Sjournals
Scientific Journals
Scientific Journal of Review (2015) 4(7) 87-94
ISSN 2322-2433
doi: 10.14196/sjr.v4i7.1896

Contents lists available at Sjournals
Scientific Journal of REVIEW
Journal homepage: www.Sjournals.com

Original article

Investigating the effect of gas flow rate and amount of zinc oxide nanoparticles on the efficacy of photocatalytic oxidation process of nitrogen oxide from waste airstream

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A R T I C L E I N F O

Article history:
Received 09 June 2015
Accepted 22 July 2015
Available online 27 July 2015

Keywords:
Photocatalyticoxidation
Zinc oxide nanoparticles
Nitrogen oxide

A B S T R A C T

Nitrogen oxides are one of the most important air pollutants in environment and industrythat due to the adverse health and environmental effects should be refined before discharging into the environment. The photocatalytic oxidation method of nitrogen oxide into nitrogen Dioxide for better absorption insolutions is a promising method for removing of nitrogen oxides. Laboratory system used in this study is included of a source of gas source, mixing chamber, photocatalytic oxidation reactor, measuring system for nitrogen oxidation. Zinc oxide nanoparticles which were simulated by UV-A radiation would be used for photocatalytic oxidation. Inlet concentration of nitrogen oxide and the amount of stabilized nanoparticles in reactor for converting nitrogen oxide into nitrogen dioxide has been investigated. Results showed that the amount of monotonic converting of nitrogen oxide into nitrogen dioxide in the amount of Nano-particles is stabilized 8mg/cm^2 for inlet concentration 100,150,200 ppm and respectively equivalent to 15, 26 and 32%. This study showed that increasing concentration of inletnitrogen oxide in system, reduce the capacity of photocatalytic oxidation for converting nitrogen oxide into nitrogen dioxide.

1. Introduction

One of the great achievements of mankind in recent decades of rapid growth and development of manufacturing industries in various chemical substances. In addition to the improvements that bring comfort has numerous problems including environmental pollution, especially air pollution ,which eventually caused one of the major concerns of human(Cooper & Alley, 2011).

Nitrogen oxides are one of the main pollutants of Air. Among these oxides, nitrogen oxide (NO) and nitrogen dioxide (NO2) are the most important. In general situation, the total amount of (NO + NO2) is shown as NOX which would be spread from combustion process and have high NO (90-95%) and lower amount of NO2(5-10%)(Kuropka, 2011).

NO is a colorless, toxic, Non-flammable which a bit of that would be resolved in water and its breathing cause vasodilatation in circulatory system in the lung. NO2 is a toxic gas with yellowish brown, corrosive and stimulus. This gas with high concentration cause acute bronchitis, fibrosis and pulmonary edema(Zandaryaa, Gavasci, Lombardi, & Fiore, 2001).

NO in the process of combustion of gaseous fuels in high amount would be formed which is as a the most important pollutants of Industry, power generation and heat plants, Transportation(Wark, Warner, & Davis, 1998). From other sources of NO in the environment , we can point out to chemical Industry, Nitric acid, chemical fertilizers, sulfuric acid with Nitric method and organic materials(Wu, Wang, Liu, Jiang, & Sheng, 2008).

The main source of NOxemissions, are motor vehicles. 40% of this pollution is because of power plants. Main methods for controlling nitrogen oxides are included Selective catalytic reduction and Selective non-catalytic reduction(SCR, SNCR), LessNOxExcessAir (LEA), Flue-Gas Recirculation (FGR), Chemical reduction (NOx), oxidation (NOx), adsorption and absorption in solutions(Hamada et al., 1993; Kuropka, 2011; Todorova et al., 2013).

Using of some methods in order to prevent NOx production more in the time of combustion would be used which is limited to changing production processes. Chemical reduction systems of NOx are sensitive to pollution and abnormal conditions. Most of SCR systems due to high pollutions which are in gas have short life. adsorption also have some absorbents which are less common because of economic reasons and problems related to reproducing absorbents or using of them(Kuropka, 2011; Yamashita et al., 1996).

One of the methods which during recent years has high progress and has been used in most of the searching fields is photocatalytic oxidation technology (PCO).photocatalyst are solid semiconductor oxides which by attracting photons, a pair ofelectron – hole would be created in them. This electron-hole can have reactions with molecules at the surface PCO and use of some semiconductors like CdS, ZnS, ZnO, TiO2, SrTiO3(Devahasdin, Fan Jr, Li, & Chen, 2003).

This method could be replaced instead of some controlling methods like adsorption, burning and catalytic oxidation. While most of the controlling methods caused regenerative response NOx and convert it to NO, PCO would cause oxidation NO to NO2. NO2 rather than NO has high absorption in alkaline solutions. therefore oxidation NO to NO2 is an effective method for absorption NOx in solutions(Kuropka, 2011; Wu et al., 2008). Titanium dioxide and zinc oxide due to high Efficiency of photocatalyst, resistance against chemical materials and its toxicity and low cost is one of the best semiconductor which is used in photocatalytic oxidation process(Li, Liu, Huang, Esariyaumpai, & Chen, 2002).

In 2008, Zhonogbiaet and et al. studied removing nitrogen oxide with a mixed method of oxidation and absorption in solutions. Wet scrubber containing sulfite solution was used as an absorption system. The experimental results showed that the efficiency for removing of NOx through this method could arrive to 75% in the maximum amount(Wu et al., 2008). in most of other studies also Nanoparticles of

Titanium dioxide used in PCO(Devahasdin et al., 2003; Haiqiang Wang, Zhongbiao Wu, Weirong Zhao, & Baohong Guan, 2007). Zinc oxide also has been used in some studies. This material has long been recognized as a byproduct of copper smelting(Moballegh, 2006).

because ZnO has high bandwidth rather than TiO2, so can absorb a wide range of wavelength(Mori, 2005; Oppenländer, 2007). in this study, photocatalytic features of zinc oxide in order to oxidation NO to NO2 have been used .the amount of stabilized Nanoparticles in reactor concentration of inlet gas have been considered in this study.

2. Materials and methods

Laboratory system which has been used in this study is included of an emission gas source, mixing chamber and photocatalytic oxidation reactor and measuring system of nitrogen oxide (Fig.1). The reactor is made of Pyrex and its form is like cylindrical till UV ray could spread all surfaces uniformly so on this case gas could move without any turbulence. By consideration to the cylindrical form of reactor and this point that stabilizing nanoparticles of zinc oxide on slope surface is not possible and also by studying previous research ,a fiberglass mesh in order to refining nanoparticles has been used. Fiberglass is permeable in front of UV ray and a layer of nanoparticles can stabilize on fiberglass.

Polluted air in combustion chamber with 10 liters capacity is provided. In order to integration pollutants and create desired concentration, a fan is used in the chamber. Polluted air after combustion chamber enters to reactor and the length and diameter would be determined by considering to the type of lamp.

Around the reactor in order to prevent light and reflection UV-A is covered with aluminum foils and the amount of flow rate of polluted air in reactor was 0.4 lit/min. concentration of 100,150,200 ppm for the amount of pollutants entering in reactor have been selected. The NO oxidation efficiency and the NOxremoval efficiency is evaluated according to this equation.

$$\text{oxidation efficiency} = (([NO]_{inlet,PCO} - [NO]_{outlet,PCO})/[NO]_{inlet,PCO}) \times 100$$

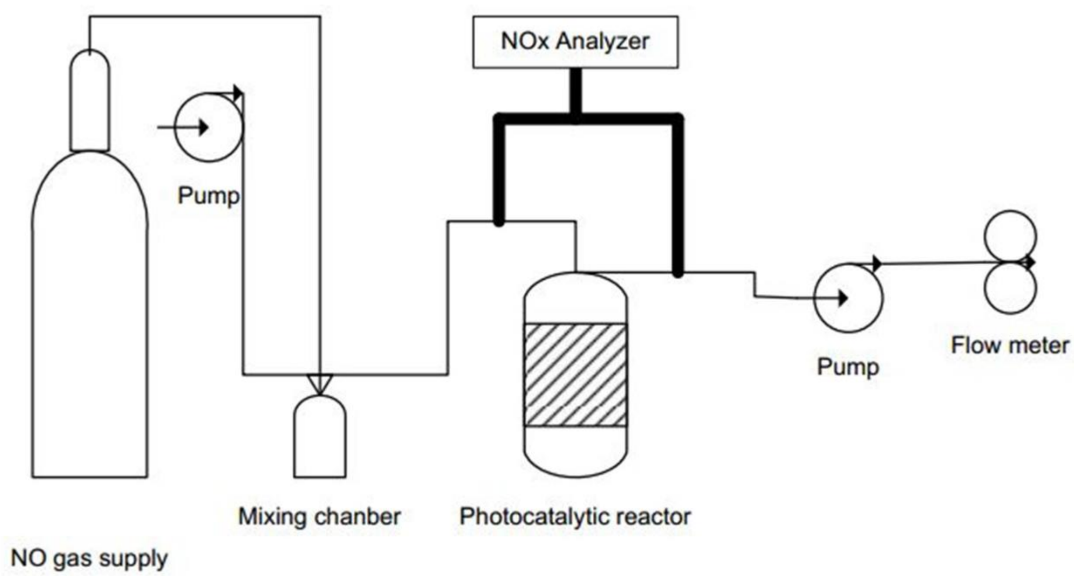


Fig. 1. Schematic of the experimental system.

3. Results

After handling photocatalytic systems in order to investigation of effects of inlet concentration of NO on conversion rate, three inlet concentrations as 100,150,200 ppm have been used. Measuring of gas concentration after the reactor by use Varioplusfrom starting gas flowing in every half-hour intervals had been done. Because of converting function effects, two variables as inlet concentration NO and the amount of stabilized nanoparticles of zinc oxide within internal wall, therefore data about converting effects of NO based on concentration within two separated curves for stabilized nanoparticles 4 ,8 mg/cm2 are presented.

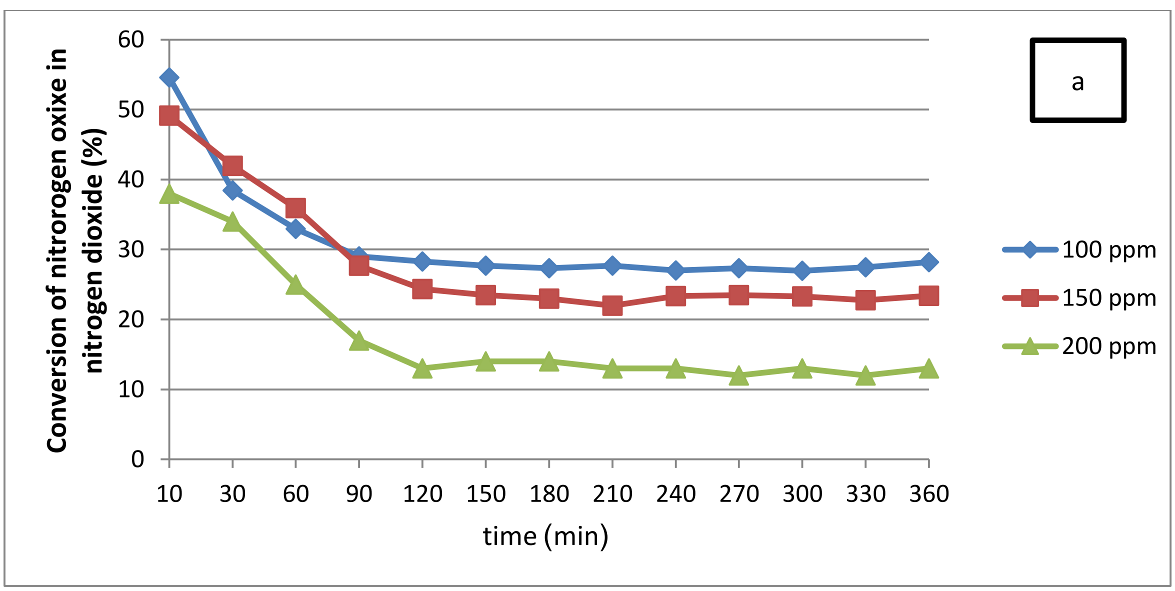
At first of PCO, aconverting is seen. Converting condition after 120 minutes reduced andbe constant. It seems that up converting condition at first was because of high absorption beside PCO.While the amount of stabilized nanoparticles is 4 mg/cm2in Fig. 2.a shown highest efficiency oxidation of ZnOis about 55% at first for 100 ppm. After 95 minutes, up converting condition for 100ppm and after 110 min for 150 ppm and 115 min for 200 ppm would be constant. Constant oxidation rate for 100, 150, 200 ppm are respectively equal to 13, 23, 28 %.

In Fig2.bseen the average constant amount of concentrations 100, 150, 120 ppm are 15 ,26 , 32 %,While the amount of stabilized nanoparticles is 8 mg/cm2. Forinlet concentration 100 ppm of the amount of NO oxidation at first is 56%. For concentrations 150, 200 ppm, the first amount of conversion is 44, 54% respectively.

Fig.3.Shownthe changes of oxidation of nitrogen oxide according to the stabilized concentration.in inlet concentration of 100 ppm in the initial oxidation of the nanoparticles stabilized at 4 and 8 mg/cm2are 55% and 56% and mean amount are 13% and 15% respectively shown in Fig. 3.a.

Fig.2.b. shown initial conversion rate is 49% in 150 ppm for amount of stabilized nanoparticles 4 mg/cm2. After 110 minutes conversion reaches a steady value that average of these values is 23%.In 8 mg/cm2 initial conversion rate is 54 to 120 minutes after a steady rate of 26%.

In inlet concentration of 200 ppm in the initial oxidation of the nanoparticles stabilized at 4 and 8 mg/cm2are 55% and 56% and mean amount are 13% and 15% respectively shown in Fig. 3.c.



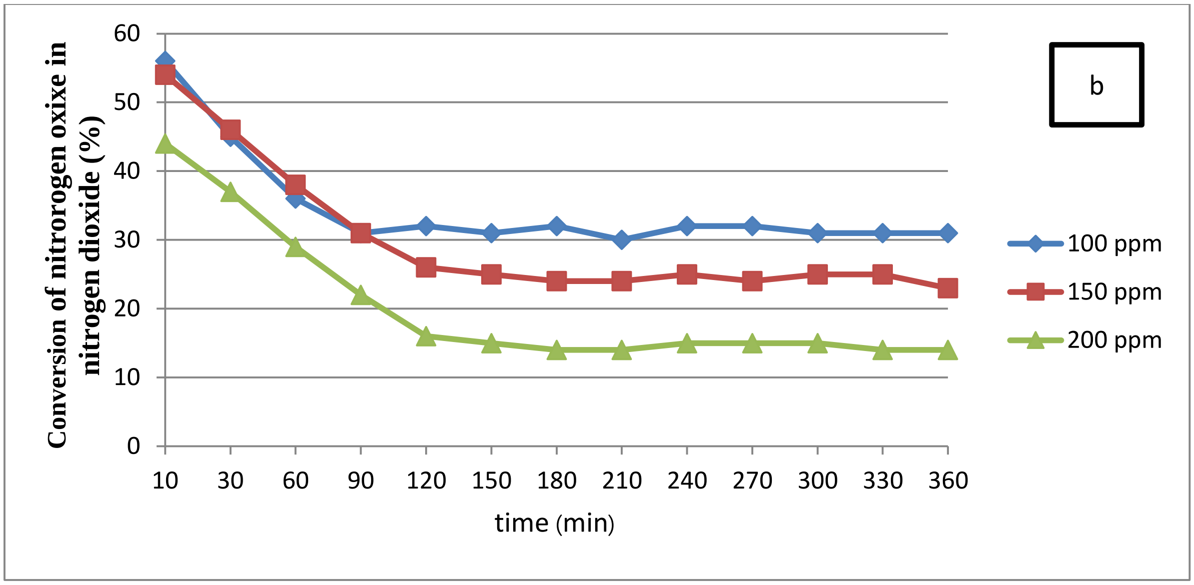
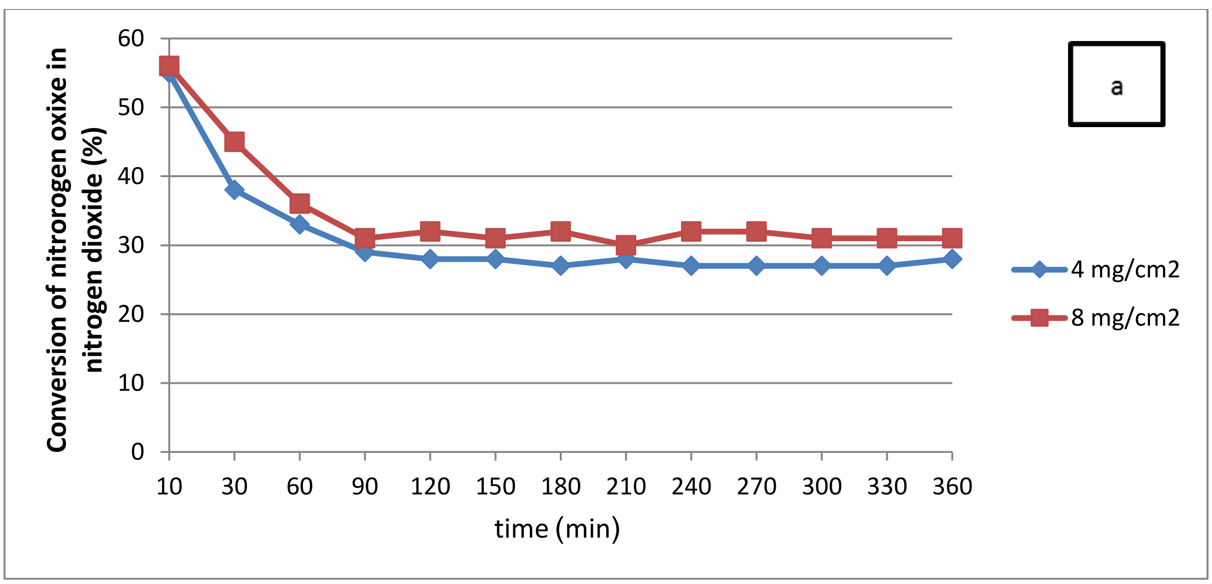
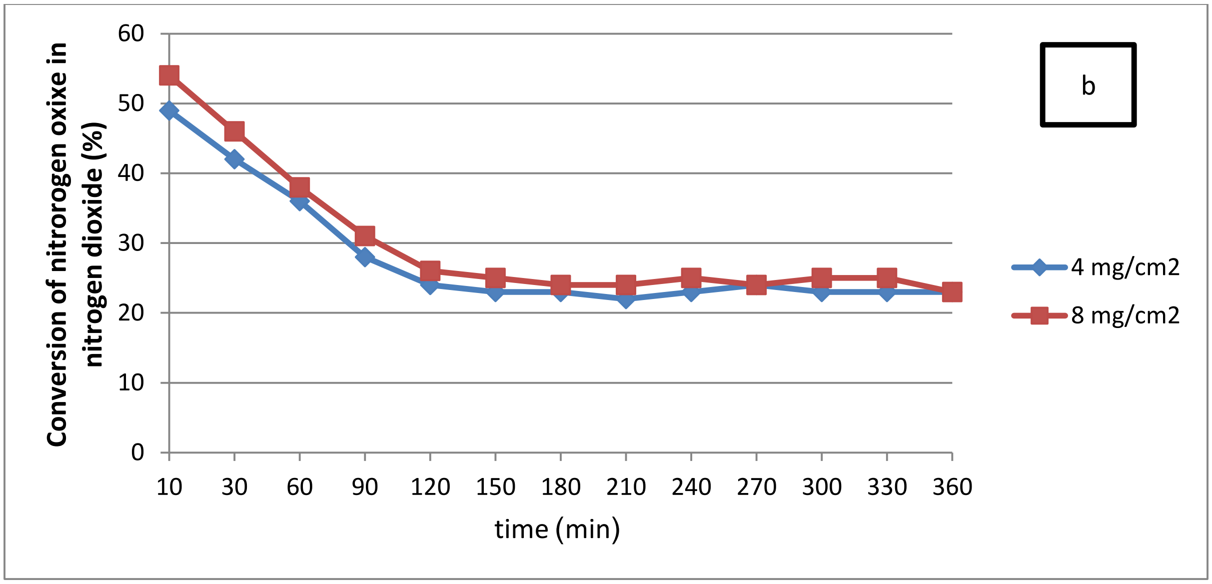


Fig. 2. Efficiency of NO oxidation with inlet concentration ina:4mg/cm2 , b:8 mg/cm2
I= 240 µW/cm2 ,Flow=0.4Lit/min





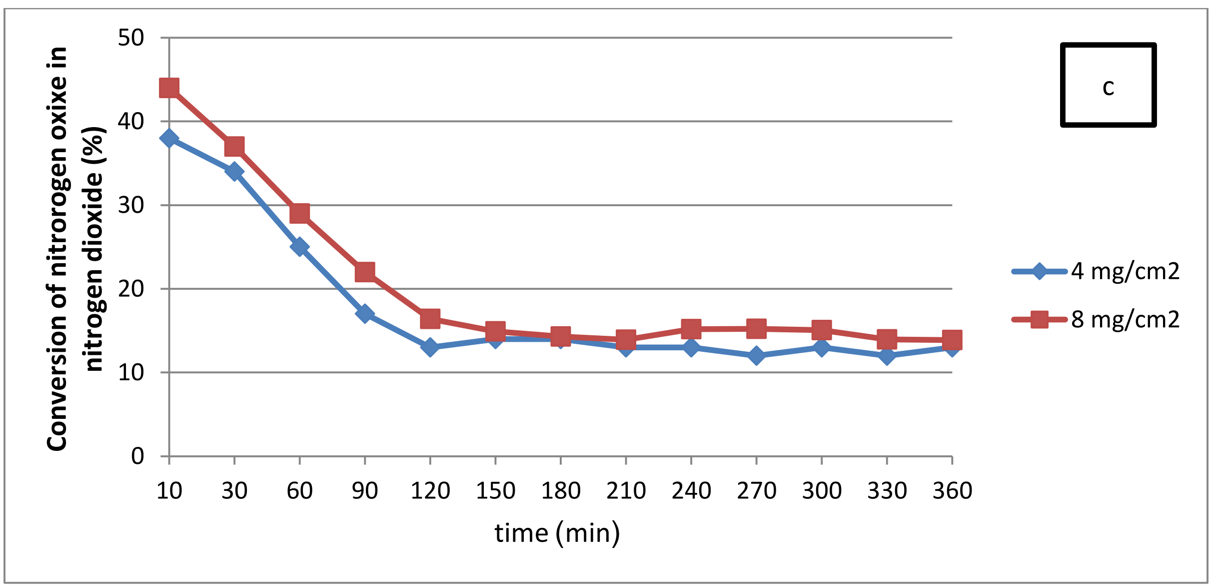


Fig. 3. Efficiency of NO oxidation with inlet concentration100, 150, 200 ppm
I= 240 µW/cm2,Flow=0.4Lit/min

4. Discussion

In this study, two variables as in let concentration of nitrogen oxide and the amount of stabilized nano particles have been investigated. Average amount of conversion rate for concentrations 100, 150, 200ppm is respectively. 13, 23, 28 percentages when the a mount of stabilized nano particlesin glass would be 4 mg/cm^2.

In a constant condition, the a mount of stabilized nano particles is equal with lower in let concentration and this cause that upper amount of conversion from NO into NO_2 would be achieved. By considering tobeing constant the level of nano particles and actives it esforoxidation, so the a mount of in let concentration will increase the a mount of out put nitrogen oxide with out any changes in reactor system.

At the beginning of this circulation, higher a mount of conversion is seen that it is be cause of chemisorption phenomena (Haiqiang Wang et al., 2007). Chemisorption is a type of surface absorption which would be created between thesurface and reactive materials (Spaull, 2000b). About the amount of NO conversion indifferent rates, the amount of stabilized nano particles are 4, 8mg/cm^2 indifferent concentrations and the amount of converting is less than 5% in different concentrations. Formation of electron-holepairsin the space-charge region has a life time that will enable it to participate in chemical reactions (Lee, Jayapalan, Bergin, & Kurtis, 2014).

$$ZnO + h\upsilon \rightarrow h^{+} + e^{-}$$

$$e- + H_2O \rightarrow H^{+} + {}^{\bullet}OH$$

$$e- + O_2 \rightarrow {}^{\bullet}O^{2-}-$$

In a constant condition, the a mount of stabilized nano particles is equal with lower in let concentration and this cause that upper amount of conversion from NO in to NO2 would be achieved. By considering to being constant the level of nano particles and actives it esforoxidation, so the a mount of in let concentration will increase the amount of out put nitrogen oxide without any changes in reactor system.

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