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Seismicity of Batubesi Dam at Sorowako Region Based on Earthquake Data and Microtremor Measurement

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ABSTRACT

Batubesi Dam which is located in Sorowako region in the middle part of Sulawesi island had been designed with seismic coefficient about 0.20g. The region constitutes an active earthquake zone with the recurrence frequency and magnitude of the earthquake are relatively high. The region is located on and active fault zone due to lateral fault movement (strike-slip) of Matano fault, Palukoro fault, and Walanea fault that categorized as shallow crustal earthquakes. To recognize characteristic of the earthquake at the site of interest, the historical earthquakes (background) data surrounding the study area and local microtremor measurements data are analyzed by means of a probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA) using some ground-motion models in attenuation relationship equations in resulting of seismic hazard parameter as represented by peak ground acceleration (PGA) values in earthquake scenario at operating basis earthquake (OBE), maximum design earthquake (MDE), and maximum credible earthquake (MCE) conditions. The PGA value in OBE condition is about 0.35g, in MDE about 0.45g, and in MCE about 0.49g. These values are used as reference to evaluate compliance of the current technical aspects with the new required design facing the updated seismicity parameters.

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NOMENCLATURE

g	acceleration of gravity	$HVSR$	ratio of H/V spectral value
X_t	probable maximum magnitude for return period T years	S_{HS}	spectral of horizontal element at rock layer
X_n	average of maximum magnitude	S_{VS}	spectral of vertical element at rock layer
Y_t	reduced variate	M	magnitude of earthquake
Y_n	reduced mean	K_g	seismic vulnerability index
S_n	reduced deviation standard	A_0	peak amplitude of microtremor
S_x	standard deviation	f_0	resonance frequency
T_G	fundamental period of the site	λ	Annual exceedance probability, AEP
R	radius or distance from site-to-source	T_g	predominant period of the ground
V_{s30}	shear-wave velocity at 30 m depth		

1. INTRODUCTION

Batubesi Dam which is located in Sorowako region at the middle part of Sulawesi island, Indonesia (Figure 1) had been designed with a seismic coefficient about 0.20g. The region constitutes an active seismic region that is having a high intensity of the earthquakes in terms of the frequency and magnitude parameters. Some lateral fault movements (strike-slip) such as Matano, Lawanopo, Palukoro, and Walanea faults categorized as shallow crustal earthquakes contribute the seismic setting.

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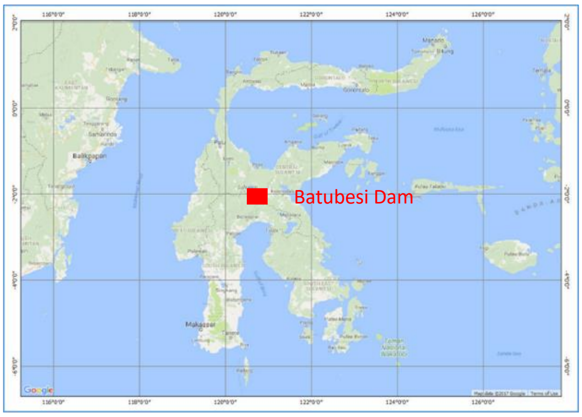

Figure 1. The index map of Batubesi Dam

The potential seismic hazard in the region had been observed widely by some national researchers such as Kertapati, et al. [1], Wangsadinata [2], Irsyam, et al. [3] and 2017 [4], and Cipta, et al. [5] as the parameter is represented by a peak ground acceleration (PGA) value. Summary of the PGA values based on the previous researches with probability of exceedance (POE) about 10% during 50 years of life service referred to return period of 500 years is stipulated as follows:

- Kertapati, et al. [1], the PGA value is about 0.10–0.15g,
- Wangsadinata, et al. [2], the PGA value is about 0.15–0.20g,
- Irsyam, et al. [3], the PGA value is more than 0.6g,
- Cipta, et al. [5], the PGA value is about, and
- Irsyam, et al. [4], the PGA value is about 0.20–0.25g.

Based on the phenomenon as prescribed, there are some differences of the PGA values that changing time to time. It is motivating the authors to do research in more detail regarding seismicity setting in the site of interest (Batubesi Dam) for design and engineering purposes. Several methods and field measurements had been performed to emphasize the research.

2. METHODOLOGY

The seismicity setting of the research area can be assessed by meaning of probabilistic seismic hazard analysis (PSHA) and/or deterministic seismic hazard analysis (DSHA) approach by considering availability of earthquake data, geological information, and soil/ rock properties at the site specific. The earthquake catalogue data is accessed from the website belong to USGS (United States of Geological Survey) within coordinate boundary between 0.44 to 4.10 South and 118.00 to 123.20 East, and magnitude more than 1.4 richter scale since 1919–2017.

The PSHA method in this study is proposed to predict values of probable maximum magnitudes that may occurs in certain return period of T years by means of Gumbel regression type I (extreme value) as shown in the following equations:

$$X_t = X_n + (Y_t - Y_n)\left(\frac{S_x}{S_n}\right) \tag{1}$$

X_t = probable maximum magnitude for return period T years
X_n = average of maximum magnitude
Y_t = reduced variate
Y_n = reduced mean
S_n = reduced deviation standard
S_x = standard deviation

$$Y_t = -ln\,[-ln\,(T-1)/T] \tag{2}$$

for $T > 20$ years, $Y_t = ln\ T$ (3)

$$S_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - X)^2} \tag{4}$$

For the 59 number of daily maximum earthquake data, reduce mean (Y_n) is 0.5518 and the reduced standard deviation (S_n) is 1.1734.

After probable maximum magnitude of respective return period (M) and distance of the source-to-site (R) are obtained, the peak ground acceleration (PGA) can be derived by following some published ground-motion models in attenuation relationship equations for shallow crustal earthquakes as previously discussed by Kanai (1966), Donovan (1973) Matuschka (1980), Boore & Atkinson (2008) and Campbell & Bozorgnia (2008) in Douglas (2011) [6].

Kanai (1966 in Douglas, 2011) [6]:

$$a = \frac{a_1}{\sqrt{T_G}} 10^{a_2 M - P\log_{10} R + Q} \tag{5}$$

a in cm/s^2, $a_1 = 5$, $a_2 = 0.61$, $a_3 = 1.66$, $a_4 = 3.60$, $a_5 = 0.167$, and $a_6 = -1.83$ (σ is not given); and T_G is fundamental period of the site [6]:

$$y = b_1 e^{b_2 M}(R+25)^{-b_3} \tag{6}$$

y in gal, $b_1 = 1080$, $b_2 = 0.5$, $b_3 = 1.32$, and $\sigma = 0.71$ [6].

$$y = b_1 e^{b_2 M}(R+25)^{-b_3} \tag{7}$$

coefficient is unknown [6].

$$ln\ Y = F_M(M) + F_D(R_{JB}, M) + F_S(V_{S30}, R_{JB}, M) \tag{8}$$

$$ln\ Y = f_{mag} + f_{dis} + f_{flt} + f_{hng} + f_{site} + f_{sed} \tag{9}$$

Detail parameters of Equation (5) until (9) as aforementioned is explained by Douglas [6].

To obtain characteristic of soils or rocks at the site of interest, a microtremor measurement is undertaken using a portable digital seismometer (short period, 3 elements) type TDL-303 for sensitive velocity sensor with sampling frequency until 100 Hz, equipped by data cable, digitizer, solar panel, GPS, and software for data acquisition and analyzing the HVSR (horizontal to vertical spectral ratio) values as shown in the following Figure 2 below. A published software namely GEOPSY is also used to acquire and analyze the HVSR values.

A procedure for processing of the microtremor data is by meaning of the horizontal to vertical seismic ratio (HVSR) to obtain resonance frequency value (f_0) and spectral amplitude (A_0) of each measurement points following the equation below [7]:

$$HVSR = \frac{S_{HS}}{S_{VS}} \tag{10}$$

$HVSR$ = ratio of H/V spectral value
S_{HS} = spectral horizontal element at rock layer
S_{VS} = spectral vertical element at rock layer

The peak value of HVSR spectral is Amplification (A_0), while the frequency value (f_0) at HVSR spectral is a predominant frequency referred to as a resonance frequency of the rock at surface. It can be influenced by physical properties of the rock, for instance, the old rocks are commonly more massive, compact, and tends to have a higher value of predominant frequency than the others.

The value of a seismic vulnerability index (K_g) is derived from the following equation:

$$K_g = \frac{{A_0}^2}{f_0} \tag{11}$$

K_g = seismic vulnerability index
A_0 = peak amplitude of microtremor
f_0 = resonance frequency

After resulting value of resonance frequency (f_0) and seismic vulnerability index (K_g) of each measurement points the data are plotted to figuring out region spatial based on the f_0, A_0, and K_g accordingly.

The value of a predominant period of the ground (T_G) is obtained from the following equation:

$$T_G = \frac{1}{f_0} \tag{12}$$

T_G = predominant period of ground
f_0 = resonance frequency

Figure 2. Tools and equipment of microtremor survey

Refer to Equation (12) above, the peak ground acceleration (PGA) values according to Douglas [6] attenuation relationship is obtained.

Furthermore, to acquire a mean of the PGA values since calculated from Equations (5) to (9), a logic tree is introduced to justify weighting factors according to author's level of confidence by considering the site characterization, geological structures, and tectonic setting as well. The logic tree is shown in Figure 3.

In terms of the PGA designs, Australian National Commission on Large Dams [8] determined the dams that considered have a high potential failure, the annual exceedance probability (AEP) is prerequisite as min. 1/500 for operating basis earthquake (OBE), 1/5,000 for maximum design earthquake (MDE) in operating stage, and 1/10,000 for maximum credible earthquake (MCE) in a closure.

Therefore, the PGA values of respective conditions are classified referring to the classification of the earthquake risk level [9] as follows:

2. RESULT AND DISCUSSION

The earthquakes catalogues of Sorowako were obtained by downloading from website belong to USGS (United States Geological Survey) then plotted into the map.

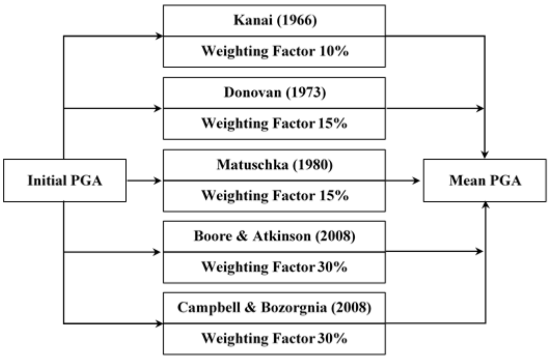

Figure 3. Logic tree

TABLE 1. The classification of earthquake risk level (modified Fauzi, *et al*., 2005 in Lunga, *et al*., 2015) [9]

No.	Risk Level	Acceleration (g)	MMI
1	Very low risk	< 0.025	< VI
2	Low risk	0.025 – 0.051	VI – VII
3	Medium risk 1	0.051 – 0.076	VII – VIII
4	Medium risk 2	0.076 – 0.102	VII – VIII
5	Medium risk 3	0.102 – 0.127	VII – VIII
6	High risk 1	0.127 – 0.153	VIII – IX
7	High risk 2	0.153 – 0.204	VIII – IX
8	High risk 3	0.204 – 0.306	VIII – IX
9	Very high risk 1	0.306 – 0.612	IX – X
10	Very high risk 2	> 0.612	> XI

The scattered points are relatively constructing some recognized alignment and arc-line patterns indicating faults (Figure 4).

Referring to the catalogues, at least the considered earthquake had occurred 934 times since 1919 to 2017 (about 100 years) with the magnitude more than or equal with 5 richter scale within radius 300 km or less from the center of Batubesi Dam. The most densely populated earthquakes in between of 5.4–5.6 richter scale and median in 5.42 richter scale (Figure 5).

Moreover, the earthquake data therefore plotted into the Gutenberg-Richter Recurrence Law as to reveal a relationship between annual exceedance probability, AEP (λ) with magnitude (M in richter scale) as shown in Figure 6 below.

Referring to Figure 6 above, the magnitude of the earthquakes for return period of 50, 100, 200, 500, 2500, 5000, and 10000 years are 6.20, 6.80, 7.00, 7.20, 7.60, 8.20, 8.30, and 8.90 richter scale, respectively.

There are 24 points of microtremor measurements scattered surrounding the dam area (Figure 7) in which resulting of the HVSR curves (Figure 8) such as amplification (A_0), resonance frequency (f_0), and predominant period of the ground (T_G) as shown in the Table 2.

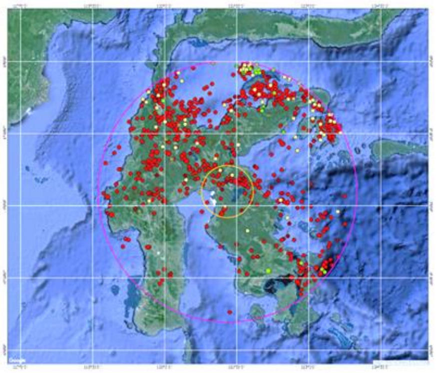

Figure 4. Plots of the earthquake epicenters

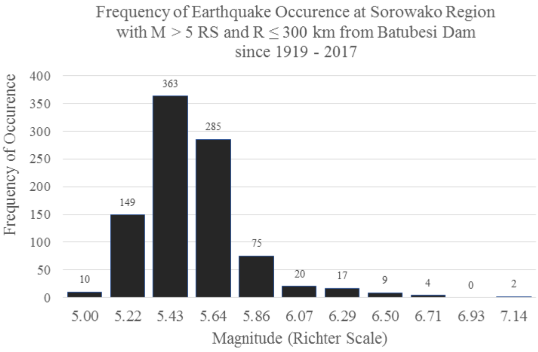

Figure 5. Frequency of earthquake magnitude

Based on the HVSR curves above, it is recognized that the Batubesi Dam site is partly seated on the hard rock layer as represented by MSB-01, MSB-02, MSB-03, MSB-08, MSB-09, MSB-11, and MSB-12 with predominant frequency about 3.37–13.68 Hz, predominant period about 0.07–0.30 second; meanwhile the soft rock layer is represented by MSB-04, MSB-05, MSB-06, MSB-07, MSB-10 and MSB-15 with predominant frequency less than 3.37 Hz and predominant period about 0.33–1.92 second.

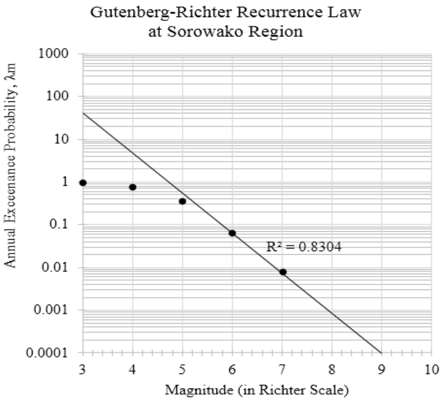

Figure 6. Relationship between AEP and M

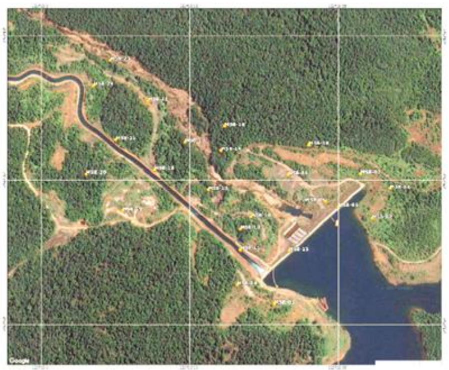

Figure 7. Microtremor measurement points

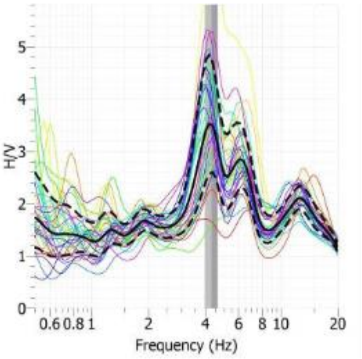

Figure 8. Example of HVSR graph

TABLE 2. Result of microtremor measurement

Point	f_0	A_0	K_g	T_0
MSB-01	3.49	4.94	6.99	0.29
MSB-02	3.98	4.67	5.48	0.25
MSB-03	3.94	6.55	10.89	0.25
MSB-04	2.99	7.78	20.24	0.33
MSB-05	0.81	5.83	41.96	1.23
MSB-06	0.92	3.28	11.69	1.09
MSB-07	2.52	3.35	3.46	0.40
MSB-08	3.37	4.79	6.81	0.30
MSB-09	4.08	3.06	2.30	0.25
MSB-10	3.03	11.47	43.42	0.33
MSB-11	3.55	6.25	11.00	0.28
MSB-12	3.84	7.70	15.72	0.26
MSB-13	6.36	2.65	1.10	0.16
MSB-14	4.14	3.51	2.98	0.24
MSB-15	0.52	2.77	4.29	1.92
MSB-16	4.30	3.51	2.87	0.23
MSB-17	6.17	4.28	2.97	0.16
MSB-18	3.75	4.75	6.02	0.27
MSB-19	0.64	3.59	17.42	1.56
MSB-20	1.91	1.98	2.05	0.52
MSB-21	13.68	3.96	1.15	0.07
MSB-22	0.82	1.35	0.28	1.22
MSB-23	0.61	1.97	2.24	1.64
MSB-24	0.69	0.69	10.80	1.45

The average of predominant period of soft rock at the site is represented by MSB-04, MSB-05, MSB-06, MSB-07, MSB-10 and MSB-15 about 0.88 second, therefore it is used in a calculation of attenuation relationship equation according to literature [6] as prescribed in Equation (5). The average of amplification value (A_0) about 4.36 times that means amplitudes of the horizontal waves are 4.36 times greater than amplitudes of the vertical waves; hence the ratio is used in an earthquake modeling.

After following Equations (1) to (4), the value of the magnitude for certain return period T years (in richter scale) are obtained as shown in the following Table 3.

TABLE 3. Magnitude for return period T years

Return Period, T	Magnitude for return period T years, X_t (in richter scale)
50	7.09
100	7.33
200	7.56
500	7.87
1,000	8.11
2,500	8.41
5,000	8.65
10,000	8.88

Following attenuation models of the ground motion according to literature [6], therefore by inputting the value of the magnitude (M) for respective return period T years within a determined radius R (distance from the source-to-site is 30 km), hence the PGA design after weighted by the weighting factors as prescribed in the logic tree (Figure 3), the PGA values of this research is obtained as follows:

TABLE 4. PGA design after weighted for T years

Return Period, T	Peak Ground Acceleration					
	10%	15%	15%	30%	30%	Total
	{1}	{2}	{3}	{4}	{5}	{6}
50	0.29	0.19	0.19	0.26	0.37	0.28
100	0.34	0.21	0.20	0.29	0.38	0.30
200	0.39	0.24	0.20	0.32	0.38	0.32
500	0.47	0.29	0.21	0.36	0.39	0.35
1,000	0.54	0.34	0.22	0.40	0.40	0.37
2,500	0.65	0.40	0.22	0.45	0.40	0.41
5,000	0.75	0.46	0.23	0.49	0.41	0.45
10,000	0.87	0.53	0.24	0.54	0.41	0.49

Note:
{1} Kanai (1966), {2} Donovan (1973), {3} Matuschka (1980), {4} Bore & Atkinson (2008), and {5} Campbell & Bozorgnia (2008) in Douglas, (2011) [6], and {6} Result of this research

The PGA values resulted in this research refer to certain return period of 50, 100, 200, 500, 1000, 2500, 5000 and 10000 years are 0.28g, 0.30g, 0.32g, 0.35g, 0.37g, 0.41g, 0.45g, and 0.49g respectively.

For the earthquake scenario at operating basis earthquake (OBE, with return period 500 years) the PGA value is 0.35g; for maximum design earthquake (MDE, with return period 5,000 years) the PGA value is 0.45g, and for maximum credible earthquake (MCE, with return period 10,000 years) the PGA value is 0.49g.

Referring to the classification of the earthquake risk level (Table 1), the earthquake scenario of OBE, MDE, and MCE for Batubesi Dam in which the PGA values ranging from 0.35 – 0.49g, is categorized as very high risk with modified Mercally intensity (MMI) scale about IX – X.

Alertness and due diligence on the condition of the existing dam should be taken into account to ensure its compliance of the current technical aspects with the new required standard facing updated seismicity para-meters in terms of OBE, MDE, and MCE earthquake design.

4. SUMMARY AND RECOMMENDATION

Sorowako region is located in a high seismic intensity activated by tectonic movement due to Matano fault as part of Palukoro fault system, constructing an elongated geological structures from Gulf Palu, Poso, Sorowako until Luwuk Banggai. About 89.53% of the earthquakes population sourced from a shallow crustal that means presenting a challenges in terms of engineering point of view especially for building and non-building structures including headworks and dams as well.

The new seismic design parameters for engineering purposes in terms of OBE, MDE, and MCE are 0.35, 0.45 and 0.49g, respectively. It should be applied to strengthen the existing dam that previously the seismic load designed just in 0.20g only.

Further field investigations i.e. geotechnical exploratory drilling (e.g. standard penetration test, full coring, undisturbed soil sampling, etc.) and geophysical tests (e.g. electrical resistivity tomography, shear-wave velocity, etc.) should be performed to obtain more detail data that can be used to correlate the ground profile one each other’s and recognizing physical and mechanical properties of the soil/rocks formation.

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6. REFERENCES

1 Kertapati, E.K., Setiawan, Y.B., Ipranta, “Earthquake Hazard Map of Indonesia”, Geological Research and Development Center, Ministry of Mining and Energy, Bandung, Indonesia, (1999).

2 Wangsadinata, W, “Seismic Resistant Design Standard for Building Structure”, Ministry of Settlement and Regional Infrastructure, Bandung, Indonesia, (2002).

3 Irsyam, M., Sengara, W., Aldiamar, F., Widi-yantoro, S., Triyoso, W., Hilman, D., Kertapati, E.K., Meilano, I., Asrurifak, M., Ridwan, M., Suhardjono, “Earthquake Hazard Map of Indonesia 2010 as Reference for Engineering and Design of Earthquake Resistant Infrastructures”, Ministry of Public Work, Jakarta, Indonesia, (2010).

4 Irsyam, M. Widiyantoro, S., Natawidjaja, D.H., Meilano, I., Rudyanto, A., Hidayati, S., Triyoso, W., Hanifa, N.R., Djarwadi, D., Sunarjito, L.F., “Sources and Earthquake Hazard Map of Indonesia 2017”, ISBN No. 978-602-5489-01-3, National Earthquake Study Center, Ministry of Public Work and Housing, Bandung, Indonesia, (2017).

5 Cipta, A., Robiana, R., Griffin, J.D., Horspool, N., Hidayati, S., Cummins, P., “A Probabilistic Seismic Hazard Assessment for Sulawesi, Indonesia”, the Geological Society of London, Special Publication, 441, April 26, (2016) http://sp.lyellcollection.org, [Online]. Available: http://doi.org/10.1144/SP441.6 [Accessed: Sept. 4, 2017].

6 Douglas, J., “Ground-Motion Prediction Equations 1964-2010”, BRGM Geoscience for a Sustainable Earth, BRGM/RP-59356-FR, February, (2011).

7 Nakamura, Y., “A Method for Dynamic Characteristic Estimation of Subsurface Using Microtremor on the Ground Surface”. Q.R. of R.T.I. 30-1, p. 25-33. (1989).

8 Jitno, H., “Short Course on Seismic Design of Earth and Rockfill Dams”. Inter-University Center, Intitut Teknologi Bandung, Bandung, Indonesia, (2016), unpublished.

9 Lunga, S., Minarto, E., Mantiri, S.Y.Y., “The Earthquake Risk Level Mapping at Jayapura City Based on Microtremor Measurement”, Spektra: Physics and Its Application Journal, Institut Teknologi Sepuluh November, Surabaya, Indonesia, Vol. 16, No. 1, June (2015).

Analysis and Evaluation of Privacy Protection Behavior and Information Disclosure Concerns in Online Social Networks

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Information Disclosure

چکیده

شبکه‌های اجتماعی برخط به بزرگترین زیربنا برای تعاملات اجتماعی مانند: برقراری ارتباط، به اشتراک‌گذاری تجربه‌های شخصی و تحویل خدمات تبدیل شده است. امروزه شبکه‌های اجتماعی به طور گسترده‌ای مورد استقبال مردم قرار گرفته‌اند. بیشتر تحقیقات درباره‌ی مدیریت حفاظت حریم خصوصی در شبکه‌های اجتماعی کاربران را به عنوان صاحبان اطلاعات در نظر می‌گیرند. با این حال، افراد نمی‌توانند حریم خصوصیشان را کنترل کنند و این کنترل توسط گروهی تعیین می‌شود. استفاده از شبکه‌های اجتماعی برخط نگرانی‌هایی در مورد حریم خصوصی مرتبط با داده‌های شخصی برخط به وجود آورده است. با توجه به مطالعات انجام شده، تابه امروز تلاش‌های زیادی برای حفاظت از محرمانگی و امنیت داده‌ها در شبکه‌های اجتماعی انجام گرفته است. امّا به‌نظر می‌رسد که درک مفهوم حفاظت حریم خصوصی برای مردم بسیار ضروری است. هدف این مقاله تجزیه و تحلیل ابزارها و الگوریتم‌هایی است که به نگرانی‌های حفاظت حریم خصوصی و موقعیت امنیتی داده‌ها در شبکه‌های اجتماعی میان بزرگسالان، نوجوانان و کودکان پرداخته‌اند. این ابزارهای آماری و الگوریتم‌ها داده‌های جمع‌آوری شده را بررسی کردند. نتایج مرور بر ادبیات نشان داد که بیشترین پراکندگی در این زمینه مربوط به سال 2014 است. علاوه براین، روش نظرسنجی بیشترین روش مورد استفاده برای جمع‌آوری اطلاعات در این تحقیقات بوده است.

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