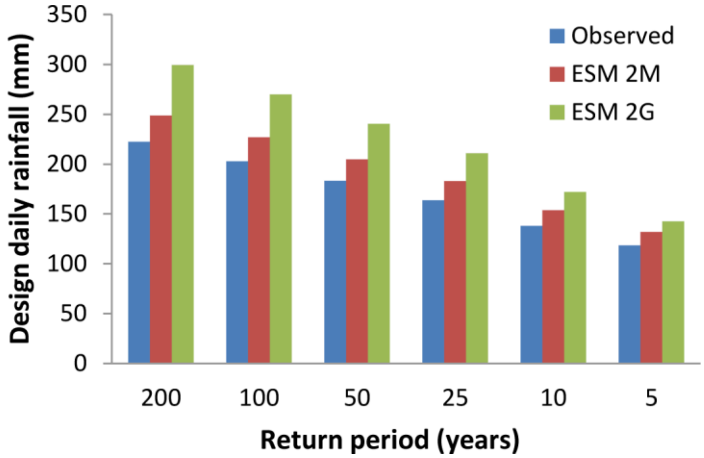


Figure 2. Design daily rainfall under the impact of climate change

The main disadvantage of using climate models is the biases involved in them, which propagates through the downscaling methods to the predicted series resulting in imprecise simulations. Especially in case of rainfall, which is an unevenly distributed parameter in temporal scale, the magnitude of these biases fluctuates to a large extent (Hazarika & Sarma, 2016; Patowary et al. 2016). Hence, necessary corrections should be done to reduce these biases, before utilizing the predicted rainfall simulations in impact assessment studies. Several bias correction methods have been recommended (Watanabe et al., 2012, Mahmood and Babel, 2013) for correcting rainfall simulations. In this study, following equation has been used for bias correction (Mahmood and Babel, 2013).

$$P_{bc} = P_{ds} \times (\frac{\overline{P_{obs}}}{\overline{P_{cont}}}) \tag{1}$$

where, P_{bc} is the bias corrected rainfall series, P_{ds} is downscaled rainfall series from MLR/SDSM, $\overline{P_{obs}}$ are mean of the observed rainfall series, and $\overline{P_{cont}}$ is mean of downscaled rainfall data series for the calibration period.

IDF curve formation: From the two forecasted daily rainfall series for the period 2012-2100 concerning the two GCM models, annual maximum values of daily rainfall have been extracted. The observed rainfall series for the period 1969-2011 was collected from Regional Meteorological Centre (RMC), Barjhar. To get the design rainfalls of different return periods, frequency analyses of the two annual maximum rainfall series along with the observed one, have been carried out by five different methods such as Gumbel, Pearson Type III, Log-Pearson Type III, Normal and Log-Normal method. D-index test (USWRC, 1981) was performed to find the most suitable frequency analysis method for estimation of extreme rainfall or design rainfall events. D-index (Varma et al. 1989) is given as-

$$D_{index} = \frac{1}{\bar{x}}(\sum_{i=1}^{6} \mathrm{ABS}(X_{i,observed} - X_{i,\mathrm{computed}})) \tag{2}$$

where, $\bar{x}$ is the mean of the observed series, $x_{i,\text{ observed}}$ (i = 1, 2,..., 6) are the highest six observations in the given data and $x_{i,\text{ computed}}$ (i = 1, 2,…, 6) are the computed values corresponding to the return period using the probability distribution.

The distribution which gives minimum D-index is considered as the best fit distribution. The same Log-Pearson Type III is found as the most suitable probability distributions for both the forecasted rainfall series of ESM2M model and the observed one. For the forecasted rainfall series of ESM2G model, it was obtained as the Pearson Type III distribution. Figure 2 shows the design daily rainfalls under the impact of climate change for different return periods. The forecasted design rainfalls under the consideration of climate change impact are found higher than that calculated with respect to the observed rainfall data. Again, ESM2G projects higher design rainfalls than the ESM2M model.

In order to get a short duration rainfall IDF curve, short duration design rainfall data are required. These have been derived from design daily rainfalls by using an empirical reduction formula given by Indian Meteorological Department (IMD). This equation has been successfully applied in many studies (Chowdhury et al., 2007; Rashid et al., 2012). The empirical equation is given by,

$$P_t = P_{24}\left(\frac{t}{24}\right)^{1/3} \tag{3}$$

where, P_t is the required rainfall depth in mm at t-hour duration, P_{24} is the daily rainfall in mm and t is the duration of rainfall in hours for which the rainfall depth is required. From the short duration rainfall data derived, rainfall intensities of various return period have been calculated and plotted to get IDF curves of different return periods as shown in figure 3.

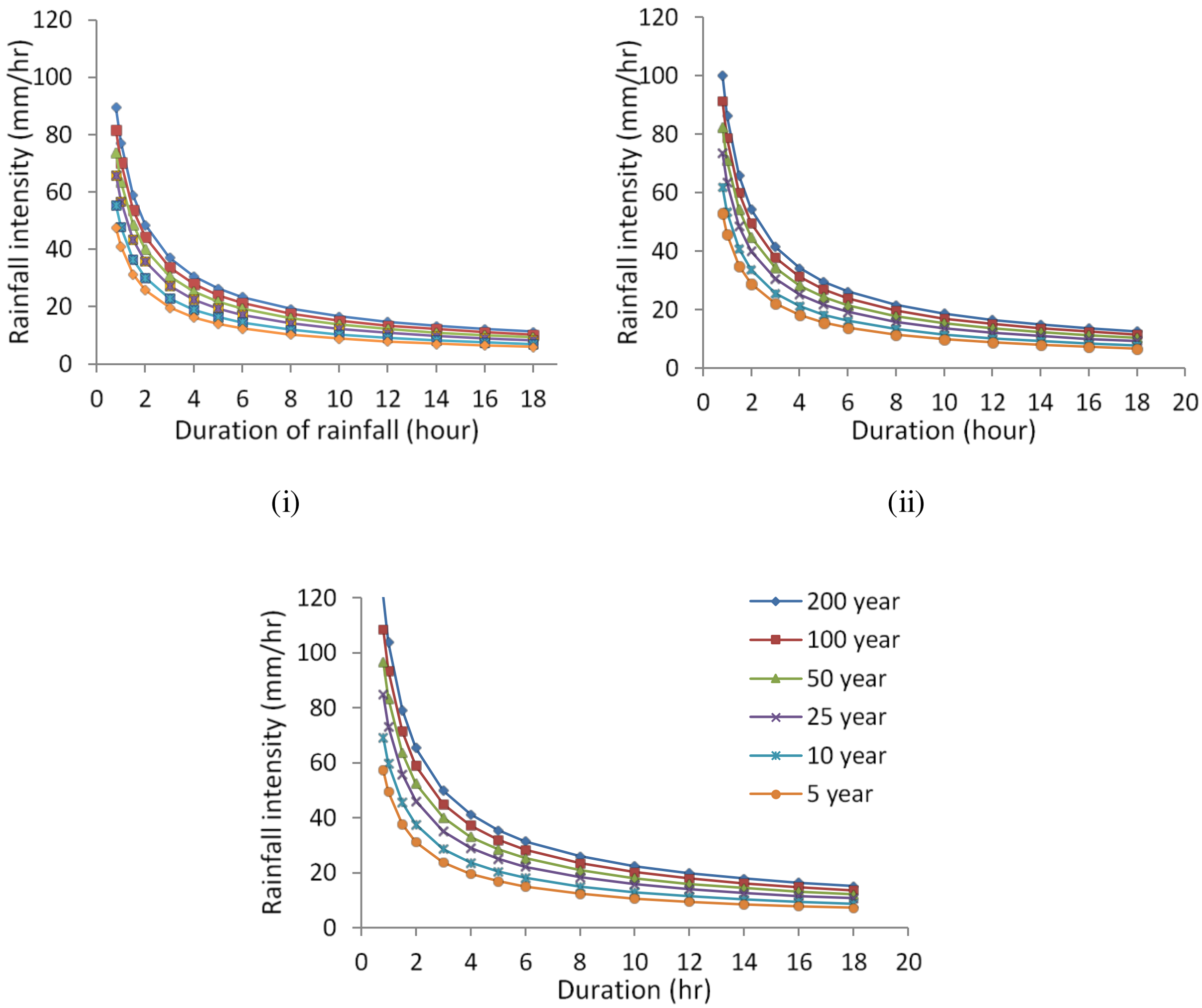
RESULTS AND ANALYSIS

Impact of climate change on rainfall intensity: By observing the IDF curves (Figure 3), it is found that ESM2G projects higher rainfall intensities than the ESM2M model. To analyse the variation of future rainfall intensities under the impact of climate change, the average changes in the future rainfall intensities (in terms of percent of observed rainfall intensity) as projected by ESM2G and ESM2M models for the emission scenario RCP8.5 have been graphically presented in Figure 4. It reveals that higher the return period higher will be the increase in rainfall intensity.

Impact of climate change on peak runoff generation: For calculation of peak runoff generation, Rational Method has been used. Here, peak flow is calculated by Q=CiA, where C is the runoff coefficient, i is the rainfall intensity for a particular return period and a duration equal to the time of concentration of the watershed and A is the area of the watershed. For the study watershed, a composite runoff coefficient C equal to 0.358 has been determined based on the area shared by the different surface covers shown in Figure 1. LULC map has been prepared form a LISS IV satellite images of the capture date 4 December 2015. Time of concentration has been calculated by Williams equation (Williams 1922), which is suitable for hilly watersheds (Christchurch City Council 2011). Again, for both the two climate change (i.e. regarding the ESM2G and ESM2M model) and the observed scenarios, values of 'i' have been computed by using the ID curves of 10 years frequency as shown in Figure 3. Finally, the peak runoff values are calculated for all the three scenarios and are shown in Table 1. As the study watershed is a mini watershed, the peak discharge values calculated from 3 sets of rainfall data are not so different from each other. However, the impact of climate change on design discharge can be interpreted by observing the percentage increase in Q_{peak} shown in Table 1. The higher value of increase in discharge indicates that the drainage system of Guwahati city should be redesigned by considering the design discharge, calculated incorporating the effect of climate change.

Impact of climate change on soil erosion: To calculate the soil loss from the watershed, RUSLE (Revised Universal Soil Loss Equation; Renard et al., 1991) has been used. Here, the average annual soil loss per unit area, A (t $ha^{-1}year^{-1}$) is given by,

$$A = R \times K \times LS \times C \times P \tag{4}$$



(i) (ii)

(iii)

Figure 3. IDF curves of Guwahati city developed with (i) observed data (ii) ESM2M model output (iii) ESM2G model output

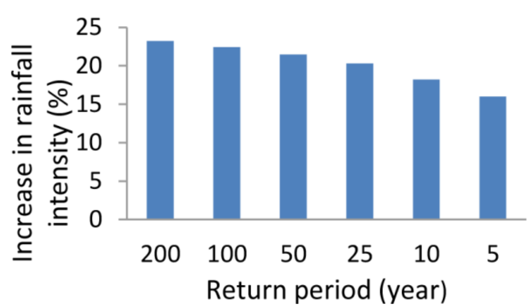


Figure 4. Average changes in rainfall intensity with different return periods under the impact of climate change

In this study, the rainfall erosivity factor, R has been calculated by using the equation given by Wischmeier and Smith (1978) and modified by Arnoldus (1980). More research is needed to be done to develop an empirical relation of R factor for the study area. Many India-based soil erosion studies have used this equation (Mondal et al. 2015). Based on the soil texture class and organic content (Stewart et al. 1976), the soil erodibility factor K is considered as 0.032925 t h $MJ^{-1}mm^{-1}$. Again, the pixel-based values of slope length and slope steepness factor, LS have been calculated in ArcGIS platform by using the equation given by Moore and Burch (1986) and revised by Desmet and Govers (1996a). The LS value for the entire watershed was determined by taking the arithmetic mean of the pixel-based LS values. The cover management factor C for the land covers in the watershed were taken from the available literature (Wishmeier and Smith 1978; Sarma 2011; Gelagay and Minale 2016). The C factor value for the entire watershed has been calculated based on the area shared by the different land covers. Again, in the watershed, no support practices are observed, and hence, the support practice factor P is taken as 1. The parameter values and the soil loss values calculated for all the three scenarios are displayed in Table 2.

Table 1. Values of input parameters for Rational Method and calculated peak runoff

Data	Rainfall intensity (m/s), i	Runoff coefficient ,C	Area, A (m^2)	Q_{peak} with 10 year RP (m^3/s)	Change in Q_{peak} (%)
Observed	1.45×10^{-5}	0.358	571197.92	2.96	
ESM2M	1.62×10^{-5}			3.31	11.62
ESM2G	1.81×10^{-5}			3.70	24.80

Table 2. Values of input parameters of RUSLE and calculated sediment loss from the watershed

Data	R (MJ mm ha^{-1} $h^{-1}year^{-1}$)	K (ton h MJ^{-1} mm^{-1})	LS	C	P	Soil loss rate, A (T/ha/yr)	Annual soil loss (T/yr)	Change in soil loss (%)
Observed	1062.47	0.032925	5.46	0.079	1	15.04	858.89	
ESM2M	1353.69					19.16	1094.31	27.41
ESM2G	1508.28					21.35	1219.28	41.96

For small hilly watershed located in Guwahati city, Sarma (2011) considered the sediment delivery ratio equal to 1. Since the study watershed is a mini watershed, the same sediment delivery ratio can be applied, and in that case, soil loss values can be used as sediment yields of the watershed. The change in soil loss values in Table 2 reveals that the sediment loss from the hilly watershed is quite high indicating a greater sensitivity to climate change than the peak runoff.

CONCLUSIONS

Following conclusions can be drawn from the study:

1. Future rainfall of Guwahati has been predicted using GCM models ESM2G and ESM2M under RCP8.5, which corresponds to the highest greenhouse gas emissions pathway. Using these downscaled data, the climate change impact on design rainfall intensity has been investigated by forming IDF curves.
2. It was found that under the projection ESM2G model with highest emission scenario RCP 8.5, for higher return periods like 200 years, the design rainfall depth may increase up to 20% by the end of this century in Guwahati city.

3. The peak runoff and sediment loss from a hilly urban watershed of Guwahati city were derived by using the downscaled data. It shows that though both the two parameters will be affected, the sediment yield will be more severely impacted than the peak runoff.
4. Peak runoff and sediment yield are two critical parameters for drainage design, and traditionally, in Guwahati city, the design of the drainage infrastructures are carried out by considering stationary climatic conditions. Hence, the analysis done in this study can provide an insight into the need of adaption of climate change impact in the design of urban sewage infrastructure in Guwahati city by the urban planners and designers.
5. Upgrading or replacement of the existing drainage system with a provision for safe release of the future design flow and sediment load can help in sustainable and cost-effective drainage management (Willems et al. 2012).

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Prediction of STP Operational Parameters Using ANN

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ABSTRACT

Predicting the plant operational parameters using conventional experimental techniques is a time consuming step. Computer-based soft computing methods have the advantages over the conventional method and were applied to overcome the changing and complex nature of the biological wastewater treatment processes due to variation in raw wastewater compositions, strengths, and flow rates, which are normally difficult to predict and control. Artificial neural network (ANN), black-box modelling approach, was used to acquire the knowledge base of a real decentralised STP which was used as process model. Detailed study of Naidu STP at Pune was carried out to predict the operational parameters such as BOD, COD, and SS one day in advance. The study signifies that the ANNs are capable of capturing the plant operation characteristics with a good degree of accuracy. The developed soft computing model incorporates the trained ANN plant model. The developed model was validated using plant scale data. This model can be a valuable performance assessment tool for plant operators and decision makers.

Key Words: ANN, BOD, COD, Prediction, SS, STP

INTRODUCTION

In urban areas, global population is growing rapidly, resulting into outstripping of urban planning and wastewater infrastructure development. Existing wastewater infrastructure for most of the cities is no longer appropriate. Management of wastewater in the urban context must be adopted accordingly, not only to the size, but also to the economic development and governance capacity of the urban area. Smart and sustained investment in wastewater management will generate multiple dividends in society, economy and environment. The decentralised approach of collection, treatment and disposal of wastewater for the Indian urban scenario is inevitable to conserve and restore the water bodies.

Wide varieties of technologies are being adopted in sewage treatment plants e.g., activated sludge process, extended aeration process, sequential batch reactors, moving bed bio reactors etc. In order to fulfil stringent pollution control board norms for stringent effluent quality requirements, technology is moving from sewage treatment plant design and construction to plant process control and operation with special emphasis on plant optimization is gaining lot of significance recently. Effective plant control and operation depends on understanding the dynamics of the process behaviour, simulation and prediction ability. Monitoring and automation of wastewater treatment plants is essential to make their operation easier, saving manpower and energy (Aguado *et al*., 2009).

ANNs have been used in predicting the plant operational key parameters like biochemical oxygen demand(BOD), chemical oxygen demand(COD) and suspended solids(SS) which are commonly used in assessing the plant performance (Oliveira-Esquerre *et al*., 2002).

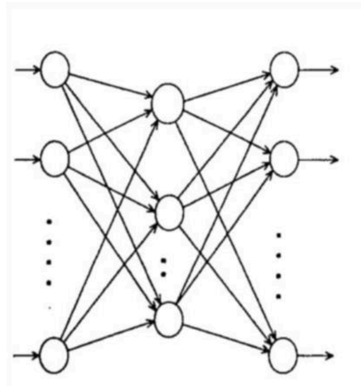

Figure 1. Typical three layer neural network

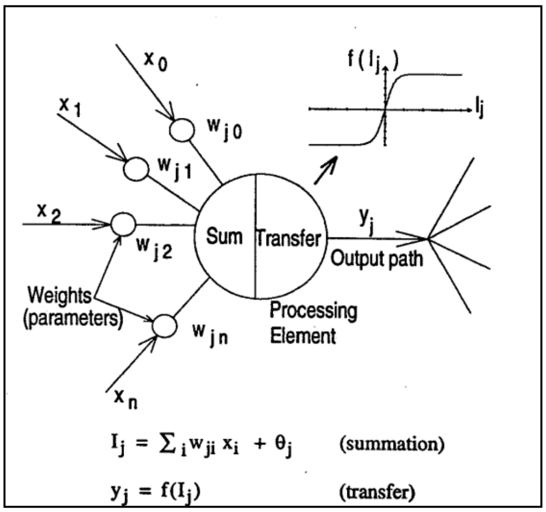

Figure 2: Operation of a typical processing element

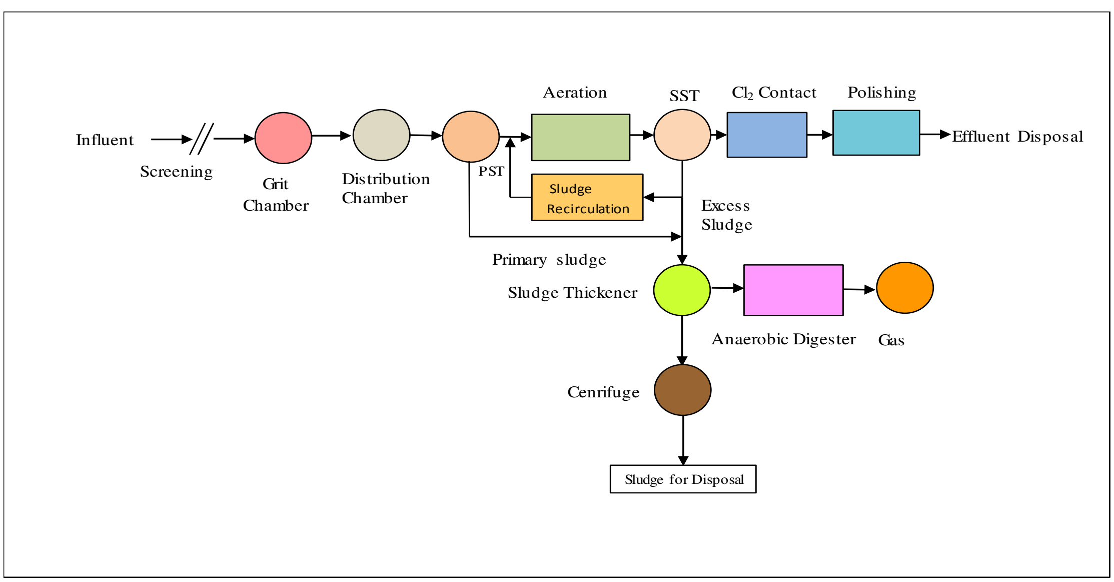

Figure 3: Flow chart of Naidu STP

Table 1: Variation of the process variables for Naidu STP

Period	Description	Parameters		
		SS, mg/L	BOD, mg/L	COD, mg/L
Jan 13 to Oct 14 and Jun 16 to Dec 16	Minimum	82	50	112
	Average	157.7	126.8	279.0
	Maximum	200	160	432

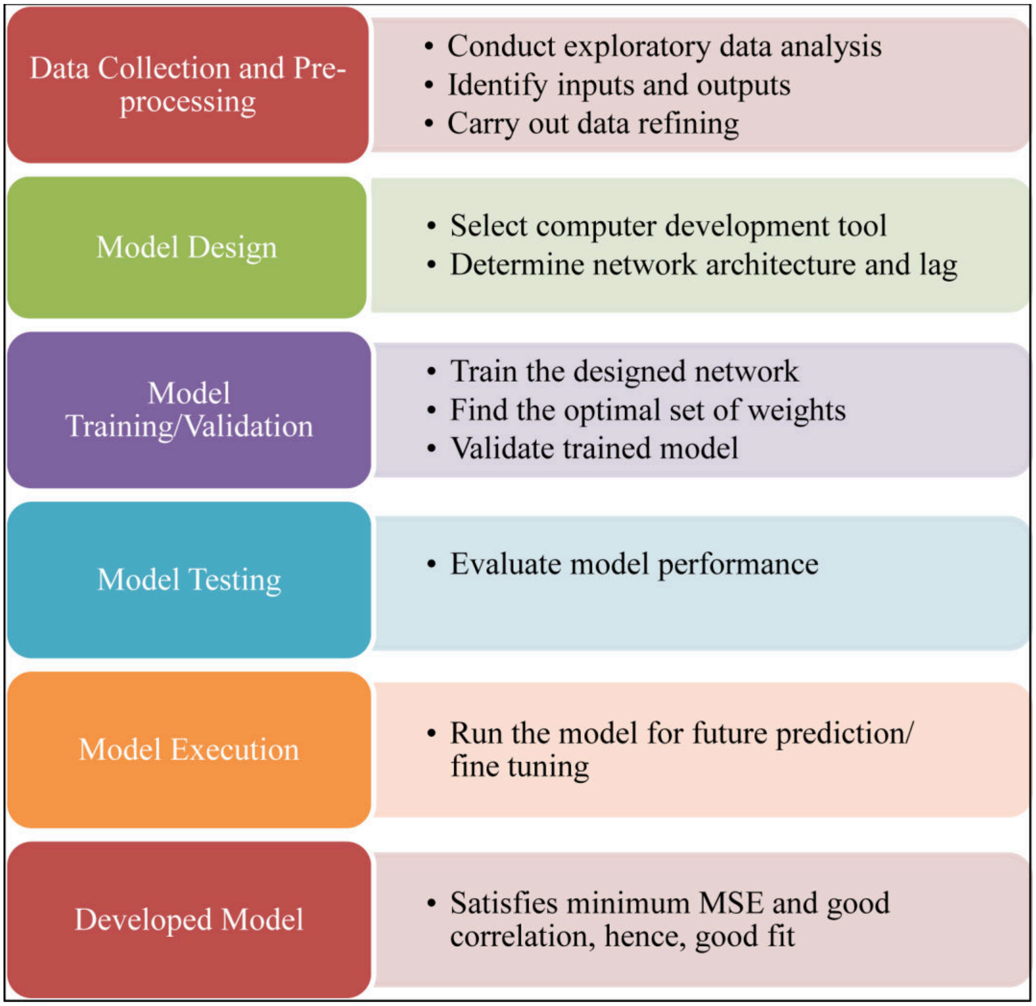

Figure 4: ANN model development process

In this study, a case study of 115 MLD Naidu STP of Pune city was selected to predict the influent BOD, COD and SS one day in advance. It was found that model was of good fit with respect to coefficient of correlation(r), coefficient of determination (R^2) and mean absolute percent error.

Table 2: Minimum MSE and final MSE for the best network (BOD)

Sr. No.	Description	Training	Cross validation
1	Epoch number	50	49
2	Minimum MSE	0.0030	0.0033
3	Final MSE	0.0030	0.0034