Concept of emergency clean water infrastructure provision for minimizing potential impact of earthquake

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Abstract. Surabaya and Waru Fault lines are crossing Surabaya, causing potential earthquake of 6.0-6.9 RS. The potential Earthquake could make significant impact including a damage to clean water infrastructure which can cause in increased casualties. In 2010 Haiti Earthquake, cholera epidemic has increased the number of fatalities. Therefore, providing emergency clean water infrastructure can significantly reduce the impact of earthquake. Using content analysis and triangulation method, this research produces 33 criteria. Those criteria are set to propose a concept for providing emergency clean water infrastructure following the stages of disaster risk management. The concept consists of relevant actions to meet the criteria and indicator. During mitigation, the concept focus on mapping, inventory, and optimizing relevant program. In preparedness, the concept focus on ensuring the amount, condition, and distribution of supporting equipment for providing emergency clean water infrastructure. In emergency response, the concept focus on protecting the water sources, improving coordination in treatment and distribution process, and providing access for vulnerable group. In recovery, the concept focus on coordination between the responsible institution and affected community in decision making process.

Keywords: earthquake, emergency, response, water infrastructures, concept and criteria, and disaster risk.

1. Introduction
Earthquakes produce fatalities and damage to infrastructure which results in increasing casualties during emergency. An earthquake affects the quality of the physical and social environment of the community, especially in vulnerable communities, such as the elderly and children (Martini, 2011). The condition of damaged water infrastructure has an impact on increasing the likelihood of disease attacks caused by contaminated water, including cholera (Sekine & Roskosky, 2018). According to the Geotechnology Research Center, earthquakes cause fatalities, damage to infrastructure, and disruption of development. The loss of life was not only caused by the earthquake disaster, but also caused by poor service of the clean water infrastructure (Tyler & Singh, 2011).

The National Center for Earthquake Studies (PUSGEN) states that there is an active fault passing through the City of Surabaya (Figure 1). This information was published by the Ministry of Public Works and Public Housing in early September 2017. The fault is named by Waru Fault that actively accelerates in 0.05mm / year (PUSGEN, 2017). The potential for an earthquake that can be caused by this fault is 6.0-6.9 SR (BMKG, 2019).
Under normal circumstances, Surabaya resilience infrastructure level is 4.135 out of 5 (Fauzan, 2015). Surabaya water supply is sourced from PDAM with 92.66% coverage of clean water service in 2015 (PDAM Kota Surabaya, 2015). However, in emergency situation, Surabaya's clean water network is unprepared to face an earthquake condition. In an emergency condition, the readiness of clean water infrastructure is 62% (Jannah, 2019). Considering the aforementioned situation, there is indeed urgency to design a concept for providing emergency clean water infrastructure.

2. Methodology
This research is a qualitative research with a rational approach (Punch, 1998), its aim is to produce concept of clean water infrastructure provision in emergency situation. Data collection is conducted using in depth interview method and online media research due to limitation during Covid-19. The in-depth interview process involves stakeholders with understanding on clean water provision in post-earthquake disaster determine based on purposive sampling. The stakeholders consist of the three main components that are government organization (Provincial Disaster Management Board-East Java (BPBD Jawa Timur) and City Disaster Management and Civil Protection-Surabaya (BPBL Surabaya)), non-government organization (Aksi Cepat Tanggap Jawa Timur (ACT Jawa Timur), Muhammadiyah Disaster Management Center (MDMC), and Indonesian Red Cross Society (PMI)) and private sectors. Due to Covid-19 situation, data collection for private sector uses online media research via Google search engine from 19 June 2020 to 28 June 2020 with keywords: “Gempa (earthquake)”; “Swasta (private sector)”; “Air bersih (clean water)”; “Sumur air bersih (well)”; “Pengolahan air (water treatment plant)”; “Tangki air (water tank)”. All the keywords are applied only for Lombok and Palu earthquake events.

The research is divided into 2 part, first, determining criteria based on selected variables (Table 1) for emergency clean water infrastructure. Content analysis tool is used to determine the criteria (Burnard, 1996) based on data from in depth interview for government and non-government stakeholders and information on the online media for private sectors. Second, formulating the concept of emergency clean water infrastructure provision using triangulation method (Brender, 2006). The triangulation process will use three main data sources that are formulated criteria, best practice, and current regulation. In the triangulation, the main objective is defining the actions. From those selected actions, the concept is then framed using the disaster risk management cycle.

3. Discussion
3.1. Criteria and actions for Emergency Clean Water Infrastructure Provision
1. Water Sources Availability Indicator
Criteria for the water sources availability indicator include water quality, equipment to support water collecting process and water quantity. This indicator emphasizes the criteria for water sources quality in
emergency condition. For instance, in normal condition, the standard parameter of raw water quality is referring to Permenkes No. 32 Tahun 2017. Meanwhile, it is hard to find the ideal quality of raw water in emergency condition. Having the emergency condition as the situation, water quality still consider its physical, chemical, and biological condition but not all of parameter from each type are taken into consideration. In emergency condition, physical parameter considers odor from water source, the minimum consistency of color in the water (min. 50 TCU) and the acceptable water taste. The criteria for water quality apply to both surface and ground water qualities.

Table 1. Indicator, variables, and sub variables.

| Indicator | Variable | Sub-Variable | Literature |
|-----------|----------|--------------|------------|
| Availability of raw water source | Surface water volume | - | (Adi, 2009); (Zhang, Ding, Hao, & Long, 2017) |
| | Ground water volume | - | (IRC International Water and Sanitation Centre, 2002); (Maryati, 2010) |
| Ease of water transmission facility | Ease of installation temporary transmission pipe | - | |
| | Transmission pipeline | - | (UDIU, 2014); (AS’AT, 2019) |
| Availability of Water treatment facility | Availability of water treatment equipment | - | (Herlambang, 2010); (Martini, 2011) |
| | Availability of water treatment building | - | |
| Clean water distribution facility | Amount of clean water needed | Disabled Elder | (IRC International Water and Sanitation Centre, 2002); (Smadi & Theeb, 2018); (Sphere Association, 2018); (Malekmohammadi, Nazariha, & Hesari, 2013); (Pagano, 2017); |
| | Number of clean water point | - | |
| | Capacity of clean water reservoir | - | |
| | Distance between water point and shelter | - | |
| | Ease of installation of temporary distribution pipe | Risk contamination | |
| | Number of trucks for transporting clean water | Cost Capacity | |
| | Clean water quality | Physical condition Chemical content | |
| | Queuing system | - | |

The criteria are formulated based on statements from determined stakeholder and supported by literature about each criterion. For instance, the formulation process for water quality considers statements from the Provincial Disaster Management Board-East Java (BPBD Jawa Timur), NGO (ACT Jawa Timur), and Indonesian Red Cross Society (PMI). BPBD Jawa Timur as follows:

“The pH level should be in normal level (7-8). It would be difficult for the water treatment technology to convert the raw water to clean water, if the pH level is too high.” (BPBD Jawa Timur, 5 February 2020, (translated)).

From this statement, pH level is considered as the criterion for water quality. In addition, ACT Jawa Timur suggests physical condition for water in emergency condition has acceptable taste.
"Because of the limitation to get the ideal raw water quality, the physical condition could be used as the indicator. The most important indicator is the acceptable taste." (ACT, 10 February 2020, (translated)).

Based on ACT Jawa Timur, ideal raw water quality is limited due to emergency condition. By observing the physical condition (acceptable odor, taste and color), it would help the responsible institution to figure out the usable raw water. The minimum color consisted in raw water is 50 TCU (true color unit) (Permenkes No. 32 Tahun 2017). The other statement about the biological condition is stated by PMI:

"We have laboratory facilities in the field during disaster, we can check the pH level and the e-coli bacteria in raw water." (PMI, 31 March 2020, (translated)).

Field laboratory is available in emergency situation. The laboratory supports the responsible institution (PMI or Public Health Department) to test the overall water condition including pH and e-coli bacteria in raw water. Although the required time is long enough to get the result of e-coli bacteria consisting in water, the test must be done (Permenkes No. 32 Tahun 2017). By combining statements from mentioned stakeholders above, it is concluded that the criteria for water quality in emergency are 1) physical condition (color max. 50 TCU, odorless and acceptable taste), 2) chemical and biological condition (pH: 6.5-8.5 and does not contain e-coli). The process of formulating the criteria in this indicator (equipment to support the water collecting process and water quantity) are same as the process of formulating the criteria for raw water quality.

To get predetermined criteria or ideal condition for water quality in emergency condition, specific action should be taken. These activities can be applied during mitigation, preparedness, emergency response, or recovery phase. As an example, to meet the criteria for water quality, in mitigation phase, the optimization of Clean River Program (PROKASIH/Program Kali Bersih) should be conducted. In preparedness phase, the potential water source along the displacement routed and near the planned evacuation shelter should be identified and mapped. In emergency response, building specific barriers to protect selected sources and separate them from sanitation facilities, at least 30 meters. Those activities can help to maintain a good quality of water during the emergency condition. Table 2 defines certain activities in responding formulated criteria for water availability indicator.

**Table 2.** Criteria and activities for water source indicator.

| Variable | Criteria                                                                 | Activities to meet criteria |
|----------|--------------------------------------------------------------------------|-----------------------------|
| Surface volume | River as the main alternative.                                           | 1.1. Optimization of current clean river program (PROKASIH/Program Kali Bersih) from program mechanism, financing, and implementation. |
| Surface volume | Physical condition (color max. 50 TCU, odorless, the taste is acceptable. | 1.2. Identify and map the potential water source along the displacement routed and near the planned evacuation site. |
| Surface volume | Chemical and biological condition (pH: 6.5-8.5 and does not contain e-coli). | 1.3. Build barrier to protect a selected source and separated it sanitation facilities at least 30 meter from the water source |
| Surface volume | Debit intake ≥ 130% of emergency water needs.                            | 1.4. Inventory of supporting equipment |
| Surface volume | 12 hours minimum duration for raw water to be available in the source (water continuity) | 1.5. Establish cooperation through sister city program to develop emergency water storage technology as response to earthquake |
| Surface volume | Ground water reservoir (DTW) as the source                              |                             |
| Surface volume | Safe from potential liquefaction                                          |                             |
| Surface volume | Availability of supporting equipment (water pump and genset)             |                             |
2. **Water Transmission Indicator**

Water transmission process involves ease of transmission and the track for pipe transmission (As’at, 2019; IRC, 2002). This indicator has 4 criteria that emphasize the cost efficiency in selecting certain type and its safety. Based on interviews pros-cons towards this indicator are exist, for example, stakeholders from government use water trucking system to transmit raw water in emergency condition instead of temporary pipe transmission. BPBL states that:

*“We use water trucking system to drop provide water needs. It will not be effective to install temporary transmission pipe in emergency condition”* (BPBL, 30 January 2020), (translated)).

On the other hand, stakeholders from NGO argue that pipe water transmission is important component in water provision including in emergency condition. MDCM argues:

*“Cost efficiency and pipe material are considered. PE is the most common material for emergency condition.”* (MDMC, 30 March 2020, (translated)).

Factors affecting installation of pipe water transmission are cost and availability of appropriate material. Pipe with PE material is cost efficient with suitable material in emergency condition (IRC, 2002).

Besides the pipe material and cost, installation of transmission pipeline considers the safety of the track. MDMC states that the track should be safe from potential liquefaction and should be put underground around 50 cm below the ground level. Pipeline should be safe from risk prone area and external interference (IRC, 2002). It is concluded that the criteria in this indicator are 1) Using PE type for temporary water transmission pipe, 2) Cost-efficient, 3) Safe from potential other disaster (such as liquefaction), 4) Temporary water transmission pipe should be put 50 cm underground.

The proposed criteria above can be obtained if the emergency response system is well prepared. Therefore, some activities are required to be completed in mitigation, preparedness, and emergency response phases. For instance, to obtain the third criteria, in mitigation phase the responsible institution should do the mapping process to know whether the piping track is safe from liquefaction. Another example is in order to use PE-pipe in emergency condition for water transmission activity, the responsible institution should ensure the availability of buffer stock for temporary pipe and the transportation mode to deliver the equipment (pipe) in preparedness phase. In emergency response phase, the responsible institution is required to establish good coordination among stakeholders to deliver pipe to selected water sources. These activities facilitate the installation process. (See Table 3)

| Variabel | Criteria | Activities to meet criteria |
|----------|----------|-----------------------------|
| Ease of installation temporary transmission pipe | • Using PE type for temporary transmission pipe, • Cost-efficient • Safe from potential disaster (liquefaction) | 2.1 Mapping the safe location to install the transmission pipe. 2.2 Inventory of supporting tools 2.3 Ensure buffer stock management (stock opname) 2.4 Establish good coordination among responsible stakeholders to deliver the pipe to selected water source. 2.5 Ensure the availability of expertise to install the transmission water network |
| Transmission pipeline | • Temporary water transmission pipe is put 50 cm under the ground | |

3. **Water Treatment Process Indicator**

Water can be treated using portable water treatment unit or water treatment building. In emergency condition, the treatment unit should be independent (Indriatmoko & Widayat, 2007). Stakeholders from government, NGO and private argue that water treatment building is not efficient and not suitable for emergency condition. In most cases, water treatment plant is used for emergency condition. PMI states that in emergency situation water treatment plant is provided at least 2 units with capacity 4,000 litre/hour.
“We usually bring 2 units to the location. WTP can convert 4,000 litre/unit/hour of raw water to clean.” (PMI, 31 March 2020, (translated)).

| Variable | Criteria | Activities to meet criteria |
|----------|----------|-----------------------------|
| Availability of Water treatment facility | • Portable  
• Suitable for narrow roads with a width of +/- 2,75 m  
• Have input equipment (pipe and water pump)  
• Have filters (manganese greensand, active carbon, cartridge filter, ultrafiltration, and sterilizer)  
• have generator (genset) | 3.1 Using WTP/WTU to have semi centralized treatment.  
3.2 Inventory of water treatment unit and its supporting tools by ensuring the amount, condition and distribution. |

Table 4. Criteria and activities for availability of water treatment facility.

Another treatment unit that can be used in emergency is sky hydrant, based on report of earthquake research in Palu, NGO use sky hydrant to convert raw water to clean water. Apart from converting raw water, water treatment unit must be portable to speed up the process of providing clean water. Water treatment unit has special motorized unit for a narrow-roads with +/- 2,75 meters wide (Iswahyudi & Warnana, 2015). The unit also has some supported equipment such as pump and generator. So, the criteria for treatment process are 1) Portable, 2) Suitable for narrow roads, 3) Have input equipment (pipe and water pump), 4) have filters (manganese greensand, active carbon, cartridge filter, ultra-filtration, and sterilizer), and 5) have generator (genset). In general, water treatment unit is completed with filters and other supporting equipment. Therefore, proper activities are applying the semi-centralized treatment process using WTU/WTP and inventory of water treatment unit and its supporting tools by ensuring the amount, condition, and distribution. (See Table 4)

4. Water Distribution Indicator

Distributing water to the earthquake survivor requires some variables such as amount of clean water needed, amount of clean water point, capacity for water storage, distance from water point to shelter, temporary distribution network, water truck, clean water quality, and queuing system. Amount of clean water needed is ± 7.5-15 litre/person/day (BNPB, 2014; Sphere, 2018; Mc Daniels et al.,2015). BPBD also states that standard for water in emergency is 10-15 litre/day.

“The minimal amount of clean water provided during emergency is 10-15 litre/person/day, included food-drink and sanitation.” (BPBD Jawa Timur, 5 February 2020, (translated)).

This number includes food and drinking water (2.5-3.5 litre), sanitation (2-6 litre), and other needs (3-6 litre). Clean water will be provided in storage water tank with capacity of 2,200-5,500 litre. Private sector provided clean water in emergency condition for earthquake disaster in Palu, using water tank with capacity of 2000 litre for water storage facility (JawaPos.com, 2018). The storage should be completed with public tap for 40-50 families per facility and lateral facility with 50 person/facility and could be access by vulnerable group (UNHCR, 2018). PMI agree that in providing clean water, it is also important to provide water, sanitation, and hygiene (WASH) facilities. Therefore, toilet is provided near public water taps.

“If we provide clean water, we should provide WASH facility in evacuation site as well. Usually, we provide toilet with ratio of 3:1, three for women and one for men.” (PMI, 31 March 2020, (translated)).
The distance between the water point and shelter should be considered. Based on in depth interview result, the minimum distance is 30 m and the maximum distance is 500 m. This statement is supported by *Perka BNPB No. 7 Tahun 2008 on Fulfilling Basic Needs*. In emergency condition, to fulfil water needs, water trucking method is used. Water is taken from nearest reservoir. Based on interview, PMI, PDAM, and government state that the capacity for the truck is ± 5,000-6,000 litre. In most cases, for water trucking, PDAM will be the responsible actor. The quality of clean water is checked by the Department of Public Health and PMI to ensure the water is not contained e-coli and safe to be used. Based on PDAM and PMI the standard quality for drinking water refers to Health Ministry Regulation No. 492 in 2010, *on Water Quality Requirements*.

In distribution process, temporary distribution network is used to channel the water from water storage to public taps. Based on in depth interview result, MDMC argues that the criteria for the temporary distribution pipe different in type. Temporary distribution network using PVC and the installation process has no differences from the temporary transmission network.

“To distribute clean water to evacuation site, we use temporary pipe with PVC material.” *(MDMC, 30 March 2020, translated)*.

The last variable that is considered in this process in queueing system. In emergency condition, the distribution system is done by involving community representatives. Based on *Perka BNPB No.7 in 2008*, distribution method should be decided through consultancy with local community. PMI adds an argument that distribution process is considered the customary law or local wisdom. By still referring to government regulations that have been arranged in logistics management, it is also necessary to prioritize local wisdom, customs, and habits that apply to disaster-affected communities *(FPT PRB, 2018)*. So, it is concluded that the community representatives should be included in the decision-making process and it should be considered the local wisdom and prioritize the vulnerable groups within the community.

To obtain criteria in distribution process, the responsible institution should be prepared. Several activities must be done in each disaster management process. For instance, inventory of water truck and water storage in mitigation phase must be done by the city/regional disaster management and civil protection in mitigation phase or other relevant agencies that use water truck and water storage for their daily activities. In preparedness phase, management of warehouse by ensuring the sufficient buffer stock (PVC, water truck, and water storage) to obtain criteria of temporary water distribution pipe and water trucking system. In emergency response phase, optimize the water treatment plant by maintaining the coordination among responsible institutions (checking the availability of water in storage and communicating with the WTP operator) and ensuring the quality of clean water before distributing it. In, recovery phase, community should be involved in decision making process of changing the distributing water system. These activities are done as steps to get the ideal system of distributing water. The detail criteria and activities can be seen in Table 5.

| Variable                  | Criteria                                                       | Activities to meet criteria |
|---------------------------|----------------------------------------------------------------|-----------------------------|
| Amount of clean water needed | Minimum clean water: 7.5lt-15lt/person/day                      | 4.3 Inventory of water truck and water storage |
|                           | Accessible for vulnerable group                                 | 4.4 Management of warehouse by ensuring the availability of buffer stock |
| Water storage point        | Provide public water taps: 40-50 families/tap                  | 4.5 Optimize water treatment process by maintaining coordination among responsible institutions |
|                           | Provide different water point between food-drink and sanitation |                             |
|                           | Distribute the water point fairly                               |                             |
|                           | Provide water storage with capacity 2,000-5,000 lt.            | 4.6 Ensure the quality of clean water before distributing the water |
### Variable | Criteria | Activities to meet criteria
--- | --- | ---
Number of clean water point | • Minimum distance between water point and evacuation site is 50 m and maximum 500 m | 4.7 Strengthening the coordination in evacuation site/communal post
Ease of temporary distribution pipe | • Using PVC as temporary distribution pipe | 4.8 Involve community in decision making process including vulnerable group
| • Using Cost-efficient pipe | | 4.9 Providing water point by gravity flow system and provide access for vulnerable group
Water trucking | • Water dropping is done 2 times a day | 4.10 Optimize coordination in decision making process for changing the new system of distributing clean water in recovery phase.
| • Water truck with capacity 5,000-6,000 lt. | | |
| • PDAM provide water from nearest reservoir | | |
Capacity of clean water reservoir | • Standard for clean water quality refers to *Permenkes 492* | |
Distance between water point and shelter | • Water collection is done in the water point by queuing | |
| • Involve community in deciding distribution system | | |
| • Consider local wisdom in deciding distribution system | | |

### 3.2. Concept for Emergency Clean Water Infrastructure Provision
Resilience has become the integrity concept in providing infrastructure system in emergency condition. The resilience of infrastructure has an impact on reducing shock during a disaster. According to (Berkeley & Wallace, 2010), the dimensions of infrastructure include robustness, resourcefulness, and rapid recovery are important values in providing emergency clean water infrastructures. In disaster risk management context, disaster phases are defined as mitigation, preparedness, emergency response, and recovery phase (Cimellaro, 2016; Perka BNPB 4/2008). Therefore, carrying out activities to meet criteria based on disaster risk management phases is an effort to reduce the impact of earthquake as on Figure 2.

### 4. Conclusion
Clean water infrastructure in emergency condition has four indicators, which are water source, water transmission process, water treatment process, and water distribution process. Each indicator has criteria to carry out the process and specific activities performed to obtain the criteria. Criteria for water source indicator focus on the quality, quantity and supporting equipment to provide the raw water in emergency. Transmission and treatment process emphasize on the equipment pipe and water treatment plant. The criteria provide reference for the use of suitable equipment to transmit and process the water during emergency condition. For every indicator, there are 2-8 key actions should be taken to meet the criteria. Those actions are classified into mitigation, preparedness, emergency response and recovery actions. In mitigation the key characteristic of action is minimizing the contamination of water and ensuring the amount of water to cover water needs during emergency. For the preparedness stage, the key characteristic of action is ensuring the availability and condition of the supporting equipment for emergency purposes. Emergency response focuses on coordination between responsible stakeholders and maintaining the quality of the clean water. And last, but not least, the recovery stage focuses on community involvement in decision making process of the new system for water distribution in recovery stage.
**Figure 2.** Concept of Emergency Clean Water Infrastructure Provision.

| Mitigation                                                                 | Preparedness                                                                 | Emergency Response                                                                 | Recovery                                                                 | Indicator |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------|
| 4.1. Optimization of clean river program (PROKASIH/Program Kali Bersih) from program mechanism, financing, and implementation. | 4.2 Identify and map the potential water source along the displacement routed and near the planned evacuation site. | 4.3 Build barrier to protect a selected source and separated sanitation facilities at least 30 meter from the water source. | Source                                                                 |           |
| 1.4 Inventory of supporting equipment to collect the water from the source  |                                                                               |                                                                                   |                                                                         |           |
| 1.5 Establish cooperation through sister city to develop emergency water storage technology as response to earthquake |                                                                               |                                                                                   |                                                                         |           |
| 2.1 Mapping the safe location to install the transmission pipe.            | 2.3 Ensure buffer stock management (stock opname)                              |                                                                                   |                                                                         |           |
| 2.2 Inventory of supporting tools for transmission process                 | 2.4 Establish good coordination among responsible stakeholders to deliver the pipe to selected water source. |                                                                                   |                                                                         |           |
|                                                                               | 2.5 Ensure the availability of expertise to install the transmission water network |                                                                                   |                                                                         |           |
| 4.2 Inventory of water treatment unit and its supporting tools by ensuring the amount, condition, and distribution. |                                                                               |                                                                                   |                                                                         |           |
| 4.1 Inventory of water truck and water storage                             | 4.2 Management of warehouse by ensuring the availability of buffer stock       | 4.3 Optimize water treatment process by maintaining coordination among responsible institutions |                                                                         |           |
|                                                                               |                                                                               | 4.4 Ensure the quality of clean water before distributing the water               |                                                                         |           |
|                                                                               |                                                                               | 4.5 Strengthening the coordination in evacuation site/communal post              |                                                                         |           |
|                                                                               |                                                                               | 4.6 Involve community in decision making process including vulnerable group      |                                                                         |           |
|                                                                               |                                                                               | 4.7 Strengthening the coordination in evacuation site/communal post              |                                                                         |           |
|                                                                               |                                                                               | 4.8 Involve community in decision making process including vulnerable group      |                                                                         |           |
|                                                                               |                                                                               | 4.9 Providing water point by gravity flow system and provide access for vulnerable group |                                                                         |           |
|                                                                               |                                                                               | 4.10 Optimize coordination in decision making process for changing the new system of distributing clean water in recovery phase. |                                                                         |           |

Source

Transmission

Treatment

Distribution
5. Reference

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