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Assessing the Impact of Reservoir Water Availability on Clean Water Quality

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Abstract

This paper aims to explore the key issues that govern water resource management in a particular District of East Tanjungpinang in Indonesia with particular reference to the reservoir systems on which the District relies heavily especially during the rainy seasons. Using both statistical analysis of water quality data and case-study / interview data, this research demonstrates that the district is exposed to climate variability, increasingly inadequate water infrastructure, and pollution threats. The research study shows that the reduction in water levels is being accompanied by poor water quality both due to poor infrastructure and increased pollution from industrial, agricultural and domestic sectors. The study provides new directions for water management, it emphasizes the need for enhanced more adaptive and resilient water management approaches that include technologies, infrastructure and green infrastructure. This also raises the call to develop better governance systems that increase opportunities for people's participation, better compliance with the law, and the incorporation of indigenous concepts with contemporary management systems. Overall, it advances the understanding of water security concept and provides findings and suggestions for other regions in the world experiencing the same issues in the management of the freshwater resources under the conditions of climate change and growing urbanization.

Introduction

One of the most vital elements of existence in the earth's ecosystems and our lives unequivocally, water, is not as secure as it should be for several reasons especially in the third world. Water has the multifaceted issue of management applying to its environment all round, and encompasses social and economic issues that require the complex solutions (Gleick, 2014). The reservoirs play an important role in water supplied in many parts of the world, but such structures are threatened by both natural and human impacts (Vörösmarty et al., 2010; Bănăduc et al., 2022; Mishra, 2023).

As applied to Indonesia, the large geographical area of the archipelago and the differing terrains all worsen water management. Source The water reservoirs that are important for the country's water management are also alarming vulnerable to environmental pollution and the effects of climate change (Ahmed et al., 2020; Upadhyay, 2020). For instance, the East Tanjungpinang District in the Riau Islands is a miniature representation of these concerns the Pulai and Gesek River reservoirs as the critical water sources for the district are under ever growing stress.

The population density of East Tanjungpinang has increased over the recent years as a result of migration from other parts within Indonesia and child birth hence exerting pressure on the availability of clean water. This demographic pressure is affecting water infrastructure

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positively but at the same time increasing competition for water resources (Buytaert & De Bievre, 2012). The water supply systems in the region especially the Pulai and Gesek River reservoirs are viewed as incapable of catering for the increasing demand. As a result, the problems of water scarcity are not uncommon especially during the dry season due to the low water levels in the reservoirs (Kumar et al., 2017; Şen, 2021).

Climate variability is therefore central to understanding how water impacts are distributed in this area of East Tanjungpinang. The research has revealed that the monsoonal climate of the area where there are clear differences between wet and dry season has influence on the changes of water levels in the reservoirs (Ahmed et al., 2020; Li et al., 2021; Liu et al. 2021). These fluctuations are further compounded by additional effects from climate change that have been associated with increased variability in rainfall, prolonged periods of drought and unseasonal and heavy rainfall (Woldeab et al., 2018). The unpredictability of climate in such a way presents great risks to water resources thus making it hard to provide set water supply throughout the year.

Also, the quality of these water reservoirs is gradually being degraded by pollution, which comes from a number of outlets (Zhou et al., 2020). There is evidence that agricultural activities in the surrounding areas make a significant contribution to water pollution: runoff from the fields delivers fertilizers, pesticides and other agrochemicals to the reservoirs (Wato, et al., 2020). This pollution exacerbates water quality putting pressure on the treatment plants leading to high operation costs with health hazards to the residents (Hughes et al., 2021). Similarly, it increases the problem through industrial wastes and domestic sewage that contain toxic compounds that are hard to filter through normal water treatment procedures (Saravanan et al., 2020).

Another problem of the reservoirs in East Tanjungpinang is sedimentation. Sedimentation is the major factor impacting the water storage capacity of the reservoirs as majority of the sediment originated from the upstream soil erosion and deforestation, and further dampening the water availability during higher demand period (Panday et al., 2015; Zaveri et al., 2020). Sedimentation results in a reduction in the available volume of water used in food production; this; in addition to adversely affecting the functionality of water supply systems, requires frequent dredging and maintenance at some extra cost.

All these interrelated issues put together call for a multi-faceted approach to the management of water resource in East Tanjungpinang. Implicit from the discussion is that water supply challenge is not just a water pipe problem but a complex problem that calls for analysis of the physical, social, economic and environmental characteristics. Novel investigations suggest that the application of the best Western water practices has to be complemented with the information that is accumulated by the inhabitants of the region (Kumar et al., 2017; 2014). It is for such reasons that this paper argues that there is need for an integrated approach to the management of water resources in the region in order to reckon with sustainable practices.

Methods

As a part of this research study, both quantitative and qualitative research approach were used in order to gain a deeper understanding of the problems that affect the availability of water in reservoir and the quality of clean water in East Tanjungpinang District. The approach is considered to ensure that it will be possible to get an overall picture of the problem and also conduct qualitative research to get the essential data from the locals and other stakeholders of the area.

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Study Area and Sampling Strategy

The study was carried out in the East Tanjungpinang District with emphasis on the Pulai and Gesek River reservoirs. These reservoirs are a source of fresh water in the district and convey the situation of water storage reservoirs and hence represents a sample case on broad water management problems in such regions. In the present study water samples were taken from several locations within the reservoir as indicated in Table 1.

Table 1. Sampling points

Reservoir	Sampling Point	Coordinates	Sample Type	Purpose
Pulai River Reservoir	Inflow	0.867, 104.345	Surface Water	Assess incoming water quality
	Outflow	0.875, 104.355	Surface Water	Assess water quality before distribution
	Mid-Reservoir	0.870, 104.350	Surface and Sediment	Evaluate sedimentation and pollution
Gesek River Reservoir	Near Agricultural Area	0.912, 104.380	Surface Water	Assess agricultural runoff impact
	Inflow	0.908, 104.375	Surface Water	Assess incoming water quality
	Outflow	0.918, 104.385	Surface Water	Assess water quality before distribution

Qualitative Data Collection

The part of the research that had a qualitative nature aimed at presenting the analysis of the perception and experience of people of the community regarding to the water resources management in East Tanjungpinang within the strategic context. This was achieved through several methods:This was achieved through several methods:

The participants engaged for the study included the residents, water managers, and environmentalist. These interviews were meant to provide clearer information on the problem with water availability, the perceived water quality and the social and economic implications of both problems. At the same time, field research involved sites that were identified in the district to have been severely impacted by water scarcity and water pollution. These types of cases enabled a close look at particular situations and some of the issues that particular populations experience.

SWOT analysis was integrated in the qualitative research in order to comprehensively look into the factors that may be as a strength, weakness, opportunity, and threat in managing the Pulai and Gesek River reservoirs. This analysis entailed focus group meetings that provided the cross-sectional list of internal and external activities that affect WRM. The SWOT framework enabled an orderly analysis of the existing management strategies so as to establish areas of strength, weakness, opportunities and threats that need to be formulated. The SWOT analysis results were applied in the formulation of the strategic recommendations in order to make them more realistic with the real-world constraints facing the local members.

Quantitative Data Collection and Laboratory Analysis

The water samples were taken with standard methods so as to avoid contamination, and the samples were analyzed to determine some physical and chemical properties of the water. Table 2 presents the details of the laboratory analysis for each subject.

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Table 2. Laboratory Analysis of Water Quality Parameters

Parameter	Instrument	Method	Purpose
pH	pH Meter	Electrode Method	Determine acidity/alkalinity
Turbidity	Turbidimeter	Nephelometric Method	Measure suspended particles
Nitrate Concentration	UV-Vis Spectrophotometer	Spectrophotometric Analysis	Assess potential agricultural runoff
Phosphate Concentration	UV-Vis Spectrophotometer	Spectrophotometric Analysis	Evaluate risk of eutrophication
Coliform Bacteria	Membrane Filtration Apparatus	Culturing on Selective Media	Detect fecal contamination and public health risk

The information gathered from these analyses enabled to assess water quality in the reservoirs and presence of health issues arising from pollution.

Statistical Analysis

The quantitative data were analyzed using SPSS (Statistical Package for the Social Sciences) in order to achieve the most substantiated approach to the statistical analysis of the results. Simple statistical analysis was then conducted using mean, standard deviation and range in order to present the correspondending values of each water quality parameter. Fixed variables followed Pearson correlation analysis to determine the existence of correlation between water availability proxied by reservoir levels and the water quality indicators such as turbidity, nitrate, phosphate content, and coliform bacteria. Multiple linear regression equations were then developed to estimate the effect of water availability on these water quality parameters. In order to control for the multicollinearity, regression models were inspected for multi-collinearity and sensitivity analysis was also conducted to look at the robustness of the regression coefficients.

Results and Discussion

Descriptive Statistics

To begin with, it is relevant to disclose basic measurements of mean values of the selected water quality parameters checked at different study points of the Pulai and Gesek River reservoirs. Such parameter includes pH, turbidity, nitrate concentration, phosphate concentration and coliform bacteria count.

Table 3. Descriptive Statistics of Water Quality Parameters

Parameter	Mean	Standard Deviation	Min Value	Max Value	Acceptable Range
pH	7.45	0.32	6.90	8.10	6.5 - 8.5
Turbidity (NTU)	12.5	5.78	5.3	24.6	< 5 NTU
Nitrate (mg/L)	5.8	2.4	1.7	9.5	< 10 mg/L
Phosphate (mg/L)	0.98	0.56	0.25	2.1	< 0.5 mg/L
Coliform Bacteria (CFU/100mL)	350	150	100	620	0 CFU/100mL

In analyzing the descriptive statistics, it was observed that the pH levels in both reservoirs are within the range of the PHS value for drinking water thus not too acidic or alkaline. However, turbidity covers the acceptable limit of 5 NTU which implies that there are particles afloat or

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suspended in the water which may be because of sedimentation or pollution. The values of nitrates are less than the maximal admissible concentration but the higher concentrations shown in some samples may be reflected agricultural impact. Phosphate contents, on the other hand are higher than the recommended level suggesting that there is a possibility of eutrophication in the water source. The high level of coliform bacteria in all samples is alarming because it points to fecal pollution which has potentially negative impact on the health of the public.

Correlation Analysis

Pearsons's 'r' correlation analysis was conducted to determine the correlation between the water availability (reservoir levels) and water quality parameters. The results are as follows: The summary of the results is highlighted in table 2 below.

Table 2. Correlation Matrix of Water Availability and Water Quality Parameters

Parameter	Water Level	pH	Turbidity	Nitrate	Phosphate	Coliform Bacteria
Water Level	1.00	0.12	-0.56**	-0.35*	-0.40*	-0.62**
pH	0.12	1.00	0.05	-0.02	0.08	-0.10
Turbidity	-0.56**	0.05	1.00	0.48**	0.52**	0.58**
Nitrate	-0.35*	-0.02	0.48**	1.00	0.45**	0.40*
Phosphate	-0.40*	0.08	0.52**	0.45**	1.00	0.47**
Coliform Bacteria	-0.62**	-0.10	0.58**	0.40*	0.47**	1.00

*Significant at $p < 0.05$ **Significant at $p < 0.01$

Analyzing correlation coefficients, we note some important findings that concerns the relationships between water levels and the quality of water. Interestingly, the two parameters were found to be inversely related, whereas water level decreases, turbidity increases thus suggesting that; suspended particles will not be diluted as water level decreases. Likewise, it was found that water levels have negative, though relatively higher and less significant, correlations with both nitrate and phosphate concentrations implying that low water level conditions intensify concentration of nutrients as may be attributed to dilution or increased concentration of runoff. The most significant negative relationship is noted for between water level and coliform bacteria indicating that this is of significant concern to human health since low water level means high contamination level.

Regression Analysis

Therefore, to investigate the effects of water availability of water quality deeper, a multiple linear regression model was created. Water level was taken as the fixed factor while turbidity, nitrate, phosphate and coliform bacteria were taken as the responses.

Table 3. Regression Analysis of Water Availability Impact on Water Quality

Dependent Variable	R^2	Adjusted R^2	F-value	Water Level	Standard Error	p-value
Turbidity	0.31	0.29	15.62	-0.58	0.15	0.000
Nitrate	0.12	0.10	6.78	-0.38	0.14	0.012
Phosphate	0.16	0.14	8.55	-0.42	0.14	0.004
Coliform Bacteria	0.39	0.38	19.45	-0.61	0.14	0.000

As supported by the regression analysis it is clear that water availability as re-presented by reservoir levels did influence the water quality in the East Tanjungpinang District. The two

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models, developed for turbidity and coliform bacteria produce the highest value of R^2 =0. 31 and 0. 39 respectively, which represent the highest variation in these parameters that can be explained by water level variation. The negative coefficients for water levels across all models further reinforce the findings from the correlation analysis: there is a higher level of water pollution as authorities and researcher find that with the drop the water quality, increased water turbidity, higher concentration of nutrients, and more dangerous bacteria present in water. The fact that all p-values that the study obtained were < 0. 05 underplays the importance of having adequate measures to deal with water impacts.

SWOT Analysis of Reservoir Water Management in East Tanjungpinang District

Table 4. SWOT Analysis

Internal Factors	**Strengths**	**Weaknesses**
Resource Availability	Reliable and consistent water source for the district's clean water needs.	Water availability is highly seasonal, with significant dependence on rainfall patterns.
Infrastructure	Existing infrastructure supports better water quality maintenance compared to alternatives like river water.	Aging infrastructure is prone to damage and requires frequent maintenance.
Water Quality	Generally better-maintained water quality compared to other sources such as groundwater.	Vulnerability to pollution from household, industrial, and agricultural waste.
Development Potential	Potential to develop reservoirs further for raw water supply, tourism, and irrigation.	Limited capacity to handle population growth and increased water demand.
External Factors	**Opportunities**	**Threats**
Technological Advancements	Adoption of advanced water treatment technologies to improve water quality.	Climate change causing droughts and reduced rainfall, impacting water availability.
Stakeholder Collaboration	Potential for collaboration between government, private sector, and community for sustainable management.	Rapid population growth increasing water demand, leading to potential water shortages.
Public Awareness	Increasing public awareness about reservoir preservation to prevent pollution.	Risk of water conflicts among users, potentially disrupting water supply and management.

The majority of the population of the district use the reservoirs as a major source of water supply, and in most of the cases, the quality of water in the reservoirs is comparatively higher than that of the river or even bore well water. The existing system may be old, although some of it, will still enable the provision of water of good quality. Further, these reservoirs can be developed more for other uses such as tourism and irrigation hence will create more benefits to the community. However, since the water in the reservoirs is dependent on rainfall, the availability of water is often erratic; especially in the dry season. Nonetheless, the currently established infrastructure is old but more or less serviceable and extremely susceptible to the effects of disasters more often calling for tender loving care. Also, the reservoirs are more vulnerable to water pollution hazards and these include domestic wastes, industrial effuls and

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agriculture drainage waters. It is also not capable of handling large population hence with the growing population people will require more water and the sources will be limited.

There are many ways through which the management of water in the district is still perceptible and hence can be enhanced. Increased use of well-developed water treatment technologies may lead to improved water quality and therefore the water can be consumed (Wu et al., 2021). In addition, involvement of the different government agencies, the private sector and the local people might help in coming up with better management practices. Likewise, the level of public concern for the preservation of reservoirs can even go a long way in minimizing pollution and guarantee sustainable sources of water supply. The existence of these threats dent the capacities of the district and the foremost of them is climatic factors where the existing climate change maladies may lead to reduced rain water availability, and defined dry spells. Population issues are also a major problem since it also leads to increased use of the water resources coupled with the expansion that may lead to water shortages (Pereira et al., 2009). Moreover there can be conflicts between various stakeholders of water causing problem of water supply and management which can hamper the water security.

Case Study Findings

Sungai Pulai Reservoir that contributes water supply to East Tanjungpinang water supply infrastructure is a perfect representation of water system fraught with the problem of rain-fed water reserve. The water level in the reservoir has decreased significantly to an average of only 90 cm of water; a fact which is symbolic of other weaknesses that define this region's water resources. It is worse, not a reproducing of drought during this dry season but a revealing of the more severe effects of climate change. The availability of the reservoir is utterly reliant on rainfall while in the past this proves effective, now the gamble is evidently ludicrously dangerous with climate instabilities.

But the problem of water availability at Sungai Pulai goes beyond fluctuation of environmental factors. The infrastructure surrounding the current reservoir was constructed at least several decades back, it is thus dismally emerging with some signs of degeneration. Although the above existing infrastructures are still functional, their condition is now deteriorating in an attempt to cater for the uganda's expanding urban population. The breakdown view indicates that the nature and frequent of occurrence and increasing maintenance needs portend that the system is living on borrowed time. This infrastructural weakness is complemented by the fact that the reservoir is contaminated by a three-pronged source of pollution including household wastes, industrial effluents and aerosols from agricultural produce. Pollution intensifies sedimentation rates that in any case are lowered by the diminished storage capacities of the reservoir. These factors affirm the necessity of a paradigm shift in the modalities of managing the reservoir especially from reactive to proactive and more so from a non-resilient defensive position.

Concerns of Sungai Pulai are reflected vividly in the challenges evident at the Gesek River Reservoir, but with some extra layers that make up total risk profile magntitude at Gesek River Resevoir more severe. The Sole source of adding water in the Gesek River Reservoir is rainfall and this makes it highly susceptible to development of seasonal dry seasons, which are occasioned by one of the severest effects of climate change, namely extended dry seasons. The present attempts at increasing the capacity of the reservoir which can be seen as a part of a more general strategic management are primarily still mostly short-term, substantive. Such measures, although help in part in mitigating the water crisis for some time and do not effectively change the problem of the absence of diverse sources of water inflow.

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Another problem is the water quality of Gesek River Reservoir. Due to neighboring farming operations, a lot of pollutants such as nitrates and phosphates found their way into the waters of the reservoir. These pollutants do not only affect the physical quality of the water to an extent that it cannot be directly consumed but has to undergo a process of purification but they also harm the ecosystem by causing eutrophication thus causing more imbalance to the existing ecosystem of the reservoir. There are also challenges in the water treatment facilities in the Gesek River Reservoir because they also fail often that compromises the water supply. The progressive costs of operations as related to the treatment of polluted water from this reservoir are evident, which underlines the costs of current practices (Tomomewo, 2021).

The status at Gesek River Reservoir is thus a clear example of a water supply system that relies on infrastructure that has outdone itself in terms of effectiveness in the current world. Forces of the external environment or demography have been pushed off to the future for continued dependence on outmoded technologies and managerial methods, and a balance of quite brittle equilirium. The case study therefore implies that the reservoir will not meet the district people's expectation of reliable and safe water supply if adequate investment in the physical infrastructure alongside research and experimentation of new management approaches is not made.

Interview Insights

In the studies, results have shown that the local users have had a strong concern about the availability and quality of the available water. This anxiety is more so especially when the water is expected to freeze during the dry season lowering the water levels in the reservoirs. Some of the respondents said they experienced interruptions of access to basic water; some of the residents said they purchase and rely on bottled water and private wells, which are costly and inaccessible. This change to other sources shows that there is no trust in the provision of public water supply as well as revealing the social and economic inequalities for safe water. People's worries in this research also highlight some of the social aspects of water insecurity, whereby the suffering is gravely felt among the vulnerable populations.

Further, according to interviews with the locals, there is increasing dissatisfaction with the local government's response to these water issues. A significant number of the population views the existing procedures of water management as inadequate and ad hoc rather than being based on the long-term water management objectives. This frustration is further aggravated by inadequate communication and information sharing by water management authorities resulting to loss of public trust. The cultural discontent of the community can be said to represent a central governance failure since such conditions, if left unchecked, presage higher levels of social instability and additional problems in controlling the flow of water in the district.

Employee interviews include water management officials who offered this comprehensive account of the challenges they have working to maintain the districts' water infrastructure and its qualities. They stressed on two factors that the existing infrastructure is old and the level of water pollution is rising which has put the water management system on the edge (Cosgrove & Loucks, 2015; Bouwer, 2002). The officials admitted that the current infrastructure is dilapidated and cannot accommodate the number of student enrolments and hence is always demanding expensive frequent repairs that the constrained district funds cannot comfortably support. In addition, the officials noted that the levels of pollution in the reservoirs have continued to rise to the point that water treatment becomes more and more costly and complicated. That has culminated to the adverse position where the true costs of achieving improved quality of water are increasing at a higher rate than the financial capabilities of the district.

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These interviews also showed understanding of the necessity to inject large amounts of cash into new technologies and structures in the water management field. But there was also understanding that such investments despite the need for them will not on their own be enough. The officials urged the need for water management to undertake a more holistic form where there is recognition of the water system and all the management activities inherent in a watershed, particularly the upstream ones that cause pollution and generation of sediments (Bogardi et al., 2021). This thinking is most relevant to the understanding that there is a paradigm shift in how the water resources must be managed in the context of East Tanjungpinang, where more attention must be paid not only to the supply of water, but the environmental effects of it.

The findings from the environmental experts shed more light on the structures of some of the key challenges to East Tanjungpinang water source further. They also underscored the need to adopt a watershed management approach that also seeks to take into consideration of all physical, social and economic influences that would affect both the quantity and quality of water in the watershed. They noted that majority of the problems affecting the district's reservoirs stem from upstream influences including deforestation, agricultural expansion, thus causing more runoff, sedimentation and pollution (Chakraborty & Chakraborty, 2021). Remaining upstream activities will cause the unsustainable use of water resources in the district if senior regulatory frameworks and better enforcement measures are not put in place, the experts noted.

The environmental experts also suggested the problem of the lack of climate adaptation initiatives pointed out also by other authors. They further explained that in the current setup the district has inadequate measures to adapt to the fluctuations and the severity in the rainfall as experienced in climate change. They urged the management to embrace dynamic management systems where provisions would be made to address new changes in an environment instead of following the conventional methods that are not in harmony with the current climatic change.

Infrastructure, Pollution, and the Escalating Costs of Water Treatment

The state of water supply systems and distribution infrastructure in East Tanjungpinang was identified as a growing concern in this study since the infrastructure became dilapidated and incapable of addressing the combined problems of demand and pollution. The presented results conform to the general tendencies described by the World Bank (2017) that indicate a long-term lack of investments in the water sector in many developing countries. In East Tanjungpinang community, timely maintenance is frequently needed and as the instances of failure not only interrupt the supply of water but also compounded the effects of pollution because the faulty structures are incapable of efficiently filtering the pollutants (Heris et al., 2023).

Industries, agriculture and domestic wastes have been cited as some of the sources that have largely been blamed for the increased pollution of the Sungai Pulai and Gesek River reservoirs water. The study also shows that higher levels of turbidity, nitrates, phosphates mean, among others, lower water level; results that are consistent with other studies conducted in regions experiencing rapid urbanization and industrialization whereby industrial and agricultural activities go unabated with severe contamination of water sources (Vörösmarty et al., 2010; Srivastava & Srivastava, 2020). This automatically means that when the water sources are low, the pollutants are also concentrated making the treatment plants the extra burden. This cycle of degradation does not only pose threat to the health of the people but also raises the issues of

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cost at which water has to undergo through more advanced technologies in order to be safe to consume as well as the technology to use (WHO, 2017).

As envision in East Tanjungpinang the problem of pollution and degradation of infrastructure, there is a necessity for a far broader framework of water management that calls for not only maintenance of the current. Some of the findings in the literature show that incorporation of green infrastructures like constructed wetlands, buffer strips and permeable surfaces can be efficient in reducing the effects of pollution since the runoff can be purified by these systems before it drains into the water bodies (Novotny et al., 2010). Additionally, enhancement of the land use planning in a way that the vital water resources are not occupied by industrial or agricultural activities should be made to ensure that water can be protected from contamination (Foley et al., 2005). This also applies to funding modernisation of infrastructure. This includes not only dealing with the improvement and strengthening of the existing facilities, but also the application of smart technologies for water management that allow monitoring the water quality, the degree of using water resources, as well as identifying system failures before their occurrence (Kumar et al., 2020). Investment in these systems though expensive initially is required to minimize the recurring expenses which are involved in water treatment so as to secure adequate water supply in the future.

Governance, Community Engagement, and the Role of Trust

Some of the governance issues noted in this study, namely the loss of public confidence and absence of community participation in water management policies are formidable barriers to water management in East Tanjungpinang. The interviews with local residents showed mistrust of the current strategies as ineffective and not able to address the needs of people. This finding is consistent with other research findings asserting that participatory governance enhances emergence of robust water systems (Ostrom 1990; Pahl-Wostl et al., 2007). Where the community participates in the decision making processes in their management, the general community will have would better support and embrace the set management strategies and hence lead to better sustainable results (Hurlbert & Gupta, 2015; ; Doppelt 2017).

It is especially the case with the loss of public trust in East Tanjungpinang since it hampers water management policies. Trust is a critical element in governance because it help to avoid conflicts and fosters the establishment of legitimate ‘rules of the game’ and actual cooperation in the implementation of decisions (Leach et al., 2010). And based on the findings of the study, some of the possible solutions aimed at reconstructing this trust include enhancing the overall transparency, increasing the level of communication, and strengthening the community engagement for the more effective and integrated management of the water-related issues in the district. This is in concord with research evidence where organizations that involved stake holders in management of water resources have the improved environmental and social returns (Reed, 2008; Carey & Sunding, 2001).

In addition, the area that calls for more stringent rules and proper implementation mechanisms as affirmed by the environmentalists in the study is the need for better regulations. This means that sound water regulation entail not only good and satisfactory sets of rules but also enforcement mechanisms in the companies in question (Gleick, 2000). However, the absence of water enforcement is a limiting factor in most developing areas including East Tanjungpinang. Another consecutive measure toward improving the standards of water management practices, as well as addressing the objective of ensuring fairest distribution of water sources, requires the enhancement of such regulations, as well as institution-building. Currently, the research results suggest that there is a need for adopting the indigenous knowledge and practice in the modern water resource management. In most societies, people

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have improvised over the years with ideas on how water could be used and properly managed (Berkes et al., 2000). The information should not only be acknowledged but included in official management frameworks to improve and develop the climate resistance of water resources and the relationship between communities and the institutions in charge of water infrastructure.

Towards a Resilient and Integrated Water Management Strategy

The integration of this research to existing literature highlighted several important strategies for development of effective and sustainable WRM in East Tanjungpinang locale. First of all, there is an imperative of investing in public works, which does not only mean merely retrofit and maintain the existing infrastructure, but to build new one that can support the demand in the coming years. This involves the application of high-end treatment system, use of automated water management systems, as well as the purchase and use of structures that will minimize the overall effects of water pollution. Second, pollution control requires special emphasis while applying policies within the total concept of water management. Reducing pollution inputs especially chemical, physical and biological inputs is an effective way of protecting water bodies through enhanced legal standards, improved land use control and assimilation of green infrastructure. This means that, the potentially applicable management approaches, which have been developed through considering the whole water cycle and the human impacts on it, can pave the way for the improved management of water resources (Falkenmark & Rockström, 2004). Third, there is need to undertake governance reforms in order to create a strong water management systems. This entails increasing stakeholders' participation, increasing accountability, and developing sound regulations. Decentralized political structures of governance that promote the engagement of community stakeholders in critical decisionmaking works towards reforming blind public trust in the existing water management systems. In addition, it may require development of institutional capability to enforce regulations as well as to efficiently manage the water resources.

Conclusion

It makes a critical qualitative analysis of important issues related with water resource management in East Tanjungpinang District to illustrate all the issues of water security, which are essential in different developing areas. The study shows that the water supply system is very sensitive to climate variability due to over reliance in reservoirs whose source is mainly rainwater and thus restricted for operation during dry seasons. These vulnerabilities are compounded by depreciation in infrastructures and increasing pollution standards which result in unprecedented loss in water quantity and quality. Comparing the two water resources, the study reveals the need for a shift in water resources management system in district. It involves the identification of the need to shift to a new water management paradigm with capacities that are compatible with climate change unpredictability. Among such factors, most important is to invest into infrastructure modernization, acquisition of the most advanced water treatment technologies, and development of the green infrastructure. In addition, commendations are made for the need to improve the governance structures that promote the involvement of the community in the decision making as well as increase the rigidity and effectiveness of the regulatory and sanctions systems. The application of indigenous wisdom and knowledge in water management in conjunction with the use of contemporary practices of management together with participation in governance could be a way of achieving a positive and secure future for water resources in East Tanjungpinang. By identifying the weaknesses and threats which exist currently, as well as continued emphasis on strengths and opportunities, the district should serve as an example to other areas that are struggling with water management issues. The conclusions of this paper provide some answers to the state and future of water security in

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developing nations, including East Tanjungpinang, but also bring some ideas for the discussion of numerous environmental and infrastructural issues in water resource management.

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