Reduction of Accelerated Sea Level Rise Problem by Using Global Desalination of Sea Water as a Mitigation Measure

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Abstract: Sea level rise (SLR) causes high threats and can deteriorate the coastal area ecosystem. Many studies had been carried out to alleviate SLR problem, but the problem still exist. This present study assesses the possibility of using engineering mitigation measures, like desalination plants, as a possible solution for the SLR problems. It presents a vision for decision makers; using globally the desalination of sea water to balance the expected increase in sea level. The aim of this paper also is to demonstrate the average rate of global sea level rise (GSLR) and the expected values in 2050, and 2100. For achieving the goals of this research, the global surface water area of seas and oceans, the rate of change of global desalinated water, the expected global sea level, and the expected global desalinated water should be calculated. Data from 128 sea level gauge stations all over the world, for more than 75 years for each station were collected. Also the sea level data from gauge stations in Egypt, at Nile Delta (Port Said, Rosetta, Burullus, Alexandria and Damietta) had been collected, for years from 1925 to 2017. Two scenarios for SLR in accordance with intergovernmental panel on climate change (IPCC), 1.0 m and 1.8 m rise in sea level, were taken as comparison values, for the calculated average rate of change in SLR of the present study values. The data of global desalination and global surface area of water had been collected also. The average rate of GSLR for more than 75 years are 0.58 mm/year for the actual present measured data, for 95% confidence interval (CI) of sea level rise is 0.05 mm/year to 1.11 mm/year. Analysis of data and calculations of the acceleration of driving force which affect sea level at different local stations showed that for Port Said, Burullus, Damietta, and Alexandria gauge stations, for long time until 2100, the accelerations are 0.031 mm yr^{-2}, 0.01 mm yr-^{2}, and 0.441 mm yr^{-2} and 0.027 mm yr^{-2}, respectively. Comparing the present accelerations of local gauge stations at Port Said, Burullus, Damietta, and Alexandria for expected accelerations to drive sea level to be 1000 mm and 1800 mm above present mean sea level, the accelerations are 2.57 times the present to reach 1000 mm, and 5.16 to reach 1800 mm for Port Said gauge station, but for Burullus, Damietta, and Alexandria gauge stations the accelerations are (8.946), (0.17), and (3.19) times the present acceleration to reach 1000 mm, and (5.158) for Port Said, and (16.94) for Burullus, but for Damietta, and Alexandria are (0.36), and (6.14) times the present acceleration to reach 1800 mm. For short term, the results of data analysis showed deceleration for Burullus gauge station, and small acceleration for Rosetta gauge station. Analysis of data showed that, increasing of desalinated water, could contribute in reduction of SLR by (16.17 %, 24.25 %, and 48.5%) for year 2050, if the rate of change is (1.50, 1.0, and 0.5 mm/year). The contribution in reduction of the increase in GSLR and reducing level using desalination are (31.22 %, 46.83 %, and 93.65%) for year 2100, if the rate of change is (1.50, 1.0, and 0.5 mm/year). It is recommended that increasing desalination plants for production of seawater can be viable as a possible solution for sea level rise problems.

[Reda M. A. Hassan. **Reduction of Accelerated Sea Level Rise Problem by Using Global Desalination of Sea Water as a Mitigation Measure.** *Nat Sci* 2019;17(9):94-109]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 12. doi:10.7537/marsnsj170919.12.

Keywords: Global Desalination – Sea Level Rise –Engineering Mitigation Measure

1. Introduction

1.1 Sea Level Rise and (IPCC) Reports

According to the report of IPCC (1998), the sea level of world coastal areas would increase approximately30 cm and flood damages would increase by 36-58%. The most suffering areas due to the coastal inundation under enhanced SLR would be the lowland areas such as beach ridges, deltas, coastal plains, estuaries, mudflats, bays and lagoons. The increase in salinity of ground water, oceanic acidification and increased burden of vector borne and water borne diseases associated with extreme weather events are additional impacts. The thermal expansion of ocean water and the melting of continental ice, lead to an increase in the volume of the oceans with change in their mass, from which the rise in sea level can be evaluated IPCC (2001). In addition, IPCC (2007) stated that, an increase in global mean sea level during this century and beyond due to anthropogenic global warming is expected to continue. Measurements and analysis of tide-gauge data indicate a rate of global-mean sea level rise during the twentieth century recently updated to 17 cm (±5 cm) by the IPCC (2007). The global sea level will rise between 15 to 95 cm; moreover, recent measurements show that the rise in sea level is happening at a rate of about 1 to 2 millimeters per year, or about 100 millimeters in the last century.

1.2 Sea Level Rise and Uncertainty of Climate Acceleration

El-Raey (1994) simulated two scenarios of sea level rise (SLR) in Egyptian coastal delta area ranging between 0.50 m and 1.0 m. The study showed that if no action is taken, azone of about 30% of the city will be lost due to inundation, almost 2 million people will have to abandon their homes, 195,000 jobs will be lost and an economic loss of over $35 billion can be predicted over the next century. Additionally to Alexandria, the Rosetta and Port-Said cities are also vulnerable to the expected increase in sea level. The study concluded to the highest priority should be given to mitigate the effects of the increase in sea level essentially due to the anthropogenic activities. Frihy (2003) studied vulnerability and adaptation to sea level rise for the Nile delta-Alexandria coast of Egypt, the study concluded to the Nile delta coastal zones are not vulnerable to accelerated sea level rise at the same level. Based on multiple criteria the Nile delta-Alexandria coast can be classified into vulnerable (30%), invulnerable (55%) and artificially protected coastal stretches (15%). These criteria include local subsidence or uplifting, relative sea level rise (RSLR), land topography, high-elevated features such as dunes and ridges, beach-face slope, width of lagoon barriers, eroding and accreting coastlines and protection works. Furthermore, the study assessed the long-term relative sea level rise and subsidence rates along the Nile delta and Alexandria coasts. Statistical analysis of long-term tide gauge data recorded at Alexandria, Burullus and Port Said with values of 1.6, 1.0 and 2.2 mm yr^{-1}, respectively. The values of relative sea level rise and long-term subsidence rate obtained from age dated sediment core sections are inconsistent: long-term subsidence appears to be larger (maximum of 7 mm yr^{-1}). Emery et al. (1988) reported an uplift of Alexandria using a short time series of annual tide gauge records by a rate of - 0.7 mm yr^{-1}because of geotectonic uplift. Many studies proposed avoiding the development near the coastal areas is the best alleviation measure. Measures that can be taken to save the coastal regions are the creation of wetlands or mangroves and construction of engineering works and services like dikes or coastal barriers to diminish the effects of sea level increase along the susceptible areas. Finally, suitable policy decisions and adaptive responses can be established, in order to mitigate SLR. On local and regional scales, sea level is also affected by vertical land motions and local climate, and oceanographic changes. Geological data from salt marshes show a clear acceleration from relatively low rates of sea level change during the past two millennia (order 0.25 mm yr^{-1}) to modern rates (order 2 mm yr^{-1}) sometime between 1840 and 1920 Kemp et al. (2011). The fourth assessment report of (IPCC) estimated that more modern rates of sea-level rise began sometime between the mid-19th and mid-20thcenturies, based on geological and archeological observations and some of the longest tide gage records Bindoff et al. (2007). Nicholls and Klein (2000), IPCC (1994) estimated that the global rise from 1990 to 2100 would be between 23 and 96 cm, with a mid-estimate of 55 cm. The mean sea level has risen globally, at a rate of 1.0 to 2.0 mm per year during last century Church and White (2006). Long tide gage records (e. g., at least 50-60 years) are commonly used to average out decadal variability of the oceans' surface Douglas (1992). The rate of sea level change is calculated by fitting a curve through the historical tide gage readings. The curve could be a straight line or a higher order polynomial over the whole length of the record or shorter sections. Jevrejeva et al. (2006). As sea level reveals considerable inter annual and decadal variability, the calculated rate of change depends on the length and start date of the record used. Church and White (2006) found that the global rate of sea level rise was 1.7 ± 0.3 mm $yr^{-1}$for the 20th century, 0.71 ± 0.4 mm $yr^{-1}$for 1870-1935, and 1.84 ± 0.19 mm $yr^{-1}$for 1936-2001. Church and White (2011) calculated the sea level rise using 16-year moving windows of data; the linear trend in global sea-level rise was 1.7 mm yr^{-1} from 1900 to 2009, with some 16-year intervals yielding rates of 2-3 mm yr^{-1}in the 1940s, 1970s, and 1990s. This variability has been attributed to natural climate variability (which causes short-term variations in global mean temperature, and to large volcanic eruptions, which briefly cool the Earth's surface and troposphere). In general, the new estimates overtheentire20th century are similar to those reported in the IPCC fourth assessment report. Rates for the last decade of the20th century are higher and similar to IPCC (2007) rates, which were estimated from satellite altimetry and were confirmed by tide gages. Because of natural temporal and spatial variability in the sea-level signal, the meaning of the higher rates of global sea-level rise since the early 1990s is subject to interpretation. For example, Merrifield et al. (2009) attributed most of the recent rise to higher rates of sea-level rise in the Southern Hemisphere and tropical regions, which had been seen by Cabanes et al. (2001) in satellite altimetry data. It is also possible that the recent higher rate of sea-level rise represents acceleration in the long-term trend. The record of sea-level rise is punctuated by periods of acceleration and deceleration. Although Houston and Dean (2010) found a slight deceleration since 1930, Rahmstorf and Vermeer (2011) argued that this result reflects the choice of start date (1930) and the regional character of the gages used in their analysis. Even if the higher rates since the 1990s represent a persistent acceleration in sea-level rise, significant additional acceleration would be required to reach commonly projected sea levels Vermeer and Rahmstorf (2009). For example, taking a rate of 3.1 mm $yr^{-1}$from satellite altimetry, sea level would rise only 0.28 m over the next 89 years. To reach 1 m by 2100 would require a positive acceleration of 0.182 mm yr^{-2} for the entire time period, based on the following quadratic equation: $H = Ho + (b \times t) + (c/2)\, t^2$, where Ho is the current sea level, b is the linear rate of sea-level rise, and c is the acceleration in units of mm yr^{-2}. In this example, acceleration would account for more than 72 percent of the future sea level rise. Such rapid acceleration is not seen in the 20th century tide gage record, except for short periods of time, such as the 1930s and the 1990s. Domingues et al. (2008) estimated that thermos steric sea-level rise for the full ocean depth increased from 0.72 ± 0.13 mm yr^{-1} for 1961–2003 to 1.0 ± 0.4 mm yr^{-1} for 1993–2003. Church et al. (2011) estimates for 1993–2008 are 0.88 ± 0.33 mm yr^{-1}.

1.3Desalination as a Global Solution for Water Scarcity

However, our population has increased globally; the amount of freshwater on the planet has remained constant. The use of water has grown more than the rate of population increase by two times in the last century. The International Desalination Association IDA (2019), according to the new IDA Water Security Handbook, published in January 2019, in the past 3 years, the overall desalination market has remained steady; however, several factors are driving the surge in desalination projects. The global contracted reuse capacity has almost doubled since 2010, with cumulative contracted capacity increasing from 59.7 million m^3/d in 2009to 118 million m^3/d in 2017. The total global installed desalination capacity stands at 97.4 million cubic meters per day (m^3/d) while the total global cumulative contracted capacity is 104.7 million m^3/d. As of June 30, 2018, more than 20,000 desalination plants had been contracted around the world. Desalination and water reuse: non-conventional, environmentally sound water supply solutions are in keeping with the circular water economy and offer solutions to water scarcity. Desalination will become a global solution for water scarcity, essentially in coastal areas in arid countries. Water scarcity is a worldwide concern. As scientists and government agencies look for answers to this crisis, desalination is the solution. Reverse osmosis is the most common type of membrane separation types. Trondalen (2009); IPCC (2014). Climate change is already affecting the distribution of water in many critical water basins. Since 1950, the renewable supply of water per capita has fallen by 58 percent Fagan (2011); IPCC (2012). Water shortages will likely provide a tipping point between war and peace for regions already on the threshold of conflict, such as the Middle East. Population growth and climate change are fueling a dangerous nexus of water shortages, political instability, and economic stagnation. Increasing desalination plants for production of desalinated seawater can be viable as a possible solution for water scarcity and sea level rise problems.

1.4 Characterization of the Study Area

The study area is located at Nile Delta coastal zone (Lat. 31°, 52.32930 N; Long. 28°, 20.6630E) which includes many gauge stations in Alexandria, Burullus, Port Said, Rosetta and Damietta. The study area has average annual temperatures from 37°C to 14°C. The study area is vulnerable to the risk of erosion and sea level rise impacts. The study area has many topographic features and different levels with respect to mean sea level like sand dunes, limestone ridges and wet lands, ponds, lakes and lagoons.

2. Objectives

This present study assesses the probability of using, globally the desalination of sea water as a possible solution, for the sea water level rise problem, and the contribution percentage of desalinated water in reduction of SLR problem. The aim of this paper also is to demonstrate the average rate of global sea level rise and the expected in 2020, 2050, and 2100, and the expected sea level rise at any time for 95% confidence interval (CI). In addition, the calculation of the present acceleration of driving force due to different factors of climate change, according to the present datauntil year 2000, and comparing it with the acceleration to raise sea level 1.0 m and 1.8 m by 2100. The calculations for long and short terms of the sea level for different gauge stations, at Nile Delta (Port Said, Rosetta, Burullus, Alexandria and Damietta gauge stations) for years from 1925 to 2017 are one of the study goals. In addition to Calculations of the acceleration of driving force which affect sea level at different local costal stations in Egypt. Achieving the goals of this research the global surface water area of seas and oceans should be calculated and the rate of change of global desalinated water, also the expected global desalinated water should be calculated.

3. Materials and Methods

3.1 Data Collection

Data from 128 sea level gauge stations all over the world, for more than 75 years for each station were collected from NOAA data files (2015). In addition, the sea level data from gauge stations in Egypt, at Nile Delta (Port Said, Rosetta, Burullus, Alexandria and Damietta) had been collected, for years from (1925 to

2017) for long term, and for short term from (Jun.2012 to May 2016). The data were dealt for calculation of local rate of sea level increasing for years 2020, 2050, and 2100. Calculations of these data for sea level rise two scenarios, in accordance with inter-governmental panel on climate change (IPCC), 1.0 m and 1.8 m rise were tabulated as shown in table (1). Equation (3) was applied as shown below, for 95% confidence interval (CI) of sea level rise. Taking a decision about the driving forces of different climate change factors, which affect the sea level to rise for 100 cm or 180 cm in 2100, acceleration of sea level rise, can be obtained using the SUVAT equation for uniform acceleration as shown below in equation (4). The data were dealt for calculation of local rate of sea level increasing for years 2020, 2050, and 2100. Frihy (2003) studied the sea level rise for Nile Delta (Port Said, Burullus, and Alexandria), the study demonstrated the following equations, for Port Said (Y= 0.2314x-442.7), for Alexandria (Y= 0.1632x+3.316), and for Burullus (Y= 0.0957x+3.36). By using AutoCAD program to redraw the curves of data and to calculate the acceleration using previous equations. The data of global desalination and global surface area of water were collected also. Knowing the contribution of desalinated water in the reduction of sea level rise needs the calculation of global volume of desalinated water and the total area of oceans and seas. Data were collected for Atlantic Ocean, Pacific Ocean, and Indian Ocean as shown in table (2). The global volume of water from desalinated water all around the world can be calculated, using the available data from IDA (2019). Data for global desalination were collected for years 1980, 2004, 2008, 2010, 2011, 2012, 2015, and 2017. The data of expected and collected global desalinated water in m^3/day from year 1980 to 2100 are shown in table (3).

4. Analysis and Results

4.1 The Expected Contribution of Global Desalination to Reduce SLR

The present study assesses the probability of using globally the desalination of sea water as a possible solution for the sea water level rise problem. For achieving the goals of this research the global surface water area of seas and oceans should be calculated and the rate of change of global desalinated water, also the expected global desalinated water should be calculated, also the average rate of global sea level rise and the expected in 2050, and 2100. The oceans cover roughly 78% of the area of the Earth, while freshwater accounts for only 2.5% of the total. Most water in the Earth's atmosphere and crust comes from the world ocean's saline seawater; the water on Earth is regarded as saline or salt water, with an average salinity of 34 grams of salts in 1 kg of seawater. The total area of oceans and seas is 361.108 (106 km^2), where the Atlantic Ocean constitutes 82.4(106 km^2), Pacific Ocean constitutes 165.2 (106 km^2), and Indian Ocean constitutes 165.2 (106 km^2) as shown in table (2). Volume of water due to the raising of sea level by (1 mm) equals, the global sea area times the thickness of sea level rise by (1 mm). The global area of seas and oceans as shown in table (2) is 361.08 x 106 km^2, and then the volume of water due to raising of sea level by (1 mm) equals 36.108 x 1013 m^2x 10^{-3} m = 36.108 x 1010 m^3, then the volume of water due to raising of sea level by (1000 mm) equals 36.108 x 10^{13} m^3, and the volume of water due to raising of sea level by (1800 mm) equals 64.99 x 10^{13} m^3. Knowing the contribution of desalinated water in the reduction of sea level rise needs the calculation of global volume of desalinated water. The global volume of water from desalinated water all around the world can be calculated, using the available data from IDA (2019). Data for global desalination were collected for years 1980, 2004, 2008, 2010, 2011, 2012, 2015, and 2017 as (5.0×10^6, 35.0×10^6, 52.33×10^6, 65.2×10^6, 67.0×10^6, 79.0×10^6,86.8×10^6, and 92.5×10^6) in m^3/day shown in table (3), to get the rate of change in desalinated water during these periods, so the following mathematical formula can be used to get the rate of change in global desalinated water Rd.

$$R_d = ((\sum (D_n-D_{n-1}) / (T\times N)) \times 100. \quad (1)$$

$$Rd = (((35.0\times10^6-5.0\times10^6) /24 + (52.33\times10^6-35.0\times10^6) /4 + (65.2\times10^6-52.33\times10^6) /2 + (67.0\times10^6-65.2\times10^6) /1 + (79.0\times10^6-67.0\times10^6) /1 + (86.8\times10^6-79.0\times10^6) / 3+ (92.5\times10^6-86.8\times10^6 /2)) / 8) \times 100 = 4.80$$

Where:-

R_d = rate of change in global desalinated water value

D_n = amount of global desalinated water at year (n)

D_{n-1}= amount of global desalinated water at year (n-1)

n = a subscript refer to the number of assigned year (according to available collected data)

N = the total number of assigned years

T = (t_n-t_{n-1}) time interval between two consecutive values

The expected increase in global desalinated water value D_{n+1} for the year (n+1) can be obtained from the following equation:

$$D_{n+1} = D_n + (R_d)\ldots\ldots \quad (2)$$

Table (1-a) shows present change rate of SLR for 128 gauge stations, & 2100 scenarios

No.	Station ID	Station Name	Present SLR Rate	SLR Rate mm/yr	SLR Rate mm/yr
			Average Rise mm/yr	Projection 1.0 m	Projection 1.8 m
36	110-092	Swinoujscie, Poland	0.8	10.6	20.1
37	120-012	Warnemunde, Germany	1.2	11	20.5
38	120-022	Wismar, Germany	1.4	11.2	20.7
39	130-001	Gedser, Denmark	1.1	10.8	20.3
40	130-021	Gedser, Denmark	0.7	10.4	20
41	130-031	Hornbaek, Denmark	0.4	10.1	19.7
42	130-041	Korsor, Denmark	0.8	10.6	20.1
43	130-051	Slipsbavn, Denmark	1	10.8	20.3
44	130-071	Fredricia, Denmark	1.1	10.8	20.4
45	130-081	Aarhus, Denmark	0.6	10.4	19.9
46	130-101	Hirtshals, Denmark	-0.2	9.6	19.1
47	130-121	Esbjerg, Denmark	1.2	11	20.5
48	140-012	Cuxhaven 2, Germany	2.5	12.3	21.8
49	170-011	Aberdeen I & II, UK	0.7	10.5	20
50	170-053	Northshilds, UK	1.9	11.7	21.2
51	170-101	Sheerness, UK	1.7	11.4	21
52	170-161	Newlyn, UK	1.8	11.5	21.1
53	190-091	Brest, France	1	10.8	20.3
54	210-021	Cascais, Portugal	1.3	11	20.6
55	210-031	Lagos, Portugal	1.5	11.3	20.8
56	230-051	Marseille, France	1.2	11	20.5
57	250-011	Genova, Italy	1.2	11	20.5
58	270-061	Trieste, Italy	1.3	11	20.6
59	280-011	Bakar, Croatia	1	10.7	20.3
60	298-041	Savastopol, Ukraine	1.3	11	20.5
61	300-001	Tuapse, Russia	2.4	12.2	21.7
62	305,021	Poti, Georgia	6.6	16.4	25.9
63	410-001	Takoradi, Ghana	2.2	11.9	21.4
64	485-001	Aden, Yamen	3	12.8	22.3
65	490-021	Karachi, Pakistan	1.1	10.9	20.4
66	500-041	Mumbai, Bombay, India	0.8	10.5	20.1
67	500-091	Chennai, Madras, India	0.3	10.1	19.6
68	611-010	Quarry Bay, North pointahina	1.4	11.1	20.6
69	642-061	Mera, Japan	3.8	13.5	23.1
70	642-091	Aburatsubo, Japan	3.6	13.4	22.9

The data of expected and collected global desalinated water in m^3/day from year 1980 to 2100 are shown in table (3). To get the contribution of desalinated water in the reduction of sea level rise, the calculated data of total volume of sea level rise, with the data of desalinated water should be compared. Global daily desalinated water for year 2017 is 92.5×10^6 m^3/day; the yearly global desalinated water for year 2017 is 3.38×10^{13} m^3/year with thickness (1 mm), for the scenario of raising global sea level by rate of change equals 0.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 18.7%, for the scenario of raising global sea level by rate of change equals 1.00 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 9.35%, and for the scenario of raising global sea level by rate of change equals 1.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 6.23%. The expected contribution percentage of desalinated water in reduction of sea level rise for years 2050 and 2100 are shown in table (3), the calculation showed that, for year 2050, the first scenario of raising global sea level by rate of change equals 0.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 48.50%, for the scenario of raising global sea level by rate of change equals 1.00 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 24.25%, and for the scenario of raising global sea level by rate of change equals 1.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 16.17%. but for year 2100, the first scenario of raising global sea level by rate of change equals 0.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 93.65%, for the scenario of raising global sea level by rate of change equals 1.00 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 46.83%, and for the scenario of raising global sea level by rate of change equals 1.50 mm/year; the contribution percentage of desalinated water in reduction of sea level rise is 31.42%.

Table (1-b) shows present change rate of SLR for 128 gauge stations, & 2100 scenarios

No.	Station ID	Station Name	Present SLR Rate Average Rise mm/yr	SLR Rate mm/yr Projection 1.0 m	SLR Rate mm/yr Projection 1.8 m
71	645-011	Hosojima, Japan	-0.4	9.3	18.9
72	647-071	Wajima, Japan	-0.2	9.6	19.1
73	680-140	Sydney, Fort Dension1 & 2, Australia	0.6	10.4	19.9
74	680-471	Fremantle, Australia	1.5	11.3	20.8
75	690-039	Auckland II, New Zeland	1.3	11.1	20.6
76	690-040	Lyttelton II, New Zeland	2.4	12.1	21.6
77	690-041	Bluff/Southland Harbour, New Zeland	1.6	11.3	20.9
78	822-001	Prince Rupert, Canada	1.1	10.9	20.4
79	822-071	Vancouver, Canada	0.4	10.1	19.7
80	822-101	Vectoria, Canada	0.6	10.4	19.9
81	822-116	Tofino, Canada	-1.7	8.1	17.6
82	8659084	Thouth port, NC	2	11.8	21.3
83	8665530	Charleston, SC	3.2	12.9	22.4
84	8670870	Fort Pulaski, GA	3.1	12.8	22.4
85	8720030	Fernandina Beach, FL	2	11.8	21.3
86	8720218	Mayport, FL	2.5	12.3	21.8
87	8724580	Keywest, FL	2.3	12.1	21.6
88	8727520	Cedar Key, FL	1.9	11.7	21.2
89	8729840	Pensacola, FL	2.2	12	21.5
90	8771450	Gaiveston Pier21, TX	6.3	16.1	25.6
91	8774770	Rockport, TX	5.3	15	24.6
92	9410170	San Diego, CA	2.1	11.8	21.4
93	9410230	La Jolla, CA	2.1	11.9	21.4
94	9410660	Los Angeles, CA	0.9	10.6	20.2
95	9410840	Santa Monica, CA	1.4	11.2	20.7
96	9414290	San Francisco, CA	1.9	11.7	21.2
97	9414750	Alameda, CA	0.7	10.4	20
98	9419750	Crescent City, CA	-0.8	8.9	18.4
99	9439040	Astoria, OR	-0.3	9.5	19
100	9443090	Neah Bay, WA	-1.8	8	17.5
101	9447130	Seattle, WA	2	11.8	21.3
102	9449880	Friday Harbor, WA	1.1	10.8	20.4
103	9450460	Ketchikan, AK	-0.3	9.5	19
104	9451600	Sitka, AK	-2.3	7.5	17

Table (1-c) shows present change rate of SLR for 128 gauge stations, & 2100 scenarios

No.	Station ID	Station Name	Present SLR Rate	SLR Rate mm/yr	SLR Rate mm/yr
			Average Rise mm/yr	Projection 1.0 m	Projection 1.8 m
105	9452210	Juneau, AK	-13.2	-3.4	6.1
106	1612340	Honolulu, HS	1.4	11.2	20.7
107	1617760	Hilo, Hi	3	12.7	22.2
108	2695540	Bermuda, Atlantic Ocean	2	11.8	21.3
109	8410140	East port, ME	2.1	11.9	21.4
110	8418150	Portland, ME	1.9	11.7	21.2
111	8419870	Seavey Island, ME	1.8	11.5	21
112	8443970	Boston, MA	2.8	12.6	22.1
113	8447930	Woods Hole, MA	2.8	12.6	22.1
114	8452660	New port, RI	2.7	12.5	22
115	8454000	Providence, RI	2.2	12	21.5
116	8461490	New London, CT	2.6	12.3	21.9
117	8516945	Kings point, NY	2.5	12.3	21.8
118	8518750	The Battery, NY	2.8	12.6	22.1
119	8531680	Sandy Hook, NJ	4.1	13.8	23.4
120	8534720	Atlantic City, NJ	4.1	13.8	23.4
121	8545240	Pheladelphia, PA	2.9	12.7	22.2
122	8557380	Lewes, DE	3.4	13.2	22.7
123	8574680	Baltimore, MD	3.1	12.9	22.4
124	8575512	Annapolis, MD	3.5	13.3	22.8
125	8577330	Solomons Island, MD	3.7	13.5	23
126	8594900	Washington, DC	3.2	13	22.5
127	8638610	Sewells point, VA	4.6	14.4	23.9
128	8658120	Wilmington	2.1	11.9	21.4
Average			0.58	10.34	19.86

Table (2) shows area, volume, and depth of the world oceans and seas, (after Qadri, 2003)

Body of Water	Area (10^6 km^2)	Volume (10^6 km^3)	Mean Depth (m)
Atlantic Ocean	82.4	323.6	3,926
Pacific Ocean	165.2	707.6	4,282
Indian Ocean	73.4	291.0	3,963
All oceans and seas	361.108	1,370	3,796

4.2Global Sea Level Rise Calculation

The aim of this paper also is to demonstrate the average rate of global sea level rise and the expected in 2020, 2050, and 2100. Data from 128 sea level gauge stations all over the world for more than 75 years for each station were collected. The data were dealt for calculation of rate of sea level increasing for years 2020, 2050, and 2100. Two scenarios for sea level rise in accordance with intergovernmental panel on climate change (IPCC) are 1.0 m and 1.8 m rise in sea level. The collected data were analyzed and tabulated as shown in table (3). The average calculated rate of global sea level rise and the expected in 2100 for more than 75 years are 0.58 mm/year for the actual present measured data as shown in figure (1). The average calculated rate of change according to the IPCC scenario for 1.0 m sea level rise is 10.34 mm/year and the other scenario for 1.8 m sea level rise is 19.86 as shown in table (3). Equation (3) can be applied for 95% confidence interval (CI) of sea level rise:

$$\text{(CI)SLR} = MSLR \pm \frac{1.96\,\sigma}{\sqrt{N}} \quad \text{.........} \quad (3)$$

Where: SLR is the expected sea level rise at any time for 95% confidence interval (CI) of SLR, MSLR is the average of measured sea level rise equals 0.58 mm/year (for present study), N is the number of gauge stations equals 128, and σ is the standard deviation of measured data equals 3.06, the resulting confidence interval is 0.05 mm/year to 1.11 mm/year (for present study).

Table (3) shows percentage of desalination contribution to reduce sea water level rise

Years	Global Daily Desalination M^3/day	Global Yearly Desalination M^3/year. mm (10^{13})	Scenario 1 if The Rate of Change is 0.5 mm/y	Scenario 2 if The Rate of Change is 1.0 mm/y	Scenario 3 if The Rate of Change is 1.5 mm/y
	Global desal. Million M^3/day To 2100	Global Desal. & The Expected to 2100	% of Contribution of Desalination in RSLR	% of Contribution of Desalination in RSLR	% of Contribution of Desalination in RSLR
1980	5.0	0.18	1.01	0.51	0.34
2004	35.0	1.28	7.08	3.54	2.36
2008	52.3	1.91	10.58	5.29	3.53
2010	65.2	2.38	13.18	6.59	4.39
2011	67.0	2.45	13.55	6.77	4.52
2012	79.0	2.88	15.97	7.99	5.32
2015	86.8	3.17	17.55	8.77	5.85
2017	92.5	3.38	18.70	9.35	6.23
2020	105.9	3.87	21.41	10.70	7.14
2050	239.9	8.76	48.50	24.25	16.17
2100	463.2	16.91	93.65	46.83	31.22

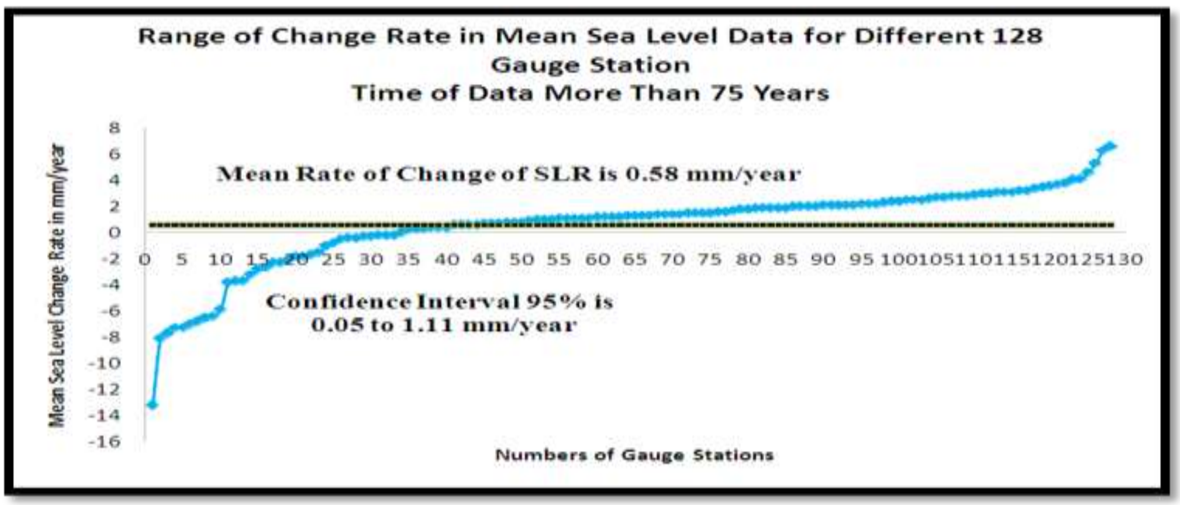

Figure (1) shows data range of change rate of mean sea level for 128 different gauge stations, more than 75 years, (Source of data, NOAA, 2015)

4.3Acceleration of Expected Global Sea Level Rise Due to Different Factors

Sea level no doubt is affected by climate change globally, and other factors, many scenarios have been set by IPCC for sea level rise, some of these scenarios are 0.30 m, 0.50 m,0.80 m,1.00 m, 1.80 m, and 2.00 m increase in sea level. The actual data of sea levels around the world indicated positive and negative values for sea level. Data of sea levels were collected and tabulated for 128 gauge stations around the world for more than 75 years. The average global sea level rise is 0.58 mm/year, and the confidence interval of 95% of SLR rate of change is 0.05 mm/year to 1.11 mm/year. Comparing the obtained values with the values of IPCC scenarios, for the scenario of increasing sea level by 100 cm, the expected sea level rise rate of change is 10.34 mm/year to reach this level in 2100, for another scenario of increasing sea level by 180 cm, the expected sea level rise rate of change is 19.86 mm/year to reach this level in 2100, this means that the rate of change to reach 100 cm is 18 times the present rate, while the rate of change to reach 180 cm is 34 times the present rate. Taking a decision about the driving forces of different climate change factors, which affect the sea level to rise for 100 cm or 180 cm in 2100, acceleration of sea level rise, can be obtained using the SUVAT equation for uniform acceleration:

$$H = H_o + (b \times t) + (c/2)t^2 \quad (4)$$

Where Ho is the current sea level, b is the linear rate of sea level rise, and c is the acceleration in units of mm yr^{-2}. Different data of six gauge stations from 128 gauge stations have been chosen to represent the acceleration of different scenarios of sea level rise rate of change compared to present rate of change of sea level rise as shown in table (4). For example, taking a rate of 1.9 mm $yr^{-1}$for North Shields, UK, the difference in sea level is 0.23 m for 75 years. To reach 0.23 m would require a positive acceleration of 0.031 mm yr^{-2} for 75 years' period. The same conditions to reach 1 m by 2100 would require a positive acceleration of more than 0.305 mm yr^{-2} for the entire period, while to reach 1.8 m by 2100 would require a positive acceleration of more than 0.59 mm yr^{-2} for the entire period. Comparing the two scenarios with the present acceleration, the driving force of different factors of climate change (acceleration) is 9 times the present driving force to reach sea level 1.0 m by 2100, and about 19 times the present driving force to reach sea level 1.8 m by 2100. Also calculations for the different stations showed that, Balboa, Panama gauge station demonstrated about 32 times the present driving force to reach sea level 1.0 m by 2100, and about 61 times the present driving force to reach sea level 1.8 m by 2100. The Buenos, Aires, Argentina gauge station showed about 29 times the present driving force to reach sea level 1.0 m by 2100, and about 56 times the present driving force to reach sea level 1.8 m by 2100. The Kungholmsfort, Sweden, gauge station showed zero change in sea levels during 75 years, but for the same period of time there is a positive acceleration 0.094mm yr^{-2} as a driving force to reach sea level 1.0 m by 2100, and a positive acceleration 0.13mm yr^{-2} as a driving force to reach sea level 1.8 m by 2100. The Landsort Norra, Sweden, gauge station showed negative accelerations about 11 times the present driving force to reach sea level 1.0 m by 2100, and about 18 times the present driving force to reach sea level 1.8 m by 2100. The Tuapse, Russia gauge station showed about 20 times the present driving force to reach sea level 1.0 m by 2100, and about 40 times the present driving force to reach sea level 1.8 m by 2100.

4.4Expected Global and Local Sea Level Rise, and Land Subsidence Calculations

Elshinnawy et al., (2009) studied coastal vulnerability to climate changes in Egypt. Intensive investigations and measurements of tide gauges at Alexandria, Al-Burullus, and Port Said had been collected, filtered, and statistically analyzed to estimate sea level rise over the last three decades at each of the three previous regions. Results indicated that sea level rise varies from region to another, because of the land subsidence effect. Estimated trends for sea level rise at Alexandria, Al-Burullus, and Port Said are 1.6, 2.3, and 5.3 mm/year respectively. These values associate the effect of both sea level rise and land subsidence. According to Fanos (1990) observations of the sea level at Alexandria (1958-1988) and Port Said (1924-1973) lead to a relative sea level rise of 1.63 mm/y and 3mm/y respectively, both are higher than the global mean sea level rise of 1.2 mm/y. Sestini (1991) showed that a relative sea level rise of 4.8 mm/y (subsidence of 3.6 mm/y) at Port Said from the analysis of tidal reports. The average increase in global warming at the end of the twenty century is about 0.6 ºC according to IPCC (Solomon et al., 2007). The projected values of the mean surface air temperature, 2000-2100, for the low scenario (B1) and for the high scenario A1F1 of SRES, cited from the First Assessment Report (FAR) are given in table (5). (CORI) during the study in 2008 stated that, the land subsidence in Alexandria is about 0.4 mm/y, while at Port Said the value is around 3.0 mm/y. The subsidence value at Port Said is 3.35 mm/y as an average value of subsidence during the past 7000 years (2.6 to 4.1 mm/y). Knowing that the global average sea level rise is 1.2 mm/y, the difference between tide gauge trend at Al-Burullus and this value was considered as the land subsidence value for the middle Delta Region. Subsidence rates and sea level rise values are presented in table (6). The projected average sea level rise at the end of the years 2025, 2050, 2075, and 2100 has been estimated applying the projected average surface warming given in table (6) (assuming that the land subsidence will occur with the same rates). Achieving the goals of present study, calculations of the local rate of sea level increasing at Nile Delta should be carried out. The sea level data from different gauge stations in Egypt, at Nile Delta (Port Said, Rosetta, Burullus, Alexandaria and Damietta gauge stations) had been collected for different time period (long and short terms) for years from 1925 to 2017. The data were dealt for calculation of local rate of sea level increasing for years 2020, 2050, and 2100 as shown in figures from (2) to (5). Calculations for long term of Port Said gauge station showed that, the average measured sea level rise equals 2.314 mm/year. Calculations for long term of Damietta gauge station showed that, the average measured sea level rise equals 4.404 mm/year. Calculations for long term of Burullus gauge station showed that, the average measured sea level rise equals 0.957 mm/year. Calculations of Alexandria gauge station showed that, the average measured sea level rise equals 1.632 mm/year. Calculations of Rosetta gauge station showed that, the average measured sea level rise equals 0.20 mm/year. For long term, the rate of change in sea level of Port Said, Burullus, Damietta, and Alexandria gauge stations are 2.314 mm/year,4.404 mm/year, 0.957 mm/year, and 1.632 mm/year, respectively. For short term calculations of Rosetta and Burullus gauge stations showed that, the average measured sea level rise equals 0.20 mm/month, and (-2.20) mm/month. Using equation (4) to calculate the acceleration of driving force, which affect sea level at different local stations. The calculations showed that for Port Said, Burullus, Damietta, and Alexandria gauge stations, as shown in figures from (6) to (8), for long time until 2100, the accelerations are 0.031 mm yr^{-2}, 0.01 mm yr^{-2}, 0.441 mm $yr^{-2}$and 0.027mm yr^{-2}, respectively. Comparing the present accelerations of local gauge stations at Port

Said, Burullus, Damietta, and Alexandria for expected accelerations to drive sea level to be 1000 mm and 1800 mm above present mean sea level for the same present conditions, the accelerations should be more than 2.57 times the present to reach 1000 mm, and more than 5.16 times the present acceleration for Port Said gauge station, but for Burullus, Damietta, and Alexandria gauge stations the accelerations are (8.946), (0.17), and (3.19) times the present acceleration to reach 1000 mm, and more than (5.158) for Port Said, and (16.94) for Burullus, but for Damietta, and Alexandria are (0.36), and (6.14) times the present acceleration to reach 1800 mm.

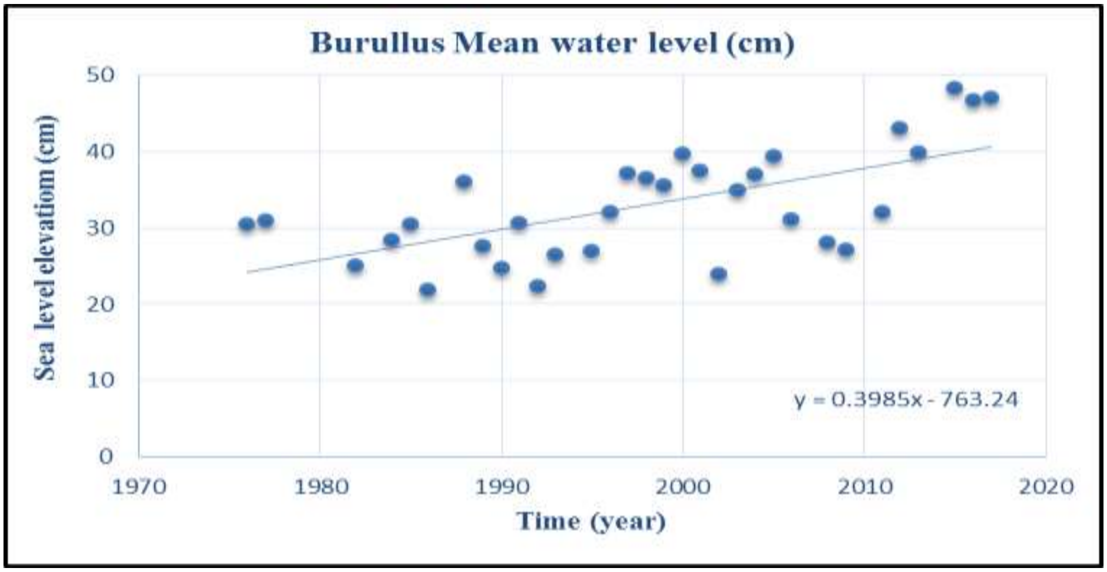

Figure (2) shows long-term change rate of (SLR) of Burullus gauge station

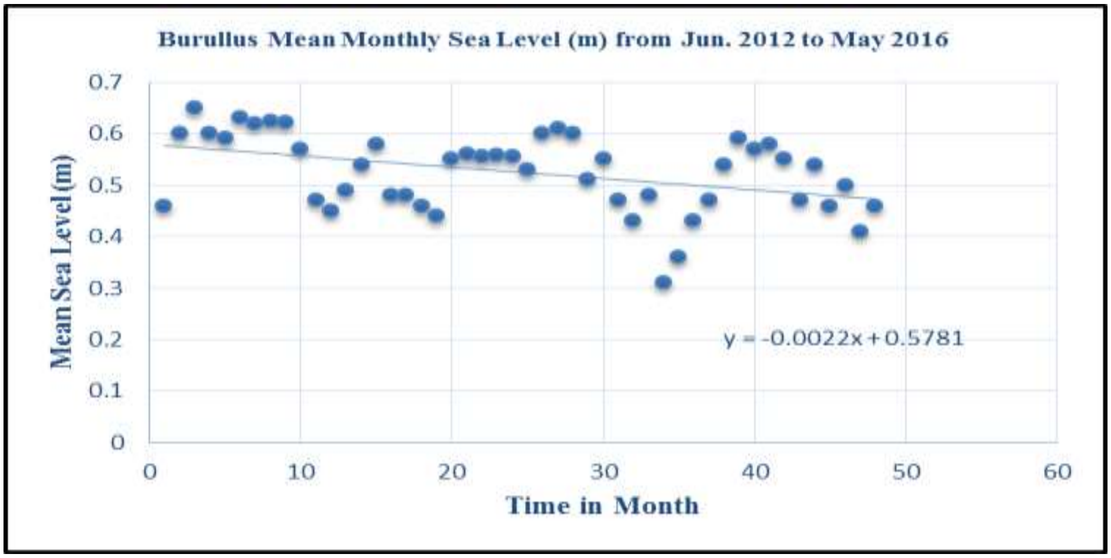

Figure (3) shows short-term change rate of (SLR) of Burullus gauge station

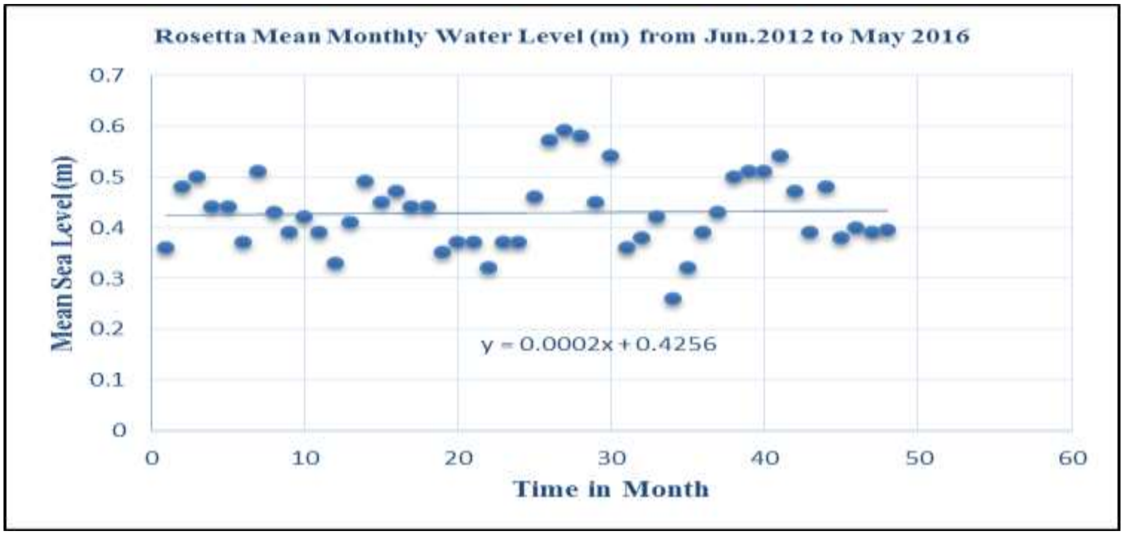

Figure (4) shows short-term change rate of (SLR) of Rosetta gauge station

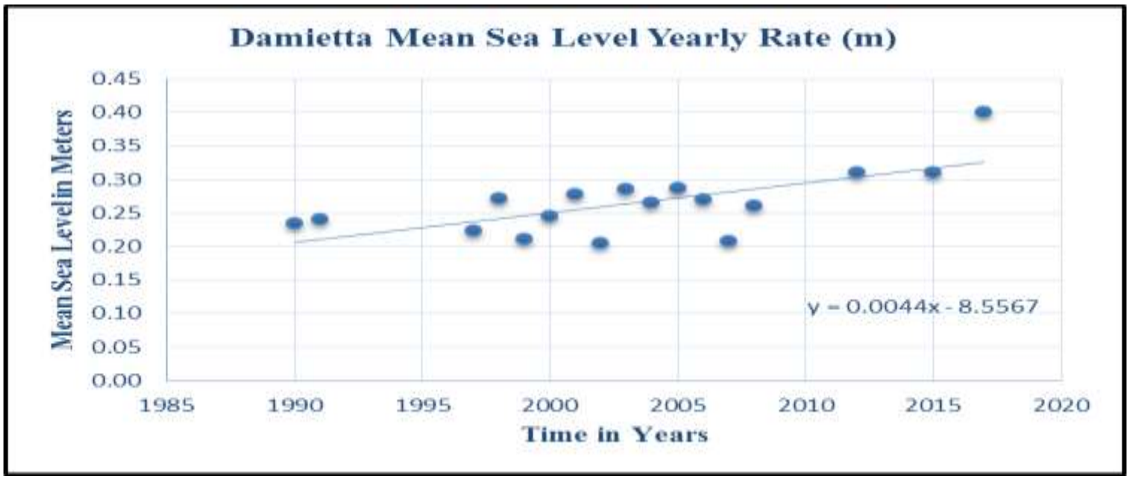

Figure (5) shows long-term change rate of (SLR) of Damietta gauge station

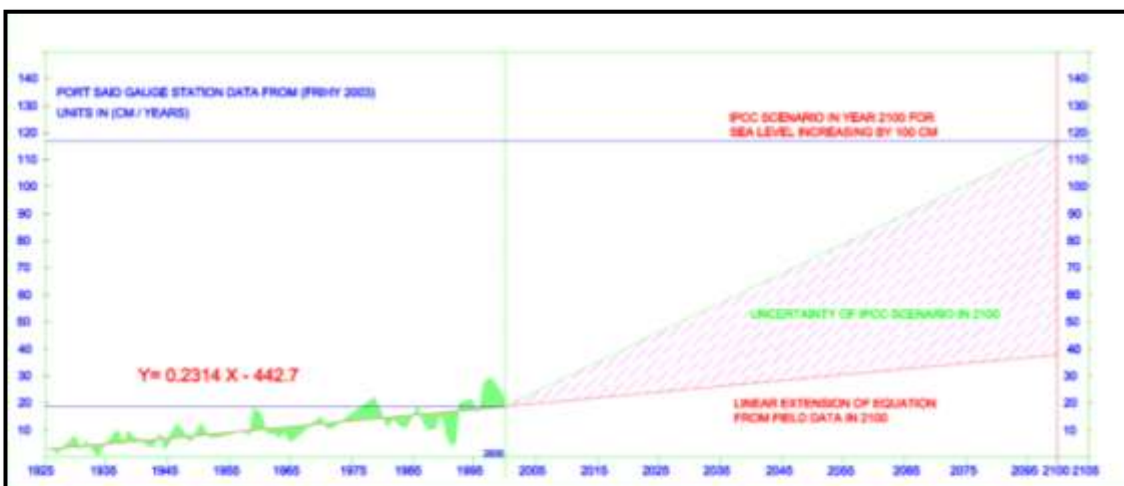

Figure (6) shows comparison between IPCC Scenario and expected long-term change rate of (SLR) of Port Said gauge station in year 2100

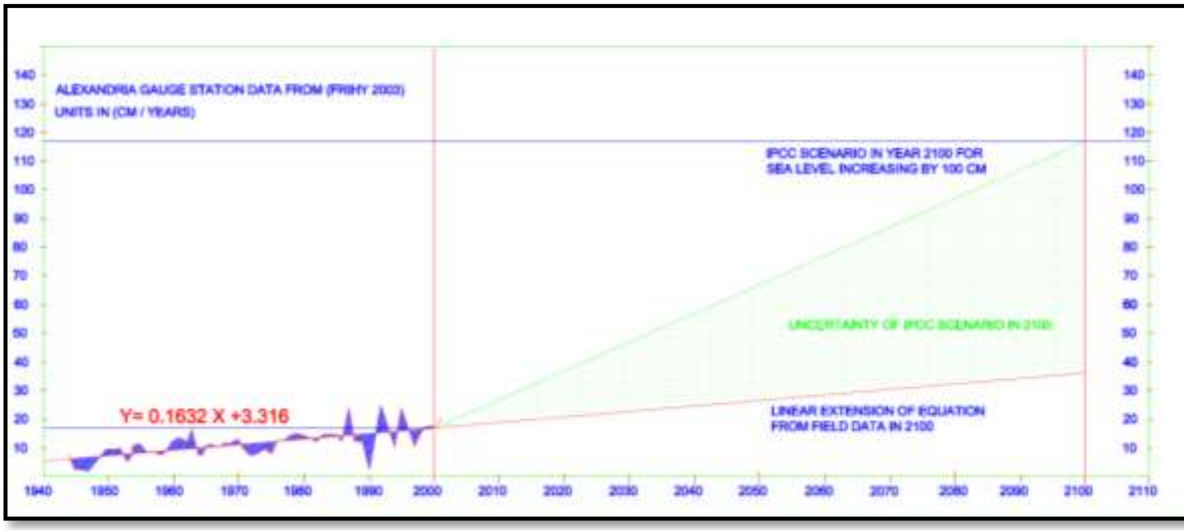

Figure (7) shows comparison between IPCC Scenario and expected long-term change rate of (SLR) of Alexandria gauge station in year 2100

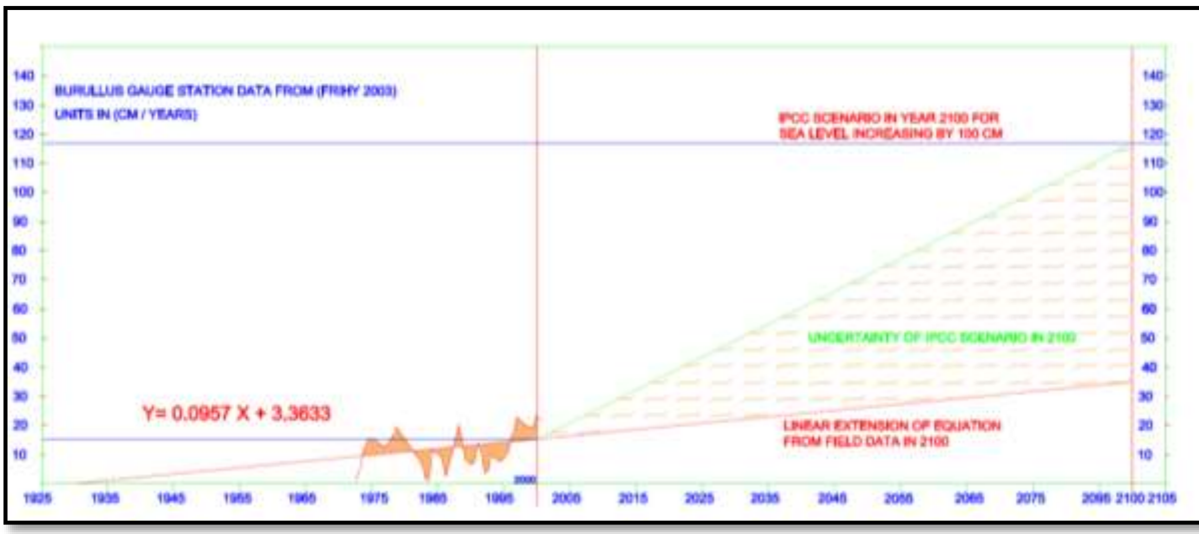

Figure (8) shows comparison between IPCC Scenario and expected long-term change rate of (SLR) of Burullus gauge station in year 2100

Table (4) shows global acceleration of sea level rise and the scenarios for year 2100

Station Name	Present SLR Rate				Projection 1000mm				Projection 1800mm				Acceleration	
	H-H0	b	t	C	H-H0	b	t	C1	H-H0	b	t	C2	C1/C	C2/C
North Shields UK	230	1.9	75	0.031	1000	1.9	75	0.305	1800	1.9	75	0.59	9.80	18.94
Balboa, Panama	140	1.5	75	0.010	1000	1.5	75	0.316	1800	1.5	75	0.60	32.27	61.36
Buenos Aires, Argentina	150	1.6	75	0.011	1000	1.6	75	0.313	1800	1.6	75	0.60	29.33	56.00
Kungholmsfort, Sweden	0	0	75	0.000	1000	9.8	75	0.094	1800	19.3	75	0.13	-----	-----
Landsort Norra &, Sweden	-320	-2.8	75	-0.039 deceleration	1000	-2.8	75	-0.430 deceleration	1800	-2.8	75	0.71	-11.00 deceleration	-18.27 deceleration
Tuapse, Russia	220	2.4	75	0.014	1000	2.4	75	0.292	1800	2.4	75	0.58	20.50	40.50

$H = Ho + (b \times t) + (C/2)t^2$, where *Ho* is the current sea level, *b* is the linear rate of sea-level rise, and *c* is the acceleration in units of mms^{-2}.

Table (4-a) shows local gauge stations data of sea level rise acceleration and the scenarios of IPCC Projection 100.0 cm, and Projection 180.0 cm for year 2100

Station Name	Present SLR Rate cm/y				Projection 100.0 cm				Projection 180.0cm				Acceleration cmy^{-2}	
	H-H0	b	t	C	H-H0	b	t	C1	H-H0	b	t	C2	C1/C	C2/C
Port-Said	20.1-2.74	0.23	75	0.0031	100-20.1	0.79	100	0.0079	180-20.1	1.59	100	0.0159	2.51	5.15
Burullus	10.54-3.36	0.095	95	0.001	100-10.54	0.89	100	0.0089	180-10.54	1.69	100	0.0169	8.94	16.95
Alexandaria	13.10-3.32	0.163	60	0.002	100-13.10	0.86	100	0.0086	180-13.10	1.67	100	0.0167	3.19	6.14
Damietta	25.18-20.72	0.44	10	0.044	100-25.13	0.74	100	0.0074	180-25.13	1.55	100	0.016	0.17	0.36

$(H - Ho) = dy$, $dt = (t_2 - t_1) = dx$, $(dy/dt) = (b_i)$, $(db_i/dt = C_i)$, where H is sea level at time t_2, and $Ho$is the initial Sea level at time t_1, b is the linear rate of sea-level rise, and C is the acceleration in unitsofcmy^{-2}

Table (5) Scenarios of IPCC 2007 for expected SLR due to increasing in surface temperature

Scenario	Temperature Change (Relative to 1980-1999 °C)	Sea Level Rise (m) (Relative to 1980-1999)
Case	Best Estimate	Model-based range excluding future rapid dynamical exchange in the ice flow
Constant year 2000 concentrations	0.6	Not available
B1	1.8	0.18-0.38
A1T	2.4	0.20-0.45
B2	2.4	0.20-0.43
A1B	2.8	0.21-0.48
A2	3.4	0.23-0.51
A1F1	4.0	0.26-0.59

Table (6) Subsidence Rates and Comparison among Field Measurements, B1Scenario, and A1F1 Scenario for Expected SLR (after Elshinnawy et al., 2009)

SLR and Subsidence Rates at the Nile Delta					
Region		Alexandria	Al-Burullus	Port Said	
Tidal Trend (mm/y)		1.6	2.3	5.3	
Subsidence (mm/y)		0.4	1.1	3.35	
SLR (mm/y)		1.2	1.2	1.95	
Trend and expected sea level rise (SLR) Till 2100 according to field measurements					
Station	Average SLR/year (cm)	SLR 2025 (cm)	SLR 2050 (cm)	SLR 2075 (cm)	SLR 2100 (cm)
Alexandria	0.16	4.0	8.0	12.0	16.0
Al-Burullus	0.23	5.75	11.5	16.25	23.0
Port Said	0.53	13.25	26.5	39.75	53.0
Expected sea level rise (SLR) Till 2100 by projected increase in air temperature (B1 Scenario)					
Alexandria	0.16	7.0	16.0	27.0	28.0
Al-Burullus	0.23	8.75	19.5	32.5	35.0
Port Said	0.53	18.125	39.5	64.3	72.5
Expected sea level rise (SLR) Till 2100 by projected increase in air temperature (A1F1 Scenario)					
Alexandria	0.16	13.0	34.0	55.0	72.0
Al-Burullus	0.23	14.75	37.5	60.3	79.0
Port Said	0.53	27.9	68.8	109.6	144.0

5. Conclusion

It is concluded from the present study that, using and increasing of desalinated water, as a possible solution for the sea water level rise, can contribute in reduction of SLR by (7.14 %, 10.70 %, and 21.41%) for year 2020, if the rate of change is (1.50, 1.0, and 0.5 mm/year) respectively, Also it can contribute in reduction of SLR by (16.17 %, 24.25 %, and 48.5%) for year 2050, if the rate of change is (1.50, 1.0, and 0.5 mm/year). The contribution in reduction of the increase in global sea level and reducing level using desalination are (31.22 %, 46.83 %, and 93.65%) for year 2100, if the rate of change is (1.50, 1.0, and 0.5 mm/year). The average rate of global sea level rise and the expected sea level rise at any time for 95% confidence interval (CI) in 2100 for more than 75 years are 0.58 mm/year, and the resulting confidence interval is 0.05 mm/year to 1.11 mm/year (for present study). The average rate of change according to the IPCC scenario for 1.0 m sea level rise is 10.34 mm/year and the other scenario for 1.8 m sea level rise is 19.86. Different data of six gauge stations from 128 gauge stations have been chosen to represent the acceleration of different scenarios of sea level rise rate of change compared to present rate of change of sea level rise. For example, taking a rate of 1.9 mm yr-1 from data for North Shields, UK, the difference in sea level is 0.23 m for 75 years. To reach 0.23 m would require a positive acceleration of 0.031 mm yr-2 for 75 years' time period, for the same conditions to reach 1 m by 2100 would require a positive acceleration of more than 0.305 mm yr^{-2} for the entire time period, while to reach 1.8 m by 2100 would require a positive acceleration of more than 0.59 mm yr^{-2} for the entire time period. Comparing the two scenarios with the present acceleration, the driving force of different factors of climate change (acceleration) is 9 times the present driving force to reach sea level 1.0 m by 2100, and about 19 times the present driving force to reach sea level 1.8 m by 2100. The Balboa, Panama gauge station showed about 32 times the present driving force to reach sea level 1.0 m by 2100, and about 61 times the present driving force to reach sea level 1.8 m by 2100. The Buenos, Aires, Argentina gauge station showed about 29 times the present driving force to reach sea level 1.0 m by 2100, and about 56 times the present driving force to reach sea level 1.8 m by 2100. The Kungholmsfort, Sweden, gauge station showed zero change in sea levels during 75 years, but for the same period of time there is a positive acceleration 0.094 mm yr^{-2} as a driving force to reach sea level 1.0 m by 2100, and a positive acceleration 0.13 mm yr^{-2} as a driving force to reach sea level 1.8 m by 2100. The Landsort Norra, Sweden, gauge station showed negative accelerations about 11 times the present driving force to reach sea level 1.0 m by 2100, and about 18 times the present driving force to reach sea level 1.8 m by 2100. The Tuapse, Russia gauge station showed about 20 times the present driving force to reach sea level 1.0 m by 2100, and about 40 times the present driving force to reach sea level 1.8 m by 2100. Such rapid acceleration is not seen in the 20th century tide gage record, except for short periods of time, such as the 1930s and the 1990s. It means that the linear expectation of IPCC for global sea level rise (GSLR) due to climate change is overvalued. The sea level data from different gauge stations in Egypt, at Nile Delta (Port Said, Rosetta, Burullus, Alexandaria and Damietta gauge stations) had been collected for different time period (long and short terms) for years from 1925 to 2017. The data were dealt for calculation of local rate of sea level increasing for years 2020, 2050, and 2100. Calculations for long term of Port Said gauge station showed that, the average measured sea level rise equals 2.314 mm/year. Calculations for long term of Damietta gauge station showed that, the average measured sea level rise equals 4.404 mm/year. Calculations for long term of Burullus gauge station showed that, the average measured sea level rise equals 0.957 mm/year. Calculations of Alexandria gauge station showed that, the average measured sea level rise equals 1.632 mm/year. Calculations of Rosetta gauge station showed that, the average measured sea level rise equals 0.20 mm/year. For long term, the rate of change in sea level of Port Said, Burullus, Damietta, and Alexandria gauge stations are 2.314 mm/year, 4.404 mm/year, 0.957 mm/year, and 1.632 mm/year, respectively. For short term calculations of Rosetta and Burullus gauge stations showed that, the average measured sea level rise equals 0.20 mm/month, and (-2.20) mm/month. Calculations of the acceleration of driving force which affect sea level at different local stations, showed that for Port Said, Burullus, Damietta, and Alexandria gauge stations, for long time until 2100, the accelerations are 0.031 mm yr^{-2}, 0.01 mm yr-^{2}, and 0.441 mm yr^{-2} and 0.027 mm yr^{-2}, respectively. Comparing the present accelerations of local gauge stations at Port Said, Burullus, Damietta, and Alexandria for expected accelerations to drive sea level to be 1000 mm and 1800 mm above present mean sea level for the same present conditions, the accelerations should be more than 2.57 times the present to reach 1000 mm, and more than 5.16 times the present acceleration for Port Said gauge station, but for Burullus, Damietta, and Alexandria gauge stations the accelerations are (8.946), (0.17), and (3.19) times the present acceleration to reach 1000 mm, and more than (5.158) for Port Said, and (16.94) for Burullus, but for Damietta, and Alexandria are (0.36), and (6.14) times the present acceleration to reach 1800 mm. For short term the results of data analysis showed deceleration for Burullus gauge station, and slightly small acceleration for Rosetta gauge station.

References

1. Cabanes C., A. Cazenave, and C. Le Provost, 2001: Sea level changes from TOPEX/POSEIDON altimetry for 1993-1999, and warming of the southern oceans. Geophys. Res. Lett., 28, 9-12.
2. Cabanes, C., A. Cazenave, and C. Le Provost, 2001: Sea level change from Topex-Poseidon altimetry for 1993–1999 and possible warming of the southern oceans. Geophys. Res. Lett., 28, 9–12. Crossref, Google Scholar.
3. Church JA, White NJ (2006) A 20th century acceleration in global sea level rise. Geophys ResLett33: L01602. doi:10.1029/2005GL024826.
4. Church, J. A., and N. J. White, 2011, Sea-levelrisefromthelate19thtotheearly21stcentury, Surveys in Geophysics, 32, 585-602.
5. Coastal Research Institute (CoRI) (2008), "Coastal Vulnerability to Climate Changes and Adaptation Assessment for Coastal Zones of Egypt", Ministry of Water Resources and Irrigation (MWRI), National Water Research Center (NWRC), March 2008-Pges 8, 11, 12.
6. Domingues, C. M., J. A. Church, N. J. White, P. J. Gleckler, S. E. Wijffels, P. M. Barker, and J. R. Dunn (2008), Improved estimates of upper-ocean warming and multi-decadal sea-level rise, Nature, 453(7198), 1090–1093, doi:10.1038/nature07080.
7. Douglas, B. C., 2001: Sea level change in the era of the recording tide gauge. Sea Level Rise: History and Consequences, B. C. Douglas, M. S. Kearney, and S. P. Leatherman, Eds., International Geophysics Series, Vol. 75, Academic Press, 37–64. Google Scholar.
8. El-Raey, M. (1994)."Vulnerability Assessment of the Coastal Zone of Egypt to the Impacts of Sea Level Rise." Phase II", US Country Study Program.
9. Elshinnawy, I. A., Abo Zed A. I., Ali M. A., Deabes E. A. M. and Abdel-Gawad S., 2009. Coastal Vulnerability to Climate Changes and Adaptation Assessment for Coastal Zones of Egypt.27th Conference, Water Treatment Technology, Alexandria, 16-18 May 2009, Egypt.
10. Emery, K. O., Aubrey, D. G. and Goldsmith, V.: 1988,'Coastal neo-tectonics of the Mediterranean fromtide-gauge records', J. Marine Geol. 81, 41–52.
11. Fagan, B. 2011. Fresh Water Supplies Are Going To Run Out, So What Can We Do To Make the Taps Keep Running. The Independent, 30 June 2011. http://www.independent.co.uk/environment/nature/fresh-watersupplies-are-going-to-run-out-so-what-can-we-do-to-make-the-taps-keep-running-2304481. html (accessed 30 April 2012).
12. Fanos, A. M., (1995) - the impact of human activities on the erosion & accretion of the Nile Delta Coast. Journal of Coastal Research, 11, 821-833.
13. Frihy, O. E. 2003. The Nile delta-Alexandria coast: vulnerability to sea-level rise, consequences and adaptation-June 2003, Volume 8, Issue 2, pp 115–138.
14. Houston, J. R., and R. G., Dean, 2011, Sea-level acceleration based on U. S. tide gauges and extensions of previous global-gauge analyses, Journal of Coastal Research, 27, 409-417.
15. IDA (2019), Water Security Handbook, published by the International Desalination Association (IDA) and Global Water Intelligence (GWI) in January 2019. (IDA- Desal. org / desalination by the numbers)
16. PCC (1998) The regional impacts of climate change, an assessment of vulnerability. Cambridge University Press, Cambridge.
17. IPCC (2001) Climatechange2001: the physical science basis. Summary for policymakers. Cambridge University Press, Cambridge.
18. IPCC (2007), Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the IPCC, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, eds., Cambridge University Press, Cambridge, 996 pp.
19. IPCC (2007)."Fourth Assessment Report of the Intergovernmental Panel on Climate Change, "4. Adaptation and mitigation options." Contribution of Working Groups II, III, and I; Pachauri, R. K and Reisinger, A. (eds.).
20. IPCC (2007) impacts, adaptation and vulner ability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge.
21. IPCC (Intergovernmental Panel on Climate Change). 2008. Technical Paper on Climate Change and Water. IPCC Technical Paper VI, http://www.ipcc-wg2.org/ (accessed May 2012).
22. IPCC (Intergovernmental Panel on Climate Change). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Summary for Policy Makers. http://www.ipcc.ch/news_and_events/news.shtml (accessed May 2012).

23. Jevrejeva, S., A. Grinsted, J. C. Moore, and S. Holgate, 2006, Nonlinear trends and multiyear cycles in sea level records, Journal of Geophysical Research, 111, C09012, doi: 10.1029/2005JC003 229.
24. Kemp A, Horton B, Donnelly J, Mann ME, Vermeer M, Rahmstorf S (2011) Climate related sea-level variations over the past two millennia. Proc Natl Acad Sci USA. doi:10.1073/pnas.10156 19108.
25. Melloul A, Collin M (2009) Key natural and anthropogenic parameters enhancing the effect of sea level rise. Ocean Coast Manage 52:39–46.
26. MWRI, (2010). "Water Resources Development and Management Strategy in Egypt – 2050", in Arabic, Ministry of Water Resources and Irrigation, Cairo, Egypt.
27. Nicholls, R. J. and Klein, R. J.: 2000, Some Thoughts on Impacts and Adaptation to Climate Change in Coastal Zone, in proceedings of SURVAS Expert Workshop on African Vulnerability and Adaptation to Impacts of Accelerated Sea-Level Rise (ASLR), Cairo, pp. 5–13.
28. NOAA, (2015), The National Oceanic and Atmospheric Administration, United State of America-sea level data – 128 different gauge stations around the world for more than 75years tide data. www.climate sanity.wordpress.com.
29. Qadri, Syed (2003). "Volume of Earth's Oceans". *The Physics Factbook*. Retrieved 2007-06-07.
30. Rahmstorf S, Vermeer M (2011) Discussion of: Houston, J. R. and Dean, R. G., 2011. Sea-level acceleration based on U. S. tide gauges and extensions of previous global-gauge analyses. J Coast Res 27:784–787.
31. Sestini, G (1991) Implication of climatic changes for the Nile Delta in Environmental and Societal impacts of Climate changes and Sea level Rise in the Mediterranean Sea Region.
32. Soffer, A. 1999. Rivers Of Fire: The Conflict Over Water in the Middle East. London, UK: Rowman and Littlefield.
33. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.
34. Trondalen, J. M. 2009. Climate Changes, Water Security, and Possible Remedies for the Middle East: United Nations World Water Assessment Programme, ent Sciific Paper. Paris: United Nations Educational, Scientific and Cultural Organization.

6/25/2019