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Appropriate Discharge from Diversion Dam to Dilute High Concentrated Community Wastewater of Riverbank Settlements along Phetchaburi River in Phetchaburi Province, Thailand

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Abstract

The research was focused on determining dilatability of traveling mass water from Phetchaburi diversion dam on high concentrated community wastewater that flowing into Phetchaburi river. The mass water quality was sampled at six-consecutive measuring stations from Phetchaburi diversion dam to the river mouth with various distances of traveling, and analyzed for 27 environmental indicators before employing ANOVA ANALYSIS which resulted with highly significant differences between indicator and station only BOD, COD, TSS, and turbidity. When the linear regression was employed to determine both the water quality indicators in relation to discharges (10, 15, 20, and 25 cms.) and the traveling distances, resulting the determination coefficients of 0.93 for BOD, 0.80 for COD, 0.83 for TSS, and 0.50 for turbidity. Only BOD value is included in the list of surface water quality standards. After employing the derived equations to calculate BOD in comparison with observed value, then it was chosen to support the decision of required BOD for 3 mg/L at Muang Municipal Bridge together with discharge of 10-15 cms from Phetchaburi diversion dam. If more or less this range in summer period, the dilatability of high contaminant concentration was decreased 2-10 folds due to less mass water flow and washing off organic and solid wastes from flooding along the riverbanks. Furthermore, the traveling mass water from diversion dam is possibly eligible to dilute the high concentrated wastewater from dense and populated community but the diluted mixture depending on the amount and concentration of wastewater inflow.

Keywords: diversion dam, dilute, community wastewater, riverbank settlement

1. Introduction

1.1 Dilution Process between Main River and Streamlets

Stream pollution is the condition of some or all parts of spaces between water molecules with physical particles, chemicals, and organisms due to driving forces of surface runoff and subsurface flow to wash off them contaminating in water (Kraus et al., 2014; Chidya et al., 2011; Derx et al., 2014; Faulkner et al., 2014; Liu & Chen, 2009; McColl, 1974; Ntengwe, 2006; Postel & Richter, 2003; Reynolds, 1995; Srigate, 2009; Streeter & Phelps, 1958). Naturally, raindrops fall on the earth coverage which can be identified as bare soils, rocks, cultivated crops, forested trees, water body, households, buildings, and roads before separating into surface runoff and subsurface flow through infiltration and penetration processes (Streeter & Phelps, 1958; Thaipichitburapa et al., 2010; Gburek & Folmar, 1999; Faerge et al., 2001; Mangimbulude et al., 2012; Metcalf & Eddy, 1979; Neal et al., 2010). Basically, the soil types are the main point sources for creating the stream water quality as the point effects of surface runoff rather than subsurface flow, and also the properties in high absorptivity, absorptivity and screening of toxicant contaminants. Actually, the contaminants as released in to stream are mostly chemical elements and compounds through soil water flow as the same manner as man-made chemicals (pesticides and herbicides, industrial toxicants) organic wastes, and microorganisms through surface runoff process (Hill et al., 2014; Robinson & Maris, 1985; Satterlund, 1972, Wahla & Kirkham, 2008; Tanji et al., 2006; Berkun, 2005; Cazelles et al., 1991). In contrary, the settlements along the riverbanks play vital role in Klong (canal) conditioning stream pollution by washing off food wastes, fats, dead animals and plants, home garbages debris, toxic chemicals, detergents, eroded soils, colors, and water-born diseases. It is noticed that the concentration of contaminants in stream pollution was varied among seasons and amount of streamflow as well as the diluting-rainwater capability (LERD, 2011; LERD, 2012; Thaipichitburapa et al., 2010; Streeter & Pheiplps, 1958; Reynolds & Edwards, 1995; Berkun, 2005; Robison & Maris, 1985; Faerge et al., 2001). In addition, the stream length was influenced in the excessive contaminants owning to the efficiency of self purification in which the longer the distance is the more the recovery (Ntengwe, 2006; Vagnetti et al., 2003; Cazelles et al., 1991; Tanji et al., 2006; McColl, 1974; Liu & Chen, 2009; Kraus et al., 2014). In the same situation, if the bacterial digesting rate is less than organic wastes (both solid and liquid) releasing rate then the stream pollution may be caused the seriousness, especially the zones of dense populated in the riverine systems (Derx et al., 2014; Pattamapitoon, 2013; Vargaftik et al., 1983; Wang et al., 1978; Tyagi et al., 1999; Penha-Lopes et al., 2011; Srigate, 2009; Streeter & Phelps, 1958).

As stated above, it is awful in case of point sources settling very close or inside the riverine systems which cannot be avoided polluting the organic wastes in forms of solids, wastewater, oil and grease, gases, and microorganisms into the river that making water resources in limited utilization. old Thai cultural settlement were familiar with along both sides of riverbanks in order to have water usage for everyday lifestyle, growing crops, livestocks, fisheries, transportation, serving ceremonies (religious, traditions, believes, and sports), restaurant and fresh food markets, and finally cleaning up human wastes. In other words, the rivers/streams have their function as spittoon for receiving all wastes which are produced by human activities and some case by natural disasters. However, most of Thais believe that streamflow as the same as running water in the rivers can powerfully be able to eliminate all waste forms without any constraints. Such the belief has been brought the stream pollution condition almost every important river in the whole country, especially in the central part such as Chao Phrya, Tha Chin, Mae Klong, Bang Prakong, and Phetchaburi rivers. It has been surprised to point out that there is exactly official wastewater treatment from households as settled along both sides of riverbanks, only protection measures being issued for public application.

Long term experiences can be brought up to initiate the dilution process for deducting higher toxic concentrations of urban effluent down to natural stream-water flowing in which the diluted water should contain non-toxic amount of contaminants (Luderitz et al., 2004; Kraus et al., 2014; Liu & Chen, 2009; Faulkner et al., 2000). Luckily, Phetchaburi watershed has been composed of Kang Krachan storage dam and Phetchaburi diversion dam for providing mainly to large irrigated areas for growing rice, fruit trees, farm plants, livestocks, and waterworks (Linsley et al., 1988; Lajoie et al., 2007; Matthews & Richter, 2007; Chunkao et al., 1981; Coleman, 1953; Cheng et al., 2002; Berkowitz et al., 2011; Brooks et al., 1991; Brooks et al., 2013; LERD, 2011; Vorawong et al., 2014, Poommai et al., 2013). It was very often that Royal Irrigation Department ignored to drain water for conditioning the environment in terms of diluting to high concentrated effluent from dense populated Phetchaburi riverbanks of downstream zone likewise Phetchaburi municipal which is the principal city of Phetchaburi province. Consequently, this research is focused on how to govern water flow from Phetchaburi diversion dam to dilute Phetchaburi municipal effluent quality under standards (for example BOD less than 4 mg/L). For accomplishing such target, the mathematical model of dilution process has to be considered by starting up with dilution equation from the concepts of Streeter & Phelps (1958), Tchobanoglous & Schoeder (1985), Mathews & Richter (2007), Tanji et al. (2006), Tyagi et al.(1999), Cazelles et al. (1991), and Wang et al. (1978) as follows:-

$$Ct = (QoCo + qaCa)/(Qo + qa) \quad (1)$$

Where

Qo = discharge of stream at the crest of diversion dam, cms

qa = discharge of streamlet inflow, cms

Co = environmental-indicator concentration at crest of diversion dam, mg/L

Ca = environmental-indicator concentration of streamlet inflow, mg/L

Ct = environmental-indicator concentration of mixed streamflow, cms

Figure 1 has intention to express the influences of wastewater inflow from point sources (such as fresh-food markets, households, medicare centers, etc.) that could be polluted more organic wastes and toxic compound as the same as disease microorganisms into non-polluted streams in which the relationships can be shown in below equations:-

$$C1 = (QoCo + q1Cb1)/(Qo + q1) \quad (2)$$

$$C2 = (Q1C1 + q2Cb2)/(Q1 + q2) \quad (3)$$

$$C3 = (Q2C2 + q3Cb3)/(Q2 + q3) \quad (4)$$

$$C4 = (Q3C3 + q4Cb4)/(Q3 + q4) \quad (5)$$

$$Cn\text{-}1 = (Qn\text{-}2Cn\text{-}2 + qn\text{-}1Cbn\text{-}1)/(Qn\text{-}2 + qn\text{-}1) \quad (6)$$

$$Cn = (Qn\text{-}1Cn\text{-}1 + qnCn)/(Qn\text{-}1 + qn) \quad (7)$$

$$Cn+1 = QnCn + qn+1Cn+1)/(Qn + qn+1) \quad (8)$$

Where

Qo, Q1, Q2, .Qn = discharge at diversion dam crest to off-town point, cms

q1, q2, q3, ...qn = discharge of streamlets 1, 2, 3 .... to off-town point, cms

Co, C1, C2, ..Cn = water quality concentration of diversion dam, and after streamlets 1, 2, 3, ...to off-town point, mg/L

Cb1, Cb2, Cb3, ..Cbn = water quality concentration of streamlets 1, 2, 3, …to the last one, mg/L

Naturally, water is evaporated from water surface during traveling that makes Qo > Q1 > Q2 > --- > Qn from the diversion dam throughout the river mouth. In principles, the flow coefficient is presumably constant throughout the stream route and given as Ks which is defined as hydrograph recession coefficient of the river (Linsley et al., 1988; Penman, 1948; Niedzialek & Ogden, 2012; Chunkao, 2008; Wang et al., 1978). The forthcoming of streamflow after mixing with streamlets can be determined by the following equations:-

$$Q1 = KsQo + q1 \quad (9)$$

$$Q2 = KsQ1 + q2 \quad (10)$$

$$Q3 = KsQ2 + q3 \quad (11)$$

-

-

$$Qn = KsQn\text{-}1 + qn\text{-}1 \quad (12)$$

In Figure 1 and equations (9) to (12), the streamflow is able to derive by substituting equation (9) through (12), and results found in the following equations

$$Q3 = Ks[Ks\{(KsQn\text{-}3 + qn\text{-}2) + qn\text{-}1\}] + qn$$

$$Q3 = Ks[Ks2Qn\text{-}3 + Ks2qn\text{-}2 + qn\text{-}1] + qn$$

$$Q3 = Ks3Qn\text{-}3 + Ks2qn\text{-}2 + Ks\ qn\text{-}1 + qn \quad (13)$$

If n is supposed to be 3 as the maximum streamflow measurement in equation (13), this can be rewritten as

$$Q3 = Ks3Qo + Ks2q1 + Ksq2 + q3 \quad (14)$$

-

-

$$Qn = KsnQo + Ksn\text{-}1q1 + Ksn\text{-}2q2 + Ksn\text{-}3q3 + qn \quad (15)$$

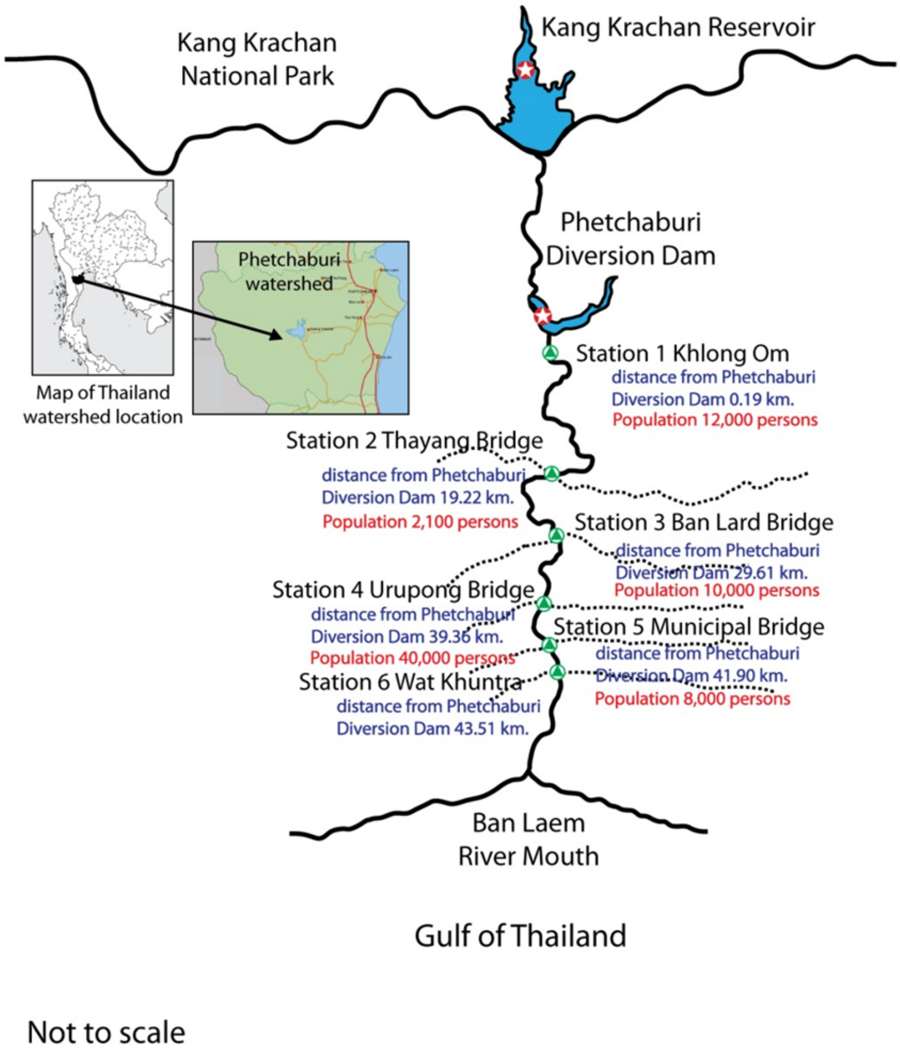


Figure 1. Hypothetical dilution process between main river and streamlets as flown from Phetchaburi diversion dam, downstream of Kang Krachan storage dam, in central-western part of Thailand

The equation (15) can be useable for calculating water flow (Qn) at the concerned point sources which is needed to diluting by river water. Therefore, the most important discharge is placed on Qo from diversion dam which provides the original water quantity to dilute the wastewater from the community point sources. However, the equation (15) has to be developed under the principles of mathematics as:-

$$Qo = 1/(Ks)n[Qn - \{Ks(nE-1)1q1 + Ks(nE-2)2q2 + Ks(nE-3)3q3 + --- + qn\}] \quad (16)$$

There are a lot of river that water has been drained out to serve needs of irrigation for growing crops, waterworks for household consumption, and any specified purposive. Unavoidably, the streamlet discharge (qi to qn) has to be changed in negative sign rather than positive sign which becomes the important factor for decreasing streamflow from the beginning to the last point. It is clearly understood that an application is possibly directed to Qn in equation (15) and Cn in equation (7) as the quantity and quality of main stream while qn and Cbn as the volume of wastewater and its concentration have to measure directly at that point sources in order to mix each other for dilution process. In addition, the application all aforesaid equations have to know the amount of point sources inflow and its quality which will be flown into better water quality of rivers, streams, and another water sources before becoming stream pollution. It is remarkable to identify the point sources in case of human settlement along the riverbanks because of no pattern availability to locate them. So, the uncertainty amount of discharge and it quality of streamlets are difficult to determine but the only indirect measurement could be obtained better results.

The research is focused on quality of water mass as drained out from Phetchaburi-river diversion dam that traveling throughout the dense populated settlements in relation to four streamflow velocities, i.e., pre-experiment (p), 10, 15, and 20 cms in order to control QoCo for maintaining the dilution process in decreasing concentration of water mass inflow as produced by dense populated zones along Phetchaburi riverbanks for better stream water quality at appreciating level. The previous researches were enhanced to hypothesize that the dilution process is preferable for decreasing concentration of community wastewater, and also increasing dissolved oxygen for accelerating bacterial digestion process as well as diluting toxicity.

1.2 Phetchaburi Riverrine Characteristics

The Phetchaburi river is about 80 km in length, 15 m in width at the Phetchaburi diversion dam and 30 m at the river mouth, and varying in depth from stream bed (60 m) up to the top (250 m) which is able to support the released enough streamflow up to 35 cms without flooding along the riverbank settlement areas. Normally, the Phetchaburi river is identified as the main stream of Phetchaburi river watershed which located between the latitude 12* 42' to 13* 38' N and longitude 99* 10' to 100* 8' E with the covering total area of 5,692 sq.km. (1,423,000 acres) including Kang Krachan storage reservoir (storage capacity of 710 MCM) 46.5 sq.km. (11,625 acres), about 227 km from highest divide downstream to Phetchaburi river mouth while distance between Phetchaburi diversion dam to the Gulf of Thailand 80 km. In addition, the Phetchaburi watershed has been comprised of 4 sub-watersheds: they are Huai Banklai (45 km),Huai Pradon (56 km), Huai Pak (30 km), and Huai Mae Prachan (62 km) as shown in Figure 2. LDD (2011) has classified Phetchaburi watershed into forest cover (58%), upland cropping (11%), paddy rice fields (13%), community (2.47%) water body (3%), and others (1%). Besides, the watershed was divided into 4 zones: firstly, headwater from highest elevation of 1,202 mMSL down Kang Krachan storage dam with coving area of 2,210 sq.km.; the middle zone area of 1,324 sq.km between Kang Krachan storage dam and Phetchaburi diversion dam; and lowland from Phetchaburi diversion dam to the river mouth (1,028 sq.km.) at the Gulf of Thailand; and seashore watershed 1,040 sq.km as shown in Figure 2 and Table 1.

The Phetchaburi river is the same as another rivers in Thailand that cover with forest cover on headwater areas in higher elevation (2,219 sq.km.) in which it has been functioned as continuously water supplier to streams in order to feed the Phetchaburi irrigated cultivating, community waterworks, municipality, aquatic lives, livestocks, and saline intrusion. Naturally, the Phetchaburi riverine has been formed on very steep main limestone rock type at high elevation and rapidly lowering slope before connecting with the Kang Krachan reservoir in upland with the stream profile of 1 m per 800 km (0.13%). In other words, the lowland area is exactly identified as S-shaped character while the mountainous land forms L-shaped stream because of more kinetic energy to scour the blocking soils to become the narrow to wide channel before going to be the streams (see Figure 2). However, it has been quite clear that the averaged slope of Phetchaburi River was identified as low stream profile of 1-m height per 800-km distance. Consequently, it would be pertained low flow velocity in total picture (high on higher elevation and lower on lowland) together with gradually increasing the width and depth throughout the river mouth. Anyhow, the said river evolution actually began from U-shaped cross section before gradually transforming to V-shaped cross section, and finally to be bowl-shaped cross section of matured river. Accordance with the aforesaid river evolution, it has been characterized in soft and fragile riverbanks and its depth rather than steady and non-fragile streams. This is why the riverbank erosion whenever the excess streamflow occurring together with heavy rain in some areas. Field observation found the riverbed nearly smooth to transfer its low streamflow velocity by gravity from Phetchaburi diversion dam throughout the river mouth at the Gulf of Thailand.

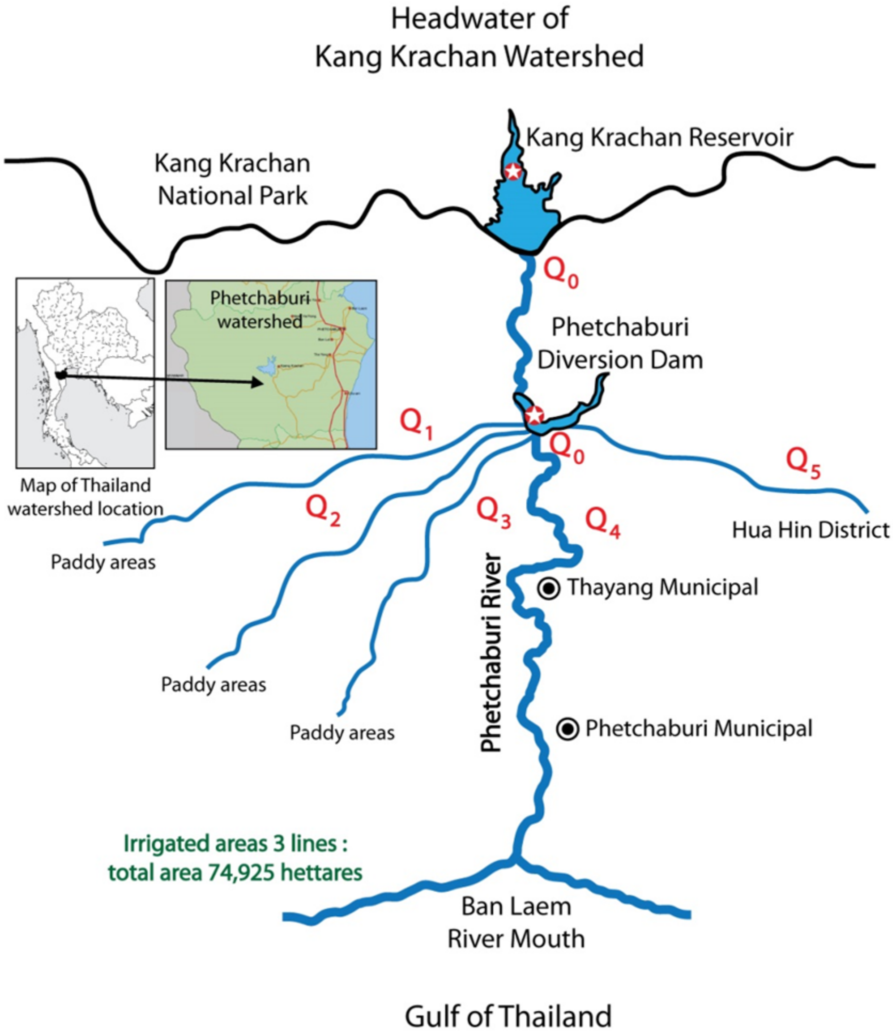


Figure 2. Characteristics of Phetchaburi watershed and Kang Krachan National Park together with riverine systems and localization of Phetchaburi diversion dam site including point sources of community wastewater, measuring points at the middle of bridges as located in Phetchaburi province, the central part of Thailand.

Table 1. Existing land using distribution in the whole Phetchaburi watershed with natural-dense forest dominance in headwater as located inside Kang Krachan National Park, Phetchaburi province, Thailand

Type of Land Use	sq.km.	%
1.Forest	3,606.28	58.43
2. Mangrove forest	39.94	0.65
3. Forestry plantations	118.66	1.92
4. Prairie and shrub	291.60	4.72
5. Pasture	0.19	0.00
6. Paddy field	770.14	12.48
7. Grass field	1.61	0.03
8. Salt filed	40.64	0.66
9. Farm crops	134.17	2.17
10. Sugarcane	111.36	1.80
11. Pineapple	175.28	2.84
12. Pineapple/standing timber	3.36	0.05
13. Horticulture	7.61	0.12
14. Standing timber	476.01	7.71

15. Livestock	2.03	0.03
16. Aquaculture	78.71	1.28
17. Lowland	25.61	0.41
18. Village	56.35	0.91
19. Government office	36.37	0.59
20. Commercial zone	37.83	0.61
21. Golf course	22.38	0.36
22. Industry	11.13	0.18
23. Mine	14.38	0.23
24. Water	109.47	1.77
25. Others	0.68	0.01
Total	6,171.80	100.00

2. Method

2.1 Streamflow Velocity and Flow Measurement

The experiments were focused on mobile massive water from beginning point, the Phetchaburi diversion dam, throughout the river mouth at the Gulf of Thailand, that makes the calculation of flow velocity necessary for getting to know where it reaches at the designated points (Linsley et al.,1988; Chunkao, 2008; Brooks et al., 1991; Brooks et al., 2011). To fulfill the experiments, the flow velocity (V) in basic equation for discharge calculation from Q equivalent to VA by constructing the following equation (17)

$$V = Q/A \tag{17}$$

Where

V = flow velocity, m/s

A = cross section area, sq.m.

Q = discharge, cms

As stated before, Q is given in discharge/streamflow that can be measured by current meter or constructed weir (90 V-Notch,120 V-Notch, and regulation weirs) together with staff gage at the deepestriver (mostly at the middle of the river) while A and V are referred to cross sectional area and streamflow velocity, respectively at the measuring point on stream.In this experiment, Q is fixed at 10 cms, 15cms, 20 cms and 25 cms on which either A or V has to be directly measured at the measuring points as shown in equation (17). However, these experiments applied V for determining the traveling time of mass water which released from Phetchaburi diversion dam at every 02:00 o'clock (night time) on four dates of 5, 6, 7, and 8 April 2010.

2.2 Sampling Point Localization

Since, the experiments were paid more attention on role of mass water in diluting the community waswastewater inflow from both sides of Phetchaburi riverbanks as dense populated areas, especially the inflow of Phetchaburi municipal having to be under surface water quality standards owning to such dilution process. In order to achieve the objective, the qualitative mass water flow has to be analyzed on the way from Phetchaburi diversion dam throughout the river while it travels to the mouth at the Gulf of Thailand. Under the selection of dense populated zones, six sampling points were identified along the Phetchaburi river as (1) Klong La Om (underneath of Phetchaburi diversion dam bridge, SW1), (2) Thayang bridge (Thakoy Temple, SW2), (3) Ban Lard bridge (SW3), (4) Urupong bridge (SW4), (5) Municipal bridge (SW5), and (6) Khunta bridge (SW6) as illustrated in Figure 3 which were taken in relation to hand in hand with traveling time for diluting streamflow of low mass water quality concentration in Phetchaburi river by making 3-consecutive time (for averaging value on each measuring point). The most important objective of this experiment is to maintain the diluted water under standards, particularly BOD less than 3 mg/L at the Municipal Bridge as the outlet of Phetchaburi Municipal zone (Figure 1).

2.3 Water Samplers Collecting and Analyzing

Water samples for flow rates of pre-experiment, 10, 15, and 20 cms at measuring points of SW1, SW2,SW3, SW4, SW5, and SW6 for three-vertical water levels at depth from the water surface of 30 cm, 0.6 D and 0.8 D (D is equivalent to water depth) at the time of 02:00, 02:30, 03:00, 14:00, 14:30, and 15:00 (which were the arriving time of water mass) on the dates of 5, 6, 7, and 8 April 2010. Water samples were analyzed temperature, DO, turbidity, BOD, COD, TSS, TKN, oils and grease, orthophosphate, NO_3-N, NO_2-N, sulfide, sulfate, hardness, chlorine, alkalinity, ammonia, total-P, CO_2, K, Fe, Zn, Mg, Mn, Cu, Cd, Pb, and Hg through the methods of APHA.AWWA.WEF (1992), AWWA.APWA.WEF (1999), and Mathews and Richter (2007). Moreover, ANOVA (Analysis of Variance) as the statistical method was employed to differentiate the most probable water quality indicators for evaluating the appropriate discharge in relation to dilute the high concentration becoming to under surface water quality standard values.

2.4 Community Wastewater Estimation

Accordance with water availability and fertile soils along both sides (about 2-km distances apart from river edges) of Phetchaburi riverbanks (lower central part of Thailand), they have been occupied with dense and populated settlements for more than 75 years as shown in Figure 1. The social inventory of populated settlements was employed the secondary data, utilizing aerial photograph, and direct interviewing in order to obtain necessary information for interpreting the characteristics and behaviors of existing community and urbanization. The numbers of population above streamflow measuring points at the middle of Phetchaburi river (practically on the bridges) were employed to estimate the community wastewater as inflow to mix with Phetchaburi river,(approximately 200 liters/person/day for towner and 50 liters/person/day).

2.5 Appropriate Discharge Choosing

The comparison between the measured and calculated values of the selected water quality indicators was made in terms of an approach to the standards of desirable water quality for the survival of aquatic lives and for sustainable supplying to waterworks of Muang Phetchaburi Municipality.

3. Results

Owning to the Phetchaburi river is identified as a single and perennial stream in Phetchaburi province and dominating dense forest cover in headwater which can provide all year round water flow of both quantity and quality. Also, the existence of good land for fruit tree plantation (rose apple, lemon, Taddy palm, and pineapple), and fain-fed and irrigated paddy rice growing have made more income to the local people than a half of all provinces in Thailand (LDD, 2011). This is the reason why the dense populated communities have been settled along the both sides of Phetchaburi riverbanks in order to obtain irrigated water (from Kang Krachan storage dam through Phetchaburi diversion dam) for their activities that causing stream pollution for long period of time. Instead of using water for only irrigation, the other part can be made use for adulterating stream pollutants without any water shortage expectation. Therefore, the means how to manage the water flow can be presented in the following sections.

3.1 Variation of Flow Rate on Measuring Water Depth

As explained in methodology, the water temperature (Tw) and dissolved oxygen (DO) were measured at depths of 30 cm from the water surface, 0.6 and 0.8 height of water depth on each measuring point at the middle of the bridges which obtained each value from the average of 3-consecutive measurement for each mass water in order to find out the vertical variation of Tw and DO values. Obviously, the vertical Tw and DO as plotted in lines were overlapped each other on every measuring points regardless of daytime or nighttime as shown in Table 2 and Figure 3.

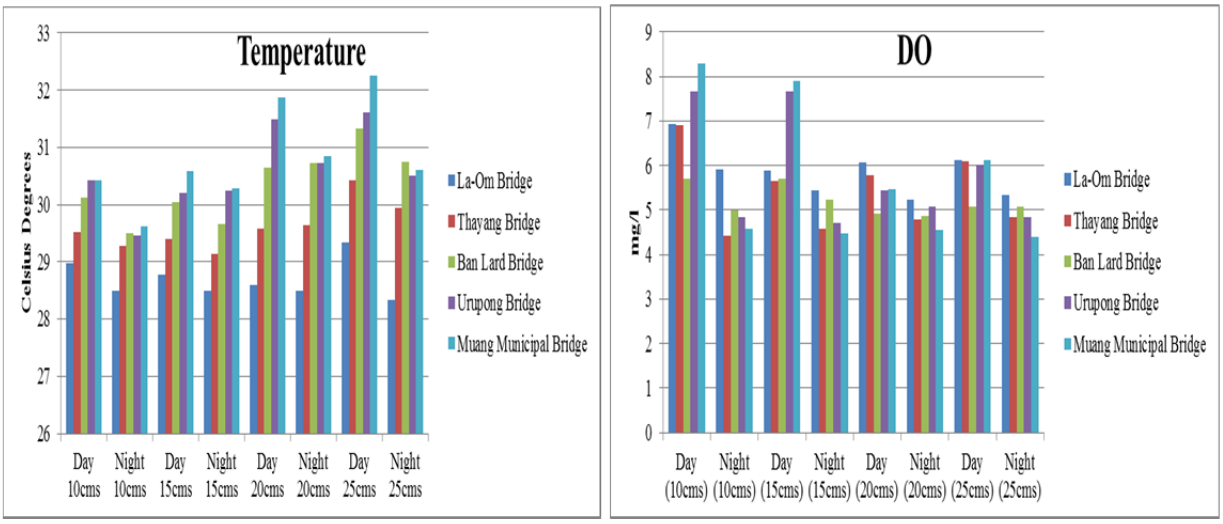
Table 2. Averaged water temperature (Tw) and dissolved oxygen (DO) at 30-cm and 0.6 and 0.8 depth below surface water as measured from flow rates of 10, 15, 20, and 25 cms at Phetchaburi diversion dam (La-Om canal), and another 5 stations of Thayang, Ban Lard, Urupong, Municipal, and Khunta Temple bridges

Sampling Station	Level	10 cms		15 cms		20 cms		25 cms	
		Day	Night	Day	Night	Day	Night	Day	Night
Temperature (°C)									
La-Om Canal	30 cms	29.00	28.50	28.77	28.50	28.60	28.50	29.33	28.33
	0.6d	28.97	28.50	28.77	28.50	28.60	28.50	29.33	28.33
	0.8d	28.93	28.50	28.77	28.50	28.60	28.50	29.33	28.33
	Average	28.97	28.50	28.77	28.50	28.60	28.50	29.33	28.33
Thayang Bridge	30 cms	29.50	29.30	29.40	29.13	29.63	29.63	30.43	29.93
	0.6d	29.53	29.27	29.40	29.13	29.57	29.63	30.43	29.93
	0.8d	29.53	29.27	29.40	29.13	29.57	29.63	30.43	29.93
	Average	29.52	29.28	29.40	29.13	29.59	29.63	30.43	29.93
Ban Lard Bridge	30 cms	30.17	29.50	30.07	29.77	30.67	30.70	31.27	30.73

	0.6d	30.10	29.50	30.03	29.77	30.63	30.73	31.37	30.77
	0.8d	30.10	29.50	30.00	29.45	30.63	30.77	31.37	30.77
	Average	30.12	29.50	30.03	29.66	30.64	30.73	31.33	30.76
Urupong Bridge	30 cms	30.43	29.47	30.23	30.23	31.50	30.70	31.60	30.50
	0.6d	30.43	29.47	30.20	30.23	31.50	30.73	31.57	30.50
	0.8d	30.43	29.47	30.20	30.23	31.50	30.73	31.67	30.50
	Average	30.43	29.47	30.21	30.23	31.50	30.72	31.61	30.50
Phetchaburi Municipal Bridge	30 cms	30.47	29.60	30.60	30.23	31.87	30.80	32.23	30.60
	0.6d	30.40	29.63	30.57	30.30	31.87	30.87	32.27	30.60
	0.8d	30.40	29.63	30.57	30.30	31.87	30.87	32.27	30.60
	Average	30.42	29.62	30.58	30.28	31.87	30.84	32.26	30.60
Dissolved Oxygen (mg/L)									
La-Om Canal	30 cms	7.16	5.88	5.98	5.34	6.21	5.17	6.23	5.25
	0.6d	6.85	5.91	5.87	5.47	6.04	5.24	6.08	5.36
	0.8d	6.77	5.93	5.84	5.50	5.98	5.32	6.02	5.41
	Average	6.93	5.91	5.90	5.44	6.08	5.24	6.11	5.34
	Thayang Bridge 30 cms	6.91	4.38	5.68	4.59	5.78	4.76	6.05	4.85
	0.6d	6.90	4.45	5.64	4.61	5.77	4.79	6.13	4.83
	0.8d	6.88	4.41	5.64	4.55	5.77	4.79	6.12	4.86
	Average	6.90	4.41	5.65	4.58	5.77	4.78	6.10	4.85

Table 2. (Continued)

Sampling Station	Level	10 cms		15 cms		20 cms		25 cms	
		Day	Night	Day	Night	Day	Night	Day	Night
Ban Lard Bridge	30 cms	5.73	4.94	5.84	5.08	5.00	4.87	5.12	4.93
	0.6d	5.68	5.02	5.68	5.26	4.87	4.87	5.08	4.96
	0.8d	5.68	5.04	5.63	5.33	4.91	4.90	5.06	5.37
	Average	5.70	5.00	5.71	5.22	4.92	4.88	5.09	5.09
Urupong Bridge	30 cms	7.69	4.86	7.75	4.72	5.44	5.07	6.05	4.75
	0.6d	7.67	4.86	7.61	4.67	5.42	5.03	6.02	4.89
	0.8d	7.67	4.85	7.65	4.73	5.45	5.10	6.01	4.90
	Average	7.68	4.85	7.67	4.71	5.44	5.07	6.03	4.85
Phetchaburi Municipal Bridge	30 cms	8.40	4.54	8.00	4.43	5.53	4.57	6.24	4.37
	0.6d	8.29	4.62	7.79	4.49	5.44	4.52	6.09	4.40
	0.8d	8.19	4.61	7.89	4.46	5.43	4.54	6.03	4.43
	Average	8.29	4.59	7.90	4.46	5.46	4.54	6.12	4.40



(a) (b)

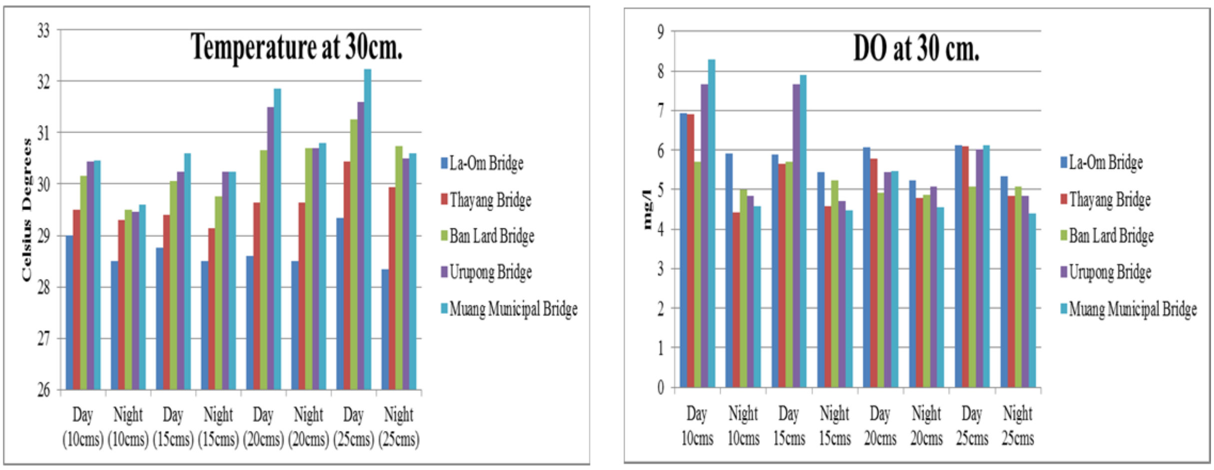
Figure 3. Variation of water temperature (a) and dissolved oxygen (b) in stream water while traveling from upstream measuring points (Phetchaburi diversion dam) throughout downstream (Phetchaburi river mouth as continuously) measured from 5-8 April 2010

Field experiences found the riverbed roughness due to the existences of sand dune, rock outcrops, riverbed subsiding, flow separation, and river width which could make the change of flow pattern from laminar to eddy flows that enhanced the overturn between surface and bottom in terms of jumping and bumbling on the way from headwater (Phetchaburi diversion dam throughout the river mouth. The said phenomena could be the causes of harmonized mixture of river water as shown those characteristics in Figure4 and Table 2. In other words, the Tw and DO lines at measuring depth of 30 cm, 0.6 and 0.8 river depths were almost overlapped each other, to form nearly one line at every measuring bridge of La-Om Canal, Thayang, Ban Lard, Urupong, Phetchaburi Municipal, and Khutra Temple bridges. So, it has to point out that the sampling point at 30-cm depth is eligible for being representative of any depth while water in motion. Therefore, the water quality studies of streamflow in Phetchaburi river will be taken from only the 30-cm depth as shown in Table 3 and Figure 4 which is the international measuring depth (PCD, 2013; APHA, 1952; APHA.AWWA.WEF, 1992; Metcalf and Eddy, 1979; Ntengwe, 2006; Postel and Richter, 2003; Pattamapitoon, 2013; Reynolds and Edwards, 1995; Streeter and Phelps, 1958; Tanji et al., 2006; Vagnetti et al., 2003;Vargaftik et al., 1983; Wang et al., 1987).

It is remarkable to indicate that the Tw values (Table 3 and Figure 4) at the Phetchaburi diversion dam (La-Om canal) found cooler than the consecutive stations either nighttime or daytime which were gradually increased with low rates because of heat releasing from scrubbing among water molecules, bacterial organic digestion process, and higher temperature of community wastewater inflow as well as heat conducting from riverbed (Sellers, 1965; Gbureck and Folmar, 1999; Wang et al., 1978; Metcalf and Eddy, 1979). At the same time, DO values (Table 3 and Figure 4) at Phetchaburi diversion dam (La-Om canal) found higher than the consecutive stations either nighttime or daytime because of draining subsurface flow from Kang Krachan storage-dam gate as originally obtained from mountainous forested Kang Krachan National Park, then gradually decreasing because of threatening heat from scrubbing water molecules, heat transferring by conduction process from riverbed, and bacterial organic digestion process from wastewater of dense populated communities as settled along the Phetchaburi riverbanks. (Wang et al., 1978, Sellers, 1965; Tchobanoglous and Schoeder, 1985; LERD, 2011; LERD, 2012). Anyhow, both water temperature and dissolved oxygen play important role in some other water quality indicators concerning with stream pollution condition of Phetchaburi river, especially on the reach between Thayang and Municipal bridges which is focused on having better water quality (under standards) in order to use water for waterworks and survival of aquatic lives.

Table 3. Averaged water temperature (Tw) and dissolved oxygen (DO) during daytime and nighttime as measured at 30 cm from water surface at the measuring points on the middle of bridges (La-Om, Thayang, Ban Lard, Urupong, and Phetchaburi Municipal)

Average Temperature	10 cms.		15 cms.		20 cms.		25 cms.	
at 30 cm. (°C)	Day	Night	Day	Night	Day	Night	Day	Night
La-Om Canal	29.00	28.50	28.77	28.50	28.60	28.50	29.33	28.33
Thayang Bridge	29.50	29.30	29.40	29.13	29.63	29.63	30.43	29.93
Ban Lard Bridge	30.17	29.50	30.07	29.77	30.67	30.70	31.27	30.73
Urupong Bridge	30.43	29.47	30.23	30.23	31.50	30.70	31.60	30.50
Phetchaburi Municipal Bridge	30.47	29.60	30.60	30.23	31.87	30.80	32.23	30.60
Average DO	10 cms.		15 cms.		20 cms.		25 cms.	
At 30 cm.(mg/L)	Day	Night	Day	Night	Day	Night	Day	Night
La-Om Canal	7.16	5.88	5.98	5.34	6.21	5.17	6.23	5.25
Thayang Bridge	6.91	4.38	5.68	4.59	5.78	4.76	6.05	4.85
Ban Lard Bridge	5.73	4.94	5.84	5.08	5.00	4.87	5.12	4.93
Urupong Bridge	7.69	4.86	7.75	4.72	5.44	5.07	6.05	4.75
Phetchaburi Municipal Bridge	8.40	4.54	8.00	4.43	5.53	4.57	6.24	4.37



(a) (b)

Figure 4. Histograms of averaged water temperature at 30 cm (Tw) and dissolved oxygen at 30 cm (DO) as measured during daytime and nighttime in order to compare among flow rates of 10, 15, 20, and 25 cms at the measuring points on middle of La-Om, Thayang, Ban Lard, Urupong, and Phetchaburi Municipal bridges

Evidently, daytime and nighttime water temperature of each measuring point was lowest degree Celsius at La-Om bridge which just drained out from Phetchaburi diversion dam, and trending to increase at Thayang, Ban Lard, Urupong, and Muang Municipal, bridges in relation to flow rates of 10, 15, 20, and 25 cms (see Table 3 and Figure 4). In contrary, the dissolved oxygen (DO) contents were totally indicated higher values in opposite flow rates of 10 cms to 15, 20, and 25 cms at La-Om canal (just draining from Phetchaburi diversion dam as water sources) and tending to decrease down to the Muang Municipal bridge but lowering when the flow rates increased, especially between the Urupong-Muang Municipal distance due to heat releasing from dense-populated settlement along the riverbanks. Such variation of DO behaviors was also occurred on nighttime measurement in relation to flow rates of 10, 15, 20, and 25 cms. It is observed that the dissolved oxygen (DO) was tended to decrease when the population was more dense owning to utilize oxygen as energy supplier for bacterial organic digestion process and more eroded quantitative materials which made the dilution process unpleasant, particularly after upstream at Thayang bridge throughout the downstream at Muang Municipal bridge (Berkun, 2005; Cazelles et al., 1991; Faerge et al., 2001; Faulkner et al., 2000; Derx et al., 2014; Mangimbulude et al., 2012).

In other words, the increasing flow rates from 10 cms to 15, 20, and 25 cms could make the increase of water temperature and decrease of dissolved oxygen according to more community organic matter inputs from dense-populated settlement along both sides of Phetchaburi River together with organic wastes from another land use patterns by bacterial digestion processing.

3.2 Point Sources of Community Wastewater

Understandably, the whole bounces of community wastewater were produced by human activities for households, arts and culture, growing crops, livestock, aquaculture, transportation, industrialization, education, public health, recreation, entertainments, and sports in various amount of desirable quality water. Fortunately, the whole areas of Phetchaburi province, particularly human settlement along both sides of the Phetchaburi river, are provided mainly community activities, e.g., households, local dessert factories (about 25 factories), fresh-food markets, restaurants, shopping centers and houses, education, military affairs, fruit tree plantation, upland cropping, paddy rice growing, cultural maintaining, and transportation. This can be the point sources of community wastewater which is mainly composed of organic wastes for household usage, fresh-food markets, small factories, local dessert factories, agro-industry factories, and livestock, and also some toxic chemicals for transport business, growing crops, and entertainment. As stated earlier, the community wastewater is produced by those human activities which generally use water approximately 200 L/person/day for towner and 100 L/person/day for urban-fringe people, and 60 L/person/day (LERD, 2012) for rural people. In order to estimate the community wastewater as inflow into Phetchaburi River, the intensive population inventory was conducted from secondary data sources by separating in specific wastewater-producing-source zones as presented in Table 4. Then after, the community wastewater was calculated by multiplying 0.85 to water use obtain the results as illustrated in Table 4.

Table 4. Estimated community wastewater as produced by 85% of water usage in each producing-source zones of settlement zones along both riverbanks of Phetchaburi River

No.	Producing-Source Zone	Estimated Population (persons)	Daily Water Use (L/person/day)	Total Use (m^3/day)	Estimated Wastewater (m^3/d)	Remarks
1	La-Om canal	-	-	-	-	Wastewater producing abour 85% of water usage of each person
2	Thayang Bridge	12,000	60	720	600	
3	Ban Lard Bridge	2,100	60	126	80	
4	Urupong Bridge	10,000	200	200	170	
5	Phetchaburi Municipal Bridge	40,000	200	8,000	6,800	
6	Khuntra Temple Bridge	8,000	100	800	680	

Actually, the high concentrated community wastewater above the measuring points were estimated in the amount of 0, 600, 80, 170, 6,800, and 680 cu.m./day for La-Om, Thayang, Ban Lard, Urupong, Muang Municipal, and Khuntra temple bridges, respectively which are inflow and expecting to be diluted by very low concentrated water of Phetchaburi river. Field inventory together with GIS technique had found the dense population in urban areas and dispersing in suburb and cultivated areas. Such situation was surely brought to overestimate the community wastewater as flown into Phetchaburi River but it might be possible because of locally higher evapotranspiration rate and based on Polluter-Pay-Principle (PPP) criteria of ONWTT (Office of National Wastewater Treatment Tax) by taking 70% of water usage becoming community wastewater that would be appropriate quantity.

3.3 Mass Water Quality and Discharge Relations

The objectives of research was focused on decreasing higher concentrated contaminants (not only from upstream but also summing up from communities along riverbanks) of mass water while traveling from upstream to downstream through the dilution process by appropriate discharge from Phetchaburi diversion dam. Consequently, the flow velocity of mass water for each discharge (10, 15, 20, and 25 cms) was needed to determine the exact time and traveling distance (see Figure1) in order to conduct for 3-consecutive collection of mass water samples at their contaminant-producing-zone outlets on time. Notably, the collected water samples were presumed as the original mass water as traveled from upstream to downstream outlets together with summing up the higher concentration inflow of community wastewater from riverbank settlements along Phetchaburi river. Anyhow, the mass water samples were analyzed the quantitative contents of concerned water quality indicators as shown in Table 5.

Accordance with each water sample of a given water mass was averaged from 3-consecutive measurements (becoming one measurement for averaging mass water quality) of each discharge (10, 15, 20, and 25 cms) within a few minutes before passing through measuring points of La-Om, Thayang, Ban Lard, Urupong, Muang Municipal, and Khuntra Temple bridges. Following from the said statement, the averaged values of analyzed water quality indicators at La-Om canal, Thayang, Ban Lard, Urupong, Muang Municipal, and Kguntra Temple bridges were presented in Table 5, Perspectively, the mass water quality started with better under standard water quality at the beginning point of Phetchaburi diversion dam (La-Om canal) and inclining to worsen during traveling through Thayang, Ban Lard, Urupong, and Muang Municipal zones but disorderly fluctuation at Khuntre Temple reach which located at river mouth. Obviously, it would be concluded that the mass water was in better quality while traveling from Phetchaburi diversion dam but it inclined to deteriorate after mixing with sewerage from communities along both sides of riverbanks, and becoming worse due to passing through the dense-populated zone between Ban Lard and Muang Municipal, and disordering fluctuation between Phetchaburi Municipal and the river mouth (Khuntra Temple) at Ban Laem district but opposite in normal routine operation (more or less 5 cms). Evidently, most of Muang Municipal wastewater have not been allowed to operate the sewerage into Phetchaburi River as belonged to the Royal LERD project on which the wastewater quality at Muang Municipal Bridge showed less contaminants. Also, it is observed that the water quality as measured, on routine operation by draining streamflow more or less 5 cms, found worser than discharges of 10, 15, 20, and 25 cms. The worst condition in summer period would be the reason because of high concentration of inflow from communities along both riverbank habitation of Phetchaburi River (Figure 1). However, all mass water quality indicators were looked better after draining discharges of 10, 15, 20, and 25 cms at measuring point, approximately 2-10 .

Table 5. Averaged water quality indicators of traveling mass water in the respective measuring stations from La-Om, Thayang, Ban Lard, Urupong, Phetchaburi Municipal, and Khuntra Temple bridges in relations to amount of discharge

No	Indicator	Discharge																													
		normal 5 cms						10 cms						15 cms						20 cms						25 cms					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1	COD,mg/L	80.0	63.3	55.3	43.7	101.3	80.3	31.3	43.3	64.0	42.0	29.3	27.3	27.0	15.7	14.0	24.0	24.0	10.7	24.0	34.0	17.3	14.0	19.0	12.3	90.0	100.0	97.3	65.7	42.3	23.7
2	BOD,mg/L	6.8	7.6	7.7	7.1	8.0	7.0	1.7	1.6	2.9	1.6	1.6	2.5	4.8	4.9	5.7	4.6	5.3	6.0	2.3	2.5	2.2	2.3	2.9	3.2	7.3	7.5	7.3	7.2	7.7	8.2
3	Turbidity,NTU	4.0	2.7	2.5	2.7	2.9	3.0	6.4	4.2	4.5	4.1	5.0	5.2	7.5	5.0	5.8	5.5	6.1	10.3	6.7	4.7	2.5	2.5	3.6	2.5	5.3	3.2	2.4	2.1	2.3	2.3
4	TSS,mg/L	54.3	94.3	135.0	78.7	115.0	115.3	20.0	14.3	22.7	18.7	27.3	8.7	58.3	65.0	63.7	59.7	42.0	33.7	38.3	54.3	37.7	38.7	35.0	20.7	96.7	78.7	73.3	82.0	120.3	109.0
5	Oil&grease,mg/L	0.1	0.1	1.3	0.1	2.4	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	10.7	0.1	0.2	0.1	0.1	0.7
6	Total - N,mg/L	1.6	1.6	1.7	1.5	1.6	1.9	3.6	2.6	2.5	2.4	3.2	2.4	3.2	2.8	3.0	3.0	3.3	2.7	3.3	2.7	2.1	3.1	2.9	3.5	1.9	1.9	1.4	1.6	1.9	1.8
7	TKN,mg/L	1.3	1.3	1.4	1.3	1.3	1.5	2.9	2.1	2.0	2.0	2.6	1.9	2.6	2.2	2.5	2.5	2.8	2.3	2.5	2.1	1.6	2.3	2.1	2.6	1.5	1.5	1.1	1.3	1.5	1.4
8	NO_3-N,mg/L	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
9	NO_2-N,mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10	Ammonia,mg/L	0.1	0.2	0.2	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.6	0.4	0.3	0.6	0.5	0.8	0.2	0.2	0.1	0.2	0.2	0.2
11	Total P,mg/L	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2
12	Phosphate,mg/L	0.3	0.2	0.4	0.1	0.1	0.2	0.4	0.2	0.3	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.3	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.4
13	Sulfide,mg/L	0.1	0.1	0.1	0.1	0.1	0.1	1.6	1.9	2.1	2.1	2.3	2.4	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.2	0.1	0.1

Table 6. (cont'd)

No	Indicator	Discharge																													
		normal 5 cms						10 cms						15 cms						20 cms						25 cms					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
14	Sulfate,mg/L	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.4	0.1	0.0	0.0	0.1	0.1	0.5	0.5	0.5	0.0	0.0	0.1	0.1	0.1	0.2
15	Hardness,mg/L	49.3	55.7	54.0	55.0	55.0	55.0	53.3	54.7	56.7	55.0	54.0	57.3	55.0	52.7	56.0	55.3	55.0	53.7	54.7	53.0	48.3	50.0	51.7	57.7	49.0	50.0	56.0	59.0	56.3	57.3
16	Chloride,mg/L	2.1	1.9	1.8	1.9	1.8	1.9	2.1	1.9	1.9	2.2	2.1	2.0	2.1	1.9	2.1	1.9	1.8	1.8	2.1	2.1	2.0	2.1	2.0	2.2	1.9	1.9	1.8	1.8	1.9	1.9
17	Alkalinity,mg/L	5.1	5.9	5.6	5.5	5.3	5.4	1.3	1.2	1.3	1.5	1.3	1.8	5.1	5.2	5.1	5.4	5.1	5.2	5.1	5.2	5.1	5.4	5.3	5.4	5.2	5.2	5.4	5.8	5.7	5.7
18	CO_2,mg/L	2.7	3.3	3.1	2.2	2.3	1.7	2.1	1.9	1.9	2.2	2.1	2.0	2.0	2.9	2.2	2.0	2.1	2.0	3.7	5.5	5.5	3.9	2.4	2.9	3.2	4.6	4.8	3.4	2.5	3.5
19	Fe,mg/L	2.6	2.1	1.4	1.3	1.0	1.4	2.8	1.5	1.5	1.2	1.1	1.0	1.6	1.3	1.2	1.1	1.2	1.3	2.1	1.6	1.3	1.1	0.7	0.8	2.4	1.6	1.3	1.2	1.5	1.6
20	Zn,mg/L	1.2	1.2	1.1	1.3	1.5	1.5	1.2	1.2	1.2	1.1	1.1	1.1	1.6	1.1	1.4	1.3	1.3	1.1	1.3	1.1	1.1	1.7	1.5	1.3	1.1	1.3	1.3	1.2	1.8	1.3
21	Mg,mg/L	16.3	17.8	17.1	17.9	15.7	13.9	16.8	15.8	18.9	14.9	17.6	18.1	16.6	14.7	15.3	15.4	16.1	16.5	12.1	14.5	12.5	13.9	15.0	18.1	14.1	16.2	18.1	18.2	16.3	17.8
22	Mn,mg/L	0.3	0.3	0.2	0.1	0.1	0.2	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.2	0.2
23	Cu,mg/L	0.3	0.2	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.4	0.3	0.3
24	Cd,mg/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	Pb,mg/L	0.8	0.8	0.9	1.0	1.0	1.0	0.6	0.7	0.8	0.7	0.9	1.0	0.9	0.9	0.9	1.0	0.8	1.0	0.5	0.7	0.9	0.9	0.9	1.0	0.8	0.9	0.8	1.5	0.7	0.5
26	Hg,mg/L	1.3	1.5	0.8	1.2	1.4	1.4	1.2	1.2	1.8	1.6	1.1	1.3	1.1	1.2	1.2	1.3	2.1	1.2	1.1	1.4	1.1	1.1	1.1	1.0	1.7	1.6	1.2	1.3	1.9	1.7
27	K,mg/L	4.2	4.5	4.4	4.4	4.2	4.2	3.8	3.8	3.8	3.7	3.7	3.7	3.8	3.8	3.9	3.9	4.0	4.0	3.7	3.7	3.6	3.6	3.5	3.6	4.2	4.4	4.0	4.4	4.6	4.6

Unluckily, the analyzed water mass quality was comprised of 27 indicators concerning with inflow contaminants from the communities along riverbanks that seemed more necessary to employ them for determining the appropriate discharge to decrease the high concentration of Municipal wastewater lowering down to the satisfied level. So, the ANOVA analysis was proposed to employ for screening out the unnecessary indicators from determining the appropriate discharge. The results of statistical calculation from ANOVA analysis were found only 4 indicators of traveling mass water quality, i.e., COD, BOD, TSS, and turbidity which showed highly significant differences except turbidity and SS which had been non significance as illustrated in Table 6.

Table 7. ANOVA analysis of all mass water quality indicators from 4 parameters through applications of four-amount of discharge, and six-measuring stations

Sampling Stations	BOD	COD	Turbidity	Suspended Solids
1.La-Om canal	0.0002**	0.0030**	0.0700ns	0.0850ns
2.Thayang Bridge	2.44×10^{-8}**	0.0010**	0.0040**	0.0200**
3.Ban Lard Bridge	4.36×10^{-5}**	4.21×10^{-6}**	6.79×10^{-6}**	5.62×10^{-7}**
4.Urupong Bridge	4.76×10^{-6}**	0.0020**	0.0050**	0.0020**
5.Phetchaburi Municipal Bridge	2.88×10^{-8}**	0.0003**	9.13×10^{-6}**	0.0003**
6.Khuntra Temple Bridge	0.0020**	4.16×10^{-5}**	3.41×10^{-11}**	4.16×10^{-5}**
Overall	1.46×10^{-38}**	2.74×10^{-14}**	1.79×10^{-12}**	1.32×10^{-9}**

Note. ns= Non significant, ** = High significant

It is observed that those four mass water indicators could be identified as near-to-be statistical materials instead of dynamism which can be either changeable-chemical forms and evaporation to sky. Also, no significant difference indicators were transformed from one form to the others, ammonia, nitrate, phosphate, sulfate, etc. as well as very less amount of elements

3.4 Contaminant-Based Requirement for Discharge Selection

The main purpose of draining water from diversion dam flew along Phetchaburi River was exactly needed to decrease the high concentrated community wastewater inflow becoming to the required standards. In this study, the concentrated BOD level (which should be related to the standard levels of COD, TSS, and turbidity) is aimed at less 3 mg/L in order to achieve the water quality for waterworks and aquatic lives and also for environmental services. Then, the contaminant levels in relation to calculated the assembling points at measuring points were conducted by employing the derived mathematical models in equations 1 to 17 and showing the calculated results of COD, BOD, TSS, and turbidity in comparison with observed values as shown in Table 7. For clearly understanding, the calculated and observed values of those four indicators were started up the same numbers since there had never the habitation above the measuring point of Phetchaburi diversion dam or La-Om canal (see Figure 1).

Table 8. Calculated COD, BOD, TSS, and turbidity of traveling mass water from Phetchaburi in relation to exact-calculated distances from Phetchaburi diversion to Thayang, Ban Lard, Urupong, Muang Municipal, and Khun Temple bridges in relation to discharges of 10, 15, 20, and 25 cms

Station	COD (mg/L)	Calculated COD (mg/L)	BOD (mg/L)	Calculated BOD (mg/L)	Turbidity (NTU)	Calculated Turbidity (mg/L)	TSS (mg/L)	Calculated TSS (mg/L)
		COD=164.6		BOD=75.6		Turbidity=21.6		TSS= 20.0
SW1/10	31.30	31.30	1.70	1.70	6.40	6.40	20.00	20.00
SW2/10	43.30	31.45	1.60	1.88	4.20	6.57	14.30	20.16
SW3/10	64.00	43.44	2.90	1.79	4.50	4.39	22.70	14.47
SW4/10	42.00	64.12	1.60	3.10	4.10	4.70	18.70	22.87
SW5/10	29.30	42.16	1.60	1.81	5.00	4.31	27.30	18.89
SW6/10	27.30	29.48	2.50	1.82	5.20	5.21	8.70	27.48
SW1/15	24.00	24.00	2.30	2.30	6.70	6.70	38.30	38.30
SW2/15	34.00	24.10	2.50	2.41	4.70	6.81	54.30	38.39
SW3/15	17.30	34.10	2.20	2.62	2.50	4.82	37.70	54.38
SW4/15	14.00	17.41	2.30	2.33	2.50	2.63	38.70	37.80
SW5/15	19.00	14.12	2.90	2.43	3.60	2.63	35.00	38.80
SW6/15	12.30	19.12	3.20	3.04	2.50	3.74	20.70	35.11
SW1/20	27.00	27.00	4.80	4.80	7.50	7.50	58.30	58.30
SW2/20	15.70	27.07	4.90	4.88	5.00	7.58	65.00	58.36
SW3/20	14.00	15.78	5.70	4.99	5.80	5.09	63.70	65.06
SW4/20	24.00	14.09	4.60	5.79	5.50	5.89	59.70	63.76
SW5/20	24.00	24.09	5.30	4.70	6.10	5.60	42.00	59.76
SW6/20	10.70	24.09	6.00	5.40	10.30	6.20	33.70	42.08
SW1/25	90.00	90.00	7.30	7.30	5.30	5.30	86.70	86.70
SW2/25	100.00	90.03	7.50	7.37	3.20	5.37	78.70	86.73
SW3/25	97.30	100.03	7.30	7.57	2.40	3.27	73.30	78.74
SW4/25	65.70	97.33	7.20	7.37	2.10	2.48	82.00	73.34
SW5/25	42.30	65.75	7.70	7.28	2.30	2.18	120.30	82.04
SW6/25	23.70	42.36	8.20	7.78	2.30	2.38	109.00	120.32

Note. 1) SW 1 = La-Om Canal, SW 2 = Thayang Bridge, SW 3= Ban Lard Bridge, SW 4 = Urupong Bridge, SW 5 = Phetchaburi Municipal Bridge, SW 6 = Khuntra Temple Bridge

2) Taking mean Municipal wastewater concentration at Klongyang collection pond as wastewater concentration inflow from every community zone

3) Taking Ks(recession coefficient) of streamflow hydrograph of Phetchaburi River as 0.95 due to less roughness of streambed dam

4) Sw1/10 equivalent to station 1 (La-Om Canal) with discharge of 10 cms, the others being the same abbreviation.

Remarkably, the stream water which drained from Phetchaburi diversion dam was affirmed to influence on dilution process due to large amount of mass water rather than community wastewater inflow, even the bigger community likewise Thayang, Ban Lard, and Muang municipals. Clean and clear mass water from Phetchaburi diversion dam, that received stream water from the dense forest watershed of Kang Krachan National Park to store in Kang Krachan reservoir, could be functioned as buffer to small increase of concentration. Anyhow, there were more dissolved oxygen content of drainage water as needed for energy supply to encourage the organic digestion process, make rapid decreasing in mixture mass water that might be another reason why the observed and calculated values were very close each other (see Table 7). In other words, the more discharging amount are the less the decreases of mass water from Phetchaburi diversion dam. After linear regression analysis between observed and calculated values was made as illustrated in Figure 5, the research results found the coefficient of determination (R-square) equivalent to 0.93 for BOD, 0.80 for COD, 0.82 for TSS, and 0.50 for turbidity which could be statistically accepted their correlations, especially BOD value.

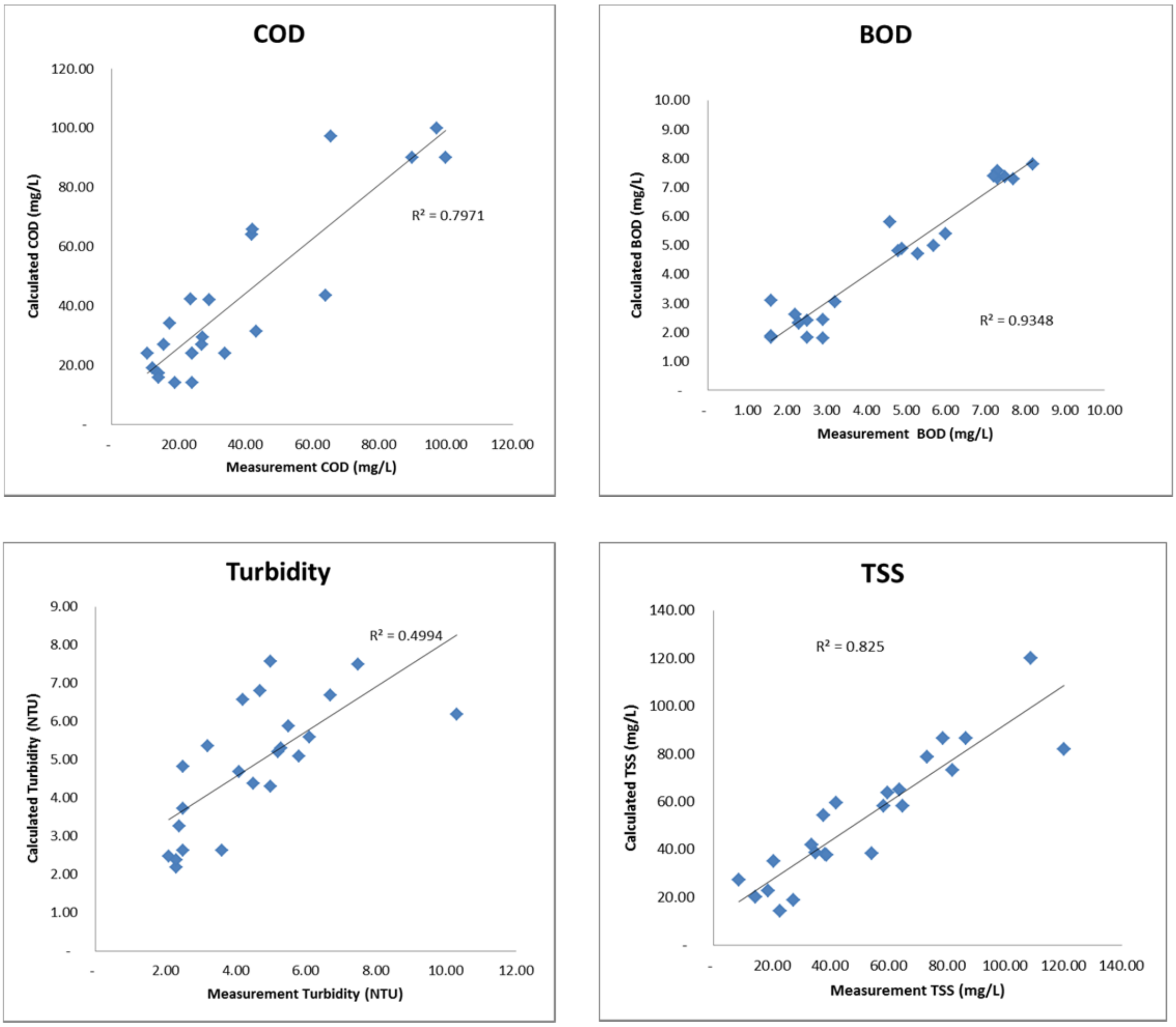


Figure 5. Linear regression analysis between observed and calculated values in relation to discharges of 10, 15, 20, and 25 cms as drained from Phetchaburi diversion dam throughout Phetchaburi mouth

Unfortunately, not only COD, TSS, and turbidity as wastewater quality indicators are not included in surface water quality standards but also their coefficients of determination were lower than BOD finding. Hence, BOD coefficient of determination was chosen to consider the appropriate discharging amount for diluting community wastewater inflow into Phetchaburi River. According to aforesaid statement, the appropriate discharging amount can be taken in 10 cms to 15 cms in order to dilute the BOD of community wastewater less 3 mg/L (PCD, 2013) which is conditioned for aquatic lives and waterworks as well as desirable usage for any activities. If discharge more than 15 cms, the diluting mixture would be highly deteriorated due to wash off organic matters and soils through flooding along the riverbanks, while less 10-cms discharge from Phetchaburi diversion dam was surely caused to low effective dilution process due to too low amount of mass water flow which were the same trends of previous research results of Wang et al. (1978); Vagnetti et al. (2003); Tanji et al. (2006); Tyagi et al. (1999); Tchobanoglous and Schoeder (1985); Streeter and Phelps (1925); Reynolds and Edwards (1995); Postel and

Richter (2003); Ntengwe (2006); McColl (1974); Luderitz et al. (2004); Lajoie et al. (2007); Derx et al. (2014), Chidya et al. (2011); Cazelles et al. (1991); Berkowitz et al. (2011); and Berkun (2005).

4. Conclusion

The research is aimed to determine the requirement of BOD in stream water in relation to traveling mass water flow from Phetchaburi diversion dam which flow through the sux-consecutive measuring points at Phetchaburi diversion dam (La-Om canal), Thayang, Ban Lard, Urupong, Phetchaburi Municipal, and Khuntra Temple bridge (river mouth connecting to the Gulf of Thailand).

Firstly, the dissolved oxygen (DO) and water temperature (Tw) was measured under discharge conditions of 10, 15, 20, and 25 cms for every 6 hours at depths of 30 cm and 0.6 and 0.8 of water depth from the surface. There were no change in DO and Tw among measuring depths due to higher discharge velocity of 10, 15, 20, and 25 cms causing eddy flow which makes water flow homogenized condition. In other word, the DO and Tw as measured at all three depths were overlapped each other. So, the measuring depth of 30 cm was taken in representing the water samples at any depth. At the same time, the mathematical equations were derived in order to select the appropriate BOD level and also discharge levels

Secondly, the 27 indicators of mass water quality which collected at the 6-consecutive measuring points of La-Om canal (Phetchaburi diversion dam), Thayang, Ban Lard, Urupong, Muang Municipal, and Khuntra Temple bridges in relation to the 4-amount discharges of 10, 15, 20, and 25 cms. After employing ANOVA Analysis between the 6-consecutive measuring points and the 4-amount discharges in relation to each indicator, the highly significant differences indicated only BOD, COD, TSS, and turbidity which were the most probable mass water quality indicators for choosing the appropriate amount of discharge to drain out from Phetchaburi diversion dam to exist high dilatability with high concentration of community wastewater inflow into Phetchaburi river. However, the dilatability of traveling mass water as flown from Phetchaburi diversion dam was estimated 2-10 folds to high concentrated community wastewater inflow of Thayang, Ban Lard, Urupong, Phetchaburi Municipal, and Khuntra Temple zones.

Thirdly, the application of the already derived mathematical equation to calculate the traveling mass water quality indicators together with linear regression analysis between calculated and observed values in relation to amount of discharge found the determination coefficients being equivalent to 0.93 for BOD, 0.80 for COD, 0.82 for TSS, and 0.50 for turbidity. Only BOD was chosen to select the appropriate amount of discharge at Phetchaburi diversion dam (La-Om canal) as the start-up point because it is included in surface water quality standard list but the others are excluded in that list.

Finally, after close consideration on linear regression between calculated and observed values of traveling mass water quality indicators, the appropriate amount of discharge was taken in 10-15 cms from Phetchaburi diversion dam which existed the dilatability for decreasing the community wastewater BOD less 3 mg/L. If discharge was less 10 cms causing low dilutability, and if greater 15 cms that might wash off organic wastes and soil erosion along the riverbanks.

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