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Risk Assessment for Groundwater Resources in Dili, The Capital City of Timor-Leste

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Abstract

As a newly independent nation-state, Timor-Leste is in the process of developing itself to achieve better condition to meet and provide the needs of its citizens. However, Timor-Leste is still facing challenges in many areas including lack of clean water supply from groundwater resources. Dili, the capital city of Timor-Leste, is an emerging urban city that makes water availability is crucial. High birth rate and continuing rural-urban migration to Dili signifies that population in Dili is likely to increase, and this has put more pressure on water resources. For the groundwater resource in Dili - deforestation, lack of waste management, and unsafe boreholes and unmanaged domestic wells - are the main issues that need to be addressed because they can greatly affect groundwater in terms of reducing the quantity and potential hazards for contamination. This paper highlights thatassessing the risk to groundwater resources is vital for the sustainable management of water supply in Dili.This paper can definitely serve as an effort to raise awareness about the groundwater issue in the country that should be considered by the government of Timor-Leste.

Key words: groundwater in Timor-Leste; water resource in Dili; risk assessment; water supply, water quality.

Introduction

Timor-Leste is located in Southeast Asia and Pacific, northwest of Australia and the east end of the Indonesian archipelago. The country has a land area of 14,610 square kilometers and a population of over one million[1] and comprises of 13 districts including the capital city, Dili (Figure 1). The country's boundaries include the eastern half of the island of Timor, the Oecusse enclave in West Timor and the islands of Atauro and Jaco. Timor-Leste gained its independence after 450 years under Portugal colonialism and 25 years of Indonesian occupation through a referendum made in September 1999. More than half of the Timorese are under 18 years of age[1]. In purely economic terms, Timor-Leste is a middle-income economy and one of the most oil dependent economies in the world. The high fertility rate, where on average women give birth to 6.7 children throughout their lifetime, is a key contributing factor to the high annual population growth rate of 3.2 per cent[1]. While much of the country remains agrarian, a phenomenon of rapid urbanization has been reported where about 22 per cent of the population lives in the urban areas.

Figure 1. A map of Timor-Leste showing the 13 districts including the capital city, Dili.

Timor-Leste is under the tropical monsoon type climate that distinguishes wet and dry seasons. Northwest monsoon winds prevail from December to March, bringing the principal wet season to most parts of the country. Meanwhile, the dry season is caused by southeast trade winds, which prevail from May until October except for the south coast and southern slopes where the wet season persists until July[2,3].Variations in topographic conditions and rainfall patternsinfluence temperature distinctions and the livelihood of the people in terms of availability of drinking water, agricultural practices and other activities that follow this usual pattern. These variations also become the natural barriers for the development efforts due to natural disasters such as regular landslides, erosion, and flooding during wet season, and drought during dry season.

As economic condition of Timor-Leste is quite weak, majority of the people in Timor-Leste depend on agriculture as the source of food and income. This condition makes rainfall pattern invaluable because it controls planting season. Rainfall is also vital for the recharge of water resources for the people as rivers, streams, and groundwater are the main sources of water.Therefore, this paper aims to assess the potential risks for groundwater in Dili the capital city of Timor-Leste. This paper hypothesizes thata better planning and management is needed to regulate insufficientpractices that can disrupt groundwater quantity and quality, henceto reduce harm to the environment and protect water resources in the country. We argue that identifying risks to water resources is vital for the sustainable management of water resources in Timor-Leste. This paper can definitely serve as an effort to raise awareness about the groundwater issue in the country that should be considered by the government of Timor-Leste.

This paper begins by briefly providing background on water resources in Timor-Leste with focus on Dili, the capital city. It then assesses the factors associated with groundwater in Dili with specific emphasis on deforestation, lack of waste management system and unsafeboreholes and unmanaged domestic wells in the country. Before drawing the conclusion, the paper presents some solutions that address groundwater resources constraints in Dili, which should be considered by the government of Timor-Leste.

Background

As a young country, Timor-Leste still faces challenges in many areas including lack of human resources, lack of institutional capacity, under-developed agricultural sectors, inadequate infrastructures, and many more that hinder the country from moving forward[1]. These challenges become a reference point for the government to determine priorities that require urgent action. Many efforts have been invested to address these challenges through many different means such as sending students overseas through scholarship programs, capacity building training within the country and abroad, hiring international advisors to share their skills and expertise where required, construction of infrastructures, and many other ways to improve the capacity of the Timorese people to help rebuilding the country.

Indeed, noticeable efforts have been devoted to manage, protect, and preserve natural resources. Water, one of these resources, is vital, yet finite and fragile, so continuous monitoring and management is crucial. In the water sector, efforts are apparent to assure access to clean drinking waterthrough various programs such as water supply and sanitation rehabilitation project, community-based water supply management system, repair the existing connection system by targeting all the main cities in the 13 districts throughout the country. These efforts are organized and carried out independently and collaboratively among different institutions and organizations through the governmentwater supply and sanitation departmentwith support from the US government, the Australian government, the Asian Development Bank and the World Bank. However, these efforts are still not enough as they focus on improving access and providing clean drinking water only in response to the emergency and immediate need of the community.

Water resources in Dili, the capital city of Timor-Leste

Dili has an area of about 372 square kilometers and it is the smallest district out of the 13 districts in Timor-Leste[1], but it has the highest number of population, a total of 167,777. High birth rate and continuing rural-urban migration to Dili contribute to increasing number of population, and it has put more pressure on water resources. The water supply system in Dili consists of 4 river intakes and 9 functioning deep bores that provide water for the city[2,3]. Table 1 shows the average daily water production of major sources (4 river intakes and 5 deep bores) of water supply to Dili.

Table 1. Average daily water production of major sources of water supply to Dili[1]

Source	Volume of Production (liter/sec)	Average (liter/sec)	Share (%)
Bemo Intake	150-250	200	27.9
Malao Intake	15-150	82.5	11.5
Bemori Intake	20-160	90	12.5
Benamauk Intake	10-150	80	11.1
Bore holes in Comoro	150-180	165	23.0

Bore holes in Kuluhun	42-52	47	6.6
Bore holes in Bidau	20-30	25	3.5
Bore holes in Becora	20-28	24	3.3
Bore holes in Bedori	3-5	4	0.6
Total	**430-805**	**717.5**	**100**

Moreover, the water in Dili is mainly distributed to households, businesses, industrial, and offices - the main areas where water is mostly used (Table 2). Both river intakes and boreholes are important source of water for Dili, and this water is distributed mainly through pipe-connection system to households, businesses, industries, offices and public taps. Although river intakes provide a great share of water supply, groundwater still contributes substantial amount to water supply, and it is the main concern because it is very difficult to clean up once polluted. Groundwater is sensitive and limited water source, and if the usage and withdrawal is greater than the recharge capacity, then it will be at risk of depletion.

Table 2. Classification of water connections and consumptions in Dili[3]

Classification	**Connections (number)**		**Consumption (m^3/month)**	
	Authorized	Metered	Authorized	Billed
Household	9174	2132	247698	57564
Offices	150	56	450	168
Businesses (large)	249	78	7470	2340
businesses (small)	218	50	3270	750
Industrial (large)	22	22	990	990
Industrial (small)	0	0	0	0
Public taps	91	0	10920	0
Social*	68	12	204	36
Water tankers			894	894
Total	**9972**	**2350**	**271896**	**62742**

Social* includes schools, hospitals, churches, and government offices.

Groundwater is not a simple phenomenon that is only related to the balance of recharge and discharge, but it alsolinks to so many different factors, especially certain land use practices that could affect the quantity and the quality of groundwater. In Dili, study about groundwater is very minimal. However, as a major source of water supply for the city, it is important to identify factors, especially practices that are instigated by people, which have negative impacts on groundwater. Identifying and understanding these factors and practices will be valuable for a better water resource management in order to protect and preserve the water resources, hence to ensure its sustainability in the future. This will help prevent issues such as shortage of water supply, groundwater depletion, and other water related problems in Timor-Leste.

Factors associated with groundwater in Dili

Dili is located along the coast and groundwater is one of the major sources for water supply. Coastal and groundwater could be a lethal combination for problems regarding water quality and quantity if it is not managed carefully. In recent years, the Geoscience Australia has created a hydrogeological map of Timor-Leste, but the current state of groundwater in Diliis relatively unknown due to lack of study and research. Thereby, it is important to identify main factors that can pose risks to groundwater so that necessary measures to prevent and reduce the risks can beundertaken.

Deforestation, lack of waste management, and unsafe boreholes and unmanaged domestic wellsare the main problems to groundwater resource in Dili. Therefore, it is important to address these issues because they can greatly affect the quality and quantity of groundwater. These problems have remained for a while at a rapidly disturbing and alarming rate. Due to their negative impacts on groundwater, it is significant to discuss these issues and assess why they can pose threats to groundwater resources. In doing so, it would enable competent bodies to explore strategies to deal with and tackle these issues, which will be essential for making a more integrative water resource management and policy.

Deforestation

The first main issue is deforestation, which is generally referred to as clearing or cutting down of trees and vegetation that results in the loss of forest. In Timor-Leste, agriculture is a practical choice for majority of the people because it is the main source of food leading to a mean of subsistence. Forest is primarily lost to agriculture, as people still practice shifting and burningfor agriculture practice[5]. The slashing and burning ofland for agriculture practice are common due to culture and belief and this has been passed on throughout the generations.

Another cause of deforestation in Timor-Leste is firewood collection that has become the main source for domestic fuel. It is estimated that 95 per cent of households in Timor-Leste use firewood to meet at least some of their coking needs, particularly in rural areas[6]. Firewood, therefore, has become a rational choice for the source of fuel for cooking because it is cheap and it has become a mean of cash income too[2,5] as compared to other options such as kerosene, which is a little bit more expensive, or electricity that is still unreliable at this stage.

Deforestation, affects water resources, which explains why it needs to be addressed when it comes to water supply for Dili. The water recharged areas for groundwater in Dili,specifically from Dare, Aileu, and Ermera have been identified to lose their forest to agriculture and firewood collection. This interrupts natural recharge cycle by reducing the quantity of water, which can result in less water infiltrates into the groundwater table. It also affects the water quality because of potential contamination from hazardous sediments, particles, and nutrients that are carried by run-off when finding their way to groundwater.

Lack of waste management system

Waste is another major concern that needs to be dealt with because it can easily contaminate groundwater as so farTimor-Leste has a poor waste management system. Waste management in Timor-Lesteis reported to be lacking due to many factors including lack of investment, facility,man-power, and understanding about waste and its effects to people and environment on so many levels. The biggest threat, nonetheless,can easily be the lack of consciousness from the people regarding sanitation and attitude towards trash and garbage disposal.

In specific to Dili, the city faces growingly disturbing condition of trash and rubbish scattered around the city without proper collection, storage, transportation and disposal system. Dili is a growing city that attracts more development activities to take place in the future due to increasing numbers of businesses and industries. This trend encourages more construction of roads, buildings and other infrastructures, and increases the import of fuels and goods, which can contribute to the increased amount of waste. The sources of waste in Dili are mostly related to the businesses and industries, domestic, and government offices, which generate substantial amount of different type of waste, with solid and liquid wastes as the predominant types. In a recent country analysis report, it is noted that both solid and liquid waste management in Timor-Leste is still poor mainly due to lack of facility to carry out the management process[7].

Solid waste in Dili mainly comes from industrial and commercial waste as well as from households. Although there have been efforts to construct waste dump in most of main road of every neighborhood, the system has not really functioned well due to lack of follow up and reinforcement. Nearby Dili, there is a landfill site located inTibar, which is a functioning landfill that was constructed during the Indonesian time, as a main waste disposal site for Dili. However, it is revealed that this landfill site does not have any treatment facility or a system for separation of waste type. This Tibar landfillaccepts all types of waste (both hazardous and non-hazardous) including hospital waste[8]. If Tibar landfill happens to have a leakage, it could have a catastrophic consequence as if the leakage finds its way to groundwater, people could be exposed to all kind diseases that are threats to their wellbeing. Therefore, the construction of this landfill raises a concern regarding whether it meets the standard safety requirements.

In the same way, liquid waste in Dili is mostly derived from domestic residences, businesses and industry. The state of liquid waste management in Dili, and throughout Timor-Leste, is still poor, but there have been attempts to manage and control the waste through government institutions, especially Directorate for water supply and sanitation under the Ministry of Public Works. In managing the liquid waste, a water waste management site was constructed in 2004 at Tasi-Tolu, about 13 kilometers west of Dili. This site has three treatment ponds that comprise of a facultative pond and two maturated ponds, and is connected to a hauling tanker hose[7]. Managing liquid waste in Dili is challenging because there is no proper storage system in addition to poor and disjointed drainage system leading to most waste flows directly and ends up in the sea. These liquid wastes comprise of human and animal waste as well as other fluid residues from different sources. It is identified that the most obvious and disturbing liquid waste in Dili is used oil because it is often reused and recycled in the automobile workshops and fuel stations without proper means of storage.

Unsafe Boreholes and unmanaged domestic wells

The water supply for Dili is drawn from 4 small rivers and 13 boreholes that produce approximately 28,850 m^3 of water every day[9]. In Dili, these boreholes deliver about 37 per cent of total share of water supply (Figure 2). Out of these 13 boreholes, it is reported that there are only 9 functioning boreholes, which are in good condition. Most boreholes are located in the residential areas; thus, it is in close proximity of residential houses, toilets, and animals dwelling areas. Such circumstances put these boreholes at risk of being contaminated. In addition, the techniques of drilling also need to be assessed in terms of whether or not sanitary measures are met.

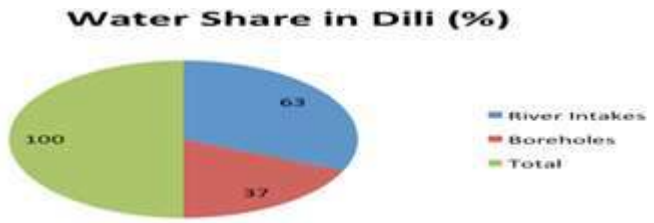

Figure 2. Water share in Dili from boreholes and river intakes.

Since many domestic wells are also at risk as they are constructed close to toilets (pit holes), and as houses are nearby, these wells are prone to contamination from washing detergent, dishwashing liquid, soaps and shampoo, and other substances that are used by the residents quite regularly. These conditions affect the quality of groundwater in terms of its suitability for human consumption. These domestic wells and local boreholes are numerous, but the exact number is not known. In the long term, this could be disastrous because if withdrawal of groundwater exceeds the sustainable yield, it will reduce groundwater table that can cause water shortage problem, and may lead to depletion of groundwater. Unmonitored and unknown withdrawal of groundwater in a coastal city such as Dili could lead to problem of salt water intrusion that makes water undrinkable.

Another important point to highlight is domestic wells and local boreholes that are unregistered and very much unknown. The main reason for the existing of these unregistered domestic wells and local boreholes is that many residential houses do not have water supply and are not connected to piped water supply. Therefore, these wells and boreholesbecome the sources of water supply. It is estimated that only about 43 per cent of Dili's households have authorized piped water supply connections, while a further 10 per cent use public taps or tanks and estimated 22 per cent of households have unauthorized connections[4]. The drilling of local boreholes and construction of wells indicates a problem in terms of inadequate and inefficient water distribution through water supply system, which requires swift attention.

What are some possible solutions?

In general, prevention is the only effective way to protect groundwater resource in Dili through raising awareness about the effects of these factors to groundwater. Efforts to raise awareness regarding this issue could be done through socialization process, training, workshops andsetting up a program in school curriculum in order to increase

people's understanding and knowledgeto change their attitude and way of thinking[10]. Possible solutions should focus on the main factors associated with groundwater risk.

Solutions to deforestation

In Dili, deforestation is related to economy and livelihood of the people as agriculture and firewood collection are related the source of food and mean of cash income for the people. Hence, these issues ought to be addressed,and a better farming method and agriculture practice also needs to be provided in order to reduce and minimizedestruction and damage. Deforestation has been taking place for a long time, not just in Dili but throughout the country so the following steps are necessary to protect the forest:

1. Forest monitoring

This is essential to see changes in the forest areas, and this could be done by visiting the areas and observe the changes over time, or by observing satellite images if available. This would help the identification of locations with rapid change so that protection and conservation efforts can be more focused.

2. Forest management

Forest management is also critical for efforts to reduce deforestation. This is where economic, social, and environmental aspects are taken into consideration to protect the forest; in a sense, forest regulations are designed in harmony with the livelihood of the people.

3. Forest plantation and reforestation

Forest plantations and reforestation programs should be encouraged and reinforced, especially in the unused farm areas and areas of critical deforestation. This has to be done with a right and practical method by involving local community to create a sense of ownership to ensure its continuation and long term protection. In addition, these efforts also need to consider the type of plants that are suitable for the particular environment so it would not disrupt the soil composition.

Clearly, those steps above are essential, not only to protect and preserve forest, but also to maintain forest capacity to hold water, hence to boost groundwater recharge and prevent erosion. As agriculture is also a cause of deforestation, a better farming technique needs to be introduced. For instance,introducing the application of crop rotation and compost techniques as a more effective way to maintain soil fertility rather than clearing a new area when the old one is no longer productive. Deforestation due to firewood collection for fuel, however, is tough one to deal with because current economic condition makes it very difficult to prevent it. Nonetheless, management process can be done in terms of identifying areas where this practice could be permitted and types of trees that are allowed to

be harvested as effort to control and reduce rapid deforestation. This effort can be revised and improved when other options such as electricity and kerosene are viable.Combining steps mentioned previously with better farming technique and control of firewood collectioncan reduce alarming rate of deforestation to avoid horrendous impacts, not only to groundwater, but also to the environment in general.

Solutions to lack of waste management

Waste management is important to monitor and control waste so that contamination of groundwater can be prevented and reduced to avoid any serious harm to the health of the people and environment. The management system needs to consider all the possible constraints and incorporate different technical matter so that appropriate method can be adopted and applied. Selecting proper management system needs a wide range of information such as knowing the sources and types of waste,understanding point and non-pointsource of pollution, identifying who and what organizations need to be involved as well as regulations to separatewaste into different categories. These are all important to facilitate a better waste management process.

In Dili, solid waste management system in terms of storage, collection, transportation and processing is still poor and needs to be improved. The Tibar landfill systemfor final disposal site is still insufficient andits structure also needs to be revised and improved as well ascontinuous monitoring and maintenance is needed to reduce hazards to the environment. Importantly, the location of the landfill needs to be reviewed in terms of its distance from residential areas because Tibar community is very much nearby.

For solid waste management in Dili, reduce, reuse, and recycle (3Rs) is another concept that needs to be explored and applied because it is an effective strategy for waste reduction application. 3Rs is an interconnected system that is essential to minimize wastebecause it promotes the idea of buying based on necessity, reuse if it is still viable rather than buy new ones, and recycle the used materials to make into new products. Combining this concept with a proper waste management system will help providing a better control to reduce risks of contamination. Also, it can create economic opportunities when a system of collection and recycle of waste is well established.

Dili has a waste water pond and tanks to store used oil, but this is very much inadequate and continuous monitoring and maintenance of these facilities are required. It is evident that Dili has a poor drainage and sewer system, or any proper system of storing used water waste. Hence, improving and upgrading existing sewer system will be essential as well as constructing new drainage and sewer system where necessary.

Another possible solution would be to ensure industries that produce liquid waste, such as automobile workshops, to have an on-site liquid storage facility so that it can be collected and transferred to the main storage site. The purpose of upgrading and constructing a proper drainage system, and on-site storage facility is to prevent uncontrolled spill of liquid waste to the ground that could put groundwater at risk of contamination.

Solutions to unsafe boreholes and unmanageddomestic wells

Regarding the existing boreholes and wells, continuous monitoring and maintenance is critical to ensure its safety. Water testing should also be done regularly, ideally twice a year in order to examine the quality of the water - whether it is safe for human consumption. In 2012, the National Directorate for Water Quality Control started its Water Quality Monitoring Program of 20 selected springs throughout the country[8], and such program should be done for public boreholes in Dili. Therefore, addressing a proper system of monitoring and controlling potential contaminants from entering these boreholes and wells should be the main priority.

For the future drilling of boreholes and well construction, a safe and sound drilling technique should be used to keep potential contaminants out. Therefore, the location of boreholes and wells needs to consider many factors such as distance from residential areas, toilets, drainage system, and any source of potential pollution to ensure their safety. In order to determine the best sites for boreholes and wells, it is essential to understandconcepts such as surface water flowas generally groundwater flows in the same direction. Thereby, identifying and understanding such concepts is invaluable for the future drilling and construction of boreholes and wells because many current boreholes and wells are located on flat area in the center of the city, which is not the best choice of site.

Ultimately, it is important to realize that many of these local boreholes and domestic wells are directly related to inadequate piped water supply connection system in reaching all the residential houses. Thus, this matter needs to be studied and analyzed so that satisfactory access to piping network by all households could be achieved. Constructing public taps has been pivotal for access to clean water, but monitoring and maintenance is also critical to ensure continuation of adequate daily water supply and the state of the public taps.

In addition, it is important to list all the local boreholes and domestic wells in Dili into a database because this will be helpfulfor the effort to estimate how much groundwater is drawnout through boreholes and wells. By knowing recharge and discharge rate, sustainable yield could be determined. Hence, this information would be invaluable for a better management and monitoring system so that problems such as salt water intrusion and groundwater depletion could be avoided.

In Timor-Leste context, there are many deterrent factors in efforts to better manage water resources to provide adequate water with good quality to the people. These challenges encompass many issues such as lack of man-power, facility, necessary equipment, financial support, and regulations to support and provide legal force for the community to follow. Therefore, collaboration among different government institutions, especially directorate of water supply and sanitation (under the Ministry of Public Works), Secretary of State for Environment, Ministry of Health, Ministry of Agriculture and Fisheries,and other relevant institutions is essential to provide platform for the efforts. Inclusion of related local and international Non-Governmental Organizations, local community, and educational bodies will also be critical for the success of the management efforts to find a practical and economically viable approach to deal with this issue.

Conclusion

Water resources are fragile but vital for every living organism, therefore, proper management for protection and preservation is crucial. The management of water resources is interlinked with many other factors that require serious consideration, and as a result, holistic approach in terms of looking at environmental, social, economic, and cultural aspects in the management process is a determinant factor for sustainability. Water is shared and used for many purposes in different areas that could contribute to the pollution of water, and thisexplains why the cooperation among different components and players are very critical for the success of maintaining the quantity and quality of water.

Groundwater resources in Dili are sensitive to contamination that can undermine quality and quantity of water, if proper protection measures are not taken. Groundwater in Dili has been identified to be affected by three main factors - deforestation, lack of waste management system, and unsafe boreholes and unmanaged wells, which can greatly reduce water quantity and quality. Protection efforts require the entire relevant bodies to work together to find practical waysin order to achieve satisfactory outcomes. In Timor-Leste, the government plays an important role because they have the legal authority and power to make things work and move forward, and therefore, cooperation amonggovernment institutions arefundamental.

As a young country, it is easy to fall into the perception that economic development supported by adequate security, infrastructures, and good governance is the priority whereas environmental issues tend to be ignored because it is considered as not a pressing and urgent matter. This view is misleading because this issue is going to haunt us in the future if proper protection and preservation measures are not takenfrom now. After all, sustainability can only be achieved if economic, social, and environmental dimensions are considered.

Therefore, it is better to take proper measures to manage water resources now to maintain its long term well-being rather than waiting until it reaches irreversible state. That is why prevention is more effective way to protect water resources because efforts to treat and cleanse water from pollution is time consuming and costly. As a new country,we have many cases from other countries to learn from, so that same mistakes cannot be repeated again, and thus, we need to be mature and strong enough to make tough decisions, not just for a good Timor-Leste today, but for a better Timor-Leste tomorrow.

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Appendix

1. Example of trash in Dili

2. Waste water pond in Dili

3. Example of used oil in small workshops in Dili