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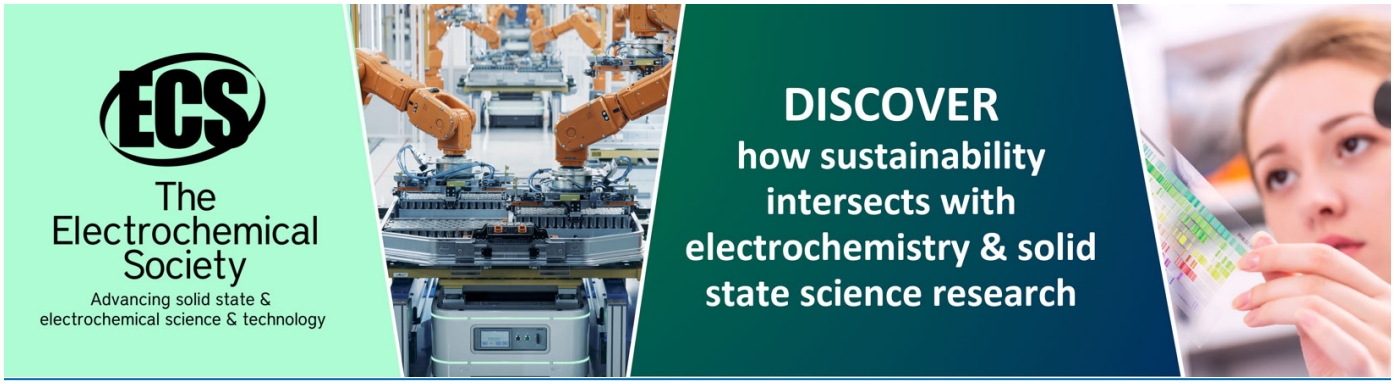

Concept of Emergency Wastewater Infrastructure Provision in Minimizing the Impact of Potential Earthquake in Surabaya

Bellatrix Indah Pratiwi[1], Adjie Pamungkas[1*]
[1]Urban and Regional Planning Department, Faculty of Civil, Planning, and Geo Engineering, Sepuluh Nopember Institute of Technology
*E-mail: adjie@urplan.its.ac.id

Abstract. Mass displacement to refugee camps often happens after an earthquake hits. Faecal oral transmission usually occurs causing disease outbreaks when people in mass displacement camps. Surabaya has a potential threat of an earthquake measuring 6.5 on the Richter Scale. However, equipment readiness in wastewater infrastructure is still low at 21% during the emergency response period. Therefore, this research is needed in formulating the concept of emergency wastewater infrastructure provision to minimize the side effects of disease outbreaks. This study obtained primary data from 17 respondents. The first objective uses content analysis method. Then the second objective adopted triangulation analysis derived from three types of data, respondent opinions, policies, and best practices. The first objective disclosed 46 criteria for the provision of emergency wastewater infrastructure. Meanwhile, the second objective presented 38 potential actions and 18 concepts adjusted to disaster management cycle (mitigation, preparedness, response, and recovery). The mitigation phase focuses on stocktaking materials, establishing partnerships, training for volunteers, and optimizing the existing sanitation program. The preparedness focuses on forming a team to assess the needs of post-disaster conditions. The response phases divided into acute, general, and stabilization. The general stage focuses on determining suitable infrastructure, mobilizing volunteers and materials, and coordinating between agencies or clusters to handle wastewater. The acute stage focuses on rapid assessment and procurement of materials. The stabilization stage focuses on community involvement, determining the location of infrastructure, and handling waste from wastewater treatment. Finally, the recovery phase focuses on repairing the existing affected wastewater treatment plant.

1. Introduction

Earthquakes are often followed by mass transfers to emergency shelters [1]. New problems often arise such as disruption of public health due to outbreaks of disease from faecal oral transmission [2,3]. Diseases that arise include cholera, diarrhoea, and intestinal worms [4]. After the earthquakes in Haiti (2010) and Nepal (2015), cholera outbreaks infected refugees and increased mortality [5,6]. This is because wastewater contains organic and inorganic pollutants as well as harmful pathogenic microorganisms [7]. Wastewater infrastructure is a series of technological units for the process of recycling wastewater and returning the residue to the surrounding environment [8]. In the case of the Yogyakarta earthquake (2005), Palu (2018), and Lombok (2018) there were findings that limited provision of wastewater infrastructure was associated with an increase in disease infections [9-11]. Therefore, the provision of wastewater infrastructure plays an important role, especially in minimizing the side effects of disease outbreaks after a massive earthquake occurs.

The city of Surabaya has the potential to experience an earthquake with a magnitude of 6.5 on the Richter scale. This is happen cause the movement of two active faults, namely Surabaya and Waru Fault, which move 0.05 mm annually [12]. The figure of the two faults can be seen in Figure 1. The level of resilience of the Surabaya City infrastructure to earthquake disasters is relatively high, namely 4.135 out of 5 [13]. However, during the emergency response period, the readiness of wastewater infrastructure, which is assessed from the availability of equipment, is still low at 21% [14]. Even though the provision of emergency wastewater infrastructure is also related to the achievement of Sustainable Development Goals (SDGs) point 6, namely regarding access to clean water and sanitation for all.

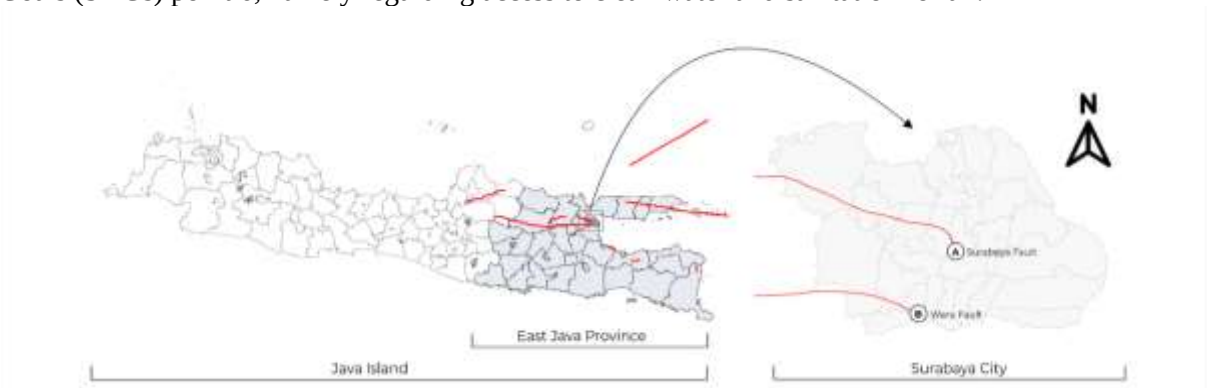

Figure 1. Active Faults in Surabaya City
Source: Author

Therefore, it is necessary to formulate the concept of providing emergency wastewater infrastructure for minimizing the impact of potential earthquakes in the city of Surabaya. This qualitative research requires two objectives, namely determining the criteria for wastewater infrastructure in the emergency response phase and drafting the concept of providing emergency wastewater infrastructure. Although there have been previous studies regarding the provision of wastewater emergency infrastructure in response to disasters, those research focuses more on faecal sludge management, the provision of overall sanitation (clean water, wastewater, and solid waste), technical wastewater infrastructure development, and the linkage of supply wastewater infrastructure with disease outbreaks. Temporary, this study seeks to see the provision concept of emergency wastewater infrastructure focusing on domestic waste (grey water and black water). Grey water in this research is waste water that produced from domestic activities such as washing clothes and washing kitchen utensils, whereas the black water is a mixture of human excreta with the grey water. In this research, concept made correspond with the four phase in disaster management cycle.

2. Methodology

There are 6 indicators and 17 variables that form the basis of the research (Table 1). Data collection methods were obtained through primary surveys and secondary surveys. The primary survey was conducted in the form of in-depth interviews, while the second survey was conducted utilizing a literature study. The population in this study are people who have an understanding of the provision of wastewater infrastructure and know the seismic potential of Surabaya. While the sample of this study was obtained by non-probability sampling method with purposive sampling and snowballing sampling.

Respondents are composed of 3 categories of groups, namely the government, community institutions (non government organization), and the private sector. The 17 respondents were selected and used as samples, namely: 1) East Java Regional Disaster Management Agency (BPBD), 2) Surabaya City Disaster Management and Community Protection Agency (BPBL), 3) Surabaya City Cleanliness and Green Open Space Service (DKRTH), 4) Surabaya City Environment Service (DLH), 5) Central Sulawesi Regional Settlement Infrastructure Centre (BPPW), 6) Indonesian Environmental Health Experts Association (HAKLI), 7) International Federation of Red Cross and Red Crescent Societies (IFRC), 8) Indonesian Red Cross Surabaya (PMI), 9) Muhammadiyah Disaster Management Centre

(MDMC), 10) Indonesian Resilient Community (MTI), 11) East Java Rapid Response Action (ACT), 12) Resilience Generation Indonesia (IRES), The United Nations Children's Fund Makassar Field Office (UNICEF), 14) University of Leeds (UOL) academics, 15) Sepuluh Nopember Institute of Technology (ITS) academics, 16) Bandung Institute of Technology (ITB) academics, and 17) PT Mitra Hijau Indonesia (MTI).

Table 1. Research Indicators and Variables

Indicators	Variables
Availability of Resources	Availability of local materials; Availability of local manpower
Ease of Accessing Fecal Disposal Facilities	Availability of fecal disposal facilities; Number of fecal disposal facilities; Distance to shelter; User suitability
Storage Safety	Availability of storage equipment; Storage volume capacity; Soil stability; Groundwater level
Ease of Transport	Availability of transportation means; Road access
Ease of Treatment	Availability of treatment technology; Availability of treatment site
Disposal Safety	Wastewater quality; Utilization of wastewater product, Availability of disposal site

3. Results and discussions

The category of the emergency response phase of wastewater infrastructure is divided into an acute emergency response (immediate response) and a stabilization emergency response (short term phase) [15,16]. The categorization was then adapted by adding general emergency response phase which is a combination of acute and stabilization. Therefore, in this study, the emergency response phase was categorized into acute, stabilization, and general. To make it easier to understand the criteria and potential actions resulting from this research on the three categories of the emergency response period, marking is carried out in the form of colour codes listed in Table 2.

Table 2. Category Emergency Response

Color Code	Category Emergency Response
	The acute emergency response period
	The general emergency response period
	The stabilization emergency response period

3.1. Wastewater infrastructure in the emergency response phase

3.1.1. Availability of resources. During the disaster emergency response period, one of the things that must be prioritized is preventing people from defecating openly [17]. Resources to build wastewater infrastructure by considering the variables of material availability and availability of manpower are urgently needed in disaster management. Based on in-depth interviews, it was found that the local element during the emergency response period was not a priority. This is because the most important thing in the emergency response period (especially acute) is that the community can be served quickly and their needs are met.

Material is needed because it is the main component in the construction. The criteria for material availability pay attention to the origin of the material (material) which can come from logistics, outside the region, local potluck, and ease of finding. Dependence on materials that are not locally available can reduce the speed of economic recovery in the affected areas [18].

The variable availability of manpower needs to pay attention to the origin of the source of manpower in construction and maintenance. This is intended so that not only buildings are available but also create

sustainable and acceptable infrastructure so that it is used by all users (especially vulnerable groups). The findings of the study were that it required personnel from sanitarians, volunteers, and local communities affected by the disaster.

The determination of the criteria in this study was carried out by content analysis. The criteria were obtained from understanding the data from in-depth interviews of respondents and supported by literature studies to strengthen the resulting criteria. One of the criteria for the availability of manpower is the need for sanitarians. This was resulted from an analysis process based on the respondent's statement from the Indonesian Environmental Health Experts Association and referring to the Regulation of the Minister of Health Number 75 of 2019 concerning Disaster Crisis Management. Based on the that regulation, it is explained that sanitarians who are members of the rapid health assessment (RHA) team are tasked with assessing and analyzing potential health crisis risks (threats, vulnerabilities, and capacities) that may occur as well as health needs.

The process of formulating the criteria above is one example of formulating the overall criteria in this study. Each potential actions that can be taken to answer the criteria specified in the resource ease indicator can be seen in Table 3.

Table 3. Criteria and Potential Actions on Availability of Resources

Variabel	Criteria	Potential Actions
Material Availability	A1.a It can come from logistics that have been prepared by the government or NGOs (internal-external) A1.b It can come from outside the region by looking at sustainability, which is easy to get locally in the future A1.c It can come from improvised local materials, such as zinc, tarpaulin, or wood waste from ruins A1.d It can come from easily found materials, such as urea, lime, molasses to carry out immediate on-site treatment of infectious fecal waste	A.1 Conduct an inventory of equipment and materials (type, quantity, condition, and distribution) supporting wastewater infrastructure in logistics warehouses owned by the government, NGOs, and the RT community level A.2 Bringing materials and equipment from outside the area A.3 Collecting debris to build a simple waste disposal facility A.4 Cooperating with shops in disaster areas to supply urea, lime, molasses, and building materials
Manpower Availability	A2.a A sanitarian is needed in Rapid Health Assessment to determine the amount of emergency wastewater infrastructure A2.b Volunteers are required who are at least trained and master the field of WASH (Water Sanitation and Hygiene) A2.c Local community workers are needed in educating survivors about hygiene promotion, building wastewater infrastructure (at least having the skills of a handyman), and maintaining wastewater infrastructure	A.5 Forming a Rapid Health Assessment Team with sanitarian staff to assess the need for wastewater infrastructure A.6 Provide technical training to volunteers in the field of Water, Sanitation, and Hygiene (WASH) A.7 Mobilization of volunteers to disaster-affected areas A.8 Conducting outreach to community cadres regarding hygiene promotion to transfer knowledge to other communities A.9 Optimizing the Community-Based Total Sanitation program

	A.10 Empowering refugees who have craftsman skills to build wastewater infrastructure A.11 Conducting training related to the operation and maintenance of wastewater infrastructure for refugees

3.1.2. Ease of accessing fecal disposal facilities. Stool disposal facilities are infrastructure that is directly related to the user or user interface [17]. There are 4 variables in this indicator, including the availability of fecal disposal facilities, number of fecal disposal facilities, distance to the shelter, and suitability for users. Based on the analysis, 12 criteria were produced on the ease of accessing fecal disposal facilities. In providing fecal disposal facilities what needs to be considered are the types of facilities needed and supporting equipment in the form of clean water and hygiene promotion facilities.

Half of the respondents (6/12) agreed that a minimum of 1 toilet is needed for 50 people in an acute state and 1 toilet for 20 people in a stabilized state. Respondents who agree that the ratio of the number of needs refers to the standard Sphere Association. The ratio of services for excreta disposal facilities in the acute emergency response phase is 1:50 people, while in the stabilization emergency response period it is 1: 20 people [19]. The standard is the same as the policy issued by the Ministry of Health (2007), namely at the beginning of the evacuation 1 latrine was used by 50-100 people, and on the next day, it was suggested that 1 latrine be used by 20 people [20].

Based on the analysis that has been done, it is known that the distance variable from the shelter has the criteria for facilities within 50 meters or can be reached in 5 minutes by foot from the shelter. As for the user suitability variable, the criteria are detailed for each category of vulnerable groups, namely women, children, the elderly, and people with disabilities.

The following is an example of the process of formulating potential actions on the user suitability variable whose process is also carried out in determining other potential actions in this study. IFRC respondents believe that the action that can be taken is to conduct discussions with affected communities (vulnerable groups) regarding the design of wastewater infrastructure. This is supported by a policy regarding the involvement of vulnerable groups in BNPB Head Rules Number 14 of 2014 [21]. Based on a literature review, there are best practices in the form of discussions with vulnerable groups that can be packaged using a community engagement approach [22]. From the 3 data sources, the potential action to answer the user suitability variable is to be able to conduct discussions with users.

Table 4. Criteria and Potential Actions on the Ease of Accessing Fecal Disposal Facilities

Variabel	Indicators	Potential Actions
Availability of Fecal Disposal Facilities	B1.a It can be in the form of appropriate and quickly applied facilities in the acute emergency response phase, such as pit latrine or toilets in buildings that are not badly damaged B1.b It can be in the form of facilities that are portable and non-permanent, such as portable toilets, toilet cars, knockdown toilets, or toilet buses B1.c For unstable soil conditions, flooded areas, and high groundwater levels, you can use a raised latrine B1.d There is a water point with a minimum of 6 liters/person/day for bath, wash, and toilet	B.1 Determine the type of means of disposal of fecal following the conditions B.2 Mobilize portable toilet to disaster areas B.3 Distributing clean water by tanker truck B.4 Carry out an inventory of equipment and materials for hygiene promotion facilities

	B1.e Equipped with hygiene promotion facilities, in the form of handwashing facilities, information communication and education posters as a means of education, and separate clothes washing facilities outside the means of disposal of feces.	
Number of Fecal sDisposal Facilities	B2.a At least 1 fecal disposal facility for 50 people in the acute emergency response phase and at least 1 fecal disposal facility for 20 people in the stabilization emergency response phase B2.b The ratio of providing fecal disposal facilities for women compared to men is 3:1	B.5 Conduct a Rapid Health Assessment (RHA) to calculate the number of refugee and the need for the number of fecal disposal facilities
Distance to Shelter	B3.a Located in a refugee area with a maximum distance of 50 meters from the shelter or can be reached in 5 minutes by foot	B.6 Determine the location of the placement of the means of fecal disposal
User Suitability	B4.a For women, menstrual hygiene management facilities are available in the form of a trash can B4.b For children, it is placed close to women's fecal disposal facilities and the footing of the squat toilet is 10-15 cm B4.c For the elderly, a handrail is available B4.d For persons with disabilities, the facilities must have a minimum size of 1.6 m x 1.6 m and are equipped with a track ramp	B.7 Conduct discussions with users (vulnerable groups) regarding the design of user-appropriate wastewater infrastructure B.8 Coordinate with competent institutions or clusters on gender, inclusion, disability in the field

3.1.3. Storage safety. Wastewater in the form of blackwater that has been disposed by the user at the fecal disposal facility should not be thrown away in the surrounding environment. The criteria that are considered in the storage equipment are the types of equipment that can be in the form of permanent or non-permanent and portable buildings. In addition, storage that require excavation must pay attention to the volume capacity, soil type, and distance from the groundwater level. The potential actions that can be taken to achieve storage safety are listed in Table 5.

Table 5. Criteria and Potential Actions on Storage Safety

Variabel	Criteria	Potential Actions
Availability of Storage	C1.a It can be in the form of permanent storage buildings, such as pits based on the plaster of cement and septic tank buildings with 2 compartments (feces room and water room) which equipped with PVC pipes to channel to infiltration C1.b It can be in the form of temporary (non-permanent) storage, such as portable fiber septic tanks, storage which located in portable	C.1 Determining the storage equipment or technology according to the conditions

	toilets, fiber or plastic drums, fiber tanks, and bladder tanks.	
Storage Volume Capacity	C2.a For storage in the form of a pit latrine, the minimum volume capacity is 6000 liters in an emptying period of 6 months	
Soil Stability	C3.a For storage that require excavation, the most suitable type of soil is clay soil, if the type of sandy	C.2 Reviewing the soil type map (sand and clay) around the evacuation area
Groundwater Level	C4.a For storage that require excavation, the minimum distance from the reservoir to the groundwater level is 1.5 meters	C.3 Carry out groundwater level measurements around the evacuation area

3.1.4. Ease of transport. If the stored sludge has met the holding capacity, then transportation is needed to the processing location if the processing is carried out at a different place (off-site treatment). The ease of transportation indicator considers the availability of transportation means and road access variables. Of the 12 respondents in the survey conducted, all of them agreed that in a disaster, they usually use a vaacum truck. However, there is also an option to use a simple means of transport as long as it is closed. This is because the choice of means of transporting fecal sludge in a disaster situation depends on the conditions. As stated by a UNICEF respondent in the case of Rohingya refugees in Cox's Bazar. The area is hilly and there are no roads, so transportation is carried out by cart.

BPPW respondents stated that in the case of evacuation after the 2018 Palu earthquake, there were shelters that were full in just one day, so the telephone number could be used as a key in the desludging process. For that, it is necessary to have completeness in the form of a telephone number in charge of desludging.

The road access variable must be paid attention to the ease of access for a minimum of 2-wheeled vehicles, the placement of storage (holding tank) by road during the desludging process, and alternative methods if the location to be vacuumed cannot be accessed via truck. In the case of locations that are difficult to reach, it is necessary to support the construction of a transport transfer station. IFRC respondents had encountered a condition where the vaacum truck could not access the field for desludging. Therefore, the method used is manual emptying which is then placed in a drum and transported to a location that can be accessed by vaacum truck. This is in line with what UOL respondents said. It is necessary to make a temporary storage that functions as a transfer station. The transfer station storage is used as an intermediary for the primary and secondary stages. In the primary stage, the faecal sludge is transported by cart to the transfer station. Meanwhile, in the secondary stage, the transfer station is emptied by a vaacum truck [23].

Table 6. Criteria and Potential Actions on Ease of Transport

Variabel	Criteria	Potential Actions
Availability of Transportation Means	D1.a It can be a vaacum truck with a capacity of 3000-5000 liters and equipped with the telephone number of the person in charge of desludging D1.b It can be in the form of a simple non-tank truck with closed conditions,	D.1 Determine the means of transporting fecal used under the conditions D.2 Cooperating with the private sector provider of vaacum trucks D.3 Coordinate in emptying and transporting the fecal sludge

	such as a cart equipped with a drum and a pickup truck equipped with a drum	
Road Access	D2.a At least it can be accessed by two-wheeled vehicles D2.b The distance from the road to the holding tank that will be sucked up by the vaacum truck is a maximum of 30 meters, if more than that, an additional 30-meter long spiral hose is needed D2.c For locations that are inaccessible to vaacum trucks, secondary storage can be provided that function as transport transfer stations	D.4 Determine the location of the shelter (evacuation tent) construction

3.1.5. Ease of treatment. Similar to normal conditions, domestic wastewater (black water and grey water) during the emergency response period requires treatment before being discharged into the environment. The ease of treatment indicator considers the availability of technology and treatment location variables. Various types of possible technologies can be used in wastewater treatment according to the conditions of the affected area. Details of the criteria for the availability of treatment technology can be seen in Table 7. In addition, a waste treatment site is needed when treating waste, especially for black water. The location needs to consider the land owner's permit, proximity to the waste source, and the minimum distance to clean water sources and settlements. The potential actions on ease of treatment can be seen in Table 7.

Table 7. Criteria and Potential Actions on Ease of Treatment

Variabel	Criteria	Potential Actions
Availability of Treatment Technology	E1.a For black water, low-tech treatments can be used, such as urea treatment, hydrated lime treatment, lactic acid treatment, or vermicomposting. E1.b For black water, treatment can be used according to the type of storage facility, such as chemical processing in portable toilet or following the process that occurs in septic tank. E1.c For grey water, it can be equipped with a grease trap which is placed upstream of the waste source before being distributed to the Waste Water Disposal Channel. E1.d For grey water in high permeability soil conditions, infiltration techniques can use infiltration wells (sand and gravel filters). If the groundwater level is high, it is possible to use infiltration ditches E1.e For grey water in arid conditions, evaporation techniques can use an evaporation pan and an evapotranspiration bed.	E.1 Determine the treatment technology (grey water and black water) used according to conditions E.2 Carry out repairs to the affected existing wastewater treatment plant E.3 Cooperating with private wasterwater treatment plant owners E.4 Cooperating with wastewater treatment plants outside the city of Surabaya E.5 Optimizing the existing sanitation based community program

	E1.f For black water and grey water, you can use existing sewage treatment plants, such as domestic aerobic WWTP owned by the private sector, community WWTP (community dewats), goverment's WWTP, and WWTP owned by the government outside the city of Surabaya. E1.g For black water and grey water, you can build an emergency communal wastewater treatment plant, such as emergency aerobic fecal waste treatment and prefabricated dewats.	
Availability of Treatment Site	E2.a Have obtained permission from the landowner E2.b Location close to existing waste sources E2.c Minimum distance of 30 meters from dug wells and 500 meters from settlements	E.6 Conducting consultations with landowners for treatment site E.7 Determine the treatment site

3.1.6. Disposal safety. It is necessary to ensure that wastewater treatment residues are safe before being returned to the surrounding environment. The quality of wastewater must be ensured that it is biologically and chemically safe. It is necessary to pay attention to the shape of the waste product when using the product. This is because the utilization of wastewater product depends on the form (solid, gas, or liquid). The availability of disposal sites also necessary to pay attention to the shape of the waste products. All measures that support disposal safety indicators focus on the stabilization emergency response period. These potential actions that met the criteria of disposal safety can be seen in Table 8.

Table 8. Criteria and Potential Actions on Disposal Safety

Variabel	Criteria	Potential Actions
Wastewater Quality	F1.a Biological conditions: E. coli levels 3000/100 mL and 1 helminth egg/liter F1.b Chemical conditions: maximum BOD 30 mg/L, maximum COD 100 mg/L, neutral pH between 6-9, ammonia (NH3) maximum 10 mg/L	F.1 Monitoring the biological and chemical content of water bodies (rivers) in Surabaya City
Utilization Wastewater Product	F2.a For solid products, it can be used as compost for non-food plants and low pH soil conditioning soil F2.b For wastewater from wastewater treatment plant, it can be reused in the treatment process as a diluent F2.c For gas products, it can be used as biogas	F.2 Determine the reuse or disposal of the resulting waste products F.3 Cooperating with institutional agencies in the use of compost and soil conditioning F.4 Cooperating with the community in the use of biogas
Availability of Disposal Site	F3.a Liquid products can be absorbed into the soil or discharged into local water bodies F3.b Solid products can be disposed of at the Benowo landfill but located separately from plastic waste or can be buried on land located at least 500 meters from the settlement.	F.5 Consult with landowners for disposal sites

3.2. Concept of wastewater emergency infrastructure provision

The definition of concept in this research is structured set of actions for reducing risk. There are 18 concept made from grouping the 38 potential actions that have the same substance. The resulting concepts based on indicators and cycles of disaster management can be seen in Figure 2. Interestingly, there are several concepts that have a relationship between phases and shown by arrows. To clarify one of the concepts produced, namely "determining the wastewater infrastructure in acordance with the conditions", this study provides an overview of the selection of tools or technology to facilitate decision making. These options can be seen in Figure 3. This was done because no one solution can suit all conditions in the selection of wastewater infrastructure in the humanitarian context [24].

Figure 2. Concept of Provision of Wastewater Emergency Infrastructure
Source: Author

Figure 3. Choice of Wastewater Emergency Infrastructure Equipment or Technology
Source: Author

4. Conclusion

One of the strategies to minimize the impact of the potential earthquake in Surabaya is by providing emergency wastewater infrastructure. The emergency response phase in the provision of wastewater infrastructure can be categorized into acute, stabilization, and general. The analysis on the first objective resulted in 46 criteria for the provision of wastewater emergency infrastructure. The ease of providing infrastructure resources must consider the origin of the material and the origin of the energy resources. Ease of accessing faecal disposal facilities must pay attention to the type of facilities, completeness of facilities, number, distance to the shelter, and suitability for users. Storage safety must pay attention to the equipment availability and technical matters on the equipment that requires excavation. Ease of transportation must pay attention to the means of transportation and road access. Ease of treatment takes into account the technology and treatment site. Meanwhile, disposal safety pays attention to the quality of wastewater, utilization of waste products, and disposal site.

In the mitigation phase, the concept is focused on inventorying materials, establishing cooperation, training volunteers, and optimizing existing sanitation programs. In the preparedness phase, the concept focuses on forming a team to assess the needs of post-disaster wastewater infrastructure. The concept of general emergency response is focused on determining the appropriate infrastructure for conditions, mobilizing volunteers and materials, and coordinating between agencies or clusters in handling wastewater. For the acute emergency response phase, the focus is on rapid assessment and procurement of materials. For emergency responses, stabilization is focused on community involvement, determining the infrastructure location, and handling waste from wastewater treatment. While in the recovery phase, the concept is focused on repairing the existing affected wastewater treatment plant.

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