Chimney Installation in *Honai* Traditional House to Reduce the Exposure of SO_2, and NO_2 in Wamena, Papua Province, Indonesia

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ABSTRACT

Biomass has been used to warm the Honai (traditional house) indoor air temperature at night in Wamena Regency. As this mountain area is cold, inhabitant burn Kasuari wood from evening to midnight to warm their body. As a result, they continuously inhale the Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) contaminated air in Honai room. This study aimed to investigate the SO_2 and NO_2 contaminated Honai indoor air and assess the potential health risks posed by community of Honai occupants in five villages in Wamena regency. Samples were collected from 15 Honai before and after the chimney installation that used to flow out the contaminated air from the Honai. Likewise, 30 inhabitants of Honai occupants were measured for their lung vital capacity as well as the personal SO_2 and NO_2 inhalation rate. Sample of SO_2 and NO_2 were collected used midget impinger technique and concentration measured by using the pararosaniline-spectrofotometri. In addition, lung vital capacity was measured use a spirometric whereas personal inhalation was measured by personal inhalation tool. Results implied that, of those five villages showed the highest concentration of SO_2 and NO_2 in five villages (Punakul, Wenabubaga, Musalfak, Kilubaga and Mulimah) prior to the chimney installation were ranged of 3.81, 5.66, 3.13, 3.45 and 4.01 mg/m^3, respectively. Likewise, the highest NO_2 concentrations were 4.25, 6.56, 3.98, 3.98 and 5.29 ppm, respectively. These values according to the US-EPA have exceeded the estimated daily exposure dose for SO_2 and NO_2 that might lead to an adverse health effects.

Keywords: *Honai, Chimney, Indoor Air Pollution, Sulfur Dioxide, Nitrogen Dioxide, Inhalation Rate and Lung Capacity.*

1. INTRODUCTION

Air pollution mostly generated by the industry, forest fire, vehicles and the burning of biomass that are currently threatening the inhaled air quality in the entire world [1]. This could potentially have an impact on human health and the environment in the form of chemical hazards both of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are sourced from industry and vehicle. The use of biomass fuels within the home is another important source of exposure that is linked to socio-economic conditions. Indoor exposure to smoke from biomass fuels and coal has long been recognized as a major cause of illness in young children, and has been estimated to be the second biggest environmental contributor to poor health worldwide [2]. SO_2 and NO_2 gas in the atmosphere may cause irritation of the mucous secretion increase and respiratory tract. People who have lower respiratory rate are highly sensitive to the SO_2 and NO_2. For instance; contaminated air exposure to SO_2 gas at 0.07 ppm along with dust particles 12.15 mg/m^3 in the short term will cause respiratory diseases. While the exposure to SO_2 gas of 0.02 ppm to 0.05 ppm or 0.10 to 0.20 mg/m3 along with dust particles in the long will lead respiratory tract disease [3]. In addition, a concentration of 500 ppm of SO_2 lead to death [3, 4].

A recent WHO [2] study estimated that 52% of the world's population uses solid fuels, with typical values in sub-Saharan Africa, South East Asia and the western Pacific of 75% [5]. Artificial sources of SO_2 and NO_2 are combustion of fuel oil, gas and coal containing high sulfur (Slamet, 2011). Sulfur content of coal related research ever conducted by Ibrahim [6], with the result that the sulfur content of Sintang Coal in West Kalimantan 4.24 %, while in Tondongkura, Sulawesi total sulfur was 4.77 %. In addition, industrial activities such as vehicles (trucks) also contributed to the increased levels of SO_2 and NO_2 in ambient air. According to the Fardiaz study [7] that the main source of pollution comes from transportation. Likewise, Wardhana [8] revealed that the main air pollution from transport is CO, NOx, SO, hydrocarbons and SOx particles which contributed 0.88 %. Local potential air pollutants around settlements can also be derived from the burning of domestic waste and the use of wood as fuel [9].

Sulfur dioxide and nitrogen dioxide potentially may adverse health effects and should not be underappreciated. These pollutants may lead to both acute and chronic diseases and become a serious health problem in many countries around the world. Recent epidemiologic studies conducted throughout the world have provided valuable insight into the associations between SO_2, NO_2, and CO exposure and increases in cardiopulmonary mortality, respiratory and cardiovascular hospital admissions, emergency admissions caused by stroke (NO_2), and myocardial infarction (NO_2 and CO) [10-12].

Very little attention has been paid to SO_2 in personal exposure studies, either of adults or children particularly in Wamena Regency and in Papua Province in general. In view of the rising indoor concentrations of SO_2 and NO_2 in regions such as in Kurulu District with a large of Honai houses that continuously use wood for cooking and warm the temperature in house, surely, this gap in knowledge needs to be addressed. In addition, SO_2 and NO_2 gas is one of the gases that may lead to air pollution and hazardous because of implications for human health and the environment. Therefore it is necessary to investigate the concentration of SO_2, and NO_2 in Honai indoor pollutant that obviously lead to air pollution and assess potential adverse health posed by the Honai's occupants. At the end, this study results will become considerate material for the decision maker policy to reduce the risk agents in Honai.

2. MATERIAL AND METHOD

2.1 Study Area

This study was conducted at five villages in Kurulu District, Wamena Province, Papua-Indonesia. The five villages namely; Punakul Village, Wenabubaga Village, Musalfak Village, Kilugaba Villages and Mulimah Village. District Kurulu was selected to be sampling areas on the basis that this region is a zone has many traditional housing (honai) and they use wood for cooking and for warming the indoor air temperature daily. In addition the majority of illnesses suffered by residents of this area were found of *ashma pnomonia* and *tuberculosis*.

2.2 Sample Design

The study was conducted by collecting data from subject and objects samples of population, then measure lung capacity by using a spirometer and proceeds with inhalation level measurements for SO_2 and NO_2 by using a personal sampler inhalation. The ambient air samples were taken for Sulfur Dioxide (SO2) and Nitrogen Dioxide (NO2) as the object sample at the houses of honai communities, sampling time of objects did at 16:00 to 17:00, 17:00 to 18:00 or 18:00 to 19:00. Each sample was collected for 60 minute every house. Numbers of sampling points were 15 Honai houses done before chimney installation. Then we do the installation of chimney (close technology) with a diameter of 30 cm that is placed along the 2.5 m above the furnace roof and wall edges out of Honai. It aims to reduce the smoke circulation in honai. Object sampling sites divided by 5 regions based on availability or honai density in the selected villages. We also taking into account the willingness of residents to involve during this research. In addition, it takes into account the distance between sample points where about 300 to 500 m each honai were selected that subsequently obtained through a Global Positioning System coordinates [13]. While the number of respondents or subjects in the study were 30 people. Respondents were split evenly by the large number of traditional houses Honai in each village.

2.3 Ethical Consideration

People (*Honai* occupants) living in the area who were requested as the respondent signed an informed consent letter prior to inclusion in the research. Samples for inhalation rate and lung vital capacity measurement were done base on the ethical clearance consideration issued by Medical Faculty of Hasanuddin University number UH13070282. Confidentiality of initial information and freedom to withdraw from the study anytime was stipulated and without any force from the third parties. Those found to have health concerns will be provided with the appropriate management and informed secretly, as necessary.

2.4 Samples Analysis

SO_2 and NO_2 samples were collected by used impinger method and measurement techniques using pararosaniline-spectrofotometri accordance with the Indonesian National Standard (SNI 19-7119.7-2005) [14]. Principle of this method is based on the absorption of SO_2 and NO_2 gas from the air on absorbent solution of potassium tetra kloromerkurat (TCM). In this case the complex formed diklorosulfito merkurat air oxidation resistant. Furthermore the complex is then reacted with formaldehyde to form pararosanilin and sulfonic acid methyl pararosanilin colored. The color intensity is measured with a spectrophotometer that occurs directly associated with the amount of SO_2 and NO_2 in the air sample has been taken. The measurement method is based on Schiff reaction that can measure the concentration of SO_2 and NO_2 in the range of 25-1000 μg/m3 in the air sample flow rate, while for the smaller than 25 μg/m3 could be measured by the volume of air that a larger sample.

3. RESULTS AND DISCUSSION

3.1. Concentration of Sulphur Dioxide (SO2) in Ambient Air

SO_2 concentration of 5 villages in the Kurulu District, Wamena Regency was measured prior to the installation of chimney models. The result is implied in Table 1. The results showed that simple installation of chimney in Honai may lead to variation in concentrations of SO_2 in the Honai home, especially during short period of high concentrations before chimney installation change into lower concentration after the installation. Table 1 implied the concentration of SO_2 at five villages; at Punakul village the highest value was 1.10 mg/m^3 and the lowest concentration of 0.79 mg/m^3. Then, the highest concentration of SO_2 in Wenabubaga Village with 1.25 mg/m^3 and the lowest was 0.93 mg/m^3. In Musalfak village, the highest was 1.15 with the lowest concentration of 0.09 mg/m^3. While in the two villages of Kilubaga and Mulima, the highest SO_2 concentration were 0.83 and 1,23 mg/m^3 respectively, whereas the lowest was 0.09 and 0.01 mg/m^3.

Table 1. Concentration of SO_2 in Honai room before and after the chimney installation in five villages in the district of Kurulu, Wamena Regency, 2013.

SO_2 Concntration mg/m^3 in Honai	**Villages**														
	Punakul			**Wenabubaga**			**Musalfak**			**Kilubaga**			**Mulima**		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Before Chimney	0.10	1.04	0.79	1.25	0.93	1.02	0.10	0.42	1.15	0.83	0.51	0.09	1.23	0.10	0.18
After Chimney	0.03	0.02	0.09	0.03	0.10	0.15	0.01	0.12	0.09	0.04	0.11	0.09	0.04	0.02	0.01

The wide range of building design leads to large variations in infiltration rate and hence indoor and personal exposure. Compare to Honai building that has a closed model design it may lead to a hazard of indoor air pollutant. Although new houses do not necessarily mean airtight houses, but it need the installation of chimney to flow out the pollutant. Study relate the in door pollution relate to the house design conducted by Sherman and Matson [15] implied that the main reasons for tighter construction are to reduce energy costs and maintain thermal comfort which is more efficient.

3.2 Concentration (NO_2) Ambient Air

Table 2 shows the NO_2 concentration of 5 villages in the Kurulu District in Wamena Regency. As we did with SO_2 assessment, NO_2 measurements were made before and after the installation of chimney design. Results indicated that before chimney installation the highest concentrations of NO_2 in five villages were 4.25, 6.56, 3.97, 3.94 and 5.29 ppm, respectively, while the lowest levels were 3.38, 4.69, 2.48, 3.05 and 2.90 ppm, respectively. Likewise, the highest level NO_2 concentration after the chimney installation was 0.73 ppm in Mulimah village while the lowest concentration was 0.12 ppm in Punakul village.

Table 2. Concentration of NO_2 in the ambient air before and after the installation of chimney models in five villages in Wamena district, Kurulu regency, 2013

NO_2 (ppm) Concntration in Honai	Villages														
	Punakul			Wenabubaga			Musalfak			Kilubaga			Mulima		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Before Chimney	3.38	3.80	4.25	6.56	5.72	4.69	2.48	2.92	3.98	3.94	3.36	3.05	5.29	2.90	3.85
After Chimney	0.64	0.38	0.12	0.37	0.55	0.67	0.25	0.17	0.09	0.16	0.21	0.28	0.73	0.23	0.27

Relevant study revealed that the mean indoor concentrations of NO_2 in the expolis study ranged from 13 mg m^{-3} to 43 mg m^{-3} in different cities [16]. Typical daily mean indoor air concentrations in homes with gas cooking vary between 25 and 200 mg m^{-3} [17]. However, maximum indoor 1 / h peak concentrations are in the range 180–2500 mg m^{-3}. Exposure at these levels could affect the pulmonary function of asthmatics, as the lower end of the range is close to the WHO guideline (200 mgm^{-3}, 1/h average), established for the protection of asthmatic individuals [18].

Gonzales-Flesca in 2007 [19] reported 48 h mean benzene and other substances personal exposures that were very similar in non-smoking, non-occupationally exposed adults and children from the same home, with both about 3 times ambient concentrations. This implies that indoor sources in homes were the dominant exposure route for both children and adults. However, same personal exposure will lead to higher uptake per unit body weight and greater health effects in children.

3.3 Lung vital capacity (spirometry) and personal inhalation

One of the objective of this study also to assess lung capacity and level of respondents based on the parameters of inhaled sulfur dioxide (SO_2) and Nitrogen Dioxide (NO_2), the measurement of lung capacity with spirometry and the level of Personal Inhalation in five villages in the district Kurulu, the results of measurement parameters can be seen in Table 3 below.

Tabel 3. Lung vital capacity (spirometry), Personal Inhalation of concentrations of sulfur dioxide (SO_2) and Nitrogen Dioxide (NO_2) at the five villages, Kurulu District 2013.

No	Respondent Initial names	Analysis Results						
		Lung Capacity Spirometric (lt)			Description	Inhalation Rate		Note
		PEV 1	PVC	%		SO2	NO2	
1	AM	2.81	3.50	136	Normal	0.09	2.19	< NAB
2	DW	1.50	1.80	91	Normal	0.14	1.12	< NAB
3	YA	1.91	1.50	136	PFP	1.01	2.55	> NAB (SO_2)
4	AW	1.44	1.65	87.3	Normal	0.14	1.46	< NAB
5	BY	2.91	3.50	136	Normal	0.15	1.13	< NAB
6	PT	1.01	4.90	86	PFP	0.57	1.21	< NAB
7	DS	1.60	1.60	100	PFP	0.10	1.64	< NAB
8	MM	2.48	2.76	120	Normal	1.03	2.44	> NAB (SO_2)
9	AA	1.19	1.19	100	PFP	0.56	2.02	> NAB (SO_2)
10	AL	1.13	1.13	131	PFP	0.43	2.13	> NAB (SO_2)
11	PS	1.51	1.57	92.6	PFP	0.63	2.32	> NAB (SO_2)
12	YA	1.16	1.16	134	PFP	0.83	2.70	> NAB (SO_2)
13	WM	2.74	3.18	86.2	Normal	0.10	1.62	< NAB
14	IM	1.98	2.22	89.2	Normal	0.10	1.15	< NAB
15	WMa	2.48	2.48	90	Normal	0.08	1.13	< NAB
16	AA	1.22	1.22	80	Normal	0.33	1.08	> NAB (SO_2)
17	SP	1.89	2.14	88.3	Normal	0.01	1.40	< NAB
18	DW	1.31	1.41	92.9	PFP	1.04	2.05	> NAB (SO_2)
19	AA	1.70	1.71	99.4	PFP	0.42	2.07	> NAB (SO_2)
20	KI	2.50	2.07	99	Normal	0.13	1.46	< NAB
21	UMM	1.88	2.64	71.2	PFP	0.31	2.11	> NAB (SO_2)
22	PK	1.28	1.28	100	Normal	0.11	1.19	< NAB
23	WW	2.41	2.41	100	Normal	0.07	1.27	< NAB
24	HA	2.17	2.17	100	Normal	0.06	1.45	< NAB
25	JD	1.83	1.83	127	PFP	1.06	2.17	> NAB (SO_2)
26	EM	1.31	1.31	127	PFP	0.92	1.68	> NAB (SO_2)
27	WW	1.77	1.78	99.4	Normal	0.06	1.39	< NAB
28	YM	1.96	1.96	100	Normal	0.06	1.19	< NAB
29	TO	2.81	2.81	132	Normal	0.08	1.05	< NAB
30	AM	2.02	2.37	85.2	Normal	0.07	1.79	< NAB

PFP: Penurunan Fungsi Paru (lung capacity decreased), NAB: Nilai Ambang Batas (Standard Limit), No 1 to 6 = Punakul Village, 7 to 12 = Wenabubaga Village 13 to 18 = Musalfak village, 19 to 24 = Kilubaga Village and 25 to 30 = Mulimah Village

Measurements of lung vital capacity in Punakul village for PEV1 shows the highest value (respondent BY) with 2.91 and the PVC was 3.50 with the percentage was 136, this value indicated that the lung capacity was normal. Then, (respondent PT) have the lowest value PEV1 of 1.02 and 4.90 with a percentage of 86,0 that showed a decline in lung vital function capacity. Likewise, in Wenabubaga lung vital capacity measurements showed the highest value of PEV1 (respondent MM) with 2.28 and PVC 2.76 with a percentage of 120 indicated normal lung capacity, while the lowest was (respondent AL) with a value of 1.13 for PEV1 and PVC 1.13 with a percentage of 133, showed a decline in lung function or lung capacity is lower.

Furthermore in Musalfak village, the highest value of PEV 1 is on the respondent with the (initials WM) with the value of 2.74 with a PVC of 3.18 and the percentage is 86.2. Lung capacity showed normal results, while the lowest value of (respondent DW) where PEV and PEV 1 were 1.31 and 1.41 with a percentage of 92.9, respectively. The test results showed a decline in lung function or lung capacity lower. Likewise, in Kilubaga village the highest PEV value is respondents with an initial (KI) at 2.50 and PVC was 2.07 and the percentage was 99 %. Results indicate no pulmonary function or lung capacity reduction. Lastly in Mulimah Village, the highest value of PEV1 is on the respondent (TO) with the value of 2.81 and PVC was 2.81 whereas the percentage is 85.2 %. As a result, lung capacity was normal. By contrast, the lowest value of PEV, PEV1 were 1.28 and 1.28 with a percentage of 100, respectively.

These conditions will continue and very risky for residents of Honai occupants. Relevant study results by Haddad [20] showed that residents who exposed with indoor air pollutant for more than 5 years will be potentially suffering from varies diseases. The study showed that 29 % respondents had been diagnosed with at least one type of respiratory disorders and 24% for adult acute [20].

Air pollutant that can cause abnormalities in the respiratory tract if inhaled pollutants from the ambient air include gas SO_2, O_3, NO_2 and dust particles. The inhaled material may affect lung function which eventually lead to an obstructive lung abnormalities. The most dangerous gases to the lungs such as SO_2 and NO_2 when burnt initiate varies complaints in the lungs and generate asthma and bronchitis [21].

3.4 Inhalation Rate

In addition, the measurement of inhalation rate for SO_2 and NO_2 parameters in Punakul village is on the respondent (initials YA) have a highest for SO_2 and NO_2 values were 1.01 and 2.55, respectively, whereas the lowest value was SO_2 0.09 or < NAB, while NO_2 was 1.13 and still < NAB. In addition level of inhaled SO_2 and NO_2 is high among respondents (MM0 in Wenabubaga village where SO_2 and NO_2 were 1.03 and 2.44, respectively. Recorded SO_2 values was not normal or > than the threshold value (NAV). The smallest value for SO_2 value is 0.10 and NO_2 was 1.64 both are still < NAB. In addition to that, respondent with the initials (DW) in Musalfak Village both SO_2 and NO_2 were 1.04 and 2.05. It revealed that for SO_2 values was not normal or > the threshold value (NAV). For the smallest value of SO_2 0.01 or still < NAB, whereas the lowest NO_2 was 1.13 or < NAB. Next, in the Kilubaga village respondents with initials (AA), recorded SO_2 and NO_2 values were 0.42 and 2.07. Here the recorded SO_2 values > the threshold value (NAB). However, the lowest value for SO2 value was 0.06 still < NAB. Similarly to NO_2 with 1.19 and still < NAB. Lastly, the magnitude of inhalation rate for SO_2 and NO_2 were high on respondents (JD) where SO_2 and NO_2 were 1.06 and 2.17, respectively. Both SO_2 and NO_2 were < NAB.

In line with study by Fernandez [22] who compared the use of home that cook with biomass and those homes cook without biomass. The result indicated that the concentration levels of SO_2 and NO_2 were much higher at home with biomass in cooking or 9.8 times compared with that home that cook without biomass. Similarly, the potential associated with respiratory disturbance among patients in the graph illustrated that residents with biomass will be faster and more likely to suffer higher than those without biomass.

3.5 Potential Risks Assessment

In order to illustrate the potential health associated with the SO_2 and NO_2 inhaled contamination air, particularly to those *Honai* occupants, the daily intake and hazard quotient were assessed by using the formulation provided by EPA [23]. As defined by the USEPA, it is the ratio of the average daily dose to the reference dose. Then, it is stated that, HQs greater than one (1) indicate that there is a risk [24, 25].

Figure 1. Intake Rate (IR) and Risk Quotient (RQ) of the respondents due to expose of SO_2 and NO_2 in five villages in the District Kurulu, Wamena district, 2013

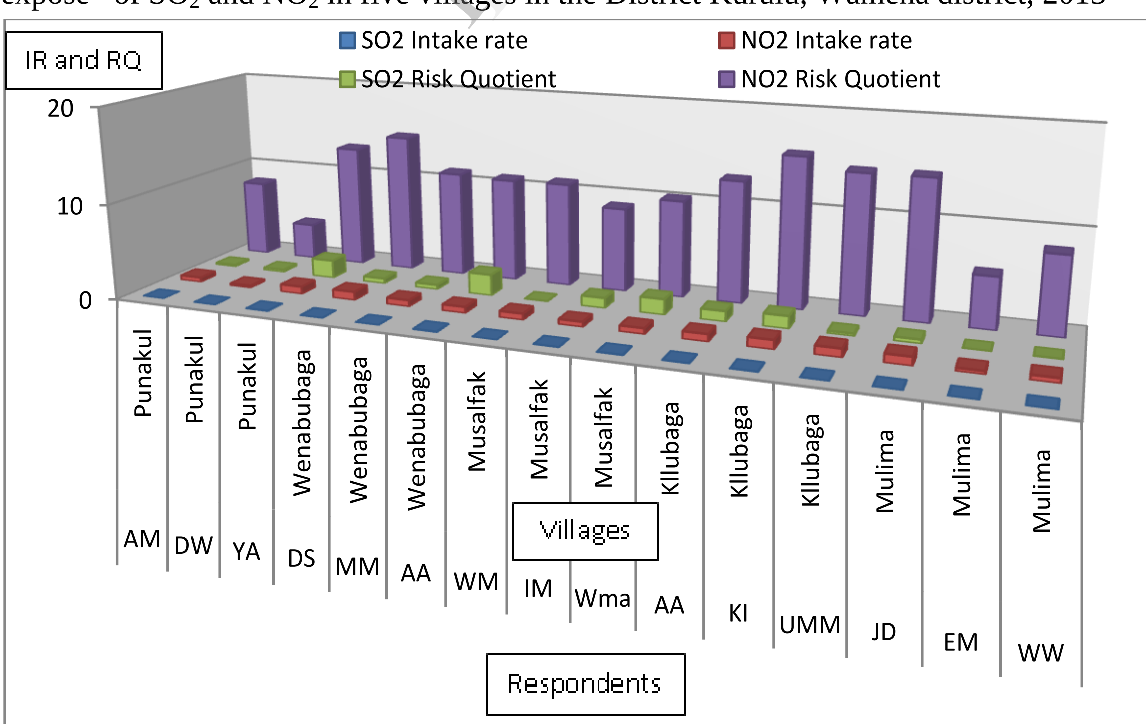

Figure 1 implied that of 30 respondents interviewed, the health risk analysis were conducted on 15 respondents, because the number of *honai* measured were for SO_2 and NO_2 concentration were 15 Honai, so the data for the value of C (chemical concentration) on the risk analysis is only available 15 honais. Representative of three respondents each village.

Results of calculation showed that the RQ for NO_2 is higher than the RQ of SO_2. The highest Risk of SO2 was in villages Wenabubaga 2,226 while the lowest was in the Musalfak village ranged between 0.054 and 0.417, respectively. The wide variations range highlight that studies comparing relationships between indoor concentrations and personal exposures in different types of area concern are required for regions outside Europe and North America, such as in Asia including in Indonesia where a different factors may influence this relationship [26]

4. CONCLUSION

Based on the results of the study, it can be concluded that the indoor air concentration of SO_2, and NO_2 in the *Honai* house mostly exceeded the standard. Measurement of lung capacity in 30 respondents who stayed in *Honai* for more than 10 years as well as inhalation rate measurements were found that all concentrations of SO_2 in the honai has exceeded the threshold value both set by National and International standards. NO_2 concentrations at several homes Honai still under NAB, but the majority has been exceeded, and potentially risk for health, especially for children who are in *Honai*. Furthermore, the value of lung capacity and inhalation rate for both SO_2 and NO_2 parameters showed decreased lung capacity and some of the respondents have experienced pneumonia and lung vital capacity were not normal.

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