Environment and Ecology Research 11(1): 218-223, 2023 http://www.hrpub.org
DOI: 10.13189/eer.2023.110116

Water Quality for River Basins after Post Earthquake Event

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Received September 28, 2022; Revised November 24, 2022; Accepted January 16, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Carolyn Payus, Siti Irbah Anuar, Baba Musta, Kawi Bidin, Felix Tongkul, Pak Yan Moh , "Water Quality for River Basins after Post Earthquake Event," Environment and Ecology Research, Vol. 11, No. 1, pp. 218 - 223, 2023. DOI: 10.13189/eer.2023.110116.*

(b): *Carolyn Payus, Siti Irbah Anuar, Baba Musta, Kawi Bidin, Felix Tongkul, Pak Yan Moh (2023). Water Quality for River Basins after Post Earthquake Event. Environment and Ecology Research, 11(1), 218 - 223. DOI: 10.13189/eer.2023.110116.*

Abstract An earthquake with a magnitude of 5.9 on the Richter Scale struck Ranau, Sabah, on the 5th of June, 2015. It was recorded as the most significant earthquake occurrence in Sabah and had many implications, such as casualties, house and facilities damages, minor injuries, and environmental disruptions. In addition, the combination of continuous heavy rainfall triggered mudflow through landslides, which impacted the river's quality and disrupted the local water supply. The degradation of water quality will be due to the excess rainwater that cannot be absorbed by the soil, bringing the remnants of landslides into the river. Therefore, this study aims to monitor and assess the water quality of selected rivers affected by the earthquake and the mudflow to ensure it is safe to be utilised by the local residents. A total of five affected rivers were studied by analysing their physicochemical parameters, namely pH, temperature, turbidity, dissolved oxygen (DO) and electrical conductivity (EC). The results indicated that the mudflow overall creates a turbid, foamy and smelly river. High turbidity readings associated with high suspended solids were detected on specific dates for respective river stations. The high readings were associated with the cause of mass fish death in Sungai Kadamaian. Next, Sungai Mesilou faced a high-temperature reading above two celcius, which was not favourable for aquatic life. Physically, Sungai Mesilou also became shallower and flowed slowly. However, overall monitoring data revealed that the river's water quality was in good condition, except for the high turbidity dates. Nevertheless, the water quality of the respective rivers can recover on its own with the drop in turbidity levels found by the end of the monitoring dates, specifically at Sungai Panataran (S1), Sungai Kadamaian (S3) and Sungai Mesilou (S4). Hence, the water quality of such rivers, in general, is practically good and safe.

Keywords Earthquake, Water Quality, River Quality, Mudflow, Landslides

1. Introduction

Earthquakes are one of the deadliest and most unpredictable types of natural disasters. On the 5th of June 2015, a moderate earthquake occurred in Ranau, Sabah, Malaysia [1], which traumatically caused 18 casualties. The earthquake, commonly known as the 2015 Sabah earthquake, was the largest in Sabah and Malaysia since 1976, with a magnitude of 5.9 on the Richter scale compared to the 1976 Sabah Earthquake in Lahad Datu with a magnitude of 5.8 on the Richter scale. The tremors can be felt at least 300km away, specifically affecting all over Sabah, Miri, Labuan and Brunei [2,3]. In addition, the mainshock was strong enough to make Kota Kinabalu residents wake up during the time of occurrence, which was in the morning [3]. The earthquake was followed by aftershocks which impacted the local residents and triggered other geological hazards [4]. Evidence from the Minerals and Geoscience Department (JMG) suggested that Ranau has substantial topographic relief in which it is vulnerable for even a moderate magnitude earthquake that can cause large-scale mass land movements, including landslides and mud floods which are among the geological hazards triggered by the earthquake [4].

Malaysia is generally affected by regional and local earthquakes, influenced by regional tectonic movements [5]. In general, Malaysia is bordered by an active seismic zone that is at least 350 km away and is underlain by the tectonically stable Indosina-Sundaland crust [6]. Specifically, in Sabah, earthquakes are mostly locally generated, with some generated in Sulu and Celebes Seas [5]. Its proximity to the boundaries of the three major tectonic plates, namely the Eurasian, India-Australia and Philippine-Pacific plates, makes it vulnerable to seismic activities [7]. Compared to West Malaysia and Sarawak, Sabah is the most tectonically active area [7]. The data from USGS showcase that a total of 221 earthquakes with a magnitude exceeding 6.0 (Mw) occurred within 1000km from Kota Kinabalu, Sabah, since 1973, with most higher magnitudes concentrated in Ranau and Lahad Datu areas [5].

Earthquakes commonly significantly impact the local's social, built, economic and natural environment [1,2,8]. Similarly, the earthquakes in Ranau, Sabah posed similar negative impacts which affected the local residents. These include the changes in physical structure, habitat and the ecosystem nearby Mount Kinabalu, which includes the nearby rivers. A few similar studies in Ranau indicate the impacts of the Ranau earthquake which primarily impacted local residents, majorly impacting their socio-economic due to the local destructions, disruptions and degradation [9-11]. Earthquakes like this can lead to alterations and water quality degradation in nearby rivers. The change and degradation of water quality may be attributed to the intermixing of water among aquifers, an influx of water from different areas to water sources, change in concentration of dissolved gases and dissolution of precipitated minerals or infiltration of pollutants from soil to groundwater table [12].

A lot of past studies suggest how interruptions of water supply occurred due to occurrences of earthquakes. In the case of Barfal et al. [13], the findings suggest that post-earthquake impacted the hydrology system in Sikkim, India. The water springs observed in Sikkim were dried up, while some discharged at a faster rate after the occurrence of the Mw 6.9 earthquake in 2011 in Sikkim. Past earthquakes in Nepal in 2015 with a magnitude of 7.8 on the Richter scale also interrupted the local water supply [12]. In addition, pond water quality was degraded for seaweed cultivation after an earthquake measuring M 7.4 in 2018 in Palu City, Indonesia [14]. Furthermore, global data suggests that a more than magnitude five earthquakes can change the hydrogeology of a region, emphasizing the impacts of earthquakes [13].

This is also in line with similar research focusing on post-earthquake-related research in Ranau Sabah, which mentioned that the 2015 earthquake led to a water shortage, disruption and degradation [9-11]. This might be attributed to landslides and debris flow, which are among the geological hazards triggered by an earthquake. For instance, the 2018 Hokkaido Eastern Earthquake led to 9295 landslides, and the Wenchuan Mw8.0 earthquake of China triggered at least 200,000 landslides in the region [15]. The sediment movement due to the earthquake towards the water source, be it due to the mud floods or not, was explained by Environment Canterbury to be one of the possible causes of the increasing turbidity in the water bodies in Christchurch post-earthquake occurrence [16].

Post-disaster drinking water quality has always been considered a crucial issue in disaster management, primarily related to healthcare perspectives like waterborne diseases and other illnesses such as diarrhea, dysentery, hepatitis and cholera in acute cases [12, 17]. As the river is an essential water source for the locals, it is critical to ensure its safety to reduce the threat of waterborne diseases to the public and the ecosystem. In the case of the 2015 Sabah earthquake, the local water supply was disrupted due to continuous heavy rainfall and mudflow triggered by the rainfall. This is in line with similar research which subtly mentioned water shortage, disruptions and degradation in the area post-earthquake [9-11]. This disruption affects the residents that depend on the river as the primary water source and livelihood. Therefore, there is a need to ensure that the river is in a good and safe condition post-earthquake. Hence, the main objective of this study is to analyze the in-situ parameters for water quality in selected rivers after the Ranau 2015 Earthquake as a way to monitor the rivers short-term to assess the level of water safety in the river and ensure that it is good and safe for the local's usage. This research is beneficial to enhance the understanding of immediate impacts on the river due to the earthquake, especially in Malaysia's context - as there are fewer studies made in the area alongside rare occurrences of an earthquake.

2. Methods

2.1. Monitoring Stations

Several rivers in the Kundasang and Ranau areas, namely Sg. Panataran in Kg. Malangkap (S1), Sg. Kadamaian, Kg. Bundu Paka (S2), Sg. Kadamaian in Kg. Kiau (S3), Sg. Mesilou in Kg. Mesilou 1 (S4) and Sg. Mamut at Poring Hot Spring (S5) were selected for river water quality monitoring. The selected rivers are among the rivers affected by the 2015 Earthquake and mudflow disaster. Figure 1 shows the locations where water quality monitoring has been done. The monitoring activity started on 11 June 2015 and ended on 14 January 2016.

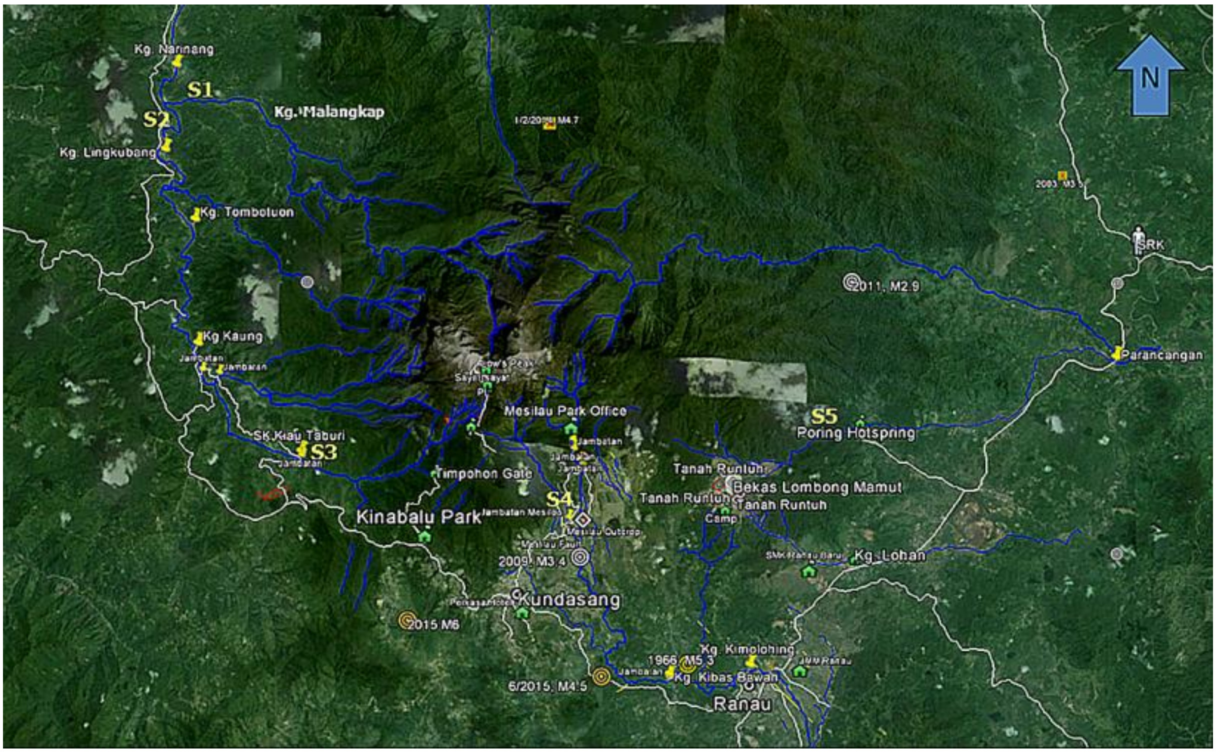


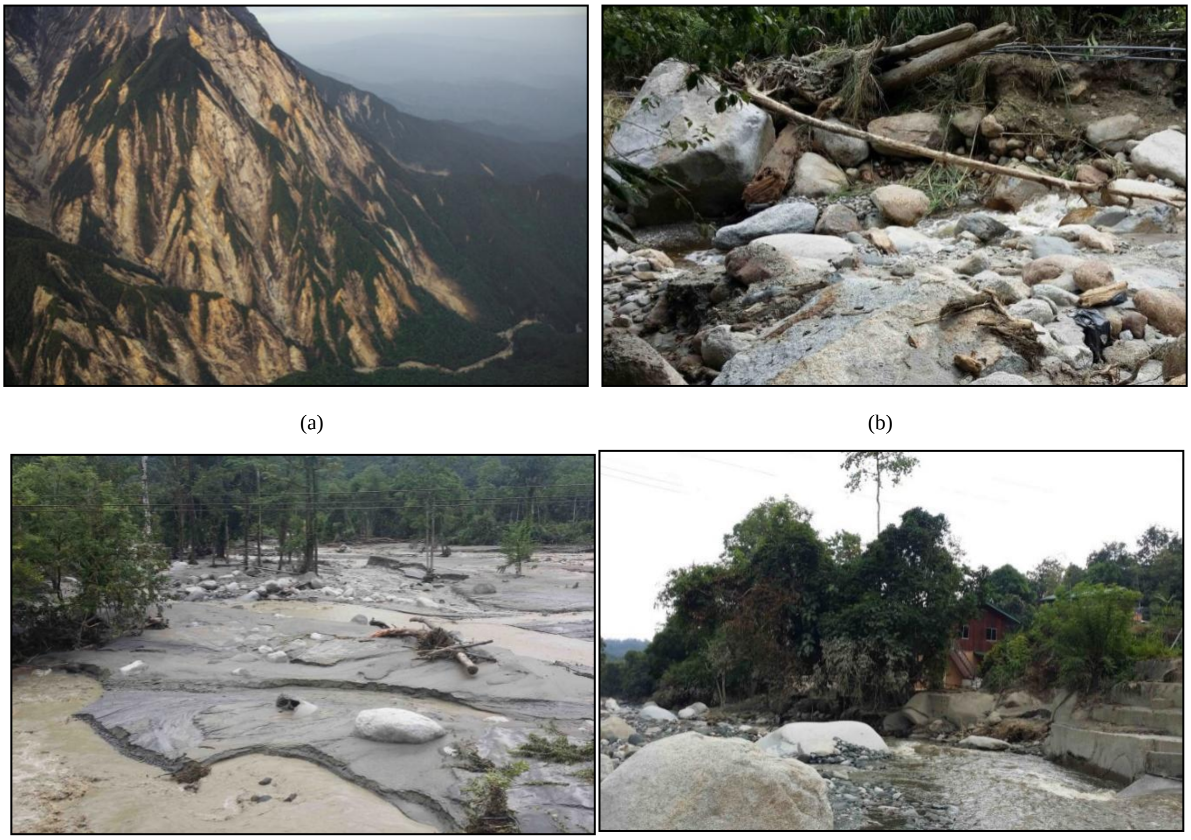
Figure 1. The rivers selected for water quality monitoring after the 2015 Earthquake and mudflow events

2.2. Water Quality Parameters

The water quality was studied *in-situ* using YSI ProDSS multimeter equipment. The physicochemical parameters studied are pH, temperature, turbidity, dissolved oxygen (DO), and electrical conductivity (EC), specifically to assess the extent of immediate pollution caused by the earthquake occurrence. Prior to usage, a calibration process was employed to the portable multimeter to enhance the features for measurement reading recovery.

3. Results & Discussion

The 2015 Earthquake with a magnitude of 5.9 on the Richter scale had a negative impact on the stability of the land around Mount Kinabalu. The continuous heavy rain aggravated this situation in the area, which triggered landslides in some mountainous areas and then brought a catastrophe of mudflow. The mudflow flood led to the flattening of residential areas and forests and brought giant stones to the foot of the mountain, as shown in Figure 2.



(a) (b) (c) (d)

Figure 2. The effects of 2015 Sabah Earthquake and continuous heavy rain

From Figure 2, the impacts of the 2015 earthquake and heavy rainfall were illustrated. Figure 2(a) illustrates landslides around Kg. Mesilou, which had a significant impact on Sg. Mesilou. Figure 2(b) shows Sg. Mesilou's condition after hit by mudflow, where large trees appeared as they were uprooted and brought there. Figure 2(c) showcases the condition of Kg. Malangkap after being hit by mud flood, followed by Figure 2(d) where larger rocks seen around Kg. Malangkap were brought by the mudflow, which also at the same time demolished the cliffs and buildings near Sg. Panataran.

The mudflows and the mud floods have caused the rivers in Kundasang and Ranau to become turbid, foamy and smelly. It was further worsened by mass fish death occurrence, which took place in Sg. Kadamaian. This incident caused increased anxiety and worries among residents who depend on river water as a source of drinking water and fish. Table 1 shows the values of the physicochemical parameters of river water tested on specific dates in 2015 and 2016.

Based on Table 1, the water quality for the monitored rivers was in good condition except for the dates marked in red in the table. The most crucial factor for the decline in water quality in the rivers was the high turbidity readings. The readings also indicate that suspended solids were so high that they caused fish gills to become clogged, leading to massive fish deaths in Sg. Kadamaian, Kg. Bundu Paka (S2). In addition, the change in water temperature in Sg. Mesilou, Kg. Mesilou 1 (S4) was also concerning as the change in temperature exceeded the standard value (+2 ℃), which was not favourable for aquatic life. In addition, further monitoring discovered that Sg. Mesilou became shallower and flowed more slowly than before.

Overall, the water quality of the studied rivers was at a satisfactory level. The water quality of the rivers will degrade during continuous heavy rainfall, where excess rainwater that cannot be absorbed by the soil will begin to bring the remnants of landslides into the river. Thus, this explained the river water that was observed to be more turbid whenever there was rain. However, it is expected that this situation will improve over time if no more landslides occur around the monitoring taken on 14th January 2016, where the reading of the physicochemical parameters of most of the rivers, especially turbidity readings, suggested that they are at a good and safe level. For instance, there was a drop in the turbidity readings for Sg. Panataran (S1), Sg. Kadamaian (S3) and Sg. Mesilou (S4) during the last date that was monitored. It can be said that all the rivers affected by the earthquake and the mudflow have recovered. In fact, with the persistence, concern and efforts of the local residents, the rivers had become more beautiful.

Table 1. Physicochemical parameters in the selected monitoring river station

Parameter	Temperature, ℃	pH	EC, μS/cm	DO, mg/L	Turbidity, NTU
Standard value	+2	6.5-9.0	1,000	>5	<50
Location: Sg. Panataran, Kg. Malangkap (S1)					
12.06.2015	23	7.4	96	8.4	18.0
02.07.2015	23	7.7	108	8.4	23.7
13.07.2015	25	7.6	110	8.6	66.8
14.06.2016	24	8.0	101	8.1	1.9
Location: Sg. Kadamaian, Kg. Bundu Paka (S2)					
12.06.2015	24	7.2	58	8.0	577
02.07.2015	26	7.6	94	7.7	122
14.06.2016	*Not Monitored*				
Location: Sg. Kadamaian, Kg. Kiau (S3)					
11.06.2015	22	8.0	109	8.1	1.7
26.06.2015	23	7.8	107	8.7	9.6
29.07.2015	22	7.5	99	8.7	281
14.01.2016	23	7.4	147	8.1	1.37
Location: Sg. Mesilou, Kg. Mesilou 1 (S4)					
11.06.2015	17	7.3	79	8.7	560.0
26.06.2015	19	7.1	76	9.1	15.2
09.07.2015	17	7.3	25	9.0	233
29.07.2015	18	6.8	45	8.6	23.8
14.01.2016	20	7.6	75	7.8	2.2
Location: Sg. Mamut (S5)					
11.06.2015	23	7.2	368	8.3	5.2
16.06.2015	22	6.5	406	8.0	11.3
26.06.2015	22	6.8	371	9.0	5.5
14.06.2016	23	6.5	464	8.2	12.4

*red fonts = exceedance from standard values

*Standard value = Interim National Water Quality Standards (INWQS)

As illustrated in Figure 3, two pictures of the condition at Sg. Kadamaian (S3) were taken at the exact location on different dates. Figure 3(a) showcases that the turbidity of the river water was very high because the collapsed soil had been carried into the river water after heavy rains, whilst Figure 3(b) showcases that the river water was naturally clear again.

(a) (b)

Figure 3. Condition at Sg, Kadamaian, Kg. Kiau (S3) on (a) 29 July 2015, (b) 14 January 2016

4. Conclusions

The 2015 earthquake and mudflows (also mud floods) have changed the physical shape of the rivers around Kundasang and Ranau. The disaster also interfered with the quality of river water due to the high content of suspended solids. However, water quality monitoring in several rivers in Kundasang and Ranau shows that most of the affected rivers, for example Sg. Panataran (S1) and Sg. Kadamaian (S3) were able to recover naturally. Furthermore, with the concern of the local people, now the rivers have a new look and have been developed into one of the famous tourist or recreational spots for its cold and clean water. The water quality of the rivers, in general, can be said to be good and safe.

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