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Downstream Community Awareness of the Failure Risk and Emergency Action Plan of Bukit Merah Dam

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Abstract Kerian and other villages further downstream are vulnerable to dam failure as Bukit Merah Dam is an aging Malaysian dam, having been used since 1906. The aim of this article is to evaluate how the demographic characteristics of downstream communities affect their perceptions of the existing dam. The article will also analyze the effect these demographic characteristics have on the awareness levels of dam failure risk and the implementation of the Emergency Action Plan (EAP) by Department of Irrigation and Drainage Kerian (DID). The vulnerability of the downstream communities to a dam failure disaster can be minimized by their own preparedness for actions that should be taken during a dam failure event. This study opted for a quantitative approach, which included a questionnaire survey. The data discussion revealed that the demographic characteristics influenced the community perceptions of the dam, their awareness of a dam failure disaster and the implementation of the EAP by DID Kerian. From the result, it can be concluded that the dam has positive impacts on the livelihoods of downstream communities as mean outputs for this analysis are above 3.0. For the standard deviation, the value was 0.595, 0.747 and 0.533, meaning that demographic characteristics influenced the communities' perceptions. They know the potential future risk (66.7% to 100% said 'yes' in the statement of risk awareness) but lack knowledge about the implementation of the EAP (42.9% to 75.0% responded 'no' in the statement of EAP knowledge). Most respondents accepted the EAP positively and are trying to understand the importance of the EAP.

Keywords Dam, Failure, Emergency Action Plan, Community, Awareness

1. Introduction

A dam is an infrastructure that is built across a stream, river or estuary and is constructed for specific functions, such as flood control, navigation, hydroelectric power, hydropower, recreation and to provide sufficient water supplies for human consumption, irrigation, aquaculture, and industrial uses. However, it can also pose a risk to public safety and surrounding consequences [1]. A dam failure-related disaster might result from the aging of the dam and can cause disastrous effects. These impact many lives and lead to social, economic and environmental damage, such as loss of life and the destruction of property. These can occur suddenly and without sufficient preparedness by downstream residents to enable them to deal with the consequences [3].

The study covered Bukit Merah Dam, which is located in Kerian District, Northern Perak State, Malaysia.It is known to be the oldest man-made lake as it was built in 1906, making it 114 years old. It is classified as a homogeneous earth embankment type of dam, a well-compacted design for water storage [4]. The dam has a reservoir area of 41 km^2 with a storage capacity of 74.98 Mm^3 at river level 9.10 m and covers a 480 km^2 catchment area in Kerian district and Larut Matang district [5].

Debates about the advantages and disadvantages of dam construction have arisen over the years and the impacts of hydropower projects have always been questioned as they pertain to the livelihood of the local community. Meanwhile, many benefits arise simultaneously with the existence of a dam but such a project can also affect the lifestyles and livelihoods of the directly affected communities settled downstream of the dam. Community perceptions of the construction of a dam vary: some regard this as beneficial to them, while some see it as detrimental [6].

The vulnerability of the directly affected downstream communities to a dam failure disaster can be minimized by their own preparedness for action that should be taken during a dam failure event. As affirmed by MyDams [8], dam risk education must be part of a dam EAP. An EAP is implemented for a dam to identify the potential or probability of the occurrence of dam incidents. The plan also acts as guidelines related to the responsibility or role of all dam stakeholders, including dam owners and the community. The EAP outlines emergency procedures to be followedby the dam operators and Bukit Merah Dam Custodians in order to deliver any announcements or early warnings to communities at risk of dam failure disaster.The EAP also provides maps of those locations vulnerable in the event of dam failures or flood events. Hence, it is important for the downstream community to be aware of the EAP implementation so they can minimize their losses.

In Malaysia, community awareness education of dam risks is still new and limited in scale. Tenaga Malaysia Berhad (TNB) is one dam owner in Malaysia that is active in educating people about dam risks and providing many community engagement programs for downstream communities, including those near Bukit Merah Dam, which is owned by DID. There are several populated areas, such as Bagan Serai town and about 20 villages, located downstream of the dam that are vulnerable in the event of dam failure [4].

In 2019, Nakamura [9] published a paper which described how nine people were killed in July 2018 during the inundation of the Hijikawa River Basin, which began directly after two dams on the Hijikawa River ran a discharge operation. The operation had to be carried out by dam operators after aheavy rainfall event in the west of Japan and the released discharge from the dam caused a sudden rise in the river level. The loss of life during the incident occurred due to downstream residents' lack of awareness of dam emergency events and crucial communication needed to evacuate residents. Thamer [10] discovered that Bukit Merah Dam experienced slope failure and problems related to seepage. They found that the seepage from the dam caused the maximum seepage rate to be1.7 m^3/min in 1966.

The goal of this study is to investigate the conscientiousness of directly affected communities downstream of Bukit Merah Dam pertaining to dam failure events. The first objective of this study is to evaluate the effect the downstream communities' demographic characteristics have on their perceptions of the existing dam operation. The second objective is to analyze the effect these demographic characteristics have on the awareness of dam failure risk and the EAP implementation among the downstream community.

2. Materials and Methods

Bukit Merah Dam is located upstream of the confluence of the Kurau River and the Merah River, as shown in Figure 1. The river water flows from upstream of the dam downstream to where the questionnaire distribution spot was selected. The coordinates of Bukit Merah Dam are 5°01'49''N 100°39'02''E, in the Kerian district.

Figure 1. Confluence of Merah River and Kurau River and Bukit Merah Dam (Source: Google Maps [15])

At the data collection stage, the questionnaire was conducted on 30th October 2019 and covered eight identified villages, as listed in Table 1. Figure 2 shows the location of the eight villages by referring to the number in Table 1. The closest village was No 7, Kampung Ban Pisang, a distance of 1.46 km from the location of Bukit Merah dam, while the farthest village was No 1, Kampung Parit Air Hitam, distance of 6.20 km. All the selected areas were less than 10 km away from the dam.

Table 1. Selected Spots for Questionnaire Distribution

Number in Figure 2	Location	Coordinates	Distance from dam (km)
1	Kg. Parit Air Hitam	5°01'23''N 100°35'43'' E	6.20
2	Kg. Tali Air Kanan	5°01'02'' N 100°37'58'' E	2.45
3	Kg. Tanjong Bugis	5°01'22'' N 100°36'58'' E	3.92
4	Kg. Ban Abu Hassan	5°02'16'' N 100°36'24'' E	4.96
5	Kg. Padang Lalang	5°00'59'' N 100°36'57'' E	4.17
6	Kg. Batu 38	5°02'35'' N 100°37'09'' E	3.76
7	Kg. Ban Pisang	5°01'38'' N 100°38'16'' E	1.46
8	Kg. Parit Hj. Aman	5°02'16'' N 100°39'03'' E	5.90

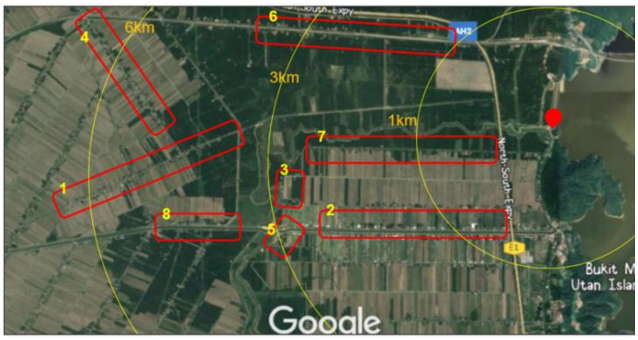


Figure 2. Location of Selected Spots for Questionnaire Distribution (Source: Google Maps [15])

The total number of respondents to participate in the data collection was 88, with the contribution of respondents as shown in Figure 3. The method used to obtain respondents for the questionnaire was a canvassing approach, with the distribution of one questionnaire per household. The interview took around 10 to 15 minutes, with each respondent requested to answer all the questions in the questionnaire in full.

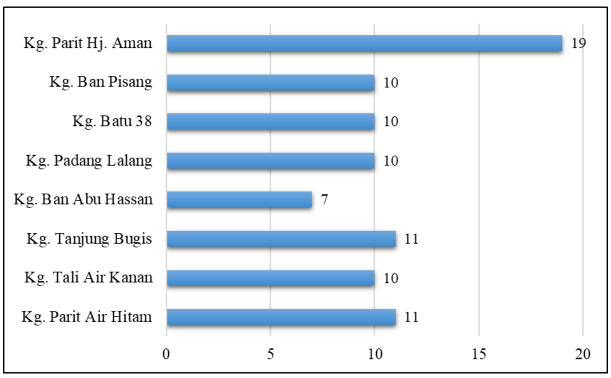


Figure 3. Frequency of Respondents byArea

The analysis conducted by most researchers is the questionnaire survey, used to observe the residents' perceptions, their awareness of the risks of dam failure and the implementation of action plans that would be used during a dam disaster event.

In research carried out by Wiejaczka [6], he used a diagnostic survey containing questionnaire interviews with 65 targeted residents (39 persons in Baluwakhani and 26 persons in Geil Khola) but only 78.5% answered the survey; the remainder refused as they did not open their doors during the survey. The same method was used by Ramzi [11]. They targeted 500 respondents who settled around the TNB Sultan Abu Bakar Hydroelectric Dam in Lembah Bertam, Cameron Highlands to participate in a questionnaire to analyze the community's experience of disasters and their perceptions of the implementation of the Early Warning System (EWS).

Al-Noor [12] used a different method from those of the above researchers. Their approachwas mixed methods, which combined qualitative and quantitative methods and was conducted in three spots in regions of northern Sudan (upstream, downstream and upstream with relocated residents). In total, 300 respondents from 34 villages downstream and 50 villages upstream participated in the questionnaire survey. The qualitative method used a five-point Likert scale (1 = Strongly negative to 5 = Strongly positive) to analyze the socio-economic impacts of the dam.The quantitative method listed the economic indicators in the study area of the Merowe Dam.

Dam risk management analysis relates strongly to the involvement of residents or communities that live in the dam downstream area. Their demographic characteristics can influence the outcome of the analysis, depending on the residents' interests in the issues highlighted in the study.

3. Results

3.1. Demographic Characteristics of Respondents

In total, 88 respondents participated in this survey. The demographic characteristics of the respondents were initially obtained from the answered questionnaire. Figure 4 illustrates the distribution of those surveyed according to gender: 60.2% of the respondents were female and the balance was male (39.8%).

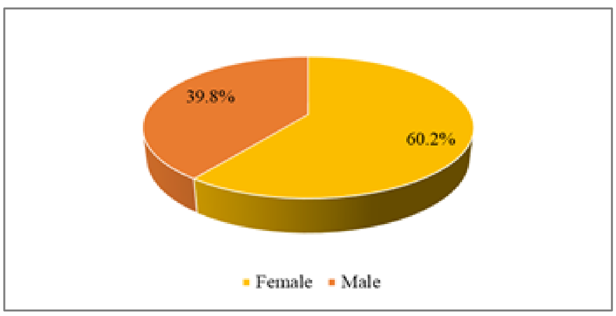


Figure 4. Distribution by Gender

Figure 5 shows the respondents' distribution according to education level. Fifty percent of the respondents had secondary school education while 38.6% of them had been educated at primary school. Eight percent of the respondents had received no proper education and only 3.4% were university graduates.

For the characteristic that showed how long the respondents had lived in the affected area, 88.6% had been living in the area for more than 10 years; 6.8% of the respondents had been residents of their village for about 6 to 10 years and 4.5% had been living there for 1 to 5 years (Figure 6).

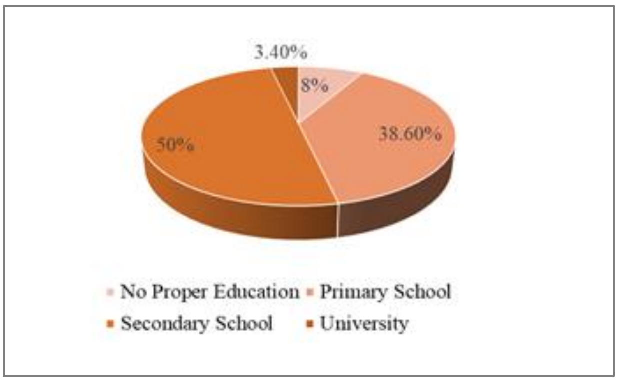


Figure 5. Distribution by Education Level

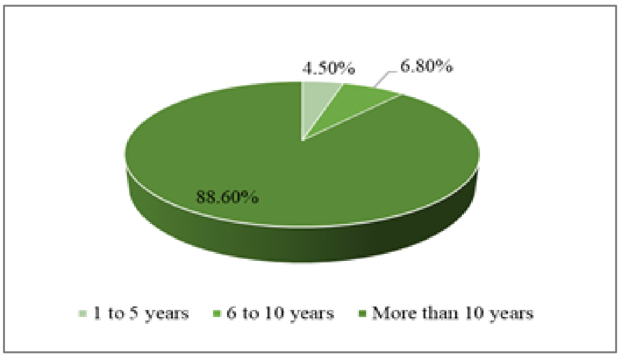
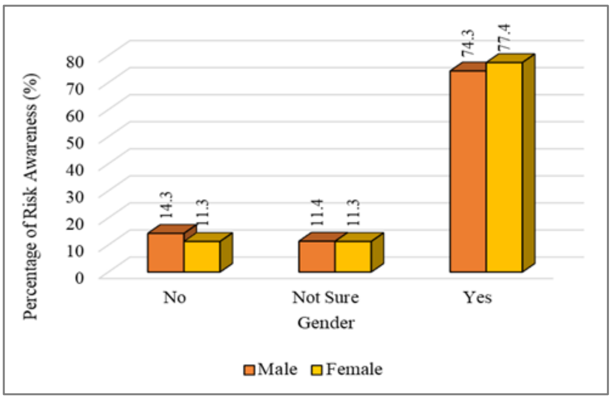


Figure 6. Distribution byDuration of Living in the Affected Area

3.2. Dam Risk Awareness and Implementation of EAP Awareness in terms of Gender

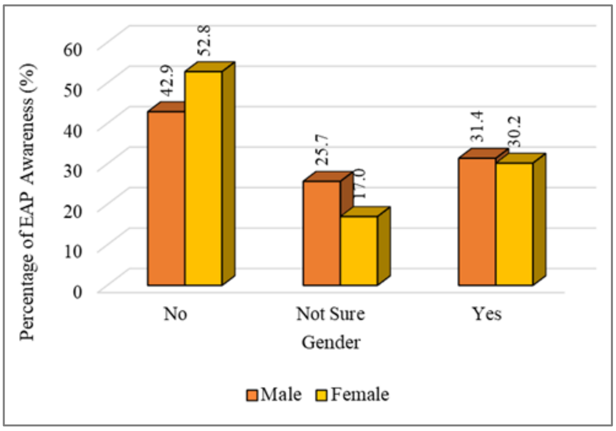
Demographic characteristics can affect the analysis result of respondents' awareness as it differs between groups. Ways of thinking for males and females are not identical as they are interested in different issues. Figure 7 illustrates the percentage of risk awareness according to thegender of the respondents and their knowledge about the risk of living downstream of the dam. When comparing gender, it is apparent that more female respondents (77.4%) know that they are vulnerable in the event of a dam failure disaster as they lived nearer to the dam location (<10 km) than males (74.3%). The percentages of respondents with no knowledge of the risk of living downstream of the dam were 11.3% and 11.4% for female and male respondents, respectively. It can be summarized that both genders know the risk of whatmay happen during a dam failure as those with knowledge accounted for a higher percentage compared to people who did not know or were not sure about the knowledge of the risk of a dam disaster. The significant Chi-square value was 0.175, df = 2 and p-value = 0.916. These show that female respondents were more aware of disaster mitigation efforts compared to males.



Chi-square = 0.175, df = 2, p-value = 0.916

Figure 7. Risk Awareness Percentage of Each Gender

Figure 8 shows the cross-tabulation result between gender and respondents' knowledge of the implementation of the EAP by DID. The result shows that only 30.2% and 31.4% from the female and male groups, respectively, were aware of the presence of the EAP. This reflects that not many respondents know about the EAP. It was found that 52.8% of females and 42.9% of males were not aware ofthe EAP. The survey also reveals that 25.7% of male respondents and 17.0% of female respondents were not sure whether they knew about EAP or not. It can be concluded that respondents' awareness of, and familiarity with, EAP exists. The Chi-square value was 1.226, df = 2 and p-value = 0.542.



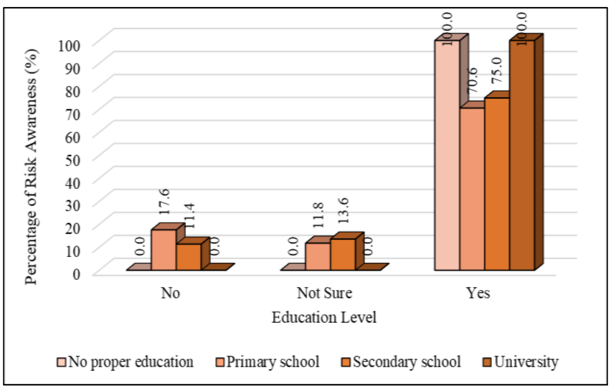
Chi-square = 1.22, df = 2, p-value = 0.54

Figure 8. EAP Implementation Awareness Percentage of Each Gender

Compared with the study at Lembah Bertam Cameron Highland carried out by Ramzi [11], this research has identified that male respondents (62.5%) knew more about the implementation of the Early Warning System (EWS) than females (37.5%). In that study, researchers analyzed the respondents' experiences of dam disasters before awareness of the EWS had been analyzed. This showed that male (64.8%) comprised a higher percentage than female respondents (35.2%). The respondents' experiences of disasters influenced their knowledge of the EWS implementation. The other characteristics studied by Thamer [10] were the age of respondents and their ethnicity.

3.3. Dam Risk Awareness and Implementation of EAP Awareness in terms of Education Level

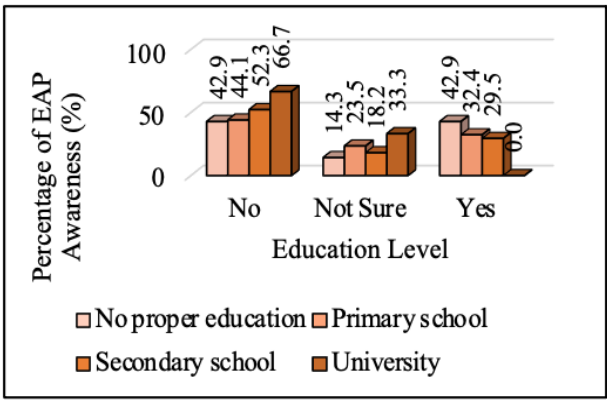
Education level can be one factor that influences the analysis result of respondents' awareness as every person has different amounts of knowledge depending on their education level. Figure 9 shows the cross-tabulation result between education levels and respondents' awareness of living downstream of the dam (<10 km). The result reveals that all respondents with no proper education (100%) and all those with university education (100%) knew about the vulnerability of living near the dam locations.This was followed by secondary school (75.0%) and primary school (70.6%). These percentages were also influenced by how many respondents participated in the questionnaire survey. The low percentage of persons from all education levels who are not sufficiently aware of the risk will be a relief to the dam authority. The Chi-Square value was 4.250, df = 6, p-value = 0.643. This shows that although over 88 persons had no proper education, those who participated in the survey were mostly aware of the disaster that could happen during a dam failure. Figure 8 illustrates the percentage of knowledge of the EAP implementation for each education level.



Chi-square = 4.25, df = 6, p-value = 0.643

Figure 9. Risk Awareness Percentage of Each Education Level

The cross-tabulation analysis in Figure 10 shows the education level of respondents in relation to their familiarity with the implementation of the EAP. From Figure 10, it can be clearly identified that respondents with all levels of education were unaware of the mitigation efforts during a disaster, as, for two out of four education levels, more than 50% (52.3%, and 66.7%) did not know the implementation of the EAP. The Chi-Square value for this case was 2.458, df = 6, p-value = 0.873. Figure 9 illustrates the bar chart of the EAP awareness percentage in terms of education level.



Chi-square = 2.458, df = 6, p-value = 0.873

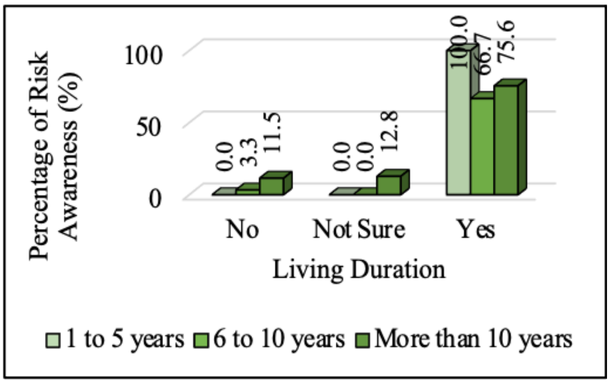
Figure 10. EAP Implementation Awareness Percentage of Each Education Level

3.4. Dam Risk Awareness and Implementation of EAP Awareness in terms of Duration of Living in the Area

How long a person had lived downstream of the dam can act as a contributory factor in the analysis result of respondents' awareness as everyone will have different experiences of the dam operation. In terms of length of time living in the area, the respondents with a level of dam disaster risk awareness are those who had lived from 1 to 5 years (100%) downstream of the dam, followed by respondents who had lived there more than 10 years (75.6%) and the respondents who had lived there for 6 to 10 years (66.7%), as shown in Figure 11. However, respondents known to belong to a directly affected community after living there for 6 to 10 years displayed a greater lack of risk awareness (33.3%) compared to other groups, which may lead to the occurrence of destruction during dam failure. It is possible to highlight other points. Respondents who had lived in the area for 1 to 5 years know the full risks (100%), without any of them being unaware of the risk of living downstream of the Bukit Merah Dam. The Chi-Square value obtained from the analysis was 4.295, df = 4, p-value = 0.367. Figure 10 illustrates the percentage of risk awareness in terms of the duration that respondents had lived in the area.

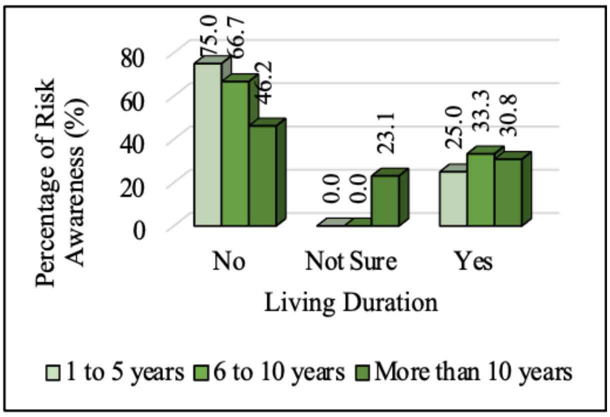
Figure 12 illustrates the EAP implementation percentage of respondents in terms of how long the respondents had lived downstream of the Bukit Merah

Dam. It reveals that respondents that lived there for 1 to 5 years (75.0%) and 6 to 10 years (66.7%) had a lack of understanding of the EAP. The same is true of respondents who had lived downstream of the dam for more than 10 years (46.2%), as the percentage stated is higher than that of the respondents who know about the presence of EAP (31.0%). The knowledge of EAP implementation is important to reduce loss of life andit leads to greater awareness of a dam failure disaster. The Chi-Square value was 3.429, df = 4, p-value = 0.489.



Chi-square = 4.295, df = 4, p-value = 0.367

Figure 11. Risk Awareness Percentage of Each Living Duration



Chi-Square = 3.429, df = 4, p-value = 0.489.

Figure 12. EAP Implementation Awareness Percentage of each Living Duration

Wiejaczka [6] studied the gender (male and female), age (18 – 38 years, 39 – 59 years and above 60 years), level of education (none, Grade 1 - 5 for primary level, Grade 6 – 8 for middle level and Grade 9 – 12 for secondary level) and source of income (construction, transportation, services as shop orrestaurant owners, quarry day laboring, other private sector operations) in order to observe how the impact of a dam directly affected residents that lived near the dam. The result of that analysis revealed that dam construction brought no benefit to the quality of the residents' lives. In fact,it caused the situation to worsen as many residents experienced a loss of income and the number of shop and restaurant customers decreased.

The analysis conducted by Arabatzis [13] selected gender (men and women), age (younger ages and above 48 years) and education level (high school and university) as demographic characteristics to analyze the respondents' acceptance of and attitudes to the development of a small hydropower facility in northern Greece. The construction of SHP offered employment for the local community and guaranteed a low environmental impact on the area surrounding the hydropower location.

Another study to carry out analysis using demographic characteristics was that of Pirog [14]. They studied gender (male and female), education level (primary, vocational, secondary and higher), age (18 – 29 years, 30 – 39 years, 40 – 49 years, 50 – 59 years and above 60 years), distance from the dam (within 1 km, 1 – 10 km, and more than 10 km), duration of residence (shorter than 10 years, 10 – 25 years, 26 – 40 years and 41 years and above) and the location in relation to the dam (downstream and upstream) to investigate local community acceptance of the Mucharski Reservoir construction in the Polish Carpathians. The outcome from this research revealed that the perceptions and opinions of residents were influenced by emotional and economic variables, not personal variables (demographic characteristics).

Residents' perceptions could vary according to the number of years since the dam had been completed, depending on the various impacts of the dam on their lifestyles and livelihoods. Analysis of these perceptions needs to be carried out to investigate such issues and seek the level of residents' acceptance of the dam. According to Wiejaczka [6], researchers conducted a diagnostic survey using a questionnaire to observe residents' perceptions of a dam project in the Teesta Basin, Darjeeling Himalayas, India, after the 1.5-year period of its completion.

The perceptions of the community before the construction of the dam, during the construction of the dam and after its completion could change. The acceptance of the dam differs depending on residents' knowledge and experience of dam-related issues. Residents who knew the tangible benefits brought by the dam were expected to respond positively in the analysis of community perceptions.

4. Conclusions

It can be concluded that factors influencing respondents' perceptions of the Bukit Merah Dam operation relate to the each respondents' demographic characteristics. This was revealed by the value of standard deviation for gender (0.595), education level (0.747) and living duration (0.533), in which all the values were more than 0.5 and near to 1, especially for the education level.

Most participants in the questionnaire survey conducted invillages downstream of the Bukit Merah Dam were aware of, and knew their vulnerability to, the risk of a dam failure disaster. Similar results were found in terms of the level of education. These respondents knew more about the potential dam risk.

Unfortunately, even if respondents were more aware of the dam failure risk, this did not lead to a better level of knowledge about the EAP implementation. It can be concluded that respondents understand more about the potential risks of dam failure. However, they lack awareness of, and knowledge about the implementation of the EAP.

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