NRIAG JOURNAL OF ASTRONOMY AND GEOPHYSICS
2019, VOL. 8, NO. 1, 84–96
https://doi.org/10.1080/20909977.2019.1617551

Site effect estimation using Horizontal to Vertical (H/V) spectral ratio technique in Nile Delta, Egypt

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ABSTRACT

Study of the seismic wave amplification is very important, as a significant part of damage observed in destructive earthquakes around the world is due to local site effects.

The local site effect may cause amplification of seismic waves induced by earthquakes and plays an important role in site-specific ground motion predictions and seismic hazard assessment. The aim of this study is to determine a seismic microzonation by using Nogoshi-Nakamura method experimental technique based on microtremor records. Horizontal to Vertical (H/V) spectral ratios were calculated on Nile Delta at 68 sites using the McSEIS-MT NEO Model 1134 McSEIS-MT NEO instrument. The site effect is typically represented by the resonance frequency (f_o) and the associated amplification of ground motion (A_o). The conclusions show the fundamental frequency (f_o) ranges from 1.1 to 1.5 at all points, and its corresponding H/V amplitude level (A_o) ranges from 3 to 6.3.

KEYWORDS

Microtremor; Nile Delta; HVSR Horizontal to Vertical; seismic microzonation; Predominant frequency

1. Introduction

The Nile Delta region is about 23,000 Km^2 forming one of the largest delta in the world. The slope direction is toward north with average slope about 1 m every 10 km. Its elevation varies from about 18 m above sea level in Cairo to zero at of Mediterranean Sea coast. The Nile Delta is very flat area (18 m above sea level near (Cairo)). Thickness of its sediments increases from South to the north direction. The width of the delta increases to the north direction.

The geological information that the delta body consists mainly of sand and clays; these layers contain several sand lenses and sand wedges, particularly toward the offshore part (Said, 1981, p. 1990). Mukhopadhyay and Bormann (2004) stated that in the soft soil sites, seismic energy gets trapped, leading to amplification of vibration that may increase damage to engineering or man-made structures.

The site effect is typically represented by the resonance frequency (f_o) and the associated amplification of ground motion (A_o). Mukhopadhyay and Bormann (2004) stated that the resonance phenomenon may occur when the natural period of the buildings and/or structures matched with the resonance frequency (f_o) of the site, and structures will have the maximum probability of getting damaged. The empirical method (Horizontal to Vertical (H/V) spectral ratios; Nakamura (1989)) is typically applied in microzonation studies and in the investigation of the local response of specific sites. The main target of this study is to determine the resonance frequency (f_o) and amplification of ground motion (A_o) in Nile Delta, in order to reduce the seismic Hazard.

1.1. Basement rocks

Sherief (1972) reported that the depth of the basement rocks is more than 1800 m in the southern part of the Nile Delta and increases northward to reach more than 7600 m. According to Ginzshurg and Gwirtzman (1979), the depth to basement surface from geophysical interpretation and well data is more than 10 km in the onshore part of the north and north east of the Delta area. A similar depth to basement was estimated in the eastern extension of the Delta and in northern Sinai through their north-west and south-east structural cross sections based on reflection and refraction seismic shooting and well data. From the wells data drilled in the north part of Nile Delta, and according to El- Fawal (1979), the depth to bed rock in Nile delta is varied (Table 1).

1.2. Comparison between the microtremors records using different types of instruments

The microtremors signals recorded at Helwan seismic station site by different instruments, such as McSEIS (Figure 1), TRILLIUM compact Broadband Seismometer, Ref Tek Strong Motion Accelerometer Model 130 SMA and TITAN Strong Motion Accelerometer are compared.

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Table 1. The maximum depth to basement in different regions.

	Name of well	Lat	Long	Max. depth (m)
1	Rosetta	31.69	30.56	2764–2767
2	Qawasim	31.39	30.876	3564–3573
3	Abu madi	31.39	31.356	3590–3596
4	Abadiya	31.40	31.00	3600–3605
5	Sidi Salem	31.27	30.78	3811–3814
6	Mataria	31.19	32.037	3812–3815
7	Kfr el-Sheikh	31.12	30.94	4181–4183
8	Sw. Bilqas	31.20	31.35	4410–4416

Table 2. Results obtained after analysis of data for different instruments.

Instrument	H/V
TRILLIUM	1.6
Ref Tek	Not clear
McSEIS	1.22
TITAN	0.86

Figure 1. McSEIS-MT NEO model 1134 McSEIS-MT NEO instrument.

Continuous recording for 14 h using the above mentioned instruments was performed. Figures 2–5 show the results obtained from the analysis data recorded by them. Comparing the data recorded by McSEIS-MT NEO Model 1134 with the other three types of instruments and also comparing the calculated spectral ratios (H/V) for each instruments, the results, Table 2 show that the McSEIS-MT NEO Model 1134 is the most suitable device to measure and calculate the resonance frequency (f_o) and also the amplification related to this frequency, A_o, because its frequency bands ranges from 0.1 to 200 Hz also it has a data acquisition instrument designed for microtremor array measurement and vibration monitoring.

Figure 6 shows the results of H/V for an earthquake occurred in 28 December 2013 at 3.22 pm recoded by Ref Tek Strong Motion Accelerometer Model 130 SMA located at Anshas Station. It is clear that Ref Tek Strong Motion Accelerometer Model 130 SMA can be used to determine the resonance frequency (f_o) and amplification using earthquakes data, but not suitable for calculating the resonance frequency (f_o) and amplification using Microtremor data.

1.3. Field survey and data acquisition

Several selected cities and locations in the Nile Delta particularly the high populated area are studied here. Most of the observation points were chosen inside the schools.

For high quality data, some precautions were considered for the recording device installations as follows:

1- Flat surface site.

2- The operation time on sites (schools) must be carried out during less crowded time and away from vehicle traffic.

3- For site of soft soil, we must lay a rigid object such as concrete plate under the instrument.

4- The instrument is oriented in the N-S, E-W and vertical directions.

5- Avoid setting the sensor on soil saturated with water.

6- Avoid recording near structures, such as buildings, trees, etc.

7- Avoid recording above underground infra structures, such as car parks, pipes, etc.

8- Avoid recording near construction machines, industrial machines, pumps, etc., and car engine must be off during recordings.

9- Recording duration of microtremor in Nile delta should not be less than 20 min.

10- Avoid recording in windy weather (faster than approx. 5 m/s).

11- Avoid recording under heavy rain weather.

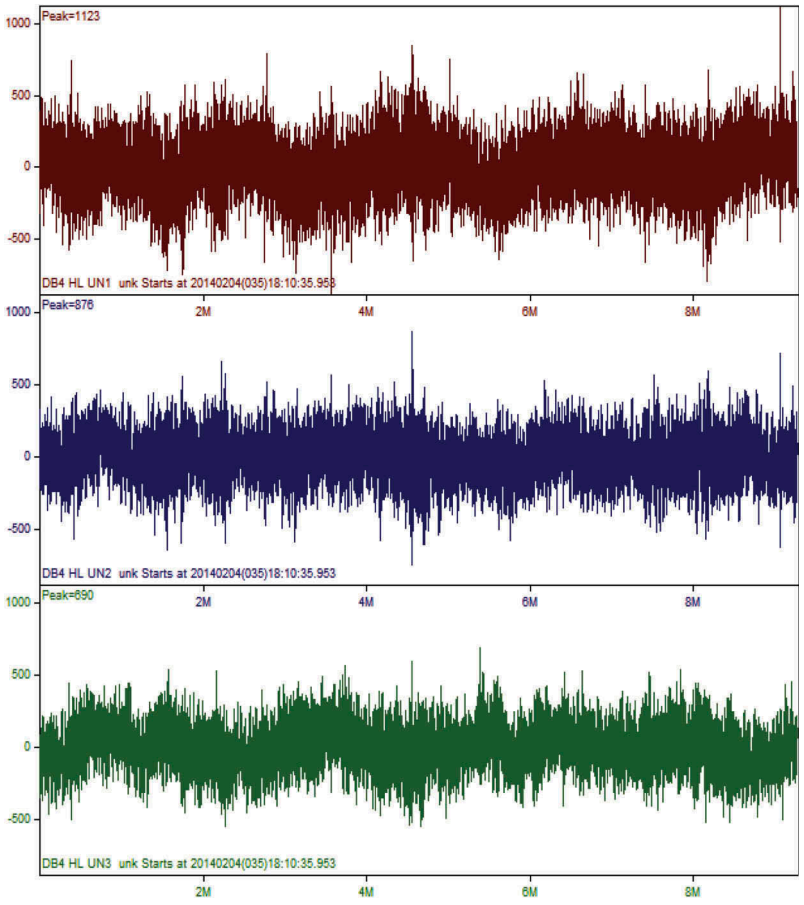
The instrument used in the present study in Nile Delta, Egypt is McSEIS-MT NEO MODEL 1134 McSEIS-MT NEO. This device was used for microtremors measurements for obtaining natural frequency, vibration characteristics of the ground and also vibration properties of the structure objects i.e. important building. The duration time of records varies according to the expected frequency. Table 3 illustrates the recommended recording duration.

Data of 68 sites in Nile Delta region and Helwan seismic station sites were collected.

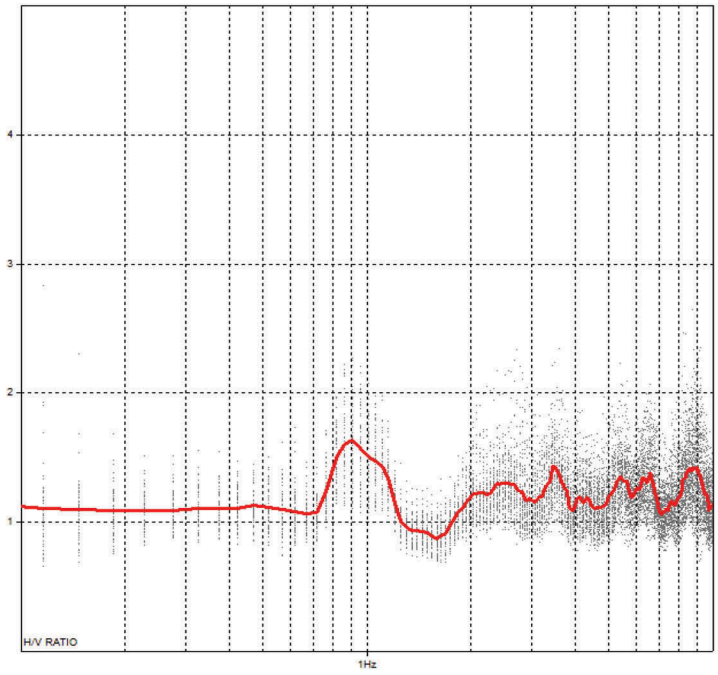
Figure 7 illustrates the location of the observations sites. The main objective of current study is to determine the site effects in terms of fundamental resonance frequency (f_o), which is associated with amplification of ground motion (A_o).

2. Data analysis

The raw microtremors data (Figure 8) are collected and analysed using SeisImegar MT-NEO software programme. This programme has the following functions:

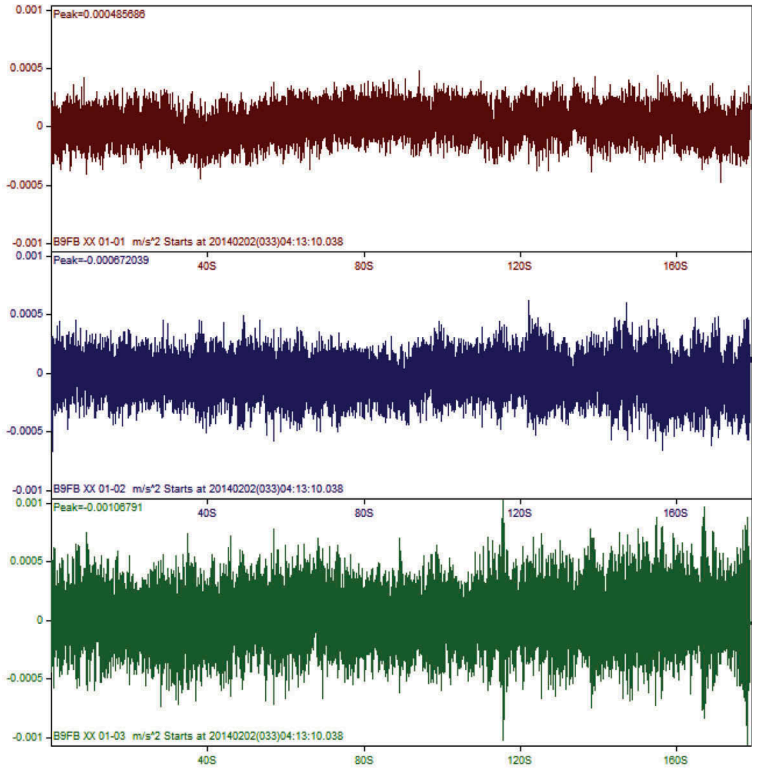


(a)

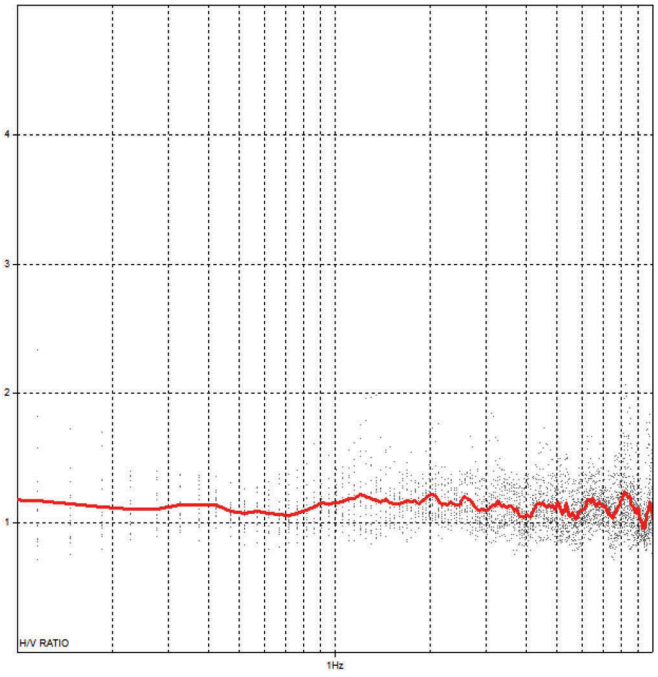


(b)

Figure 2. TITAN compact broadband seismometer.
(a) Record; (b) H/V value.



(a)



(b)

Figure 3. Ref Tek strong motion accelerometer model 130 SMA.
(a) Records; (b) H/V value.

1- Read and display all the record data
2- Calculate and edit dispersion curve
3- Calculate the H/V Fourier spectral ratio for the three components of all the record
4- Invert the data for a one dimensional Shear wave velocity

3. Results

Sixty eight sites were selected for microtremors measurements in Nile Delta area. Figures 9–17 show H/V Spectral ratio in the study area. Table 4 summarises all the parameters; Name, latitude, Longitude, Elevations, H/V and amplification value for a number of sites.

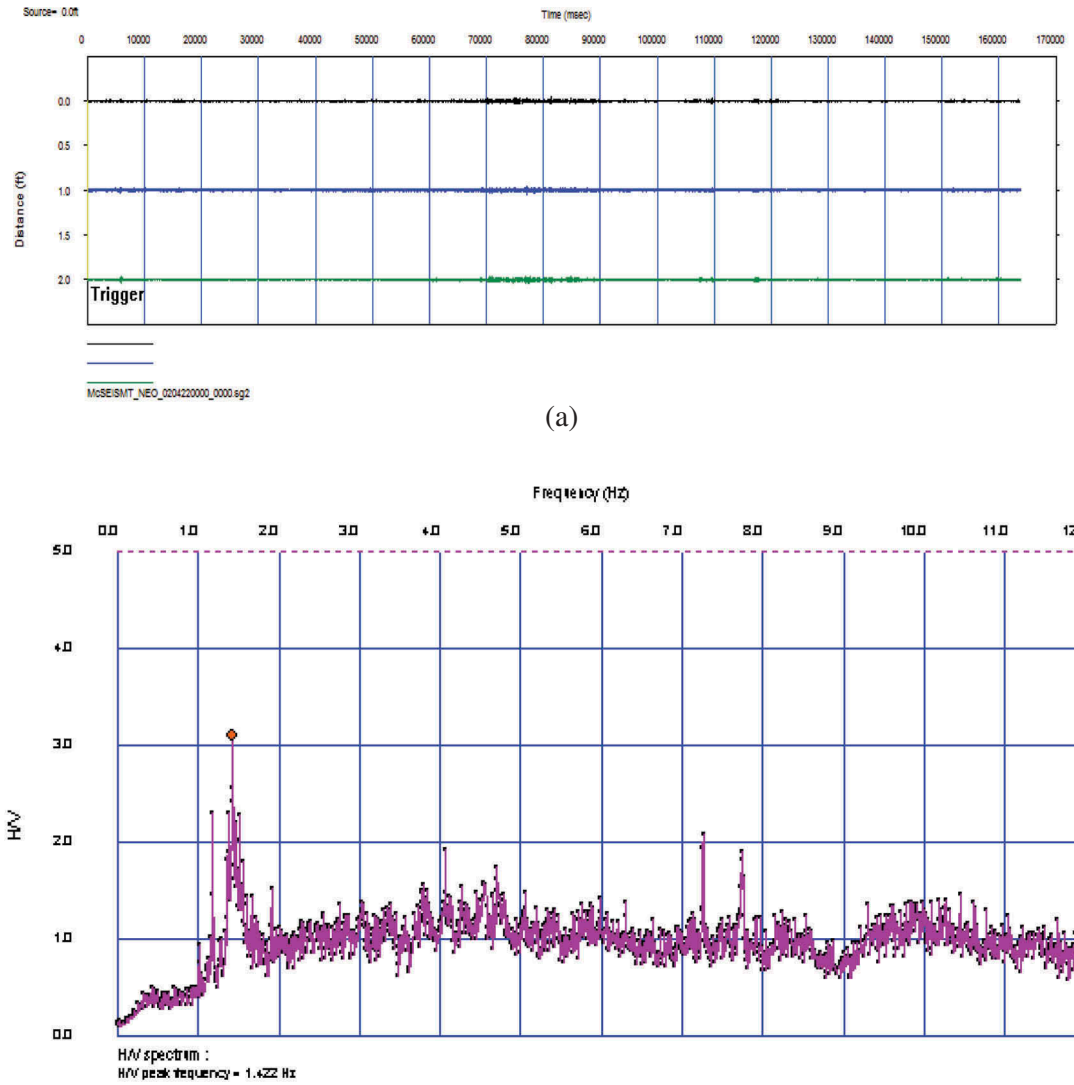


Figure 4. McSEIS-MT NEO model 1134 strong motion accelerometer.
(a) records; (b) H/V value.

Contour map of extrapolated Resonance frequency (f_o) of Nile Delta area is shown in Figure 18. This map demonstrates the following:

A- The value of resonance frequency (f_o) is nearly similar in all sites in Nile Delta region, especially in the central part of Nile Delta. From the results we can conclude that the value of resonance frequency (f_o) is nearly similar at all the points range from 1.1 to 1.3 in the area controlled by the Nile branches, this is due to depth to bedrock is nearly the same in all these area. These results are agreed with Parolai et al. (2001). The resonance frequency (f_o) is inversely proportional with depth to basements.

B- According to Alexandria Governorate, the resonance frequency (f_o) values varies from points to points from 0.9 to 1.8.

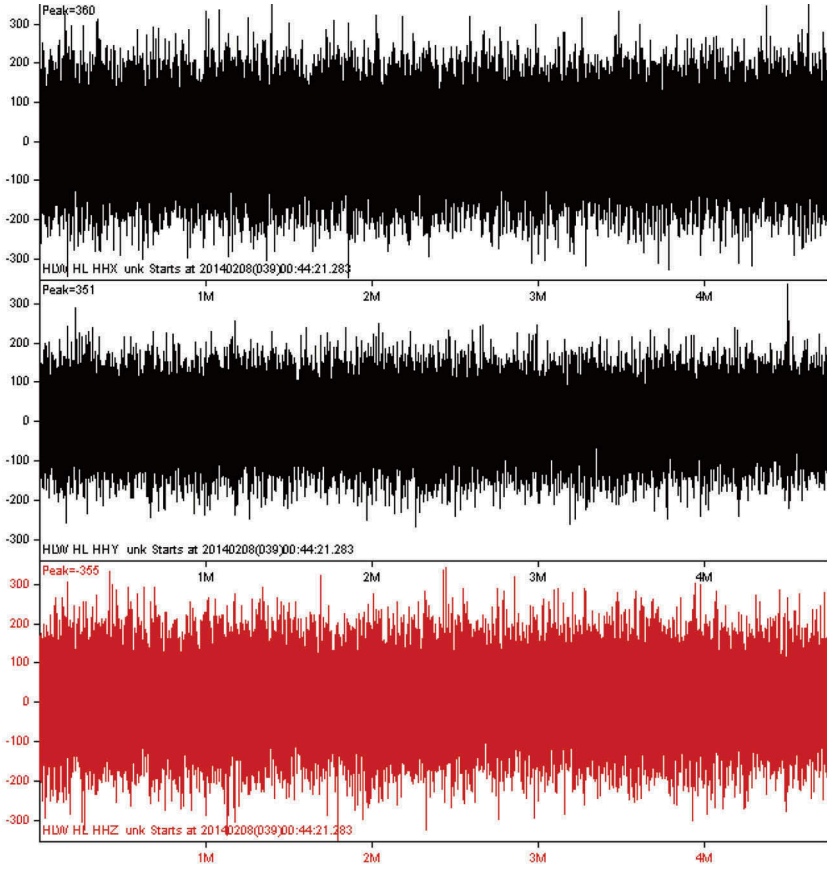
A extrapolate contour map of the associated amplification of ground motion (A_o) of Nile Delta Area is shown in Figure 19. This map demonstrates the following:

A- The value of A_o in the Central, Eastern and Northern part of Nile Delta is the same in most sites (from 4 to 5).

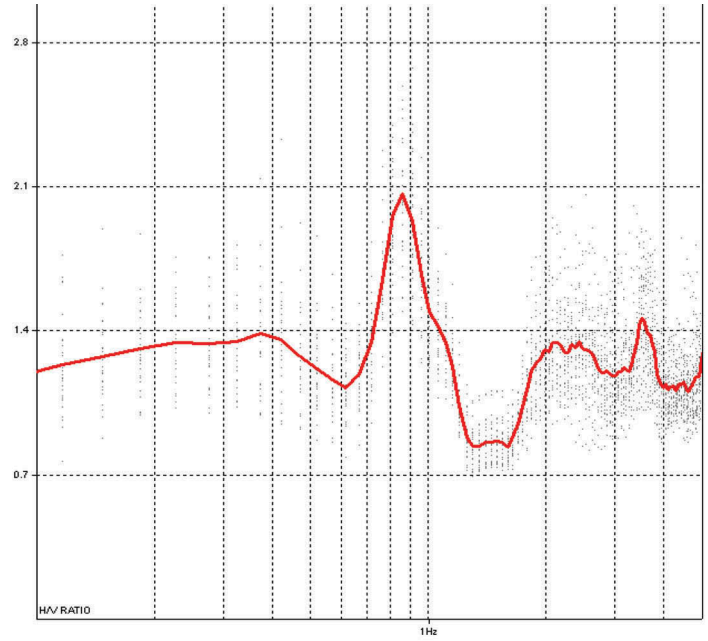
B- The value of A_o in the north western part of Nile Delta and Alexandria is nearly similar (from 5 to 7). This is may be one of the reasons for the building collapse in Alexandria governorate.

4. Conclusions

In this study, the H/V spectral ratio has been studied at different governorates in Egypt. The mean value of fundamental frequency (f_o) and its corresponding H/V amplitude level (A_o) in Nile Delta Egypt are summarised in Table 5.



(a)



(b)

Figure 5. TRILLIUM strong motion accelerometer.
(a) Records; (b) H/V value.

The present study is important for seismic microzonation mapping. Ambient vibrations H/V spectral ratio technique concludes zones of high potential damage (amplification of ground motion) in the study area. This technique performs fast data acquisition, relatively low cost and reliable results.

Comparing the results with El-Eraki et al. (2012), we found that the fundamental frequency (f_o) in Zagazig city in eastern Nile Delta ranges from 0.5 to 1.7 Hz and amplitude level (A_o) ranges from 1 to 6. This result presents that in zagazig city is 0.9 Hz and amplitude level (A_o) is 4. At Elshrqia Governorate,

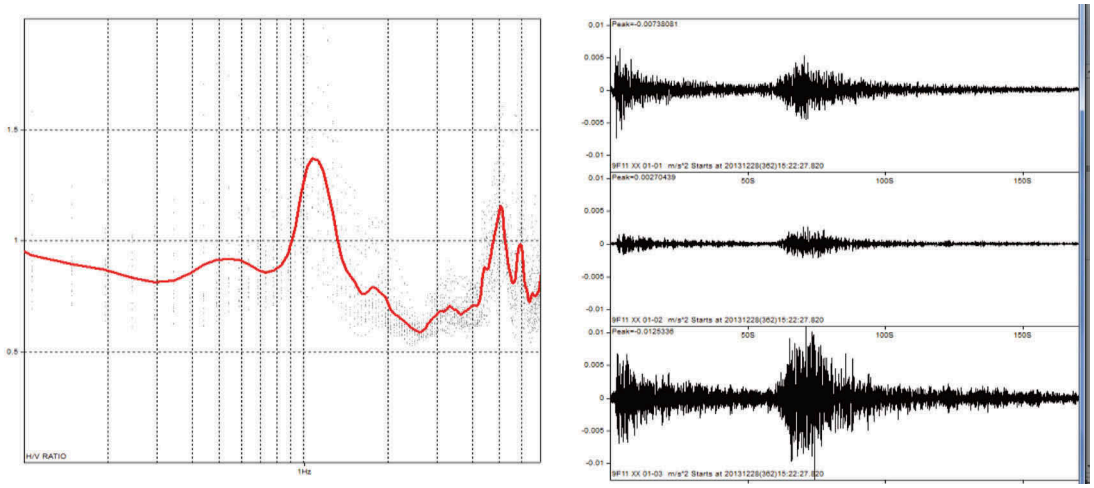


Figure 6. (a) Records and (b) H/V of Anshas station using the Ref Tek instrument to the 2013-12-28 earthquake.

Table 3. Recommended recording duration for the target frequency.

Expected frequency f_o (Hz)	Minimum record duration (min)
0.2	30
0.5	20
1	10
2	5
5	3
10	2

the fundamental frequency (f_o) varies from 0.9 to 1.5 Hz and A_o varies from 4 to 6. Fergany et al. (2009) studied the central part in Nile delta from North to South and reported that the fundamental frequency (f_o) varies from 0.89 to 1.21 Hz and A_o varies from 2.1 to 5.8, which are consistent with results of the present study.

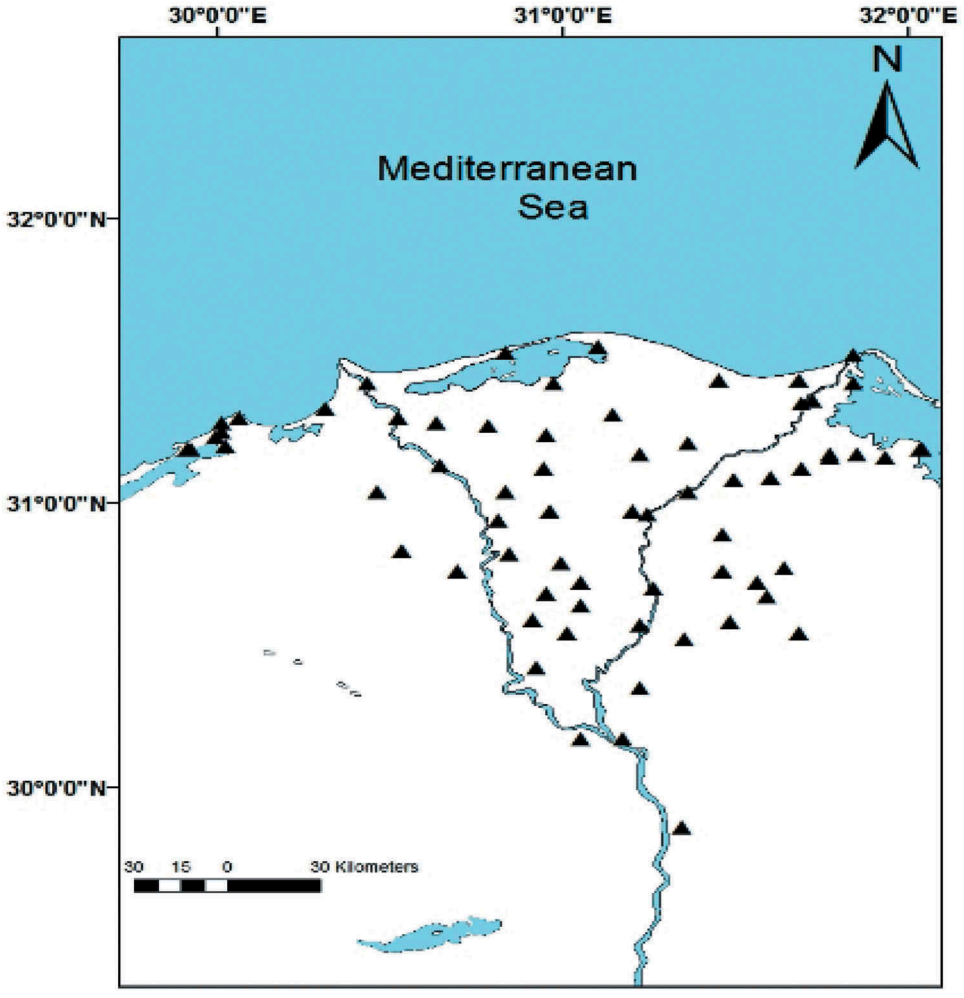


Figure 7. Location of noise points.

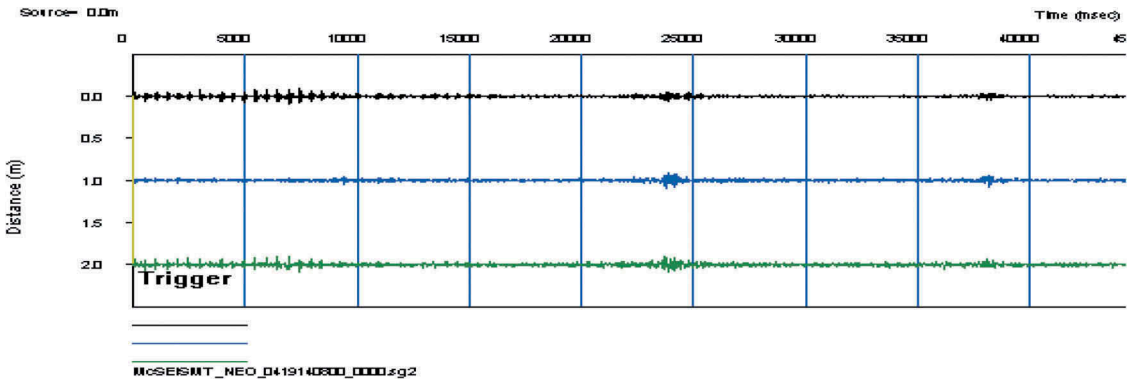


Figure 8. Example of data a recorded by the Microtremor instrument.

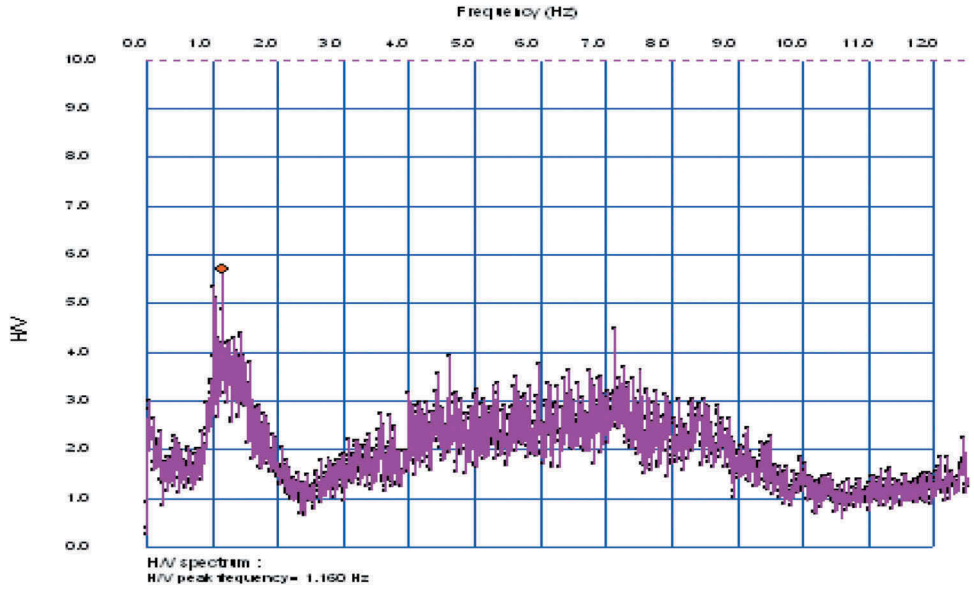


Figure 9. H/V peak frequency is 1.16 in Hamoul site – Kfr El Sheikh.

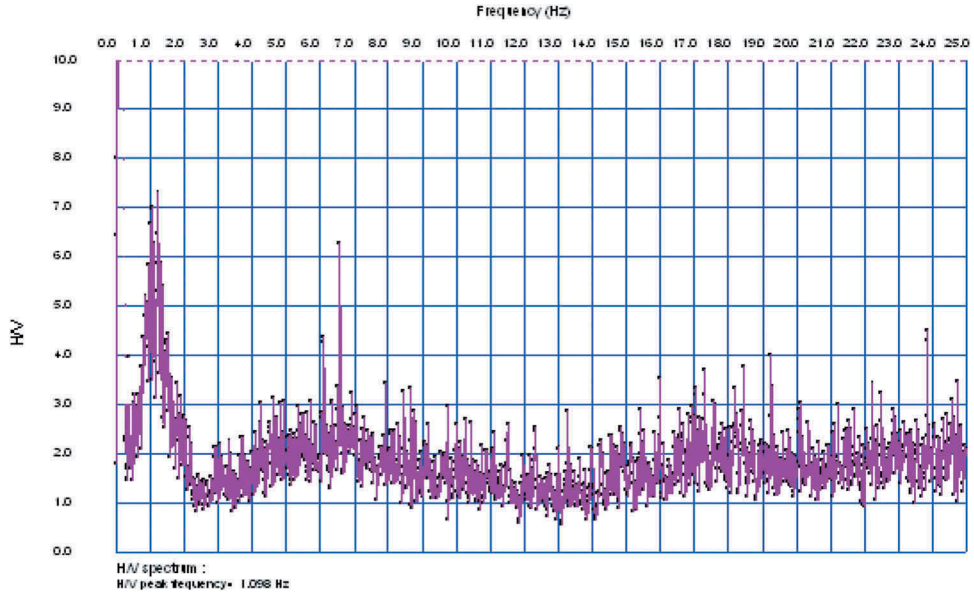


Figure 10. H/V peak frequency is 1.098 In Qleen site – Kfr El Sheikh.

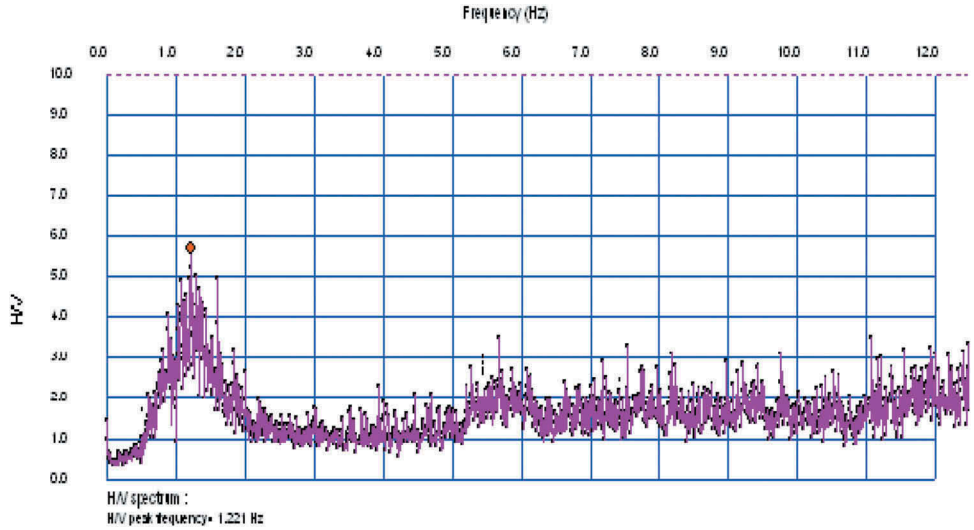


Figure 11. H/V peak frequency is 1.221 in Dsouk site – Kfr El Sheikh.

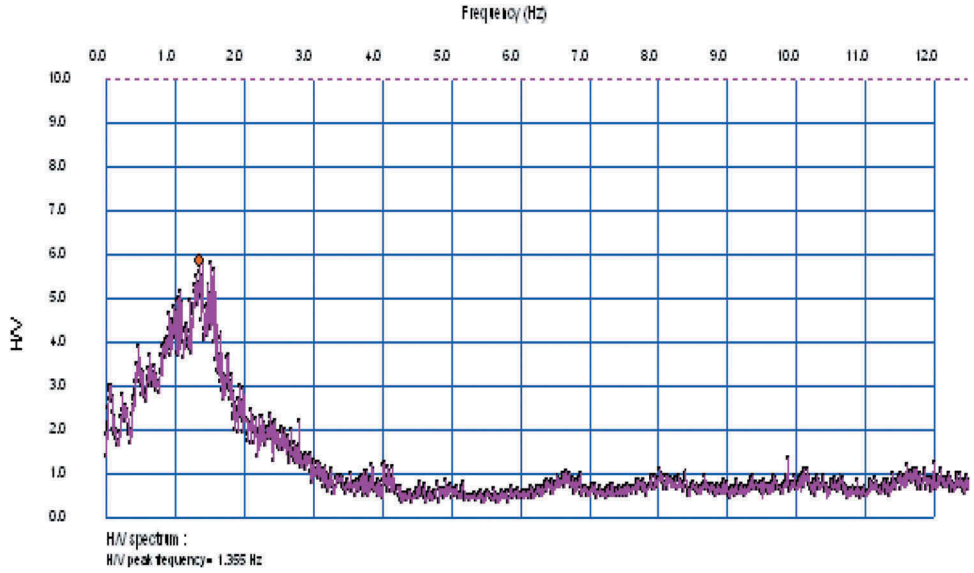


Figure 12. H/V peak frequency is 1.355 in Sidi Salem site – Kfr El Sheikh.

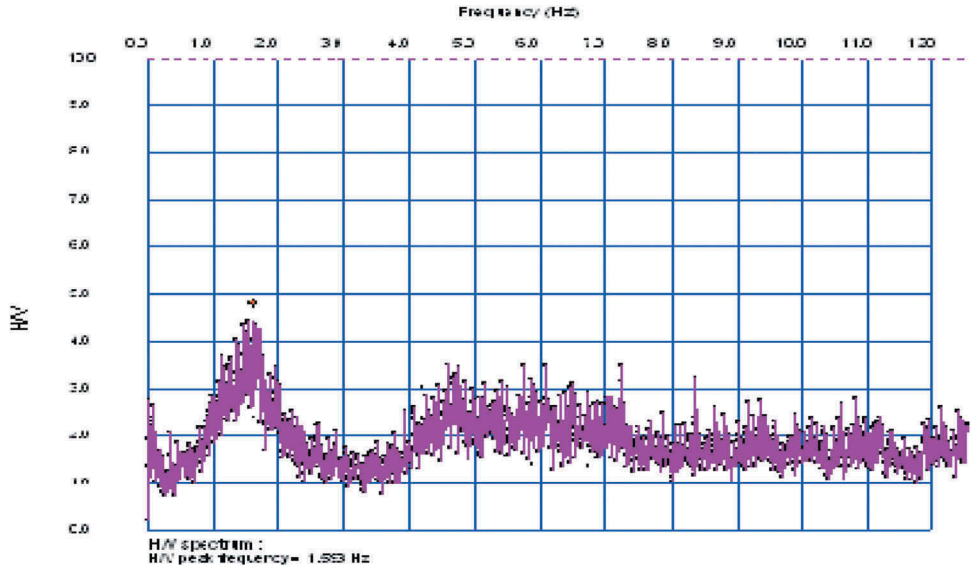


Figure 13. H/V peak frequency is 1.5 in Minia El Kamh – Zagazig.

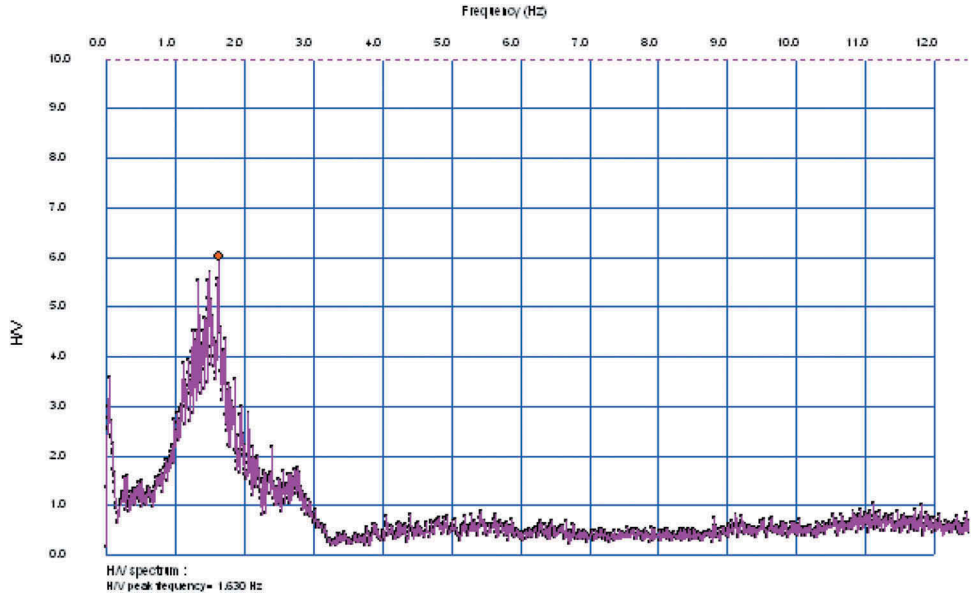


Figure 14. H/V peak frequency is 1.63 in El Gamalia – El Dkhlia.

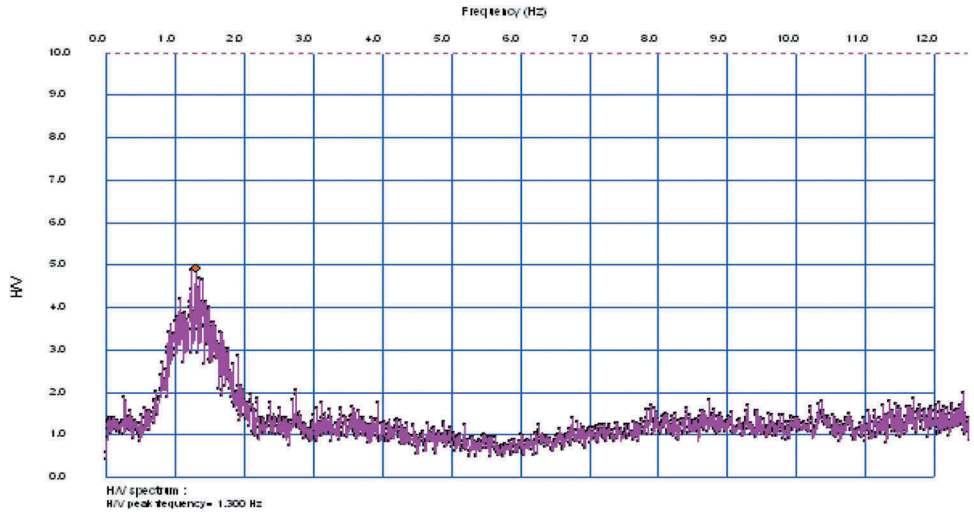


Figure 15. H/V peak frequency is 1.3 in Al Senblween – El Dkhlia.

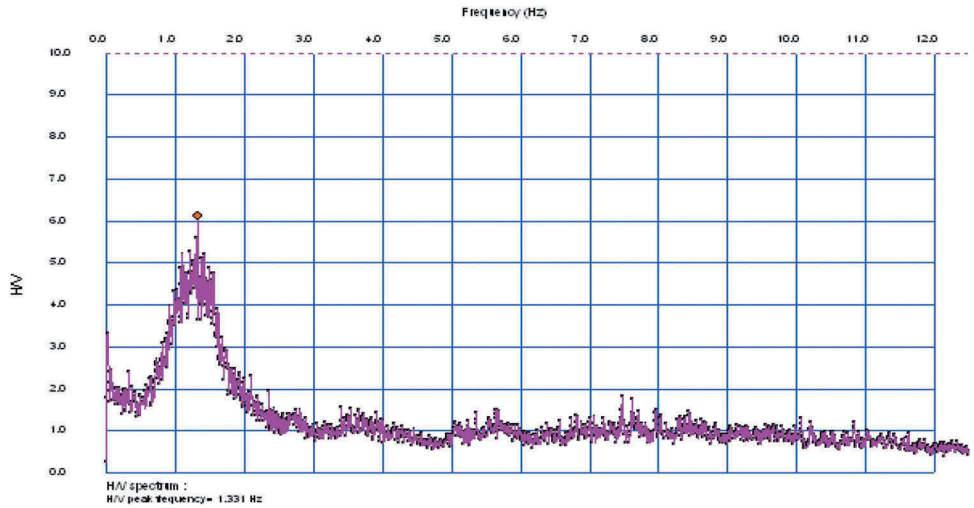


Figure 16. H/V peak frequency is 1.331 in Al Khrqania site.

Table 4. Results of microtremors in the study area for all observation points.

No.	Name	Lat.	Long.	Elevation	H/V	Amplif.	Governorate
1	University	31.19	29.91	1.1	1.59	6	Alex
2	Abees (A)	31.20	30.02	1.3	1.811	6	Alex
3	Suof (A)	31.23	29.99	1.1	1.808	7	Alex
4	Zraa (A)	31.25	30.01	1.5	1.629	7.3	Alex
5	El Mountazaa	31.28	30.01	1.4	1.08	5.5	Alex
6	Mamoura	31.30	30.06	1.8	0.955	7	Alex
7	El Hadraa	31.19	29.92	1.2	1.62	5	Alex
8	Helwan	29.86	31.34	121	1.508	3	Cairo
9	East Damietta	31.42	31.84	0.1	1.27	4	Damietta
10	Elsenania	31.43	31.45	6.2	1.2	4	Damietta
11	Ras el Bar	31.52	31.84	2.1	1.13	5	Damietta
12	Frescour	31.36	31.72	1.0	1.237	4	Damietta
13	Kfr Sad	31.35	31.69	7.4	0.893	4	Damietta
14	New University	31.43	31.68	1.3	1.385	6	Damietta
15	Rasheed	31.42	30.43	1.2	1.1	4	El Behira
16	Edco	31.33	30.31	1.3	1.3	4	El Behira
17	Edfina	31.30	30.52	3.8	1.2	5	El Behira
18	Dmnhour	31.04	30.46	4.5	1.15	6	El Behira
19	Dlengat	30.83	30.53	8.8	0.989	6	El Behira
20	Kom Hmada	30.76	30.69	19.7	1.038	5	El Behira
21	Tanta	30.79	30.99	4.2	1.3	4	El Grbia
22	Meet gazal (A)	30.72	31.05	5.2	1.3	4	El Grbia
23	Kfr El Ziat	30.82	30.84	6.1	1.2	4	El Grbia
27	EL Mahalla	30.97	31.20	3.9	1.204	4	El Grbia
28	Smnoud(A)	30.96	31.24	7.1	1.6	5	El Grbia
24	Basuon	30.94	31.81	5.9	0.958	3	El Grbia
25	Zfta	30.70	31.26	7.3	1.111	4	El Grbia
26	Shnta Elhagar	30.64	31.05	13.3	1.142	5	El Grbia
29	Qtour	30.97	30.96	2.2	1.314	4	El Grbia
30	University	30.58	31.48	15.5	0.9	4	El Shrqia
31	Abu Hammad	30.54	31.68	8.9	1.02	4	El Shrqia
32	Diarb Negm	30.76	31.46	4.1	1.35	4	El Shrqia
33	El Ebrahimia	30.72	31.56	11.0	1.43	5.5	El Shrqia
34	Kfr Saqre	30.77	31.64	5.2	1.1	5	El Shrqia
35	Hihia	30.67	31.59	4.3	1.25	6	El Shrqia
36	Minia El Kamh	30.52	31.35	12.3	1.5	4	El Shrqia
37	Mataria	31.19	32.04	1.8	1.0	5	El Dkhlia
38	Mataria	31.19	32.03	2.4	1.06	6	El Dkhlia
39	EL Manzalla	31.16	31.93	1.2	1.1	4	El Dkhlia
40	El Gamalia	31.17	31.85	17.9	1.63	5	El Dkhlia
41	El Courdy	31.17	31.77	10.1	1.1	4	El Dkhlia
42	Minia Elnassr	31.12	31.69	3.5	1.1	7	El Dkhlia
43	Dkrness	31.09	31.60	10.5	1.171	5	El Dkhlia
44	Mhala damana	31.08	31.49	7.2	0.9	4	El Dkhlia
45	El Senblween	30.89	31.46	5.4	1.3	5	El Dkhlia
46	University	31.04	31.36	4	1.24	4	El Dkhlia
47	Plqass	31.21	31.36	5.1	1.1	4	El Dkhlia
48	El Khrqania	30.17	31.17	32.1	1.26	6	El Qluobia
49	Moshtohr	30.35	31.22	27.7	1	6	El Qluobia
50	Niklla	30.17	31.05	13.1	1.213	4	El Qluobia
51	Shenta Elhagar	30.64	31.05	9.9	1.36	4	El Monofia
52	Talla	30.68	30.95	14.9	0.995	5	El Monofia
53	El Shohadda	30.59	30.91	11.8	1.2	3	El Monofia
54	Meet Bakhom	30.57	31.22	6.6	1.173	4	El Monofia
55	Shbeen el Koom	30.54	31.01	7.1	1.245	3	El Monofia
56	Kamshosh	30.42	30.92	11.5	1.121	4	El Monofia
57	Billa (A)	31.17	31.22	22.7	1.215	5	Kfr el Sheik
58	El Hamoul	31.31	31.14	3.6	1.160	6	Kfr el Sheik
59	El Riaad	31.24	30.95	2	1.28	4	Kfr el Sheik
60	Kfr el Sheik Hospital	31.12	30.94	9.9	1.037	5	Kfr el Sheik
61	ElAgozeen	31.16	31.77	4.5	1.269	3	Kfr el Sheik
62	Qleen	31.04	30.83	2.7	1.1	5	Kfr el Sheik
63	North Coast	31.53	30.83	1.8	1.203	4	Kfr el Sheik
64	Palteem	31.55	31.10	4.2	1.219	4	Kfr el Sheik
65	Dsouk	31.13	30.64	7.1	1.221	5	Kfr el Sheik
66	El Ghnaym	31.28	30.63	6.8	1.363	4	Kfr el Sheik
67	Sidi Salem	31.27	30.78	18.7	1.355	6	Kfr el Sheik
68	Ezbt El Sokna	31.42	30.97	1.3	1.325	6	Kfr el Sheik

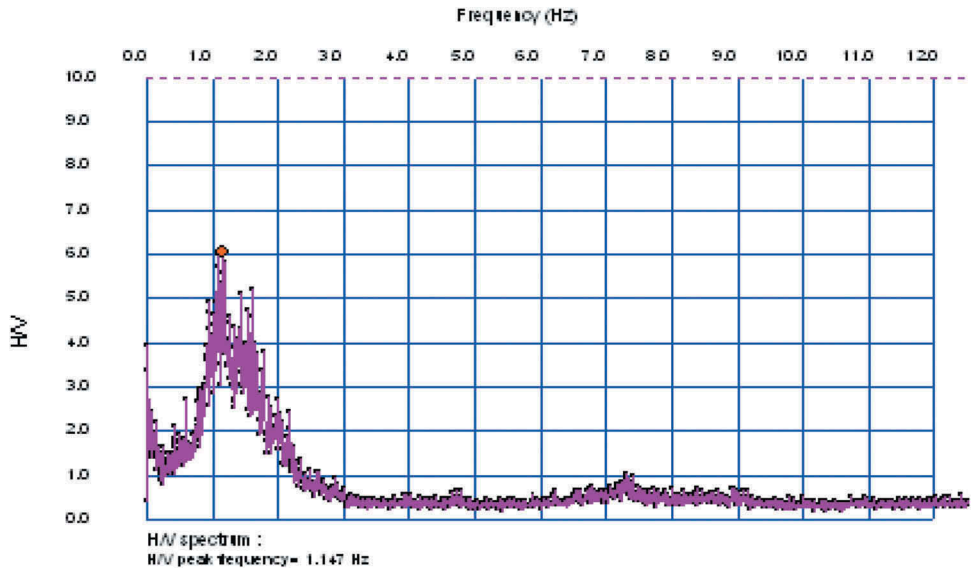


Figure 17. H/V peak frequency is 1.147 in Damanhur site.

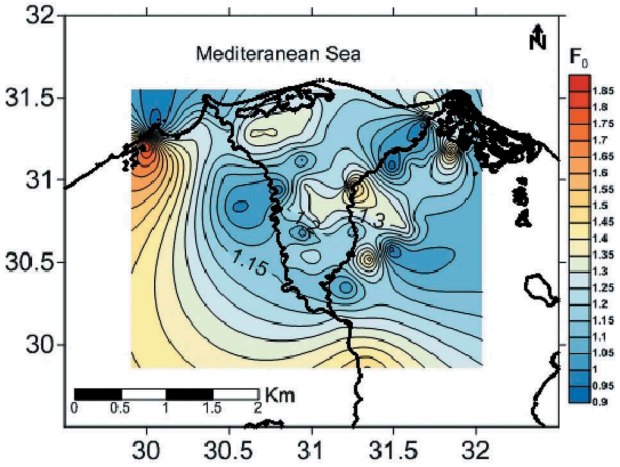


Figure 18. Extrapolate resonance frequency (f_o) map of Nile Delta Area.

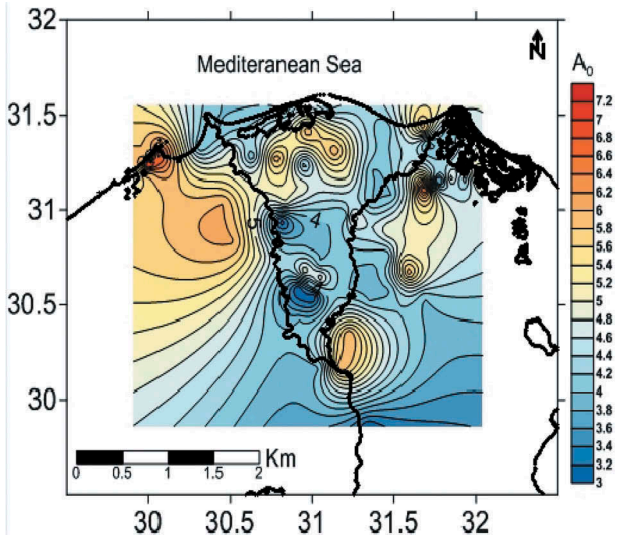


Figure 19. Extrapolate associated amplification of ground motion (A_o) of Nile delta area.

Table 5. The values of fundamental frequency (f_o) and amplification level (A_o) for different governorates.

No.	Governorate (area)	No. of locations	f_o	A_o
1	Alexandria	7	1.34	6.25
2	Helwan	1	1.508	3
3	Domietta	6	1.185	4.5
4	El Bohira	6	1.1	5
5	El Gharbia	9	1.24	4.1
7	El Shrqia	7	1.21	4.64
8	El Dkhlia	10	1.15	4.8
9	El Monofia	6	1.15	5.3
10	Kfr el Shik	10	1.18	3.8
11	Elqaluobia	3	1.23	4.75

Acknowledgments

We would like to express our appreciations to all members of Seismology Department. National Research Institute of Astronomy and Geophysics (NRIAG), specially Dr Soud Abd Elhady.

Disclosure statement

No potential conflict of interest was reported by the authors.

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