambodia

Cambodia's climate is impacted by the monsoon winds, which characterize two main seasons. The rainy season starts from mid of May to early October because this is when the strong wind from southwest (the sea) brings in heavy rain and high humidity. The dry season starts from early November to Mid of March, where the wind from northeast (land) is lighter and drier (Chhuon et al. 2012). The average temperature in Cambodia is high all over the year ranging from 28 degree Celsius in January, which is the coldest month, to about 38 degree Celsius in April, which is particularly the hottest month (Dewan 2015). The Annual precipitation fluctuates noticeably throughout the country according to land elevation. The seaward slopes of the southwestern highland receive more than 5,000mm, while those in the central lowland receive about 1,270-1,400mm of rainfall during the year. In fact, 75 percent of the annual rainfall happens during the rainy season, while the 25 percent happen during the dry season (Thoeun 2015).

2.4 Economy

Cambodia has started to transform themselves from centrally planned economy to an open market economy since 1989 (Hang 2015). In 1993, the very first Royal Government of Cambodia was established with the help of UNTAC (Frost 1994). After the first election was done, the country started up with the first legislature. A number of national plans and development strategies were made in other to fulfill the development of the country. Since then, the government has adopted the free-market economy and has given the priority of development policies in the promotion of socio-economic development in order to lift up the country's deficient out of poverty and put the country on a route toward sustainable economic growth (RGC 2018). After two and a half decades of solid economic growth, Cambodia has achieved the low middle-income status with gross domestic product (GDP) per capita reaching USD 1,510 in 2018. Cambodia has maintained the average growth rate of 7 percent between 1995- 2020 (WB 2020). The economic growth in Cambodia comes from tourism and agriculture sectors. Most of the government's development policies focus on agriculture sector as economic growth, poverty reduction and food security (Samreth et al. 2019). The three main leading sectors are services, agriculture, and industry. The agriculture sector is the most important sectors accounting for 22 percent of the country GDP and employed 31 percent of the population (ODC 2020).

2.5 Hydrogeology and water situation in Cambodia

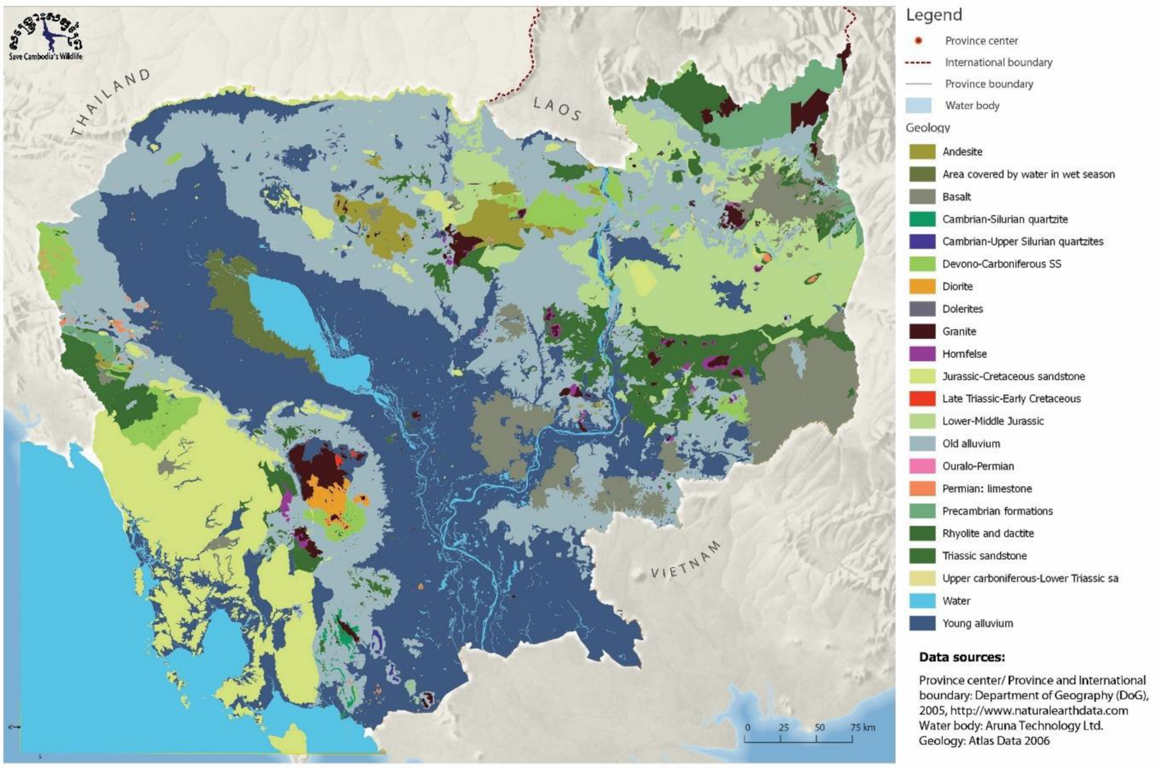


Figure 1 Cambodia geology and hydrogeology map

Source: ODC 2006

Cambodia has a unique hydrogeology system. It is determined by Mekong River and Tonle Sap Lake system. Cambodia has total internal renewable freshwater resources per capita of 7,533 cubic meters of (WB 2017). The country is blessed with great climate circumstances and great geological conditions.

Cambodia's average rainfall is estimated to be around 1,904mm yearly, with the precipitation volume of about 344 billion cubic meters (Knoema 2017). The rainfall is distributed according to the elevation of the area. The south-west region which is the coastal and high land area receives more than 5000mm while the central lowland receives around 1200mm (Tsujimoto et al. 2018).

The volume of groundwater is likely to be about 17.6 billion cubic meters. While the volume of surface water is estimated to be around 116 billion cubic meters (Knoema 2017). Although Cambodia highly have inherited high advantages with decent amount of rain and underground water, people still struggle with water supply. Roughly 3.4 million of people do not have access to safe drinking water, in other words, 2 out of every 10 people. With around 77 percent of Rural Cambodians have poor access to safe water and as a result, this affects their rural community. Even though Cambodia is one of the fastest economic growing countries in Asia, getting hand on water is still a barrier for rural families to secure water for their home usage. Cambodia government has tried to set a goal of providing 100 percent of rural people the access to water by 2025 (Water.ORG 2020).

2.5.1 Cambodia main river

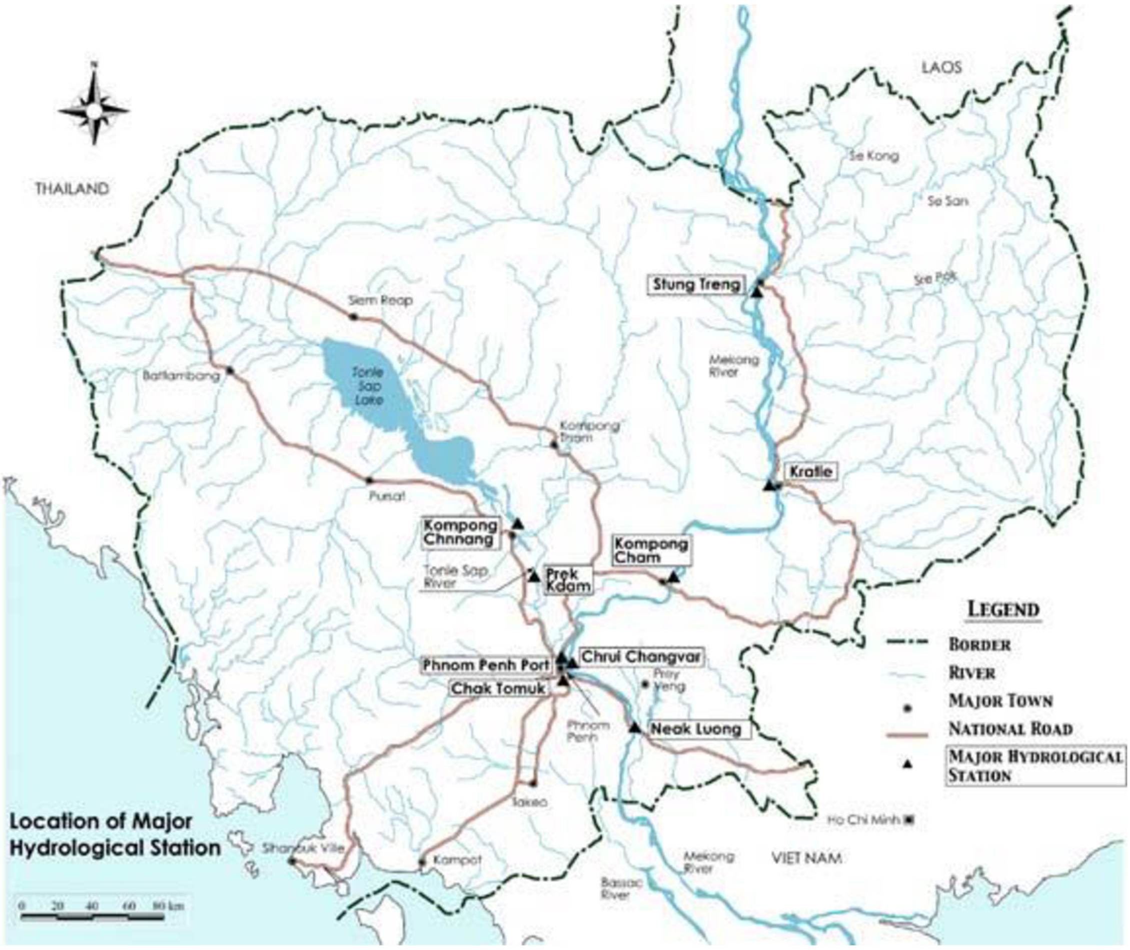


Figure 2 Hydrological system of Cambodia
Source: Morishita et al. 2004

2.5.1.1 Mekong river

The Mekong known as Mekong River, is the world 12th longest river and the 6th longest river in Asia. Its length is about 4,909 km with the drains area of 795,000 km^2 providing 475 km^3 annually (Sok et al. 2020). The river is originated in Tibetan Plateau in China, flowing through Myanmar, Laos PDR, Thailand, Cambodia, Vietnam before it reaches the sea. Mekong is the major trade route between western China and Southeast Asia, but because of the variation in flow and existence of rapid flows and waterfalls, the navigation becomes a bit difficult in some parts (Serrat 2004).

The Mekong River is separated into two main parts, the upper Mekong basin and the lower Mekong basin (FAO 2011). The upper Mekong basin flows around 2,200 km from Tibetan Plateau, with elevation of 4,500 meters and decreases it attitude before it enters the lower Mekong basin in Yunnan province, the border of Myanmar, Lao PDR, Thailand and China so called the Golden Triangle. Following the Golden Triangle, the lower Mekong River keeps on flowing further 2,600 km through Lao PDR, Thailand, Cambodia, and Vietnam before it enters the South China Sea (Pokhrel et al. 2018).

2.5.1.1.1 The upper Mekong basin

The upper basin covers roughly 24 percent of the total area and providing about 15 to 20 percent of water flowing in Mekong River (Pokhrel et al. 2018). The catchment area of the upper basin is steep and narrow; therefore, soil erosion usually occurs and approximately 50 percent of the river sediments flow from the upper basin (Mekong River Commission 2005).

In Yunnan Province China, the river and its tributaries are enclosed by narrow and deep gorges. This part of the tributary river systems is small and there are only 14 have catchment areas that go above 1,000 km^2, although it can be considered a great amount of loss in forest area in the whole river system per square kilometer. It occurred in this region because of the heavy unrestrained demand for natural resources. In the southern region of Yunnan mainly in Simao and Xishuangbanna, the current of the river is moving slower because the valley becomes bigger, and the flood plain becomes wider (Adamson et al. 2009).

2.5.1.1.2 The lower Mekong basin

There are major tributary systems found in the lower basin. The systems can be separated in two groups: tributaries that drain low relief regions of lower rainfall, and tributaries that contribute to the major wet season flow. The primary group is found along the left bank, which pumps out the high rainfall areas of Laos PDR. The secondary group located on the right bank, which known as Chi River and Mun river, that pumps out a large part of northeast Thailand (FAO 2011).

Laos relies almost completely within the lower Mekong basin. The climate, landscape and land usage are the main factors shaping the hydrological system of the river. There are only 16 percent of the country, which is mountainous area, therefore most of the farm areas are under lowland terrace and upland shifting cultivation (Mekong River Commission 2005). The upland shifting cultivation (slash and burn) delivers problem to the soil. The soils fertilization could recover within 10 to 20 years, but the vegetation does not. Shifting cultivation is commonly used in the upland of northern Laos, which is about 27 percent of the total land used under rice cultivation (Lacombe et al. 2010). The biggest problem around the basin in the last three decades are the rapid loss of forest cover which is caused by shifting cultivation and permanent agriculture. There is no clear measurement toward the amount of loss and the cumulative impacts, but it is certain that it effects the lives both under water and on land around the basin (Leinenkugel et al. 2015).

In the past 60 years, the forest lost in Thailand around the lower Mekong basin has been recorded as the highest amount among all the Lower Mekong countries. The forest area was reduced from 42 percent in 1961 to about 13 percent in 1993 in Khorat Plateau, including Chi and Mun tributaries (Mekong River Commission 2005). Even though the northeast of Thailand has about 1,000 mm of rainfall annually, but a high evaporation in the area makes it classified as a semi-arid region (Nawata et al. 2005). Chi and Mun basins drain about 15 percent from the Mekong river and they contribute about 6 percent of the average annual flow (Mekong River Commission 2005). The most common soil types that can be found in the northeastern Thailand are mostly sandy and saline, which mean that most of the land is not suitable for wet rice cultivation. Despite the poor fertility rate in the soil, the agriculture in that area is very intensive. People cultivate tons of glutinous rice, cassava, and maze. Because of the soil type that they have, drought have been the major hydrological threat in northeastern of Thailand (Arunrat et al. 2020).

After Mekong flows through Myanmar, Thailand, and Lao PDR, it eventually continues to Cambodia. Over 95 percent of the Mekong flows have come together and enter to Cambodia river and tributaries system. From this point flowing toward downstream, the terrain becomes flatter and the movement of the water across the landscape is determined by the volume of water distributed from upper stream. There is a unique water flow in Cambodia, which distinguish by Phnom Penh where 4 rivers meet each other. The unique flow known as the "flow reversal" is caused by the seasonal changes of water levels in Phnom Penh. The water flows into and out of the great lake Tonle Sap through Tonle Sap River depending on the level of water. Phnom Penh is the mark of the beginning of the delta system of Mekong (Kummu et al. 2014). Because of the good soil condition with low drainage, wet rice cultivation becomes the main crop and is grown throughout the flood plains of Tonle Sap, Mekong and Bassac rivers. The forest area around the rivers in Cambodia remains enclosed with diverse evergreen forest, although the forest cover had certain loss, it decreased from 73 percent in 1973 to 63 percent in 1993 (Mekong River Commission 2005).

Before Mekong River reaches the sea, its last destination is Vietnam. The area is known as Mekong delta. This area is blessed with fertile soil that is brought from the upper stream (Dapice & Xuan 2011). Due to this reason the forest area had decreased significantly from over 95 percent in 1950s to around 50 percent in mid 1990s in order to use for agriculture purpose (Mekong River Commission 2005). The major reasons that affect the landscape changing and land used are from the population pressure and the agricultural expansion. Drought and flood are commonly happening in the Mekong delta, which happens due to the change of water flowing from upstream Cambodia (Hung 2016).

2.5.1.2 Tonle Sap

Tonle Sap is a seasonally overwhelmed and the largest freshwater lake in Southeast Asia (Uk et al. 2018). The lake connected with Mekong River and Bassac river in Phnom Penh, Cambodia. The rivers in Cambodia form the complex hydrological system with the length of 12,876 km^2. The floodplain covered with a variety of natural and agricultural habitations which filled by the Mekong with water and residues annually. The central plain pattern is the consequence of millions of years of Mekong sedimentary discharge and deposition (Olson & Morton 2018). With a geological viewpoint, the Tonle Sap Lake and river are a current freeze-frame interpretation of the slowly, but continuously moving to lower Mekong basin (Campbell et al. 2009). The annual rise and fall of the Mekong's water level, accompanied by the monsoon regime create a reversal flowing of the Tonle Sap River back and forward. Tonle Sap is the largest freshwater lake in Southeast Asia, it has an extraordinarily large variety of interrelated eco-regions with a high amount of biodiversity. The lake was given the title of UNESCO biosphere reserve in 1997 (Mitchell 2005).

Tonle Sap Lake inhabits a geological depression, with the enormous sedimentary and lacustrine floodplain from the lower Mekong basin. The size, length and water volume of the lake varies noticeably during the year (Kuenzer 2012). In the end of the dry season during the late of April, the area of the lake is around 2,500 km^2, length of 160km and a volume of 1 km^3. During rainy season during September and early October the length of the lake expands to around 16,000 km^2, length of 250 km and a volume of 80 km^3 (Uk et al. 2018). Tonle Sap Lake directly and indirectly provides many benefits to the rural livelihood, with enough water supply for crop cultivation and a high amount of biodiversity for food supply throughout the year (Chou & Nop 2014).

In recent years the lake and the surrounding ecosystems meet a tremendous pressure through deforestation, climate change and infrastructure development. Most of the Mekong riparian countries have constructed dams in other to exploit the river's hydroelectric potentials (Baran & Myschowoda 2009). Due to this matter, it has become a threat to the Tonle Sap ecology by reducing the flow of water into the lake and reducing the tributaries connectivity. On the other hand, climate change has caused a severe drought in Cambodia in the 2010s, which has impacted the annual water flow into the lake. At the same time, fisheries and food security of the population around the area have been affected by the lack of water in drought season (Chhinh & Millington 2015).

2.5.1.3 Bassac River

The Bassac river is the distributary of Mekong and Tonle Sap river. The river originated in Phnom Penh, Cambodia and flows to the south, crossing border toward Vietnam in Chau Doc province. The Bassac river has a length of 190 km (Kuenzer 2012). This river is a very important trade route and transportation between Vietnam and Cambodia. The name of Bassac river came from the ancient temple name Prasat Prey Bassac, which was built in 2nd and 3rd century near the Cambodia and Vietnam border this day (Chandler 2008).

2.5.2 Water Quality in Cambodia

Water pollution in Cambodia can be defined in many diverse ways. The water pollution is the contamination of water when contaminants are liquidated into water forms without treatment. The water pollution in Cambodia is mostly caused by agricultural, industrial, and household waste, which considerably harm human and animal health and as well the water bodies quality (ODC 2016).

Access to clean and safe water in Cambodia remains a major challenge, mainly to rural households since there is always limitation for accessing to water facilities outside the cities. According to UNICEF 2014 reported, 6.3 million out of 14.9 million Cambodians lacked the access to clean and safe drinking water. Rural regions frequently struggle to have standing water and mostly runoff giving a result of insufficient infrastructure, especially happen between May to November during the monsoon season (Irvine et al. 2006). In majority of rural villages, the water consumptions are based on rainwater and mostly it is kept and stored in cement tanks (Pheng 2019). Due to this circumstance, the stored water could contain parasites. Because the country is affected with monsoon climate, there are mostly heavy rains and this could leave stagnant water behind, which added to the spread of pests like mosquitoes and snakes. These heavy rains and the stagnant water usually create problems when normally trash and waste are left around the households (Poirot et al. 2020). For that reason, the water is mostly contaminated and drained to nearby agricultural fields and later consolidated with the groundwater.

Arsenic concentrations in groundwater in different zone of Cambodia, mostly along the Mekong River region have become a main concern in recent years. According to Phok et al. 2018, between 2005 to 2009, they have used test kit to test 30,839 of 47,950 national well in 7 provinces such as Prey Veng, Kampong Chhnang, Kampong Cham, Kampong Thom, Kratie, Kandal and sub-urban of Phnom Penh. The result illustrated that 35 to 38 percent of the well are contaminated with Arsenic above the Cambodia clean water standards (0.05 mg/l). Figure 3 show that ground water at Kandal province have the most Arsenic contamination of an average up to 94.7 ppb (0.94 mg/l).

Province	Tested Wells	Average As (ppb)	% Wells >=50ppb	% Wells >=250ppb	Estimated Impacted Pop.
Kampong Cham	7775	52.5	36.5	6.8	25,552
Kampong Chhnang	1083	11.0	8.1	0.7	3,932
Kampong Thom	1955	10.9	6.6	0.1	2,358
Kandal	17709	94.7	35.9	17.4	69,593
Kracheh	1010	16.3	13.8	1.3	1,144
Prey Veng	10648	32.0	16.8	5.2	40,922

Figure 3 Provincial summary of Arsenic in Cambodia

Source: RDI 2020

According to Asian Development Bank 2016, almost 80 percent of wastewater remains untreated after it is released to the environment. Within these issues it creates waterborne diseases, and it becomes a huge concern throughout Asia-Pacific region, and it is clarified as a global hot location of water insecurity. Waterborne disease causes diarrhea which is the second largest problem contributing to the death of children under the age of five. There are about 35 percent of clinics and 40 percent of primary schools in Cambodia, which are still unfortunately facing the shortage of clean water (Poirot et al. 2020).

2.6 Phnom Penh

2.6.1 Basic Information

Phnom Penh is the capital of Cambodia and the largest city in the country with the population of around 1.5 million and around 2.2 million people live around the metropolitan area (NIS 2019). Phnom Penh is situated in the central of Cambodia. It was established in 1434 after the fall of Angkor period and become the capital of Khmer but it was abandoned many times before its being reestablished back by king Norodom in 1865 (Chandler 2008). This capital was functioned as the processing center with pharmaceuticals, machine manufacturing, textiles, and rice milling. Big institution for higher learning was formed including Royal University of Phnom Penh was form in 1956 with schools of technology, engineering, fine arts, and agricultural sciences (Tyner et al. 2014).

2.6.2 Geography

Phnom Penh is located in the central region of Cambodia, surrounded by Kandal province. Phnom Penh is blessed with 4 rivers intersecting each other in the middle, upper Mekong river, lower Mekong river, Tonle Sap river and Bassac river (JICA 2002). All of these advantages provide Phnom Penh with sustainable freshwater supply and natural resources. Phnom Penh is about 12 meters above the river level, therefore during the monsoon rainy season there are flooding problem, and usually the river overfloods the city (Ly et al. 2018). Phnom Penh covers up an area of 679 square kilometers (MLMUPC 2020). The city comprises typical flood plain areas which are covered with rice fields and other different agricultural plantations. Figure 1 demonstrates how Phnom Penh has such a nice geographic area with enough yearly water supply.

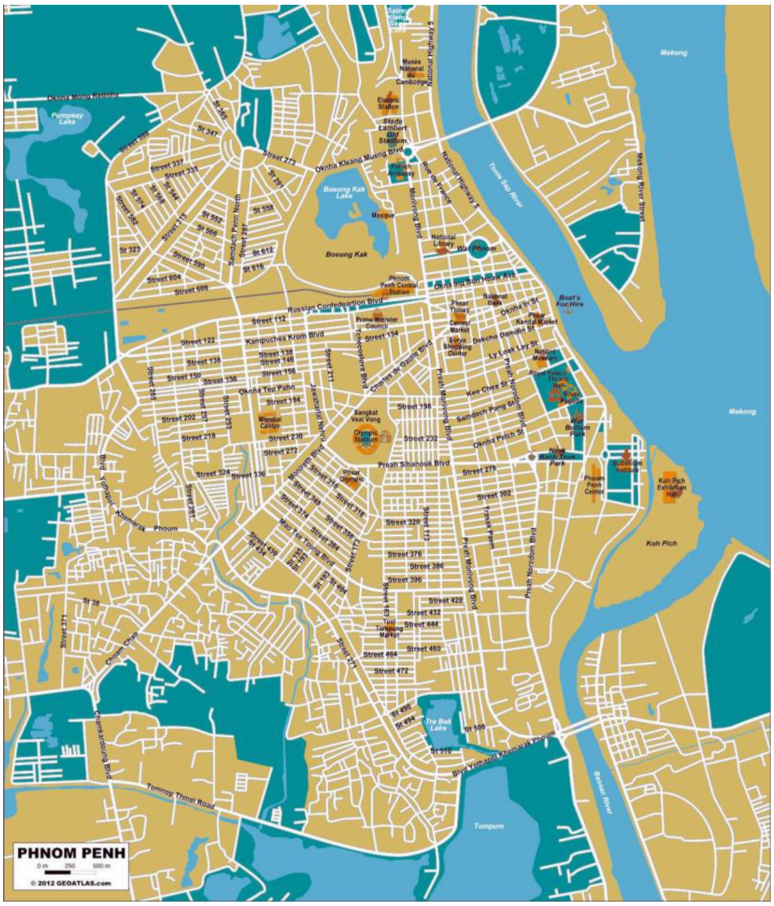


Figure 4 Map of Phnom Penh

Source: Orange Smile 2021

2.6.3 Climate

Month	Mean Daily Minimum Temperature (°C)	Mean Daily Maximum Temperature (°C)	Mean Total Rainfall (mm)	Mean Number of Rain Days
Jan	21.9	31.5	25.5	2.8
Feb	23.0	32.8	11.5	2.4
Mar	24.1	34.9	58.0	5.2
Apr	25.0	34.9	101.0	8.6
May	25.3	34.3	111.6	16.4
Jun	25.0	33.5	177.1	16.6
Jul	24.7	32.5	195.9	19.6
Aug	24.6	32.5	172.0	21.4
Sep	24.3	32.3	248.8	19.8
Oct	23.8	31.1	318.9	24.0
Nov	22.7	29.9	135.0	11.8
Dec	21.7	30.1	80.3	4.8

Figure 5 Phnom Penh mean temperature/rainfall 1997-2019

Source*:* Ministry of Water Resources and Meteorology Cambodia 2020

According to Koppen Climate classification Phnom Penh climate is tropical wet and tropical dry. The temperature normally ranges from 22 to 35 degree Celsius because the weather is mainly influenced by the tropical monsoons (Kottek et al. 2006). Between May and November, the southwest monsoon wind blows from the Gulf of Thailand toward the land bringing in moisture. While from December to April, the northeast monsoon wind blows contrasting from land back to the sea causing the wind to be dry (Chhuon et al. 2012). Phnom Penh encounters the heaviest precipitation between September and October, while the driest months are January and February. The city meets two distinct seasons rainy and dry. The rainy season run between May to November and this causes high humidity. The dry season goes between December to April, when night temperature can drop to around 22 degrees Celsius (MOWRAM 2020).

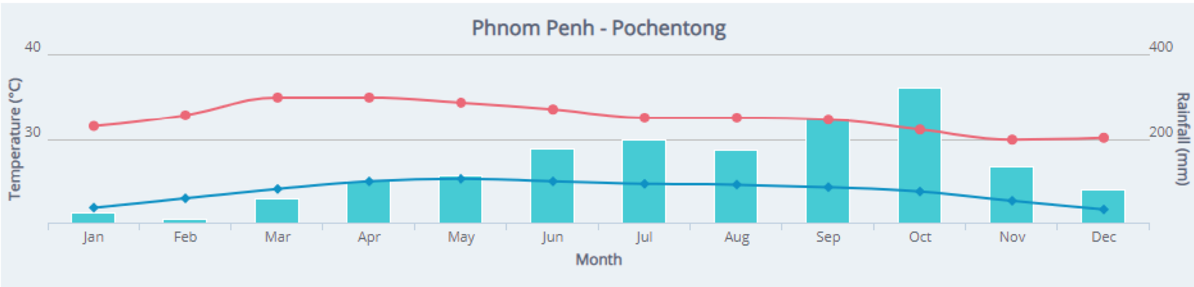


Figure 6 Phnom Penh average rainfall

Source: Ministry of Water Resources and Meteorology Cambodia 2020

2.6.4 Administration

Phnom Penh is a capital of Cambodia with the area of 679 square kilometers and have a government status equally applied to all Cambodian provinces (MLMUPC 2020 and NCDD 2020). The city is separated into 12 administrative divisions namely Khans (districts). The districts are segmented into 105 Sangkat (quarters) than sectioned into 953 Phums (villages) (NCDD 2020). All of the districts are governed by Cambodia Royal of Government which is located in Phnom Penh. The Royal Government of Cambodia usually appoints one officer to govern and act as the top executive of the city as well as supervising the city military, city police and all departments of urban affairs. After the governor, there are first vice governors and other five vice governors to help support when the governor and the first vice governor are not active. Another leading position is the chief of cabinet, who have the same status as the vice governor. There are eight deputy chiefs of cabinet taking turn in charge of the 27 administrative departments. Every district also has its own chief (PPCH 2020).

2.6.5 Economic

The capital city is one of the largest Cambodia's economic centers, representing a large fraction of Cambodian economy. Due to the stable economic growth of 7 percent in Cambodia, Phnom Penh has flourished significantly with new restaurants, hotels, bars, skyscrapers, and big residential buildings springing up around the city (WB 2020 and RGC 2018). Phnom Penh economy is centered on commercial interest like trading, garments, small and medium enterprises. Following the economic boom in the country, the price of real estate has been increasing rapidly. Another major revenue stream of Phnom Penh economy is tourism. The city has quite a lot of history, many commercial and shopping centers followed by the other two big destinations in the country; Siem Reap (Angkor Wat) and Sihanoukvile (seaside) become one of the major tourist destinations in Southeast Asia. According to Knoema 2019, travel and tourism contribute 8.7 billion US dollars to Cambodia GDP, which is about 32.7 percent.

2.6.6 Source of water in Phnom Penh

Cambodia is well endowed with available water resources. It has a high rate of annual rainfall (up to about 4000 mm in the highlands), three major rivers (Mekong, Bassac and Tonle Sap) and their many tributaries, and excellent sources of groundwater both in terms of quantity and quality (Thoeun 2015). In the late 1960s, urban water supply in Phnom Penh was comparable to what then existed in many other neighboring countries. Many of the residents of Phnom Penh had an uninterrupted 24-hour water supply of reasonable quality water (Biswas & Cecilia 2010).

Phnom Penh is where all 4 of the rivers meet together, therefore many of residents had no problem access 24 hour with reasonable quality of water (Pokhrel et al. 2018). Phnom Penh have its own water utility agency workiing to provide clean and sustain water for the city called Phnom Penh Water Supply Authority (PPWSA).

PPWSA was first establish in 1960 by king Norodom Shihanouk. Its main focus is on water treatment, water supply and to ensure income for expenses in water treatment investment (Biswas et al. 2020). PPWSA have increased access for Phnom Penh population from 25 percent in 1993 to 92 percent in 2010. This shows that they have put big effort to make better water access for people in Phnom Penh much better. The capacity was increased from 65,000 cubic meters per day to 592,000 cubic meters per day in 2020 (PPWSA 2020 and JICA 2006).

PPWSA daily water supply and treatment is based on water consumption of people within the service area. The demand could fluctuate with seasonal or weather-related factors. The management of four plant's operation is based on water demand and economic competence of each plant (PPWSA 2020).

2.6.6.1 Water Distribution in Phnom Penh

Phnom Penh's portable water supply network is divided into two parts main pipelines and water distribution pipelines (JICA 2006)

Main pipelines come with large diameters of about 250mm or more. Main pipelines are used to manage potable water from pumping station to distribution pipelines. These days PPWSA have the biggest main pipelines of up to 1600mm. The main pipelines are made from ductile iron, due to the pressure of water flowing from pumping station (PPWSA 2020).

Distribution pipelines are the pipelines with diameters between 50mm to 200mm. Distribution pipelines are used to supply treated water from the main pipelines to customers. Currently PPWSA uses HDPE pipes to transfer water to customers because they are reasonably inexpensive and offer sensible quality. Most of the distribution pipelines are consist of HDPE pipes while only 2 districts – 7 Makara and several parts of Toul Kok have replaced HDPE with ductile iron pipe thanks to the grant from Japanese government (JICA 2006, Kataoka et al. 2018)).

Since 1993, PPWSA pipelines have been incessantly replaced, extended, and upgraded owing to the supports from French, Japanese, Korean and Chinese governments. These days some of the quarters have a hand on cast iron pipes to support the water distribution (Biswas & Tortajada 2010, Horn 2011). So far, the replacement and upgrade of PPSWA pipelines to the old legacy pipelines are:

- In 1993, French government offered a grant to replace 8km of distribution pipelines with size from 80mm to 200mm in 2 districts, Sras Chak and Daun Penh. The main purpose of this project was to help provide training to PPWSA employees in other to get along with the installation of water pipelines (Biswas & Tortajada 2010).

- Between 1994 and 1996, PPWSA received a grant from ADB and WB to replace 68km of pipeline in order to extend the service to Daun Penh district (ADB 2012).
- From 1997 to 1999, a funding from Japanese aid through JICA helped PPSWA replace old pipelines in 3 districts, Daun Penh, 7 Makara and Toul Kok. At the same time, PPWSA also took loan money from ADB to install pipelines at Chamkamon district with the length of 99km (JICA 2006).
- In 1998 to 2001, World Bank and Asian Development Bank once again provided financial support for the replacement of old pipeline and extending the pipeline diameters. The project was to build 221 km of distribution pipelines in Chamkamon and Toul Kok district. The old 700 mm pipeline was replaced with the new 900mm to 1,600 mm (ADB 2012).
- In 2002, after the replacement of old pipelines and the extension of the distribution network in the existing service areas, new grants from WB, ADB, AFD, JICA and many others came in to help in extending new service as the city keeps on expanding. The figure shows how long the distribution pipeline expanded between 1997 and 2018 (ADB 2012, JICA 2006).

2.6.6.2 Water quality in Phnom Penh

The treated water provided by PPWSA follows the drinking water norms of the WHO and public drinking water principles. PPWSA tests the condition of the water that is already treated three times every day at the WTPS and examine 80 water samples every week at different locations of the distributors. Furthermore, the samples of potable water delivered by PPWSA are analyzed at the laboratories in Singapore and Shanghai yearly and the result will be presented whether the water supply by PPWSA is potable (PPWSA 2019).

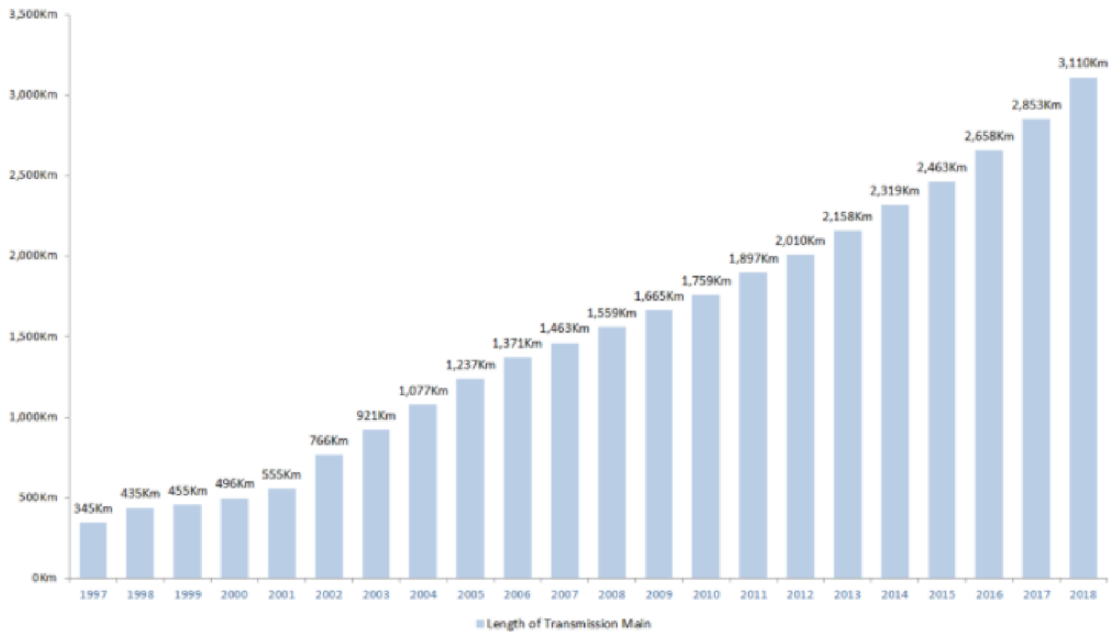


Figure 7 Length of main water transmission pipeline in Phnom Penh

Source: PPWSA 2019

The upkeep of the water treatment framework is directed by PPWSA's operatives, as a result in terms of technical and economic efficiency it is better to outsource the upkeep function. PPWSA’s operator has the necessary skills to perform the maintenance. Additionally, PPWSA has established Standard Operation Procedures (POP) in order to provide maintenance of electrical systems and mechanical systems of the water treatment. The Standard Operation Procedures were first provided by PPWSA in 2006. Generally, most of the repairment of the water treatment system were executed by PPWSA’s worker, except the one that goes beyond their expertise (Seng & Samnang 2019, PPWSA 2020).

2.6.6.3 Water Treatment process

2.6.6.3.1 Raw water intake tower

Figure 8 Water intake tower in Phnom Penh

Source: PPWSA 2021

The intake tower pumps fresh water from the river through the central transmission pipelines to the water treatment plant. There are four main water treatment plants in Phnom Penh, namely Phum Prek, Chamkamorn, Chrouy Changva and Niroth. The Phum Prek WTP drains water from Tonle Sap River, The Chamkamorn WTP drains water from the Tonle Bassac river while the Chrouy Changva WTP drain water from the upper Mekong River and the Niroth WTP uses water from the lower Mekong River. Phum Prek, Chrouy Changva and Niroth WTP were constructed by the concrete and have stable locations to pump water in the river, while Chamkamorn WTP has a floating intake tower. Generally, the water level of the rivers in Phnom Penh varies depending on the seasons (Seng & Samnang 2019). Annually, the level of the water is varied reliant mainly on the Mekong water current and weather condition (Dang et al. 2015).

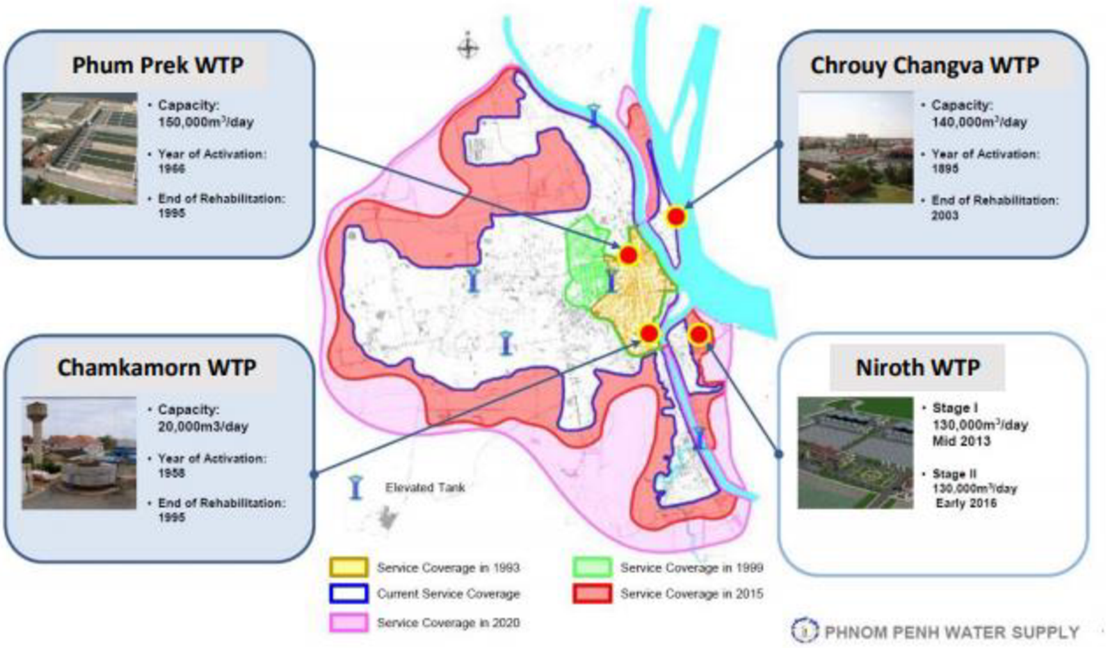


Figure 9 Location of Phnom Penh water treatment plants

Source: PPWSA 2021

2.6.6.3.2 Water treatment plant

The water treatment system in Phnom Penh is separated into 6 stages including receiving basin, stirred basin, flocculation basin, sedimentation basin, filtration basin, and clean water reservoir (PPWSA 2020). The treatment of raw water from the river to potable water involves the use of a variety of chemical components such as lime, alum and chlorine. Every component has various unique functions for the water treatment.

- Lime: Help increase the pH value of the water, this helps lowering the amount of acidity in the water (Ghernaout et al. 2018).
- Alum: Accumulate small particles of residues into larger and heavier particles, which can be cleared out of the water as residues at the bottom of the reservoir. Those small particles involve clay, organic chemical substances, alluvial soil, and other different kind of wastes from the water treatment process (Zhao et al. 2018).
- Chlorine: This chemical help kill bacteria, viruses and eliminate other biological substances like algae from the water.

PPWSA has performed experiments and examinations on the use of compounds call Poly Aluminum Chloride (PAC) in order to substitute lime and alum with PAC. PAC provides better technical and economic performance in water treatment. PAC has been used in PPWSA's operation in some area since 2012 (PPWSA 2013).

The step of potable water treatment process is:

Firstly, the fresh water from the river is drained by the raw water intake tower than transfer to a receiving well. In the receiving well, which is the starting point of the treatment process, the chemical components such as lime, alum and chlorine are added into the water. The water then flows toward the stirring well. In the string well, the water and the chemical components are combined with a high velocity agitator and by the changes in velocity of the water flowing in the well (Seng & Samnang 2019).

Figure 10 Recieving well

Source: PPWSA 2021

After finishing with the stirring process, the water is transferred to the flocculation basin utilized for agglomerating turbidity. This well is equipped with low velocity agitator in order to stimulate the agglomerating and turbidity colliding, so that the large particle can be formed (PPWSA 2020).

Figure 11 Flocculator tank

Source: PPWSA 2021

Next, the water is transferred to sedimentation well. In this place, large particles that were formed from the agglomerated turbidity drain into the well's bed and flow into filtration well. In this step, the large particles and rubbish that float on top are to be removed and some mosses are at the same time to be filtered out. During this step the water translucency should be between 4 to 8 NTU (Seng & Samnang 2019).

Figure 13 Sedimentation tank

Source: PPWSA 2021

Figure 12 Filtration tank

Source: PPWSA 2021

When the water passes through a filtration well, the chlorine is added once again in order to eliminate the bacteria and help remove the excessive mosses. The water translucency should not exceed 5 NTU and at this level the chlorine amount is maintained to meet the clean water standard. After the filtration well the water then move to the reservoir and ready for pump into distribution lines (PPWSA 2020).

The water treatment in Phnom Penh is treated according to the need of the city. The water is treated hourly according to the requirement for water swings, therefore the clean water reservoir is balanced, and the quantity of the treated water is available to meet the demand. The capacity of the reservoirs of clean water are:

- Phum Prek WTP 25,000 m^3
- Chamkamon WTP 1,500 m^3
- Chroy Changva WTP 25,000 m^3
- Niroth WTP 23,000 m^3

Figure 14 Storing tank

Source: PPWSA 2021

2.6.6.3.3 Potable water pumping station

The water pumping station plays an important role in delivering potable water to water distribution systems. The pumping station is equipped with motors and automatic water pressure management system in order to assure the stability of water supply to household (JICA 2016). The main expense of water distribution and water treatment is chemicals and electricity, but electricity remains the higher cost. Without electricity there is no way to supply water to all districts in Phnom Penh, therefore the electricity has been the main concern for PPWSA. While the volume of chemical inputs in the water treatment process are based on the water quality from the river. The chemicals used in water treatment in Phnom Penh are based on the standard of Cambodian national standard and World Health Organization (WHO) (PPWSA 2020).

Figure 15 Controlling room

Source: PPWSA 2021

Table 1 Water standard quality comparison between PPWSA and WHO

Parameter	Unit	WHO standard	Raw water	Phum Prek	Chroy Changva	Chamkamon	Niroth	Distribution Network
Turdibity	NTU	≤ 5	102	0.52	0.63	0.3	0.43	0.82
pH		6.5-8.5	7.64	7.34	7.77	7.32	7.71	7.5
FAC	mg/l	0.1-1.0	0	1.24	0.92	0.94	1.01	0.18
TAC	mg/l	< 2	0.05	1.36	1.03	1.13	1.16	0.3
Total Coliform	cfu/100ml	≤100	21,313	-	-	-	-	-
Faecal Coliform	cfu/100ml	≤ 1,000	5,391	-	-	-	-	-
E. coli	cfu/100ml	≤100	5,391	-	-	-	-	-

Source: PPWSA 2020

2.6.6.3.4 Water Coverage in Phnom Penh

The figure below illustrates the map of Phnom Penh with water coverage from 2015 to 2020. The green area in the middle denotes where PPWSA started the first full-service coverage in 2015. Between 2016 to 2020, PPWSA have expanded the service coverage as shown in the figure by the highlighted area. While the unhighlight area is expected to have access to clean water in 2021 (Biswas & Cecilia 2010). The city has been expanding drastically fast in the past 10 years. The unhighlight area on the figure also demonstrates the city expansion area.

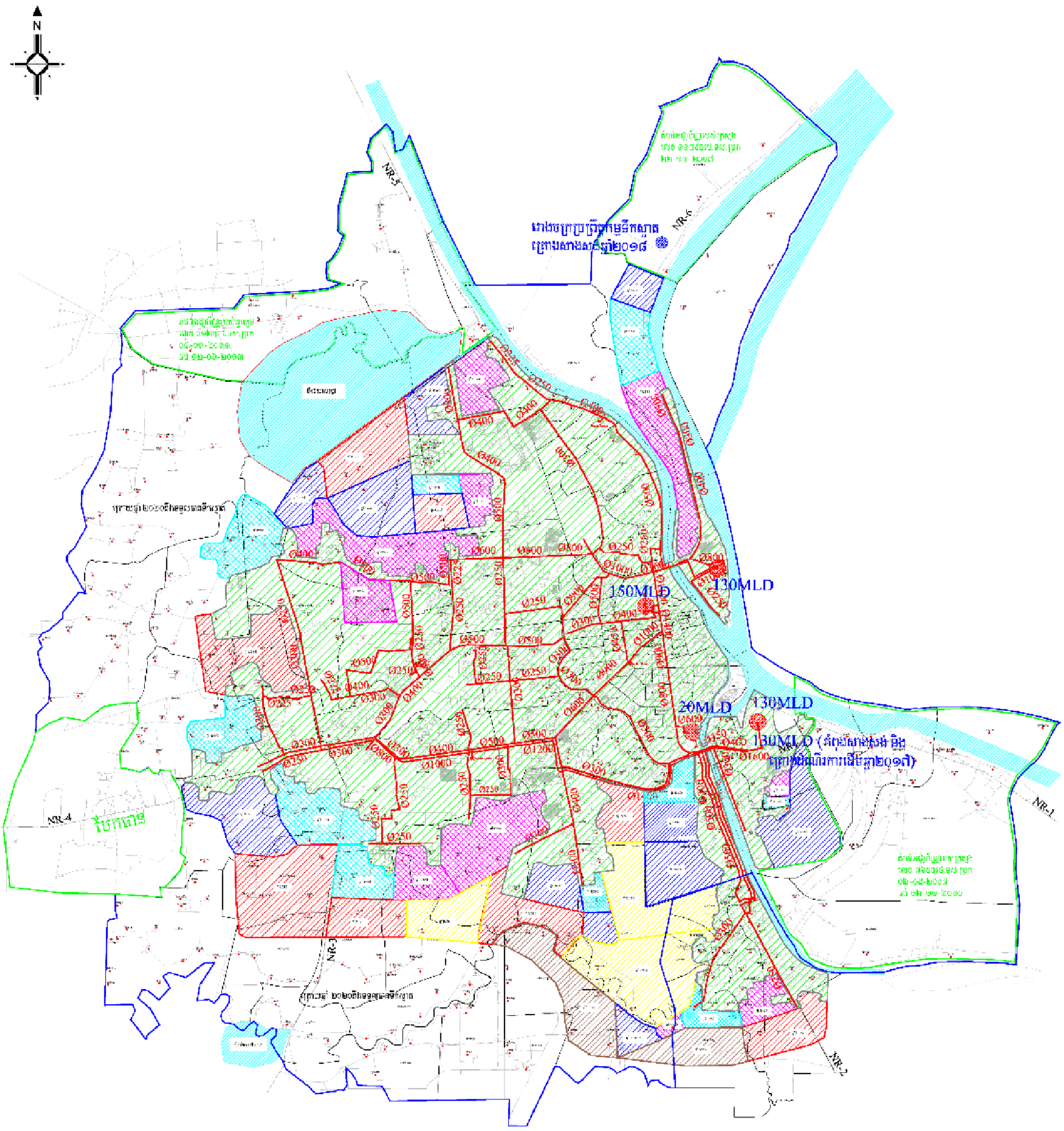


Figure 16 Phnom Penh water coverage

Source: PPWSA 2019

3 Aim of the Thesis

The aim of the study is to study the water pollution level in the four sources of water for Phnom Penh, Cambodia and suggest the technologies that can help maintain the safe water quality level in the town. In order to achieve this aim, we defined the beneficial and different elements of various water treatment techniques. The proposal methods should fulfill the WHO guideline for safe drinking water.

• Specific Objective

A further aim of the thesis is to:

- Verify the unsafe chemical parameters in water usage.
- Test the chemical level of four sources of water.
- Identify the level of pollution
- Provide recommendation of proper water treatment technique

4 Material and Methods

The research starts by collecting water samples across Phnom Penh to use as primary data. Next the secondary data is collected from professional scientific literatures and articles, which are related to the water treatment topic. After primary data is collected, the data is tested in Phnom Penh laboratory and in Prague laboratory in order to put on comparison. The data is then analyzed, evaluated and processed to determine the apparent quality of the treated water. The secondary data is applied in order to support the primary data. The very last step is to suggest and propose different technology design for water purification technology, which could maintain the water quality according to WHO standards.

4.1 Study area

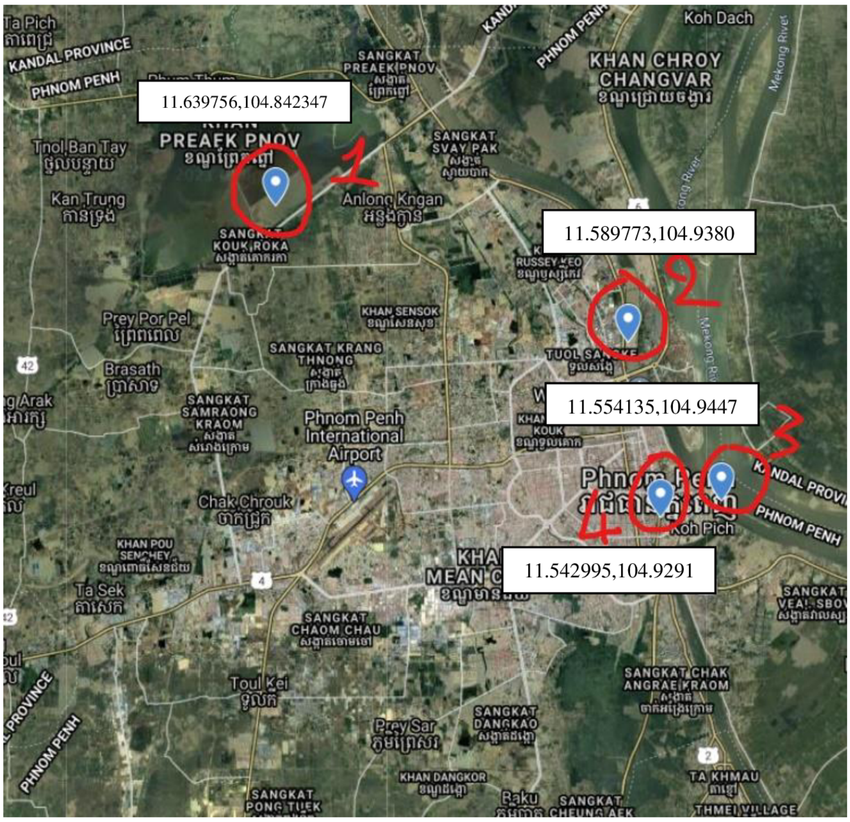
Phnom Penh is the capital and heart of Cambodia located in the middle of the country, with the population of 2,129,371 (NIS 2020). Phnom Penh comprises a total of 14 districts divided into 105 quarters and 953 villages. The main water sources for agriculture activities and drinking are from the 4 rivers that intersect each other in Phnom Penh as well as those small lakes around the city. Minority of the population living at the outskirt of the city still use rainwater and underground water for agriculture purposes. The major of safe drinking water is from boiling, buying plastic bottle and small amount from self-filtration from tap water at household. Although the quality of water that run from PPWSA is safe and could be drunk directly, the bulk storage tank and pipelines are still at pollution level.

Figure 17 Phnom Penh districts

Source: PPCH 2016

4.2 Data collection

The data for this case study was achieved in Phnom Penh, Cambodia. This research thesis is led by doc. Ing. Vladimir Krepl CSc. The purpose of this research study is to understand the water composition in Phnom Penh Cambodia through different sources and to suggest the suitable water treatment technology for this capital. The figure below illustrates the location where four sources of water sample were collected for analysis. The sources are from Tamuak lake, Upper stream river, downstream river and a local tap water. The researcher could obtain one 1.5 liter plastic bottle of each sample for the analysis. The researcher as well gathered information from different scientific literature of initial water tested from certain sources. The first water result was collected from Phnom Penh Water Supply Authority literature.



Key

1- Point 1: Tamuak Lake
2- Point 2: Upper stream river
3- Point 3: Downstream river
4- Point 4: Local tap water

4.3 Data analysis

The gathered data were encapsulated and converted into the main idea of the thesis study. The samples from the 4 sources, were immediately sent for testing with Science, Technology and Innovation National Laboratory in Phnom Penh after collected in order to find out the water components, contamination and pollution. Theses analysis were supported by ilac-MRA and NATA follow the ISO/IEC 17025 standards. Afterward the remaining water samples were frozen to maintain its COD and BOD before it is transported to the Czech Republic. The samples were once again tested at the faculty of Agrobiology to control and compare the differences between the three results. The water testing results are as well compared with the PPWSA previous testing results in other to see the differences throughout the year.

4.4 Limitation

Due to the pandemic situation around the world, the researcher could not request and have access to PPWSA water facility, therefore was forced to collect the samples from the various sources around the city. This has led to the very limited sample for proper analysis. Researcher could not collect water through out the year as comparison with PPWSA yearly report. As well, water test samples should be identified throughout the year in order to obtain knowledge on water quality in different seasons. At the same time, there are limitations on secondary data sources on water quality in Phnom Penh, due to the lack of up-to-date data from PPWSA and different scientific database. Within these situations, the researcher could only bring the data of PPWSA in 2011 as a comparison with the analysis of water tests done by the researcher from both laboratory in Phnom Penh, Cambodia and in Prague, Czech Republic.

5 Results

5.1 Water supply status

Table 2 Phnom Penh water supply status

Number of Treatment plant	4
Number of Worker in PPWSA	1,092
Length of Distribution Line	3,344 km
Population	2,129,371
Number of Household	399,203
Non-Revenue Water	9%
Average water demand	616,347 cubic meter/day
Average Water Production	587,935 cubic meter/ day

The table above demonstrates the water supply status in Phnom Penh. There are 4 main water treatment plants in Phnom Penh, which in total produce an average of 590,000 cubic meter of water per day. The average water demand and average water production data were taken from PPWSA annual report in 2019. As the table mentions, the average water demand is higher than the average water production per day. The main reason behind this number is from the expansion of the city. As the city keep on growing bigger and bigger, there are more and more demand on water usage at household level. The majority of the villages located at the outskirt of the city are facing water scarcity due to the lack of expansion of water distribution. It is clear that there needs to be an improvement on water management and a considerable amount of effort in developing water distribution pipelines in order to have sufficient supply to meet the demand. Furthermore, it is necessary to ensure the cleanliness and to sustain the water usage with efficiency, hence this paper will focus on designing and providing various water treatment methods which could help improve the current method used by PPWSA.

5.2 Water test report

5.2.1 Water test report before and after treated

Item	Unit	Phum Prek WTP		Chruoy Changvar WTP		Chamkar Mon WTP	
		Mean	±STD	Mean	±STD	Mean	±STD
Physical test							
Temperature	°C	28.86	1.31	28.87	1.51	28.4	1.25
pH		7.17	0.21	7.89	0.29	7.30	0.22
Turbidity	NTU	115.17	62.48	112.03	109.57	142	133.51
Conductivity	µS/cm	106.43	33.42	148.97	37.62	116	36.14
SS	mg/l	94.37	55.17	92.77	94.13	108	101.06
Colour	TCU	46.30	31.58	23.45	18.26	37.31	19.16
TDS	mg/l	53.49	16.68	74.89	18.75	58	17.67
Chemical test							
Ca hardness	mg/l	25.91	10.76	43.80	10.47	30	10.95
Total hardness	mg/l	39.40	12.56	60.74	15.10	43	13.92
Magnesium hardness	mg/l	13.71	3.60	16.94	5.40	13.8	4.44
Alkalinity	mg/l	36.69	10.09	58.06	13.65	39	10.15
Organic substance	mg/l	17.90	5.94	9.14	3.99	14.39	4.79
Dissolved Oxygen	mg/l	5.68	0.96	7.44	0.20	7.25	0.29
UV, absorption		0.25	0.14	0.12	0.08	0.203	0.08
Aluminum	mg/l	0.00	0.01	0.03	0.05	0.006	0.01
Ammonia	mg/l	0.45	0.39	0.13	0.11	0.206	0.20
Ammonium nitrogen	mg/l	0.38	0.35	0.11	0.09	0.17	0.16
Carbon dioxide	mg/l	14.39	11.88	5.51	3.70	8	4.93
Copper	mg/l	0.02	0.02	0.02	0.02	0.02	0.02
Chloride	mg/l	17.09	5.09	17.87	7.13	16.8	5.26
Cyanide	mg/l	0.00	0.00	0.00	0.00	0.001	0.00
Chromium total	mg/l	0.01	0.01	0.01	0.01	0.01	0.01
Chromium hexa	mg/l	0.01	0.01	0.01	0.01	0.01	0.01
Fluoride	mg/l	0.13	0.13	0.14	0.08	0.12	0.08
Iron	mg/l	0.45	0.69	0.13	0.16	0.30	0.26
Manganese	mg/l	0.02	0.01	0.02	0.04	0.019	0.02
Nitrate nitrogen	mg/l	1.61	1.24	1.21	0.36	1.26	0.39
Nitrate	mg/l	6.363	2.708	5.33	1.57	5.55	1.71
Nitrite nitrogen	mg/l	0.010	0.012	0.01	0.01	0.009	0.01
Nitrite	mg/l	0.034	0.040	0.02	0.01	0.028	0.04
Zinc	mg/l	0.05	0.04	0.06	0.03	0.04	0.03
Phosphate	mg/l	0.15	0.12	0.08	0.06	0.13	0.11
Sulphide	mg/l	0.010	0.008	0.01	0.01	0.009	0.01
Sulphate	mg/l	4.8	5.5	11.35	6.15	6.3	6.20
Biological test							
Total coliform	cfu/100 ml	17,010	21,676	3251.20	2772.95	4776	8832.88
Faecal coliform	cfu/100 ml	3993	5186	408.89	290.33	422	446.63

Figure 18 Water test report from PPWSA before treated

Item	Unit	Standard		Chruoy Changvar-WTP		Phum Prek-WTP		Chamkar Mon-WTP	
		CNDWQS	WHO (2004)	Mean	±STD	Mean	±STD	Mean	±STD
Physical test									
Temperature	°C			28.6	1.5	28.6	1.3	28.3	1.3
pH		6.5–8.5	6.5–8.5	7.5	0.3	6.9	0.2	6.9	0.2
Turbidity	NTU	5	5	0.8	0.2	0.9	0.4	1.8	0.5
Conductivity	μS/cm		400	153	36	122	31	124	35
Colour	TCU	5	15	1.7	0.8	3.0	1.3	3.9	1.7
SS	mg/l		1	0.1	0.1	0.3	0.3	0.6	0.4
TDS	mg/l	800	1000	77	18	61	16	63	17
Chemical test									
Ca hardness	mg/l		70	43	10	31	11	30	11
Total hardness	mg/l	300	100	60	15	45	13	43	13
Magnesium hardness	mg/l		30	17	6	14	4	14	4
Alkalinity	mg/l		350	50	15	29	10	31	10
Organic substance	mg/l			2.79	0.82	4.88	2.42	4.35	2.19
Dissolved oxygen	mg/l			7.56	0.21	7.01	0.38	7.47	0.24
UV, absorption				0.024	0.006	0.048	0.020	0.044	0.018
Aluminum	mg/l	0.2	0.05–0.2	0.08	0.08	0.02	0.03	0.03	0.02
Ammonia	mg/l	1.5		0.03	0.03	0.03	0.05	0.04	0.04
Ammonia nitrogen	mg/l		0.05–0.5	0.03	0.03	0.02	0.04	0.04	0.04
Carbon dioxide	mg/l			6.67	5.05	13.11	11.37	8.82	6.48
Copper	mg/l	1	0.02–1.0	0.02	0.02	0.02	0.02	0.02	0.02
Chloride	mg/l	250	25–250	19	6	20	6	19	5
Cyanide	mg/l	0.07	0.07–1.0	0.001	0.002	0.001	0.002	0.001	0.002
Chromium total	mg/l		0.05	0.014	0.016	0.012	0.007	0.011	0.006
Chromium hexa	mg/l	0.05	0.05	0.006	0.007	0.005	0.006	0.006	0.007
Fluoride	mg/l	1.5	0.1–1.5	0.13	0.09	0.15	0.10	0.15	0.11
Iron	mg/l	0.3	1.0–0.3	0.01	0.01	0.03	0.02	0.03	0.02
Manganese	mg/l	0.1	0.05–0.5	0.010	0.024	0.011	0.015	0.015	0.018
Nitrate nitrogen	mg/l			1.13	0.58	1.51	0.45	1.29	0.42
Nitrate	mg/l	50	5.0–50	4.9	2.5	6.7	2.0	5.7	1.9
Nitrite nitrogen	mg/l			0.004	0.002	0.004	0.001	0.003	0.001
Nitrite	mg/l	3	1.0–3.0	0.011	0.005	0.011	0.004	0.011	0.004
Zinc	mg/l	3	0.5–3.0	0.036	0.034	0.026	0.021	0.032	0.038
Phosphate	mg/l			0.055	0.057	0.097	0.096	0.088	0.086
Sulphide	mg/l	0.05	0	0.002	0.003	0.002	0.003	0.003	0.003
Sulphate	mg/l	250	25–250	17	5	17	4	18	6
Biological test									
Freely available chlorine	mg/l	0.2–0.5	0.1–1	0.8	0.1	0.8	0.1	0.8	0.1
Total AC	mg/l		2	0.9	0.1	1.0	0.1	0.9	0.1
Total coliform	cfu/100 ml	0	0	0	0.0	0	0.0	0	0.0
Faecal coliform	cfu/100 ml	0	0	0	0.0	0	0.0	0	0.0

Figure 19 Water test report from PPWSA after treated

The figure above demonstrates the water quality before and after treated in the first three water purification facilities in Phnom Penh, Cambodia in 2011 in comparison with WHO 2004 water quality standard. As shown from this test in physical test section before treated, we can see that the level of turbidity, suspended solids and color are relatively high compared to the WHO standard, but after the purification performance the water quality became much better in term of quality. In the chemical test result, there is no significant difference between untreated water and treated water comparing with the WHO standard. Meanwhile, in biological test the number of total coliform and Fecal coliform in untreated water is quite huge. These coliforms are really harmful to human health and cause major diseases. The typical coliforms found in water in Cambodia are Escherichia coli. The most common problems that affect people in Cambodia in terms of the quality of water are diarrhea and vomiting. The majority of uneducated people living in the outskirt of the city are facing these water pollution problems. The problems may be caused by consuming raw water, not properly boiled water or wrong filtration method. Even though the raw untreated water is contaminated, the PPWSA work really well in order to supply the corrected clean water through distribution pipeline for household. As shown in the treated water figure, we can see that the PPWSA treated water are correctly correspond to the WHO clean and safe water standard.

5.2.2 Water test report from CZU laboratory

Table 3 Water test report from Czech University of Life Science Prague, Faculty of Agrobiology, Food and Natural Resources

	V	Cr	Co	Ni	Cu	Zn	As	Cd	Tl	Pb
Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Standard (WHO)	100	50	110	70	50	500	10	3	2	10
Standard (Cambodia)	100	50	110	20	1	3000	50	3	2	10
1 – local lake	1.227	0.05	0.191	<0.1	0.2	4.6	4.01	0.038	<0,001	0.49
2 – upper river	0.587	0.03	0.021	<0.1	0.8	2.5	0.56	0.029	0.003	0.45
3 – downstream river	0.492	0.04	0.023	<0.1	1.0	3.4	0.46	0.045	0.005	0.53
4 – tap water	0.647	0.05	0.022	<0.1	0.9	8.8	0.16	0.071	0.001	0.76

Table 3 illustrated the water test report done by the Agrobiology faculty in Czech University of Life Science. The sample was collected by the researcher in four different sources in Phnom Penh Cambodia during rainy season. The result showed that there are certain pollutions in water sources, but it is not relatively cross over the water standard of WHO and Cambodia standard.

Table 4 Water test sample prediction for dry season by Czech University of Life Science Prague, Faculty of Agrobiology, Food and Natural Resources

	V	Cr	Co	Ni	Cu	Zn	As	Cd	Tl	Pb
Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Standard (WHO)	100	50	110	70	50	500	0.01	3	2	10
Standard (Cambodia)	100	50	110	20	1	3000	0.05	3	2	10
1 - local lake	1.595	0.066	0.248	<0.1	0.237	5.948	5.210	0.049	<0,001	0.636
2 - upper river	0.763	0.040	0.027	<0.1	1.047	3.260	0.725	0.038	0.004	0.588
3 - downstream river	0.640	0.048	0.030	<0.1	1.268	4.476	0.597	0.059	0.007	0.685
4 - top water	0.841	0.060	0.029	<0.1	1.190	11.404	0.211	0.092	0.001	0.987

Table 4 demonstrated the prediction of water test results in dry season based on the result from Table 3 which was collected during the rainy season. According to WHO the pollution could raise around 30 percent in dry season compared to the rainy season.

Table 5 Water Test by Science, Technology and Innovation National Laboratory

Water Source	Unit	Methods	Standard Raw Water Quality	Tamuak Lake	Upper Stream River	Downstream River	Local Tap
Temperature	℃	25					
pH		AOAC 973.41	5.5-9.0	6.65	7.56	7.33	7.38
As	μg/l	Photometric	≤ 50	6	0	0	0
NO_2	mg/l	AOAC 973.50	≤ 3	1.2	0.02	0.02	0.3
Pb	μg/l	AOAC 974.27	≤ 50	4.03	5.07	5.18	4.86
Cd	μg/l	AOAC 974.27	≤ 3	ND	ND	0.67	ND
COD	mg/l	AOAC 973.46	≤ 10	56	4	4	5
CN	μg/l	APHA 4500-CN-E	≤ 70	0.002	0.001	0.001	0.001
K	mg/l	AOAC 973.53	-	10.35	2.41	2.16	2.13
Total Coliforms		ISO 9308-2	5,000	2,400	43	ND	4
Presumptive E. coli,		ISO 9308-2	5,000	2,400	43	ND	ND

5.3 Water test comparison

As mentioned above, the water samples were collected from four different places throughout Phnom Penh, Cambodia. The samples are from the local lake (Tamuak Lake), Uppers Stream River, Downstream River, and last but not least from local tap water. The reason behind the two separate tests is to see and compare the differences and accuracy of the water test in order to propose the accurate and proper water treatment technology for the city. The main outlook for these tests is arsenic level in the water. As shown in both tables, the arsenic level appears higher in the lake rather than the flowing rivers. The flow of water creates a water cycle, which could not trap or hold arsenic from the industrial areas in one place. While there is a larger amount of arsenic chemicals found in the lake water, due to the no streaming of water in that lake. Another important thing to take into consideration for proposing water treatment technology is the biological hazard. As the table mentions, there are numbers of Escherichia present in the water. Although they are quite low compared to WHO standards, it is important to note that the water sample was collected in the rainy season. If we take a look at the 2011 water test result conducted by PPWSA, there were huge numbers of coliform bacteria present in the water. Therefore, it is hard to consider that there is a low amount of Coliform bacteria present in the water throughout the year.

5.4 The water treatment process

Water needs to be treated and cleaned after taking from water sources in order to make sure it is safe and secure for consumers. There are many steps before the clean water can reach the distribution pipelines and eventually reach the customers (Water Human 2021). The schema below illustrates an example of water treatment process from pumping raw water from water sources to the final consumers.

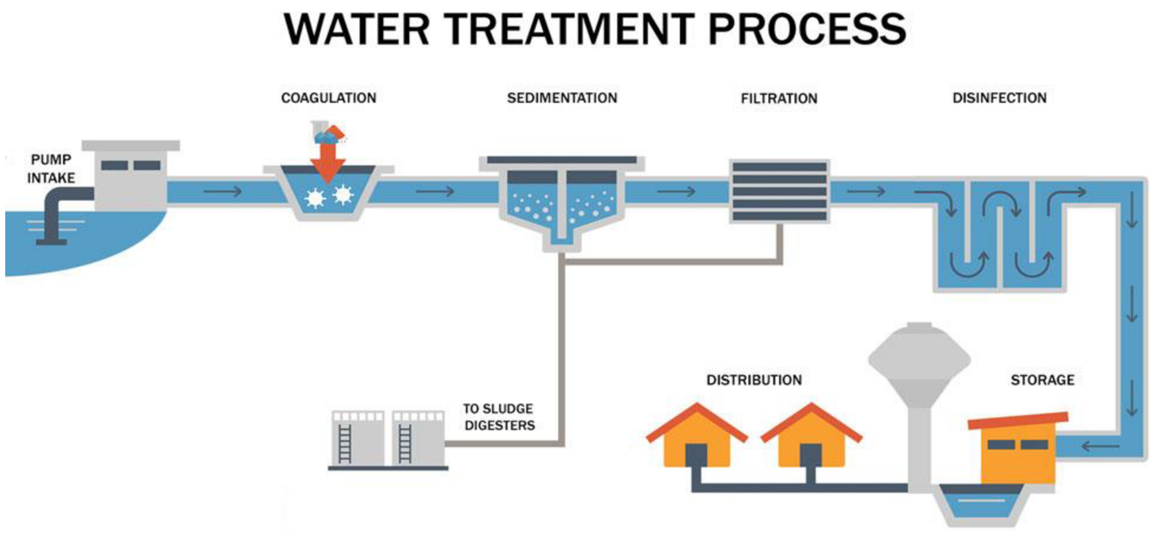


Figure 20 Water treatment process in water treatment plant

Source: Hensler 2018

The first step is pump intakes, which in our cases are the lake and the river. The second step is coagulation, where liquid aluminum sulfate or polymer are added to the raw water. The mixture causes the tiny particles in the raw water to merge and become bigger or so-called flocs. This procedure is done in order to ease the removal process of the particles during next step. The third step is sedimentation, where the water travels slowly so that the heavy floc could settle at the bottom of the tank. The floc that gets collected at the bottom of the tank is known as sludge. The fourth step is filtration, in which water flows through filer technology. The technology can be varied according to what the treatment plant implement. Last but not least here comes the disinfection step. The quality of water is controlled and disinfected before it can be transferred to the distribution system. This step plays a significant role in order to make sure that there will be no harmful microorganisms in the water. Typically, chlorine is applied due to its effective disinfectant (CDC 2021).

5.5 Water treatment technology

5.5.1 Activated carbon treatment

Activated carbon also known as activated charcoal is a type of carbon that has already been processed to affect an extremely large surface area. A tiny amount of pores delivers a surface for both chemical and absorption reactions (Henry 2016).

5.5.1.1 Physical structure

Activated carbon is consisted of three components including single plane reticular carbon, amorphous carbon and graphite microcrystal. Among the three, graphite microcrystal is the core element of active carbon. The microcrystalline configuration of activated carbon is unique from graphite. That interlayer layout of the microcrystalline configuration is measured between 0.34-0.35 nanometer. The microcrystalline can tolerate the temperature higher than 2000 degree Celsius, but it is not possible to transform to graphite. This type of microcrystalline formation is known as non-graphite microcrystal. Most of the activated carbon fit in to non-graphite configuration. The microcrystalline grouping of graphite formation is regular, and after the treatment it can be converted into graphite. Non-graphite microcrystalline formation creates activated carbon, which have developed pore structure. The pores' structure is described by the pore size distribution. The pore horizon allocation of activated carbon is very broad and varying from one to thousand nanometers (Changjia et al. 2019).

The pore dimension of activated carbon is divided into three classifications: the pore dimension that is smaller than 2 nanometers, the pore dimension that is mesoporous between 2-50 nanometers, and the pore dimension that are larger than 50 nanometers.

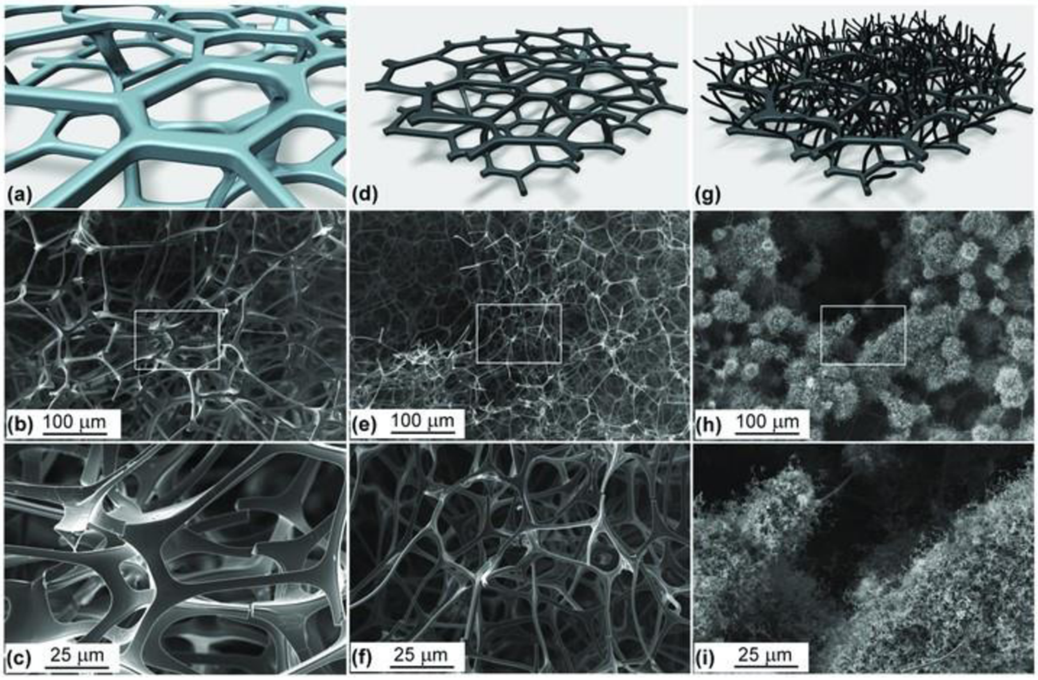


Figure 21 Physical structure of carbon

Source: Desotec 2021

5.5.1.2 Chemical structure

The internal of activated carbon is pore structure and crystal structure, while the external of activated carbon is chemical structure. The concentration performance of activated carbon depends on both physical and chemical structure. For the preparation of activated carbon, the edge chemical connection from the aromatic layer is developed during the carbonization phase which breaks down to develop an edge carbon atom along with unmatched electrons. Those marginal carbon atoms contain unsaturated chemical which bonds together and can be reacted with heterocyclic atoms like hydrogen, nitrogen oxygen, and sulfur in other to form various surface groups. The existence of those surface groups unquestionably involves the adsorption possessions of activated carbon. The exterior groups of activated carbon involve alkaline, acidic, and neutral (Desotec 2021).

The activated carbon can promote the alkaline adsorption through carboxyl, lactone, hydroxyl carbonyl, phenol and ether. Basic exterior functional groups mostly contain cyclic ketones and its derivatives, which promote the acidic adsorption elements on activated carbon.

5.5.1.3 Carbon filters

Activated carbon is an excellent source for water filtration. It helps reduce a massive number of impurities from untreated water so that it is drinkable. Generally, carbon filters are effective at easing 52 chemicals and can get rid of at least 81 other chemicals (EPA 2012). According to the United States Environmental Protection Agency 2011, activated carbon is the only filtering material that eliminates all identified 14 pesticides, 12 herbicides, and 32 organic contaminants. Activated carbon can as well also eliminates chemicals, like chlorine, which affect the aesthetic quality of drinking water. Most of the public water in the world contain chlorine as a purifier. However, chlorine can bring an obnoxious smell and taste in tap water as well create potentially carcinogenic byproducts. Activated carbon helps filter out chlorine byproducts and VOCs and deliver clean water.

Currently, there are two types of carbon which are mostly used for water filtration in water purification technology: granular activated carbon (GAC) and powdered activated carbon (PAC). Powdered activated carbon is smaller than granular activated carbon in term of particle size and generally more efficient and effective at eliminating a wide range of contaminations from the untreated water. In most of the filters, the activated carbon is blended with a secondary component such as silver in other to give the filter extra bacteriostatic properties (SSWM 2020).

Fixed-bed carbon filter

Fixed-bed Carbon Filter also known as granular activated carbon filters are mostly cylinder-shaped containers which carry fragments of granular activated carbon (GAC). The untreated water is flowing through the containers with GAC system, then the carbon particles filter out the impurities from the water. The common problem related to GAC filter is channeling. As the untreated water enters the chamber, it is automatically flowing through the system by the path that present the least carbon substances. This means that the water bypassed the carbon particles are underutilized, reducing the speed and overall proficiency of the filtration system. The negative outcome of GAC filter is the growing of bacteria. As the water flows frequently down and travel through the activated carbon, the pouches of carbon and stationary water persist behind. With these matters, the areas of relatively stagnant and untreated water are ideal locations for bacterial growth (EPA 2018).

Carbon block filters

Carbon block filters are densely packed block of GAC and PAC particles of different size. Water is pushed through the pores of the carbon cell block, and as it moves through the filter, the small carbon particles eliminate a wide range of impurities. The main advantage of carbon block filters over fixed-bed carbon filters is the exclusion of channeling. With the carbon block filters, carbon fragments are stationary, and every particle is utilized to its maximum effectiveness. After this process, a wide range of contaminants is eliminated from the water — small impurities are adsorbed by carbon, while larger foams are too large to go through the pores of the cell block and therefore are missing behind.

Carbon block filters are more effectiveness and efficiency than fixed-bed carbon filter. The carbon block filter does have one disadvantage. It consumes more time for the water to go through than GAC filter, which means that it is not suitable for circumstances where we need a huge quantity of water to be filtered like in municipal water system. However, carbon block filter can filter drinking water more than enough for households' consumption (CBTECH 2019).

Figure 22 Carbon filtration system

Source: Samco 2021

5.5.2 Ferrate technology

Ferrate technology is appropriate for the elimination of heavy metals, organic and inorganic pollutants, pharmaceutic wastes, pesticides in the untreated water. The technology is therefore ideal for purification of the water around the agriculture area which contains fertilizers, pesticides, and insecticides. It as well can be used in any other concerning problem with polluted water. The purpose of using ferrate technology as water purification is to remove any substances that is considered harmful to human health. Ferrate treatment is one of the least expensive and probably one of the most effective water treatment option for better safe drinking water (Ferrate Treatment Technologies 2021).

Ferrate is a modified iron particle which iron is over 6 oxidation states. This is known as Iron VI. Ferrate treatment is exceptionally powerful, it can provide multiple treatments as of one application. Ferrate treatment is very environmentally friendly because it does not generate disinfection byproducts, and at the same time- it resolves complicated treatment challenges which other oxidants cannot treat. The Ferrate treatment is the most effective conventional oxidant and disinfectant for wastewater treatments. It is believed to be stronger than ozone, hydrogen peroxide, hypochlorite, perchlorate, chlorine, permanganate, dissolved oxygen and chlorine dioxide as an oxidant (Virender K. et al. 2015).

In one dose, Ferrate can instantaneously function as an oxidant, disinfectant and coagulant. Ferrate can be used to replace coagulants such as alum, ferric chloride, and polymers as the elimination of humic acids, metals, and non-metals. It surpasses other disinfectants such as hydrogen peroxide, UV and chlorine and it can eradicate others chlorine repellent organisms such as sulphite-reducing clostridia and aerobic spore-formers. Ferrate is very flexible, powerful, multi-purpose wastewater treatment technology (Ferrate Treatment Technologies 2021).

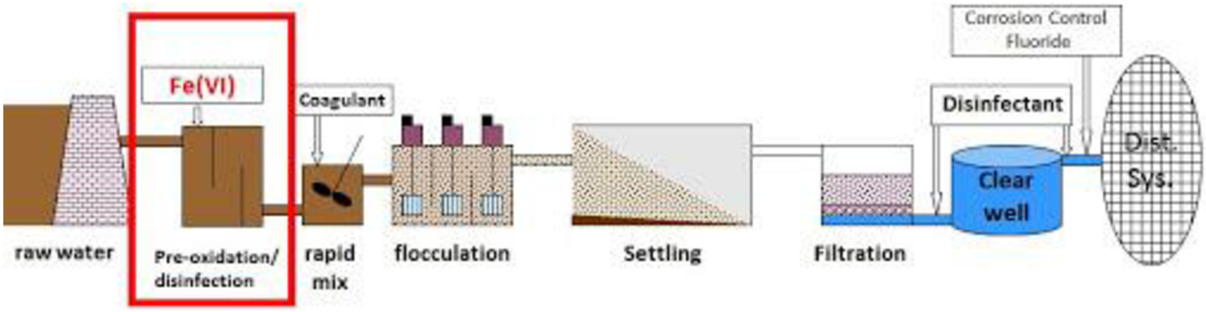


Figure 23 Ferrate treatment process

Source: UMASS 2021

5.5.3 Ion exchange technology

Ion exchange is a water treatment process regularly applied for water demineralization or softening; however it can also be used to remove other components from the water in methods such as deionization, de-alkalization, disinfection and denitrification (Envirogen 2021). Ion exchange illustrates a particular chemical procedure in which unneeded dissolved ions in untreated water and wastewater. The unwanted components are nitrate, sulfate, fluoride, and arsenic, which can be exchanged for other ions with a parallel charge. Ions are mainly atoms or molecules which contain total number of electrons that are not equivalent to the total number of protons. There are mainly two identified groups of ions – positively charged cations and negatively charged anions. There are many advantages of ion exchange technology. It is an appropriate technology for eliminating dissolved inorganic ion, possibly for regenerating resin, and it is one of the technologies that is inexpensive for initial capital investment. On the other hand, there are as well disadvantages. The technology alone is not effective in removing bacteria, its operation cost is very high in long-term, and the regeneration process of ion exchange beds dump salty water to the environment (SSWM 2020).

5.5.3.1 Removing ionic contamination

Ion Exchange is applied in order to eliminate dissolved ionic contaminants in the water. The ion exchange procedure occurs between a solid (zeolite or resin) and a liquid (water). In this procedure, the less desired components are traded with those which are believed to be more desirable. All of the desirable ions are stacked onto the resin material. The resins can be utilized alone or in group so it can eliminate ionic contaminants from water (Fluence 2021).

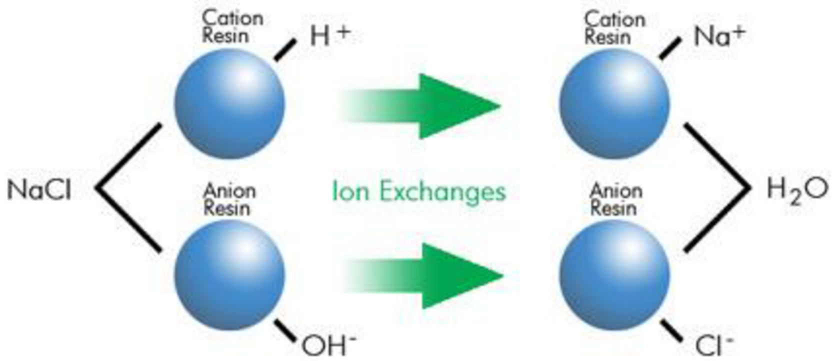


Figure 24 Ion exchange process

Source: APEC Water 2021

5.5.3.2 Recharging resins

Resin resources are limited in exchange capacity. Each of the specific exchange positions will become complete with prolonged usage. When the resin is unable to exchange ion because overused, it needs to be regenerated or recharged in other to restore to its initial condition. The substances used for the recharging of resin are sodium chloride, sulfuric acid, hydrochloric acid, and sodium hydroxide. The main substances remain from the procedure is known as "spent regenerant". It includes both ions removed and extra regenerant ions. It will as well have a high-level of total dissolved spheres. Regenerant can be handled in a municipal wastewater facility, but discharges require monitoring (Fluence 2021).

The efficiency of ion exchange used for water treatment can be restricted by surface clogging, mineral scaling, and other issues which contribute to resin contaminating. Pretreatment procedures such as filtration and addition of different chemicals can help prevent and reduce these issues.

5.5.3.3 Ion exchange in drinking water treatment

Lately, ion exchange resins have been gradually applied in other to produce drinking water. Specialized resins have been constructed to treat various contaminants including boron, uranium, and perchlorate. There are many resins created for all these purposes, such as strong base and strong anion resin, which is used to remove perchlorate and nitrates. Ion exchange is used significantly in water softening, where it is considered as a solid and proven technology (Fresh Water System 2021).

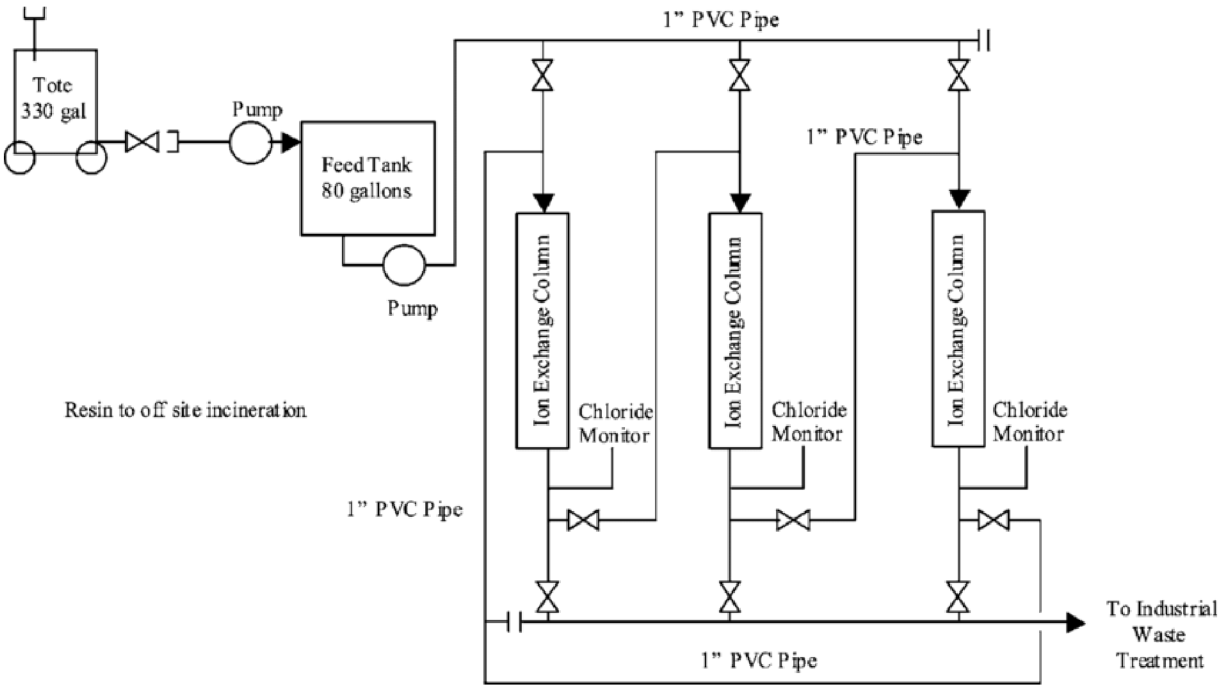


Figure 25 Schema of Ion exchange technology in water treatment plant

Source: Fresh Water System 2021

5.5.4 Reverse Osmosis Technology

Reverse osmosis is a water purification procedure mainly for salt water. The reverse osmosis utilizes permeable membrane to eliminate contaminants from raw water, unfiltered water and wastewater, when the pressure forces it through a semipermeable membrane. Reverse osmosis is the reverse method of osmosis. Osmosis happens naturally without energy needed and reverse osmosis is the process of osmosis in reverse, which you need to utilize energy to the additional saline solution. Reverse osmosis membrane is the semi-permeable membrane which allows the movement of water molecules but not most organics, dissolved salts, pyrogens and bacteria. Nevertheless, applied pressure is needed to use in other to push the water through the reverse osmosis membrane which is greater than the naturally happening osmotic pressure to desalinate, deionize or demineralize water in the process. This allows pure water to go through while some of the contaminants is holding back. The water run through more concentrated side (contaminants) of the reverse osmosis membrane to the least concentrated side (fewer contaminant) in order to produce clean water (Puretec Industrial Water 2021).

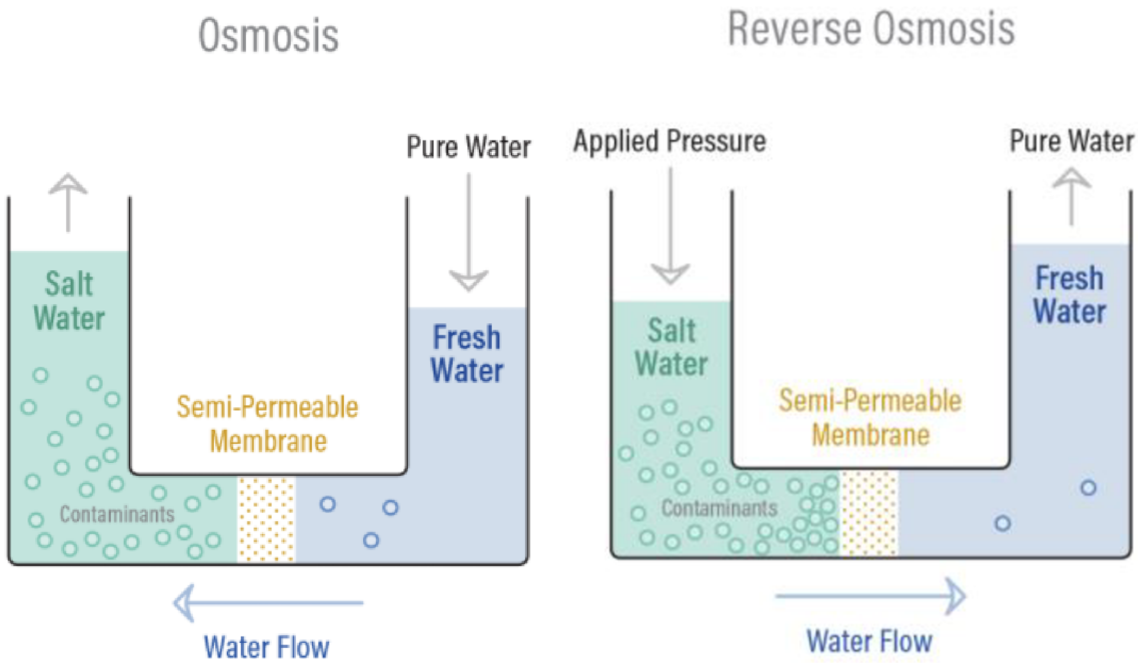


Figure 26 Osmosis and reverse osmosis diagram

Source: Puretec Industrial Water 2021

Semipermeable membrane has small pores which help block contaminants, but it allows water molecules to go through. In osmosis, the water become more concentrated when it goes through the membrane in order to get the equilibrium on both sides. Reverse osmosis does block contaminants from getting into the least concentrated part of the membrane. For instance, when the pressure is applied to saltwater during reverse osmosis, the salt is eliminated, and only clean water can pass through.

5.5.4.1 Function of reverse osmosis technology

Reverse Osmosis works by utilizing a high-level pressure pump to rise the pressure on the saltwater side of the reverse osmosis and then force the water across the semi-permeable reverse osmosis membrane. The process leaves behind almost the entire (between 95% to 99%) dissolved salts in concentrated form behind and transfer to the rejecting stream. The amount of pressure needed depends on the salt concentration of the supply water. The more concentrated the supply water is, the more pressure is needed to surmount the osmotic pressure. The clean and fresh water is later then known as the permeate. The concentrated water which is left over is called brine or waste (Fritzmann et al. 2007).

As the supply water enters the reverse osmosis membrane under the pressure, the water molecules go through the semi-permeable membrane, and salts and other different contaminants are not permitted to pass through. Then later are discharged through the discard stream. The unneeded contaminant water is drained out or can be distributed back into the water supply system in some circumstances in order to be recycled through the reverse osmosis system again so we can save water. The water that pass through the reverse osmosis membrane is known as product or permeate water, which normally has around 95% to 99% of the dissolved salts eliminated from it.

It is crucial to understand that reverse osmosis system utilizes cross filtration over standard filtration where the contaminants are accumulated within the filter media. Because of cross filtration, the water solution passes or crosses through the filter with two different outlets: the contaminated water goes one way, and the filtered water goes the other. So as to avoid the cross-contaminants, cross flow filtration permits the water to wash away contaminant buildup and further let enough turbulence to keep the membrane exterior clean (Greenlee et al. 2009).

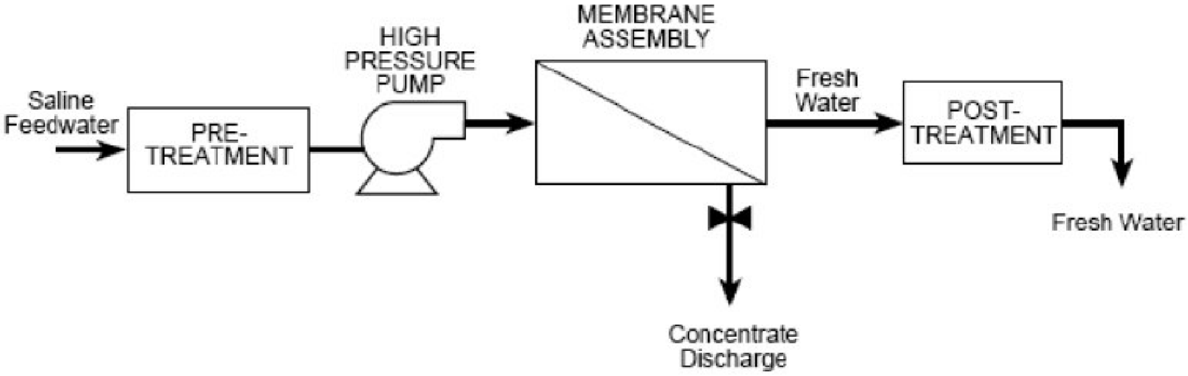


Figure 27 Schema of reverse osmosis in water treatment plant

Source: Eltawil et al. 2008

5.5.4.2 Contaminations that reverse osmosis remove

Reverse Osmosis is capable of eliminating up to 99 percent of the particles, colloids, organics dissolved salts (ions), pyrogens and bacteria from the supply water. However, the reverse osmosis system should not be trusted upon to remove 100 percent of bacteria or viruses. Reverse osmosis membrane denies contaminants according to their charge and size. Most of the contaminant that has a molecular weight larger than 200 is likely to be rejected by appropriately running reverse osmosis system. As well the larger the ionic charge of the contaminant, the more possibly it will not be able to go through the reverse osmosis membrane. For instance, sodium ion has just one charge (monovalent) and calcium has two charges, therefore it is not rejected by the reverse osmosis membrane. Due to this matter, the reverse osmosis system does not eliminate gases like CO_2 well. They do not have high ion charges while they stay in solution which have low molecular weight. Since reverse osmosis system does not eliminate gases, the permeate water can have a slightly lower pH level than normal pH level in water. This depends on CO_2 levels in the supply water, as the CO_2 is transformed to carbonic acid (Khawaji et al. 2008 &Fritzmann et al. 2007).

Reverse Osmosis is extremely effective and efficient in treating surface, brackish, and ground water for both small and big flow applications. There are many industries that use reverse osmosis water treatment system such as boiler feed water, food and beverage, pharmaceutical, semiconductor manufacturing, and metal finishing (Puretec Industrial Water. 2021).

Figure 28 Reverse osmosis technology

Source: SAMCO 2021

5.5.5 SWOT Analysis of Technology

According to the results, the research has come up with a fundamental technology SWOT analysis, in other to show which technology is sufficient and relevant for Phnom Penh, Cambodia. The SWOT analyses are based on the recommendation considering the area, current economic potential of the country, and efficiency and effectiveness of the technology over the pollutants and contaminants of the area. In researcher's viewpoint, reverse osmosis is being recommended to the central part of Phnom Penh, while Ferrate is the most effective and should be used in the outskirt of the city as it is good for agricultural and heavy industrial area.

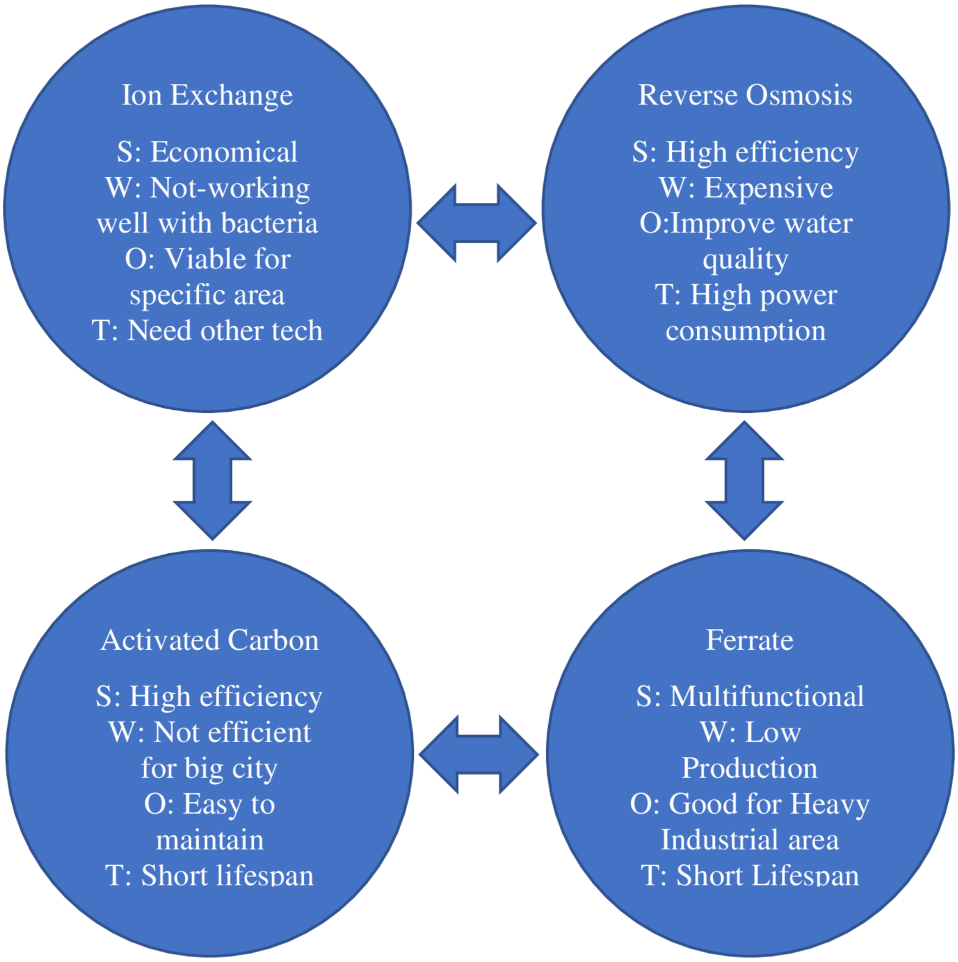


Figure 29 SWOT analysis of proposed technology

6 Discussion

Figure 30 Young children in dirt water

Source: Lifewater 2021

Cambodia still faces water scarcity as more than three million Cambodian lack access to clean and safe drinking water. JMP reported that 21 percent of Cambodians still have problems getting drinking water in around 30-minute round trip. In 2017, 11 percent of Cambodians relied on surface water, for example, springs, ponds, lakes, and rivers. Although Cambodia is a fast pace growing economic country but getting access to safe and clean water remains a challenge. From this viewpoint, we can see that many young children are in contact with contaminated water. They have little knowledge regarding which water is safe for drinking. The unsafe drinking water in Cambodia causes children morbidity, mainly in young children from low-income families. Getting safe drinking water for children is crucial for country development. Within this problem, it brings motivation for the author to put effort to provide the follow-up research. This research can be used for improving Phnom Penh water quality and can be used as an example for rural development especially improving rural community livelihood and sustainable environment.

The result from the test samples shows that there is arsenic pollution in the water and mainly in the lake water which is not streaming around unlike the river water. The amount of Arsenic in the river is relatively low due to the fact that the sample was collected during the rainy season, where the current of the water was moving relatively fast. According to Phok et al. 2018, it is stated that there is high arsenic pollution in groundwater in different regions of Cambodia.

They conduct research in the provinces along Mekong and Bassak rivers. They find out that the majority of groundwater close to the rivers has arsenic pollution of more than 0.05 mg/l which is higher than the Cambodian National Standard and WHO limit. This leads to the dangerous fact that a huge amount of arsenic contaminants could led out from underground water to the rivers. The arsenic in Cambodia is introduced into the environment through several anthropogenic and biogenic activities. The anthropogenic is mainly from commercial wastes, mining industry, steel industry, coal ash, pesticides, and herbicides. As well arsenic trioxide (As_2O_3) is used extremely in the manufacturing of glass, ceramic, cosmetic, electronics, and Cu-based alloys. While the biogenic only contributes a small amount of arsenic through biotransformation and bioaccumulation. According to Sophary 2009, it is also stated that the majority of arsenic was found in underground water from the well in Kandal province near the rivers, which is only 11 kilometers from Phnom Penh. A lot of country has common rivers system which flow from mountain ranges and the water carry with them large volume of sediments. Arsenic is one of the common compounds that can be found in the sediments. Due to this matter, the Arsenic can be stored in several floodplain and deeper in riverbanks (RDI 2020).

The result also illustrates the biological test. There are total coliforms, fecal coliforms, and Escherichia coli present in the water test sample. Total coliform and fecal coliform mainly can be found in soil, in water that has been shaped by surface water, and in animal and human waste. Water pollution which is caused by coliform contamination is a serious problem as it could potentially cause contracting diseases from diseasing-causing organisms (pathogens). The majority of coliform bacteria do not create diseases that affect the human body, but E. coli is the main biological hazard contaminating water that could cause serious problems to human health. E. coli could cause humans to have bloody diarrhea, kidney failure, and in some serious cases death. It is dangerous mainly target children and adults with the weak immune system. According to PPWSA 2011 water test before treatment, we can see that there is a huge number of total and fecal coliform present in the water sources for Phnom Penh. This test correlates to the water test performed by the author of this thesis in the Phnom Penh laboratory. Within this finding, there is no question about the existence of pollutants and contaminants in Cambodia's water sources.

7 Conclusion

According to the finding, it can be revealed that there are certain pollutions in water in Phnom Penh, Cambodia. The pollutions from untreated water can be classified according to physical, biological, and chemical test (PPWSA 2011). The main physical pollution is from turbidity and total dissolved solid. The biological pollution are mainly total coliforms and fecal coliforms. While the chemical pollutions are mainly from arsenic and other metal compounds.

Although the results of the water test sample illustrated that the Arsenic compounds is relatively low at the moment, but we can see that there are Arsenic available in water across Phnom Penh and the most important fact is that there was huge Arsenic compound found in underground water in nearby province (Kandal) (Phok et al. 2018). In other to be aware of future used of underground water the study has proposed new methods of water purification system for future use in Phnom Penh. The new water treatment system are activated carbon treatment, ferrate treatment, ion exchange, and reverse osmosis technologies for water treatment and purification measure which can be used to purify water for daily usage in the city.

The water management in Phnom Penh should be improve and extend as the city keep on expanding drastically and the need of clean water consumption is required more and more. At the same time the water treatment technology should apply according to the quality of the water in the area to have its capability and capacity fulfil. According to water needed of Phnom Penh reverse osmosis technology is the most suitable and useful water treatment technology for central part of Phnom Penh as it is not heavy industrial area. The reverse osmosis is effective and efficiency for water treatment, but the technology itself is quite expensive and consume a lot of energy. As the city keep on growing and the economic is moving forward it is the ideology technology for future used in the center of Phnom Penh. Meanwhile, ferrate technology should be used in the outskirt of Phnom Penh as it is the most suitable technology for agricultural and industrial area. Ferrate technology is more effective and efficiency in term of elimination of heavy metals, organic and inorganic pollutants, pharmaceutic wastes, and pesticides in the water.

The paper would suggest Cambodia government to take precocious on Arsenic level in the water. As at the moment populations of Cambodia is still low and Cambodia only required surface water for daily usage, but in the future if the population rise, the adaptation of new industrial activity and other sort of huge water requirement activity happen then the country might need to grab the underground water to fulfill the needs. By doing so, the government should start by preparing and adopting new water treatment techniques.

The research as well suggest that the government should step in and provide knowledge about safe drinking water to people from outskirt of the city and rural communities, especially to unknowledgeable people. The government should as well implement new water treatment technologies so that the tap water is safe for drinking directly. Clean and safe drinking water are the most important elements for country development; therefore, the government should prioritize it before improving other sectors.

8 References

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9 Appendix

មន្ទីរពិសោធន៍ជាតិ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍

Science, Technology and Innovation National Laboratory

ផ្លូវជាតិលេខ៥ ភូមិបឹងឈូក សង្កាត់គីឡូម៉ែត្រលេខ៦ ខណ្ឌឫស្សីកែវ រាជធានីភ្នំពេញ

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STINL

N° 16124 0820

លេខ (N°): **166W08/20**

ថ្ងៃ (Date): 04/09/2020

វិញ្ញាបនបត្រវិភាគ

Certificate of Analysis

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ឈ្មោះផលិតផល (Designation of Product) : Lake(**គាមក**)

ពាណិជ្ជសញ្ញា(Trade Mark) :

ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft.) : លោក-លោកស្រី: CHHOUR PUNLOEU

អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft.): ផ្ទះលេខ៣៨-៨១H ផ្លូវនពោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ

ឈ្មោះអ្នកផ្តល់សំណាក(Sample Submitted by) : CHHOUR PUNLOEU ស្ថាប័ន (Organization) : Czech University of Life Science Prague

ថ្ងៃទទួលសំណាក (Sample Receive Date) :24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) :01/09/2020

ថ្ងៃចេញលទ្ធផល (Result Date) :04/09/2020

ផ្នែកគីមីសាស្ត្រទឹក (Water Chemical Section)

ល.រ N°	លក្ខណៈរូប~គីមី Physical Chemical Characteristics	វិធីសាស្ត្រវិភាគ Reference Methods	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	Limit of Quantitation (LOQ)	លទ្ធផលវិភាគ Results
1	ប៉េហាស់ (pH)	AOAC 973.41	5.5 - 9.0	-	6.65
2	អាសេនិច (As)	Photometric	≤ 50 µg/L	-	6 µg/L
3	នីត្រាត (NO_3)	AOAC 973.50	≤ 50 mg/L	-	1.2 mg/L
4	សំណ (Pb)	AOAC 974.27	≤ 50 µg/L	-	4.03 µg/L
5	កាត់មីញ៉ូម (Cd)	AOAC 974.27	≤ 3 µg/L	0.025µg/L	ND
6	តំរូវការគីមីអុកស៊ីសែន (COD)	AOAC 973.46	≤ 10 mg/L	-	56 mg/L
7	ស្យានីត (CN^-)	APHA 4500-CN-E	≤ 70 µg/L	-	0.002 µg/L
8	ប៉ូតាស្យូម (K)	AOAC 973.53	-	-	10.35 mg/L

បញ្ជាក់ដោយ

Certified by

Quality Manager

គេខ ម៉ាន់ជារិទ្ធ

សំគាល់១ :លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ(៦១២) ។ ទំព័រ 1/1

Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 166W08/20

Note 2: STINL does not engage in sampling.

មន្ទីរពិសោធន៍ជាតិ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
Science, Technology and Innovation National Laboratory
ផ្លូវជាតិលេខ៥ ភូមិបឹងឈូក សង្កាត់គីឡូម៉ែត្រលេខ៦ ខណ្ឌឫស្សីកែវ រាជធានីភ្នំពេញ
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លេខ (N°): **167W08/20**
ថ្ងៃ (Date): 06/09/2020

STINL
N° 16224 0820

វិញ្ញាបនបត្រវិភាគ
Certificate of Analysis

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ឈ្មោះផលិតផល (Designation of Product) : Up Stream River (pumping station)
ពាណិជ្ជសញ្ញា (Trade Mark) :
ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU
អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft): ផ្ទះលេខ៣៨-៨១H ផ្លូវនរោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ
ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) : CHHOUR PUNLOEU ស្ថាប័ន (Organization) : Czech University of Life Science Prague
ថ្ងៃទទួលសំណាក (Sample Receive Date) : 24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 01/09/2020
ថ្ងៃចេញលទ្ធផល (Result Date) : 04/09/2020

ផ្នែកគីមីសាស្ត្រទឹក (Water Chemical Section)

ល.រ N°	លក្ខណៈរូប~គីមី Physical Chemical Characteristics	វិធីសាស្ត្រវិភាគ Reference Methods	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	Limit of Quantitation (LOQ)	លទ្ធផលវិភាគ Results
1	ប៉េហាស់ (pH)	AOAC 973.41	5.5 - 9.0	-	7.56
2	អាសេនិច (As)	Photometric	≤ 50 µg/L	-	0 µg/L
3	នីទ្រីត (NO_2)	AOAC 973.50	≤ 3mg/L	-	0.02 mg/L
4	សំណ (Pb)	AOAC 974.27	≤ 50 µg/L	-	5.07 µg/L
5	កាត់មីញ៉ូម (Cd)	AOAC 974.27	≤ 3 µg/L	0.025µg/L	ND
6	តំរូវការគីមីអុកស៊ីសែន (COD)	AOAC 973.46	≤ 10 mg/L	-	4 mg/L
7	ស្យានីត (CN^-)	APHA 4500-CN-E	≤ 70 µg/L	-	0.001 µg/L
8	ប៉ូតាស្យូម (K)	AOAC 973.53	-	-	2.41 mg/L

បញ្ជាក់ដោយ
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គេង ម៉ាន់ដារិទ្ធ

សំគាល់១ :លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ(២១៣)។ ទំព័រ 1/1
Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 167W08/20
Note 2: STINL does not engage in sampling.

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Accreditation No.17165

មន្ទីរពិសោធន៍ជាតិ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍

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ផ្លូវជាតិលេខ៥ ភូមិបឹងឈូក សង្កាត់គីឡូម៉ែត្រលេខ៦ ខណ្ឌឫស្សីកែវ រាជធានីភ្នំពេញ

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អ៊ីម៉ែល (E-mail) : hcs_cambodia@yahoo.com

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Accredited by National Association of Testing Authorities, Australia.

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N°....178240820.....

វិញ្ញាបនបត្រវិភាគ

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លេខ (N°) :199B08/20 ថ្ងៃ (Date):..28.08.2020..

ឈ្មោះផលិតផល (Designation of Product) : Local Tab Water

ពាណិជ្ជសញ្ញា(Trade Mark) :

ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU

អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft.): ផ្ទះលេខ៣៨-៨១H ផ្លូវនពេត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ

ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) : CHHOUR PUNLOEU ស្ថាប័ន (Organization) : **Czech University of Life Science Prague**

ថ្ងៃទទួលសំណាក (Sample Receive Date) : 24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 24/08/2020

ថ្ងៃចេញលទ្ធផល (Result Date) : 28/08/2020

ផ្នែកមីក្រូជីវសាស្ត្រចំណីអាហារ (Food Microbiological Section)

ល.រ N°	**វិភាគមីក្រូជីវសាស្ត្រ** Microbiological Test		**វិធីសាស្ត្រ** Ref Method	**ស្តង់ដាគុណភាពទឹកប្រភព** Standard Raw Water Quality	**លទ្ធផល** Results
1	Total Coliforms,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3$(=5000)	4
2	Presumptive *E. coli*,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3$(=5000)	None found

P.D.W.W.I

បញ្ជាក់ដោយ

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វ៉ែហម ចាន់ធន

សំគាល់១ : លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ (2198) ។ ទំព័រ 1/1

Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 199B08/20

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មន្ទីរពិសោធន៍ជាតិ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍

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Accredited by National Association of Testing Authorities, Australia

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N°...179240820......

វិញ្ញាបនបត្រវិភាគ
Certificate of Analysis
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លេខ (N°) :200B08/20 ថ្ងៃ (Date):..28..08..2020..

ឈ្មោះផលិតផល (Designation of Product) : Up Stream River (pumping station)

ពាណិជ្ជសញ្ញា (Trade Mark) :

ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU

អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft.): ផ្ទះលេខ៣៨-៨១H ផ្លូវនរោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ

ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) :CHHOUR PUNLOEU ស្ថាប័ន (Organization) : **Czech University of Life Science Prague**

ថ្ងៃទទួលសំណាក (Sample Receive Date) : 24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 24/08/2020

ថ្ងៃចេញលទ្ធផល (Result Date) : 28/08/2020

ផ្នែកមីក្រូជីវសាស្ត្រចំណីអាហារ (Food Microbiological Section)

ល.រ N°	វិភាគមីក្រូជីវសាស្ត្រ Microbiological Test		វិធីសាស្ត្រ Ref Method	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	លទ្ធផល Results
1	Total Coliforms,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3(=5000)$	4.3X10 (=43)
2	Presumptive *E. coli*,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3(=5000)$	4.3X10(=43)

P.D.W.W.I

បញ្ជាក់ដោយ
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វ៉ែហម ចាន់ថន

សំគាល់១ : លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ (2199) ។ ទំព័រ 1/1

Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 200B08/20

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អ៊ីម៉ែល (E-mail) : hcs_cambodia@yahoo.com

ទទួលស្គាល់ដោយសមាគមជាតិនៃអាជ្ញាធរធ្វើតេស្ត ប្រទេសអូស្ត្រាលី

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ILCC N° 180240820

វិញ្ញាបនបត្រវិភាគ
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លេខ (N°) :201B08/20 ថ្ងៃ (Date): 28.08.2020

ឈ្មោះផលិតផល (Designation of Product) : Lake(**តាមក**)

ពាណិជ្ជសញ្ញា(Trade Mark) :

ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU

អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft.): ផ្ទះលេខ៣៨-៤១H ផ្លូវនរោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ

ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) :CHHOUR PUNLOEU ស្ថាប័ន (Organization) : **Czech University of Life Science Prague**

ថ្ងៃទទួលសំណាក (Sample Receive Date) : 24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 24/08/2020

ថ្ងៃចេញលទ្ធផល (Result Date) : 28/08/2020

ផ្នែកមីក្រូជីវសាស្ត្រចំណីអាហារ (Food Microbiological Section)

ល.រ N°	វិភាគមីក្រូជីវសាស្ត្រ Microbiological Test		វិធីសាស្ត្រ Ref. Method	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	លទ្ធផល Results
1	Total Coliforms,	MPN / 100ml	ISO 9308-2	$\leq 5.0 \times 10^3$(=5000)	2.4×10^3 (=2400)
2	Presumptive *E. coli*,	MPN / 100ml	ISO 9308-2	$\leq 5.0 \times 10^3$(=5000)	2.4×10^3(=2400)

P.D.W.W.I

បញ្ជាក់ដោយ

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ហែម ចាន់ថន

សំគាល់១ : លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ (2200) ។ ទំព័រ 1/1

Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 201B08/20

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Science, Technology and Innovation National Laboratory

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អ៊ីម៉ែល (E-mail) : hcs_cambodia@yahoo.com

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N°...189.24.0820.........

វិញ្ញាបនបត្រវិភាគ
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លេខ (N°) :202B08/20 ថ្ងៃ (Date):..27..08..2020

ឈ្មោះផលិតផល (Designation of Product) : Down Stream River

ពាណិជ្ជសញ្ញា(Trade Mark) :

ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU

អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft): ផ្ទះលេខ៣៨-៨១H ផ្លូវនពេក្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ

ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) :CHHOUR PUNLOEU ស្ថាប័ន (Organization) : **Czech University of Life Science Prague**

ថ្ងៃទទួលសំណាក (Sample Receive Date) : 24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 24/08/2020

ថ្ងៃចេញលទ្ធផល (Result Date) : 26/08/2020

ផ្នែកមីក្រូជីវសាស្ត្រចំណីអាហារ (Food Microbiological Section)

ល.រ N°	**វិភាគមីក្រូជីវសាស្ត្រ** Microbiological Test		**វិធីសាស្ត្រ** Ref Method	**ស្តង់ដាគុណភាពទឹកប្រភព** Standard Raw Water Quality	**លទ្ធផល** Results
1	Total Coliforms,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3$(=5000)	None found
2	Presumptive *E. coli*,	MPN / 100ml	ISO 9308-2	$\leq 5.0x10^3$(=5000)	None found

P.D.W.W.I

បញ្ជាក់ដោយ
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Technical Manager of FML

ថែម ចាន់ថន

<u>សំគាល់១</u> : លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ (2201) ។ ទំព័រ 1/1

Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 202B08/20

Note 2: STINL does not engage in sampling.

Note 3: The report shall not be reproduced except in full, without writing approval of STINL.

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Science, Technology and Innovation National Laboratory
ផ្លូវជាតិលេខ៥ ភូមិបឹងឈូក សង្កាត់គីឡូម៉ែត្រលេខ៦ ខណ្ឌឫស្សីកែវ រាជធានីភ្នំពេញ
(National Road N° 5, Boeung Chhouk, Km 6, Russey Keo, Phnom Penh, Cambodia.)
ទូរស័ព្ទ (Tel) ៖ (855) 12 826 035 / 92 549 281 / 12 820 475
អ៊ីម៉ែល (E-mail) : yuk.sokunsreiroat@misti.gov.kh

STINL
N° 163.24.08.20

លេខ (N°): **168W08/20**
ថ្ងៃ (Date): 04/09/2020

វិញ្ញាបនបត្រវិភាគ
Certificate of Analysis

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ឈ្មោះផលិតផល (Designation of Product) : Local Tab Water
ពាណិជ្ជសញ្ញា (Trade Mark) :
ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU
អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft): ផ្ទះលេខ៣៨-៨១H ផ្លូវនរោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ
ឈ្មោះអ្នកផ្តល់សំណាក (Sample Submitted by) : CHHOUR PUNLOEU ស្ថាប័ន (Organization) : Czech University of Life Science Prague
ថ្ងៃទទួលសំណាក (Sample Receive Date) :24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) :01/09/2020
ថ្ងៃចេញលទ្ធផល (Result Date) :04/09/2020

ផ្នែកគីមីសាស្ត្រទឹក (Water Chemical Section)

ល.រ N°	លក្ខណៈរូប-គីមី Physical Chemical Characteristics	វិធីសាស្ត្រវិភាគ Reference Methods	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	Limit of Quantitation (LOQ)	លទ្ធផលវិភាគ Results
1	ប៉េហាស់ (pH)	AOAC 973.41	5.5 - 9.0	-	7.38
2	អាសេនិច (As)	Photometric	≤ 50 µg/L	-	0 µg/L
3	នីទ្រីត (NO_2)	AOAC 973.50	≤ 3mg/L	-	0.03 mg/L
4	សំណ (Pb)	AOAC 974.27	≤ 50 µg/L	-	4.86 µg/L
5	កាត់មីញ៉ូម (Cd)	AOAC 974.27	≤ 3 µg/L	0.025µg/L	ND
6	តំរូវការគីមីអុកស៊ីសែន (COD)	AOAC 973.46	≤ 10 mg/L	-	5 mg/L
7	ស្យានីត (CN^-)	APHA 4500-CN-E	≤ 70 µg/L	-	0.001 µg/L
8	ប៉ូតាស្យូម (K)	AOAC 973.53	-	-	2.13 mg/L

បញ្ជាក់ដោយ
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តេខ ម៉ាន់ដារិទ្ធ

សំគាល់១ :លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ(2314) ។ ទំព័រ 1/1
Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 168W08/20
Note 2: STINL does not engage in sampling.

មន្ទីរពិសោធន៍ជាតិ វិទ្យាសាស្ត្រ បច្ចេកវិទ្យា និងនវានុវត្តន៍
Science, Technology and Innovation National Laboratory
ផ្លូវជាតិលេខ៥ ភូមិបឹងឈូក សង្កាត់គីឡូម៉ែត្រលេខ៦ ខណ្ឌឬស្សីកែវ រាជធានីភ្នំពេញ
(National Road N° 5, Boeung Chhouk, Km 6, Russey Keo, Phnom Penh, Cambodia.)
ទូរស័ព្ទ (Tel) ៖ (855) 12 826 035 / 92 549 281 / 12 820 475
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N°.......164240820.........

លេខ (N°): **169W08/20**
ថ្ងៃ (Date):.04/09/2020.

វិញ្ញាបនបត្រវិភាគ
Certificate of Analysis
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ឈ្មោះផលិតផល (Designation of Product) : Down Stream River
ពាណិជ្ជសញ្ញា(Trade Mark) :
ឈ្មោះម្ចាស់ ក្រុមហ៊ុន សិប្បកម្ម (Name of entrepreneur of Company / Handicraft) : លោក-លោកស្រី: CHHOUR PUNLOEU
អាសយដ្ឋាន ក្រុមហ៊ុន សិប្បកម្ម (Address of Company / Handicraft.): ផ្ទះលេខ៣៨-៤១H ផ្លូវនរោត្តម សង្កាត់ទន្លេបាសាក់ ខណ្ឌចំការមន រាជធានីភ្នំពេញ
ឈ្មោះអ្នកផ្ដល់សំណាក(Sample Submitted by) : CHHOUR PUNLOEU ស្ថាប័ន (Organization) : Czech University of Life Science Prague
ថ្ងៃទទួលសំណាក (Sample Receive Date) :24/08/2020 ថ្ងៃវិភាគ (Date of Analysis Commenced) : 01/09/2020
ថ្ងៃចេញលទ្ធផល (Result Date) :04/09/2020

ផ្នែកគីមីសាស្ត្រទឹក (Water Chemical Section)

ល.រ N°	លក្ខណៈរូប~គីមី Physical Chemical Characteristics	វិធីសាស្ត្រវិភាគ Reference Methods	ស្តង់ដាគុណភាពទឹកប្រភព Standard Raw Water Quality	លទ្ធផលវិភាគ Results
1	ប៉េហាស់ (pH)	AOAC 973.41	5.5 - 9.0	7.33
2	អាសេនិច (As)	Photometric	≤ 50 μg/L	0 μg/L
3	នីទ្រីត (NO_2)	AOAC 973.50	≤ 3mg/L	0.02 mg/L
4	សំណ (Pb)	AOAC 974.27	≤ 50 μg/L	5.18 μg/L
5	កាត់មីញ៉ូម (Cd)	AOAC 974.27	≤ 3 μg/L	0.67 μg/L
6	តំរូវការគីមីអុកស៊ីសែន (COD)	AOAC 973.46	≤ 10 mg/L	4 mg/L
7	ស្យានីត (CN^-)	APHA 4500-CN-E	≤ 70 μg/L	0.001 μg/L
8	ប៉ូតាស្យូម (K)	AOAC 973.53	-	2.16 mg/L

បញ្ជាក់ដោយ
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គេង វ៉ាន់ដារិទ្ធ

សំគាល់១ :លទ្ធផលនៃវិភាគនេះ មិនអាចប្រើប្រាស់សំរាប់ការផ្សព្វផ្សាយបានទេ និងមានតំលៃចំពោះតែគំរូដែលបានបញ្ជូនមកប៉ុណ្ណោះ(៦៦ទ) ។ ទំព័រ 1/1
Note 1: The result of analysis is not to be used for advertising purposes and valid for the submitted sample only. 169W08/20
Note 2: STINL does not engage in sampling.