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Abstract

This study summaries several monitoring and surveys on ambient concentrations of NOx, SO_2, CO,O_3 particulate matters, lead and black smoke which have been carried out by the authors, Bangladesh Atomic Energy Commission and Department of Environment (DOE) in Bangladesh. Airborne lead was a major concern but the phase-out of lead in gasoline implemented throughout South Asia in the year 1999 and the early 2000s has contributed greatly to reducing the lead concentration in ambient air. Analysis of the time series air quality data (of specific air pollutants, NO_X, SO_2, CO,O_3 and particulate matters, for selected stations from the years 2002 to 2004) indicates that the ambient air of Dhaka City, the capital of Bangladesh, is polluted more than 55 percent of the year. The level of pollutants at 49 important road intersections shows the quality of air at the roadsides of Dhaka City. The air quality index (AQI) estimated at various locations of the city reveals that more than 70 percent of the roadside environments are severely polluted and the rest are highly polluted on the basis of the WHO guideline value. This pollution level at roadside environments is closely related with the density of motor vehicles plying on the roads. With the increase in the number of motor vehicles caused by economic growth and industrialisation, the level of pollution is expected to worsen further in the future. To improve the situation, proposals for some pollution abatement measures including the introduction of unleaded gasoline and CNG-powered 3-wheelers instead of 2-stroke 3-wheelers are critically discussed in this paper.
Keywords: air quality, Dhaka City, particulate matters, gaseous pollutants.

1 Air pollution in Bangladesh

Air is a life sustaining precious natural resource. Fresh air is one of the most indispensable gifts of nature without which human will not survive. And human activities can be interfered by the pollution of this vital resource. It is only in recent times that mankind has become aware of the extent to which this interference is sustainable.

The level of air pollution in many of the developing countries is so bad that it is being recognized as one of the priority issues. This is an important public health problem in most of the cities in developing countries. Pollution in the cities like Bangkok, Cairo, Delhi, Mexico and Dhaka far exceeds the acceptable limits set by the World Health Organization (WHO). Epidemiological studies show that air pollution in developing countries accounts for tens of thousands of excess deaths and billions of dollars of lost productivity every year (Faiz et al., 1996). In South Asian region, urban air pollution is estimated to cause over 250,000 deaths and billions of cases of respiratory illness every year (WB, 2004). The children are more vulnerable to such situation.

Presently, on any working day, filthy gray haze emits mists from auto exhausts and chemicals hang lower and lower than ever over the city. The smog causes the eyes to water, coats lungs with layers of microscopic, noxious soot. Emissions from all types of automobiles like car, jeep, bus, truck, minibus, microbus, two- stroke engine driven vehicles (auto-rickshaw, tempo, mini-truck) and motorcycles have been unabatedly polluting the city's air. Aircraft, railway engines, industrial plants, power plants, brick fields, open burning incineration, solid waste disposal sites and dust particles are also contributing to the air pollution. Dust pollution due to road diggings, constructions arid other development activities further compound the city's air pollution situation. This poor air quality threatens human health, structures, and vegetation; lowered visibility; and, enhanced greenhouse gas emissions. It has been estimated by the World Bank (WB) that the country could avoid 15,000 deaths and save $200 million to $800 million annually by reducing in cities of Dhaka, Chittagong, Rajshahi and Khulna (UNEP, UNICEF & WHO, 2002). The yearly costs of health maintenance due to air pollution in Dhaka City have been estimated in excess of US$ 100 million and cause more than 8,000 excess deaths in the city. The loss caused by air pollution and the associated degradation in quality of life impose a significant burden on people in all sectors but especially the poor. Thus it attracted growing attention from the industry, government, civil society and the public at large.

The World Health Organization (WHO) classifies sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), Ozone (O_3), suspended particulate matter (SPM), and lead as key or "classical" pollutants. The same pollutants are called "criteria" pollutants by the U.S. Environmental Protection Agency (EPA). Health-based ambient air quality standards are normally set for the classical pollutants first, and their measurements are examined to judge the magnitude of the air pollution problem. In Bangladesh perspective, this study summaries several monitoring and surveys on ambient concentrations of NOx,

SO_2, CO, O_3, particulate matters, lead and black smoke have been carried out by the authors, Bangladesh Atomic Energy Commission and Department of Environment in Bangladesh. It also investigates the level of air pollution on the basis of air quality index (AQI), assess its consequences on human health. The result of this study will assist decision-maker in formulating national policies to combat air pollution.

2 Traffic volume in Dhaka city

Dhaka, which is both the nation's administrative capital and business hub, has a total estimated population of more than nine million and it is projected to swell to 16 million by the year 2015, making it the seventh largest populous city in the world. This overcrowded city is already considered as one of the world's most polluted urban centres and it has the highest volume of traffic comparing to other cities of Bangladesh so that Dhaka has the prime attribute of air pollution in Bangladesh. The Figure 1 represents the increasing trend of no. of vehicles in each year of Dhaka City. It is apparent from the Figure 1, as of 2001 an estimated total of 168,718 automobiles are on roads of Dhaka, has heterogeneous traffic flows. A substantial part of total traffic is non-motorized vehicles enhance severe congestion and pollution problem especially in road intersections. Around 80% of total trips in Dhaka city is comprised of non-motorized transport (NMT) and only 5.9% trips are made by motorized transport (MT). Average trip length of MT is 27 minutes. Trips made by public transport specially buses are very low, only 0.9%. The maximum trips of vehicle modes are made by using rickshaws are 43%. Though it is very difficult to quantify pollution contribution from such heterogeneous traffic combinations, the influence of NMT on pollution are averaged upon the pollution considering the average speed of traffic flows. Based on data from different sources and road surveys conducted by the authors the traffic pollution contribution in Dhaka city has been assessed and presented in the following sections.

3 Air particulate matters and gaseous pollutants

To satisfy the basic national need for monitoring air quality and to control air pollution in the major cities of Bangladesh, Department of Environment (DOE) set up the first ever in the country, the Continuous Air Quality Monitoring Station (CAMS) in 2002 in the open space of the most important public institution of Bangladesh, the Parliament Buildings, in the centre of the Dhaka city. Twenty-four hour average, monthly measurements of PM_{10} and $PM_{2.5}$ particulate matters, collected over the period of 22 months are illustrated in Figure 2. The systematic trend observed in these data is the peaking of the concentrations from October to April beyond which the concentration of both PM_{10} and $PM_{2.5}$ are decreasing due to rain out effect. The other time-series data for $PM_{2.5}$ have been collected at two sampling sites: Farm Gate (Figure 3) which faces an intersection of several major roads, and a semi-residential site located about 50 meters from a road with moderate traffic (Figure 4). These Figure 3 & 4 (WB 2004) show the seasonal pattern observed throughout the year; high particulate concentrations in winter when it is dry and when low temperatures cause thermal inversion whereby pollutants are trapped near ground level, and low concentrations during the rainy season. There is a considerable fall in $PM_{2.5}$ concentrations at the Farm Gate between 2002 and 2003. As discussed below, this could be in part due to the ban on all existing two-stroke engine three-wheelers that went into effect on January 1, 2003 by promoting the vehicles that use compressed natural gas (CNG). The average $PM_{2.5}$ concentrations for the month of January in 2001 and 2002 were 87 and 136 $\mu g/m^3$ (before the phaseout), respectively, compared to 55 and 54 $\mu g/m^3$ in 2003 and 2004, respectively (after the phaseout). The monthly concentrations were 125, 75 and 74 $\mu g/m^3$ in December for 2000, 2001 and 2002 (before the phaseout) and 44 $\mu g/m^3$ in 2003 (after the phaseout).

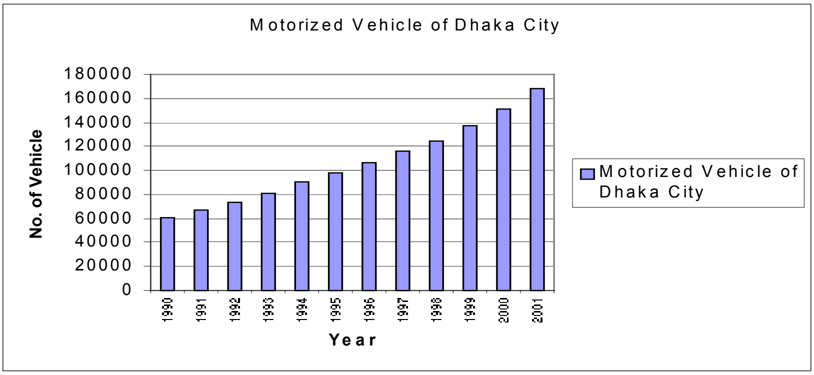

Figure 1: Motorized Vehicles on Road in Greater Dhaka.

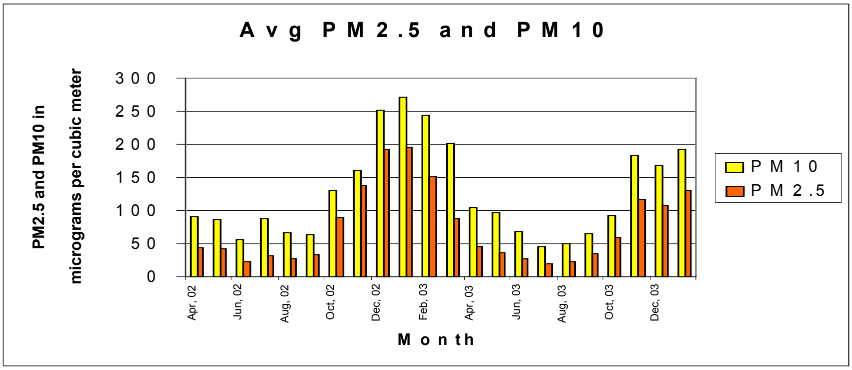

Figure 2: Monthly 24 hr Average of PM concentration at CAMS, Sangsad Bhaban.

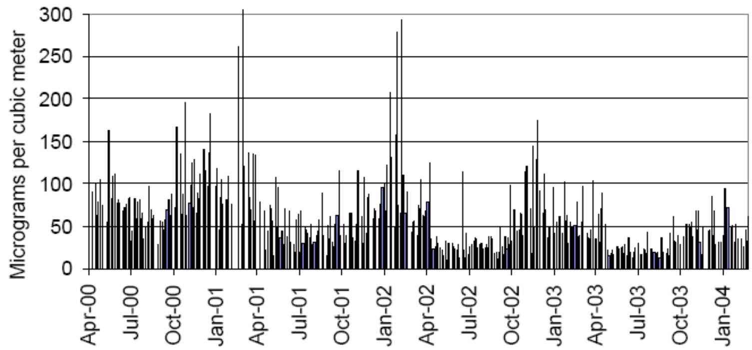

Figure 3: 24 hour Average $PM_{2.5}$ Data at Farm Gate, Dhaka, Bangladesh.

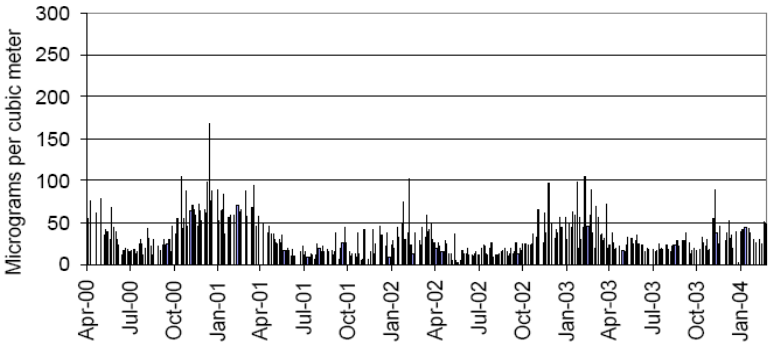

Figure 4: 24 hour Average $PM_{2.5}$ Data at Semi-Residential Area, Dhaka.

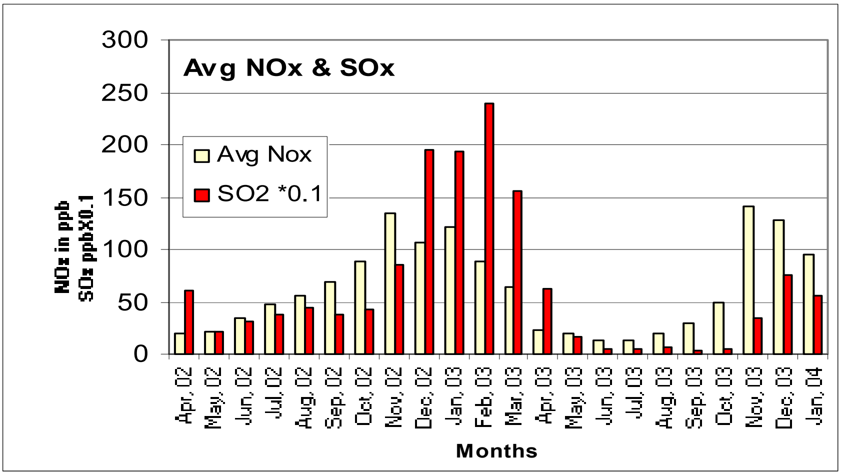

Figure 5: Monthly 24 hr Average of NO_2 & SO2 concentration at CAMS, Sangsad bavan.

The monthly average of SO_2 and NO_2 in ppb are Figure 5. The level of CO during this monitoring period had the value range from 0.2 to 2.0 ppm which has been shown in Figure 6

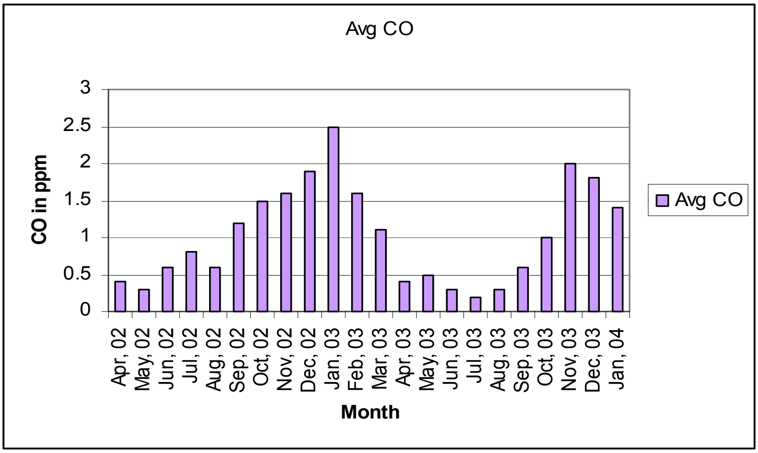

Figure 6: Monthly 1-hr Average CO at CAMS, Sangsad Bhaban.

During the monitoring period, very few measurements of ozone were made above the detection limit of the method. The maximum value of 299 ppb was observed in December 2002, for an hour average, as one event only, against the proposed Bangladesh standard of 120 ppb. It is clear from the Figures 2, 3 and 4 that the levels of PM from October 2002 to March 2003 exceeded the Bangladesh Air Quality Standard (Table 1) in high volume traffic area having maximum concentration of 271 $\mu g/m^3$ in Jan'03 while the SO_2 levels exceed the standard during the dry winter season (December 2002 to March 2003) having maximum concentration of 19.5 ppb in December 2002. The NOx levels appear to be below the acceptable limit defined by the air quality standard. It should be borne in mind that Bangladesh Standards are not directly comparable with international air quality standards because of differences in averaging time. However, in general terms, PM and SO_2 concentrations exceed US standard and WHO guideline (Table 1) of ambient air quality during whole year in Dhaka.

The Bangladesh Atomic Energy Commission measured 14.6 $\mu g/m^3$ of Pb in ambient air in Dhaka over the period November 1995 to January 1999 (Biswas et al., 2003), whereas the WHO guideline (1 year average) for Pb in air is 0.51 $\mu g/m^3$. The Table 2 represents the concentration of Pb in different periods of the year. It can be observed that the yearly average Pb concentrations in the ambient air have declined by approximately two-thirds from their earlier values after the introduction of unleaded gasoline.

The effect of unleaded gasoline introduction can be seen from Figure 7, is the plot of the monthly average of the ratio of Pb and Black Carbon (BC) % as a function of time. This ratio is a weather independent estimate of Pb concentration. Two steps of Pb reduction can be seen in this Figure 7. The first reduction occurred around October 1998. This is probably the effect of making regular gasoline Pb-free earlier in July. The concentration started increasing again, probably because of increased consumption of leaded-premium gasoline. Although the high-octane unleaded gasoline was introduced in July 1999, the reduction of the Pb concentration in air could be seen only after October. This lag phase could be caused by old leaded stock or a contaminated distribution system. This time, the ratio appears to be steadily dropping, which is consistent with a fully unleaded supply system.

Table 1: Comparison of air quality standards, ambient air quality in Bangladesh.

Pollutant	Average Time	WHO Guideline	US Standards	Bangladesh Standards	Ambient Concentration in Dhaka
CO Carbon monoxide	1 hour	30 mg/m^3	9 ppm 10 mg/m^3		11 ppm (instantaneous average)
	8 hour	10 mg/m^3	35 ppm 40 mg/m^3		
Pb Lead	24 hour	0.5-1. $\mu g/m^3$			4.63 $\mu g/m^3$
	Quarterly		1.5 $\mu g/m^3$		
NO_2	Annual		0.053 ppm 100 $\mu g/m^3$	80 $\mu g/m^3$ (Residential) 100 $\mu g/m^3$ (Commercial)	41.8 $\mu g/m^3$
Nitrogen dioxide	24 hour	150 $\mu g/m^3$			0.063 ppm 119 $\mu g/m^3$
O_3 Ozone	1 hour	150 - 200 $\mu g/m^3$	0.12 ppm 235 $\mu g/m$		
PM_{10}/TSP/SPM	Annual	60-90 $\mu g/m^3$	50 $\mu g/m^3$	200 $\mu g/m^3$ (Residential) 400 $\mu g/m^3$ (Commercial)	1245-1601 $\mu g/m^3$ (Commercial) 445 $\mu g/m^3$ (Residential)
	24 hour	150-230 $\mu g/m^3$	150 $\mu g/m^3$		
SO_2 Sulfur dioxide	Annual	40-60 $\mu g/m^3$	0.03 ppm 80 $\mu g/m^3$	80 $\mu g/m^3$ (Residential) 100 $\mu g/m^3$ (Commercial)	472.9 $\mu g/m^3$ (Commercial) 63.5 $\mu g/m^3$ (Residential)
	24 hour	100-150 $\mu g/m^3$	0.14 ppm 365 $\mu g/m^3$		

Source : www.eng-consult.com/air/standard.html.

Table 2: Changes in Pb concentration in Dhaka city.

Period	Pb (Before 1996) ng/m^3	Pb (After Oct. 1999) ng/m^3	Comments
Low Rainfall Period(LRF) November – January	463	212	Average over LRF months
Medium Rainfall Period.(MRF) February-May, September-October	253	170	Average over MRF months
High Rainfall Period.(HRF) (June – August)	160	66	Average over HRF months
Average	312	106	12 months

Source : Biswas, et al, 2003.

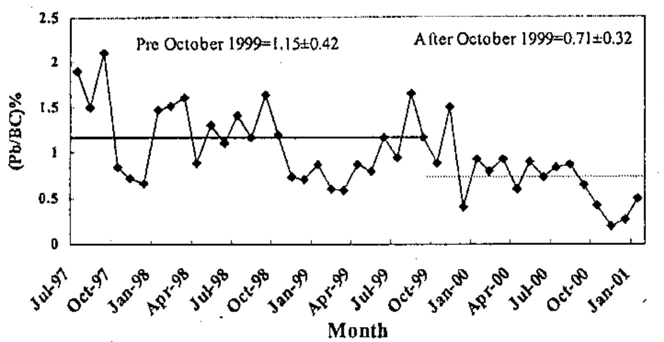

Figure 7: Average Monthly Pb/BC % ratios vs. time for July1997-January 2001 Source: Biswas, et al, 2003.

Besides government information, there are several independent researchers' data available from the mid to late 1990's on CO monitoring, NOx concentration in selected urban intersections Dhaka, PM measurements at DOE's Agargaon office and the rooftop of World Bank office. These data are listed in Table 1 and compared with local and international ambient air quality standards. All measured data exceed Bangladeshi and/or international standards. Again, it is evident from the Figures 2 to 6 that from the late October to late April, this 6 to 7 months are the most air-polluted period in a year, which comprises more than 55 percent of days of a year.

4 Air quality index

On the basis of the observed data and the proposed air quality standards, some calculations have been performed to provide some air quality index (AQI) numbers so that the public understanding of the air pollution problems becomes clear. The index is calculated on the basis of Air Quality Rating for each of the pollutants which is defined as the ratio between the observed level of the pollutant in the air and the allowable limit for the same expressed in percentage. For a number of pollutants, AQI is obtained from the geometric mean of the Air Quality Ratings. Based on the Air Quality Index, the categorization of ambient air environment is presented in Table 3 (Alam et al, 1999). Hereafter, AQI's have been calculated using ambient concentration of CO, NO_2 and SO_2 measured at 49 important roadside intersections of Dhaka city (Alam et al, 1999) on the basis of the permissible level of the concentrations provided by both WHO and DOE, Bangladesh. The results are summarized in Table 4. It is observed that if AQI is calculated on the basis of WHO standards, in 70% of the areas the roadside environment is severely polluted and 30% of the areas is heavily polluted. For the standards set by the Government of Bangladesh, all the areas are very severely polluted. The most highly polluted areas are Mohakhali, Jatrabari and Panthopath where the AQI is above 200 (Based on WHO guideline). Even at roads besides residential areas like Dhanmondi and Jigatola the AQI is above 100. Again, according to US-EPA model, AQI has been calculated using single pollutant as parameter from the data of Sangsad Bhaban. The Figure 8 shows that the average AQI is 100 or more than 100 throughout the year. According to US-EPA model (www.epa.gov), the pollution represents Unhealthy for Sensitive Groups, which include national monuments, health resorts, hospitals, archeological spots and educational institutions.

Table 3: Categories of Ambient Environmental Quality on the basis of AQI.

Categories	AQI	Description
I	Less than 10	Very Clean
II	10-25	Clean
III	25-50	Fairly Clean
IV	50-75	Moderately Polluted
V	75-100	Polluted
VI	100-125	Heavily Polluted
VII	More than 125	Severely Polluted

Table 4: Air quality levels in the roads of Dhaka City.

Standard	Category of Air Quality	Range of the Estimated Value of AQI	Average AQI for the Category	Number of Locations in the Category
AQI calculated on the basis of Bangladesh Standard	Severely Polluted	209-454	318	49 (100%)
AQI calculated on the basis of WHO Standard	Severely Polluted	131-215	167	34 (70%)
	Heavily Polluted	102-124	114	14 (30%)
	Polluted	99	-	1

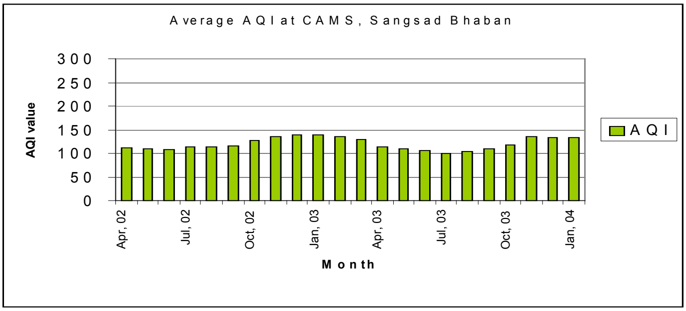

Figure 8: Average AQI measured at CAMS, Sangsad Bhaban.

5 Conclusion

Air pollution in Dhaka is a high priority concern as it is seriously affecting the quality of life in the city and represents a major public health issue Although pollutants emitted from the transport sector clearly constitute the major pollution problem in Dhaka, no emission inventory detailing sources of pollution is currently available. The study shows that seventy percent of the roadsides of the city are severely polluted. Its consequence on the health of the city dwellers is very concerning. The ambient levels of PM, SO_2, Pb far exceed the Bangladesh air quality standards and WHO guidelines, resulting pollution, which comprises more than 55 percent days of a year. There is also evidence that ambient NO_2 concentration regularly below the acceptable limit defined by the air quality standard. Although there is a lack of time-series data, the air quality measurements available indicate that Dhaka's air pollution is worsening. Some positive steps like replacement of 2-stroke 3 wheelers by CNG powered 3-wheelers and introduction of unleaded gasoline have improved the quality of air, but still lack of regular monitoring and examining of emission from motor vehicles, limited no. of streets comparing to increasing volume of traffic, lack of management of traffic system hamper the quality of air immensely, which must be addressed and assessed accordingly.

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