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Environmental Chemistry and Remote Sensing Data to Discuss Wastewater Discharging Within a Carbonate Plateau Through Chemical Reactions

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Abstract
The integration between the environmental chemistry and remote sensing data can be considered a new approach introduced through this study to investigate and monitor the ambient environment. The research findings relative to chemical and bacteriological analyses show disparities in the elements' concentrations of wastewater (influent, effluent, seepage, and overflow) with a salinity range between 3539 and 9509 mg/l. Groundwater salinity values range from 3680 to 11471 mg/l, NO_3 (1.4 to 11.2 mg/l), viable bacteria(16 to 70), COD (70 to 125 mg/l), BOD (15 to 40 mg/l), and TOC (90 to 192 mg/l). These data reveal the penetration of the wastewater till a depth of 125 m. To discuss the impact of wastewater on the carbonate landform, a new chemical approach has been presented. In this approach, the water chemistry was expressed by their hypothetical salts, whereas the rocks were expressed via their main chemical constituent ($CaCO_3$, 95%). The approach provides the possibility of creating all the potential chemical reactions with their equations. The obtained equations indicate possibility of rock dissolution, crumbling and continuous release of CO_2 (agreenhouse gas). The results of the study led to recommendations to protect the region's unique landform and work to resist environmental degradation.

*Keywords:*Environmental chemistry; Wastewater; Groundwater; Marmarica Plateau; Remote sensing.

1. Introduction

The environmental chemistry is an approach depending on the five environmental spheres and their interactions together where it can be considered the main key for any of sustainability and industrial ecology as well as the green chemistry [1]. The present research deals mainly with two of these spheres; hydrosphere (water) and the geosphere (earth). It also can extend to discuss the anthrosphere where humans modify the overall environment [2]. Scientists and politicians are working to integrate policy and administration with the physical and natural sciences to reduce and avoid environmental degradation considering the complexity of the environmental issues we face today [3]. Lack of effective regulation and administration has placed restrictions on the physical, chemical, and technological procedures used to lessen and minimize the negative consequences of environmental pollution. Although many political boundaries have been established, pollution does not follow these limits and to be able to defend natural limits, political ones must be crossed [4]. Science's responsibility includes not just identifying previously unknown facts and occurrences, but also flaws in earlier research [5]. In this regard, the current research discusses the non-planned construction of wastewater plant over a fractured carbonate plateau that can lead to plateau and environment deterioration. This means that the scientific studies should be carried out before any constructions lead to changes in land use and affect the ambient environment. The present study attempts to apply a scientific approach on the Marmarica Plateau in a specific area along the Southern Mediterranean coast. The Marmarica Plateau lies on the northern outskirts of the Libyan Desert between Nile Valley, and Central Sahara (Northwestern-Egypt and North-eastern-Libya), [6]. The plateau's landscape is karstified where the Marmarica limestone (belonging to Middle Miocene)

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displays a variety of karst shapes [7]. This plateau is composed of limestone, dolomitic limestone, and chalky limestone with intercalations of marl and shale [8-9]. It characterized elevation ranges between 220 m above sea level (m.a.s.l) to the south and 5 m along the coast. The composition of this plateau's surface as well as its subsurface can be influenced due to changes in land use that involve wastewater discharges. Theland use changes can have an impact on groundwater under arid conditions [10]. They cited cases from around the world about the impact of land use changes on the environment, including; the Shabestar basin in Iran [11], the Trans Pecos region in Texas, USA [12], and the Monte Desert in Argentina [13]. Indeed, the changes in land use and land cover (LULC) are directly affecting the ambient environment such as groundwater contamination, surface water runoff, and the ability to discern local development [14]. In this research, a new approach is presented to address and assess thepossible hazards of the wastewater plant constructions within a fractured carbonate plateau. Particularly in the context of environmental research, the combination of remote sensing (RS) and geographic information systems (GIS) can be viewed as an efficient way for data collecting and data display [15].The current research approach based on the chemical biochemical and bacteriological data for both the surface water (wastewater) and subsurface water sensing and GIS applications. The plateau is chosen to (groundwater) that are occurred over and inside the (groundwater) that are occurred over and inside the plateau, together with the data extracted from remote apply this approach as a pilot area from the coastal zone of the Southern Mediterranean coast and represents the arid environment[16] where this area is called locally "Ras Alam El Roum" which appear as a headland inside the Mediterranean Sea and involves Matrouh City (the capital of the governorate), (Fig. 1). The plateau in this area suffers from huge wastewater discharges particularly during the summer seasons that represent the main touristic season. Accordingly, in the summer, about 80,000 m^3/day of wastewater is pumped to the plant where its capacity only about 25,000 m^3/day. Therefore, the plant discharges the wastewater to the two forests which are also established over the plateau. The situation is very hard because the wastewater was spreading over the plateau rocks in the form of seepages and wastewater overflow. The main objectives of this study are to pay attention to protect the Marmarica Plateau that can be considered a unique landscape in the North of Africa coast. Also, to discuss interactions between the wastewater discharge and the plateau (surface and subsurface). Finally, the study aims to focus on the science-based policies through this case study where the unplanned constructions can affect the land use and causes many problems to the inhabitants and the environment.

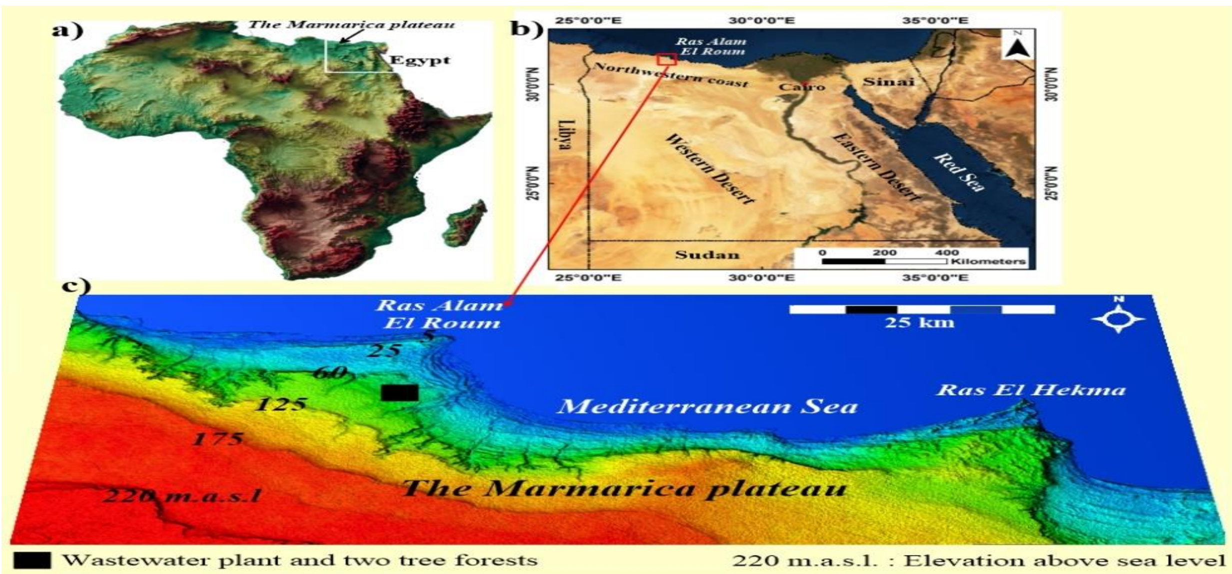

Fig. 1. The key map of the study area. a) the relief map of Africa shows the extension of the Marmarica Plateau (carbonate landform) in North Africa. b) Egypt map shows the location of the area. c) Three-dimensional model (3D) of the Marmarica Plateau shows the elevations in the study area and its vicinities

2 Materials and methods

2.1 Field work

The field investigation was achieved to monitor the problem of wastewater discharge over the plateau and to collect the water and rock samples. Throughout the field trip, 10 water samples were collected where; five water samples are representing the surface wastewater forms and other five water samples were collected from groundwater (deep and shallow wells).

The groundwater was sampled to identify if the wastewater penetrated the plateau at different depths or not. The sites of each water sample were located using a Garmin global positioning system (GPS, model C60). A portable pH conductivity meter was used to measure the total dissolved salts (TDS), electric conductivity (EC), and potential of hydrogen (pH) (model EXTECH EC 500). During the field trip, the geological data and the available hydrogeological data were identified.

2.2 Geologic sections

Three stratigraphic composite sections were measured and sampled from the area in the vicinities of the wastewater plant.

These sections were investigated and described to understand the nature of the Middle Miocene rocks which form the plateau and located in a direct contact with the wastewater. A total 35 rocks and sediments samples were collected and subjected to careful investigation in the laboratory.

Then, the stratigraphic sections were drawn, and the location of each section is illustrated on a map.

2.3 Remote sensing and GIS applications

The satellite images and Digital Elevation Model (DEM) are providing various datasets for this research. The images and DEM were assigned to a projection (Datum; WGS 84: UTM zone; 35North) through ArcGIS software (version 10.4).

The datasets that were employed in the current study including: (1) Landsat 8 images (bands: 7, 4, 2 with spatial resolution 30-meter, origin: USGS website), was used as base map. (2) Landsat ETM+ was used to extract the structural lineaments affecting the plateau. (3)

The Shuttle Radar Topographic Mission (SRTM) DEM were employed to generate many data layers including: slope, flow accumulation, TIN (vector - based representation of the physical land surface), and 3D model with high-resolution for a better visualization of the studied plateau. (4) Hill shaded relief layer that clarifies the main drainage lines.

This layer was overlaid by the structural lineaments. (5) The collected samples were interpolated over the Tin layer to clarify their spatial distribution.

2.4 Land use/land cover and change detections

Change detection over the plateau and urban area is created throughout the period from 1990 to 2020 using four satellite images from Google Earth engine through historical images tool.

The wastewater infrastructures and the different changes were illustrated by visual interpretation. Consequently, the datasets for the land use land cover (LULC) of the specific area of the plateau were obtained via the European Space Agency (ESA). These datasets of ESA contain World Cover Images that show a global land cover map with high resolution (10m) and are depending on the bands of Sentinel-1 and Sentinel-2 satellite images (https://www.sentinel-hub.com/).

2.5 Satellite precipitation and temperature data

In the current research, the data of rainfall estimates from Rain Gauge and Satellite Observations (CHIRPS), was used. CHIRPS is a quasi-global rainfall data set with long-term temporal coverage (from 1981 to near real time), relatively high spatial resolution (°0.05 °0.05), and a processing chain that combines satellite and gauge rainfall estimates [17].

Early studies concentrated on fusing models of terrain-induced augmentation of precipitation with interpolated station data. More recently, high resolution (0.05°) gridded precipitation has been developed using new satellite observational resources, such as gridded satellite-based precipitation estimates from NASA and NOAA.

These improved climatologies can eliminate systematic bias from satellite-based precipitation fields, which was a crucial step in the creation of the CHIRPS data set from 1981 to recently (https://www.chc.ucsb.edu/data/chirps).

Therefore, the current study depends on the precipitation daily data of CHIRPS to monitor the amounts and frequency and determine the main rainfall trend under the current climate change.

On the other hand, the temperature is also can be considered an important parameter to discuss the factors affecting any process in arid coastal area and to discuss the climate change issues. Therefore, the daily maximum temperature of satellite data is collected in Modern-Era Retrospective analysis for Research and Applications ver.2 (MERRA-2). This model achieves the reanalysis of the satellite era produced through NASA Global Modeling and Assimilation Office using the Goddard Earth Observing System Model (GEOS) version 5.12.4 [18]. The spatial resolution of the data is 0.5 X 0.625 degree.

2.6 Laboratory (Chemical and bacteriological) analyses

The water samples were gathered for chemical and biological investigation in firmly closed 100 ml sterile plastic bottles. Ion Chromatography was used in the chemistry lab of the Desert Research Center in Cairo, Egypt, to analyze the primary elements (DIONEX ICS-1100). Sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), and sulphate (SO_4^{2-}) are among these elements.

The Kjeldahl distillation method, often known as "Kjeldahl nitrogen" was used to find out the amount of NO_3^- in the water samples under investigation [19]. On the other hand, TOC (Total Organic Carbon), COD (Chemical Oxygen Demand), and BOD (Biochemical Oxygen Demand) were measured in various water samples in accordance with the published manuals of [19-20].

On the other hand, there are numerous techniques for quantifying bacterial cells in bacteriological research, but the most common one is bacterial plating, which enables live cell detection using colony forming unit (cfu) counts. Using the pour plate technique, the total number of bacteria is counted at the incubation temperature of 30°C [21]. As a result, the concentration of live microorganisms in the examined water samples is also determined using the Most Probable Number method (MPN) by replicating liquid broth growth in ten-fold dilutions.

3 Results

3.1 Climatic datasets

The continuous observing of annual rainfall has special importance to identify the possibility of the surface runoff occurrences which can join the wastewater and affect the fractured plateau. The remote sensing satellite daily data (CHRIPS) for 40 years during the periods of 1982–2021, were analyzed (Table 1, Fig. 2).

The obtained records reveal that the area receives average annual precipitation reaches to 101.24 mm (average of 40 years).

From the environmental viewpoint, these amounts can recharge groundwater and also can be used for drinking and other purposes, only in the absence of a pollution source (wastewater plant). On the other hand, the analysis of annual maximum temperature (1982-2021) shows values range between 25.2°C to 25.8°C that means a general increasing trend (Fig. 2).

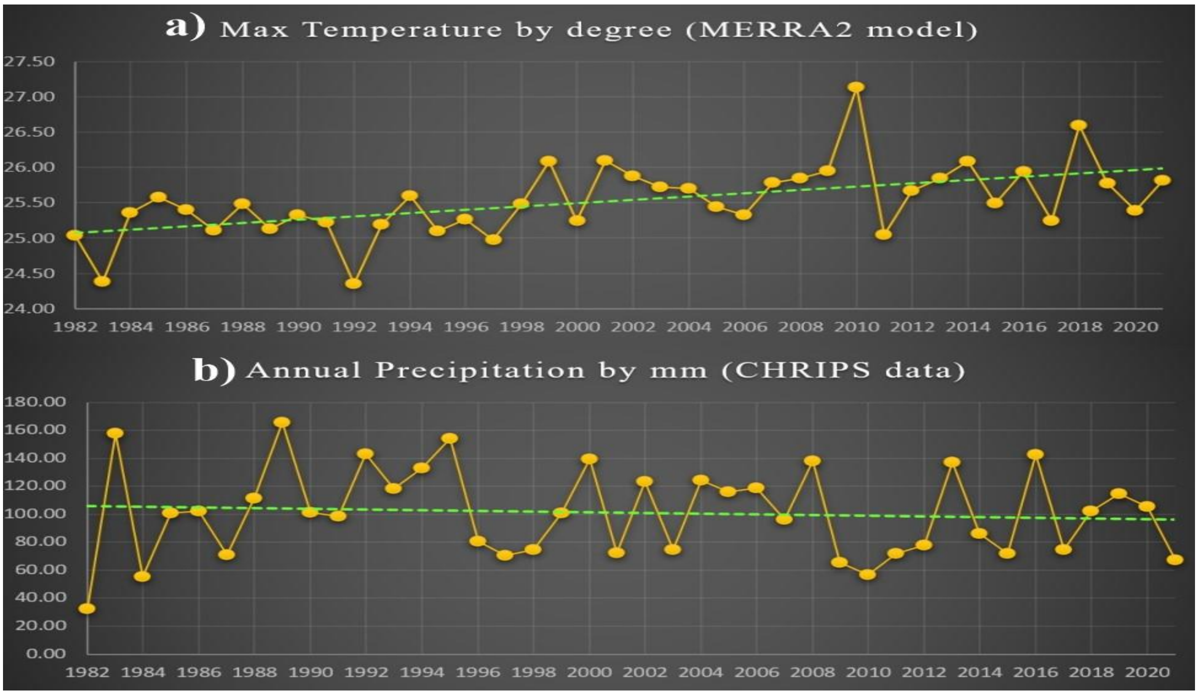

Fig. 2. Climate datasets for 40 years obtained through the satellite observations. a) the maximum temperature. b) The annual precipitation.

Table (1): The data of 40 years annual maximum temperature and total annual precipitation.

Year	Temperature °C	Year	Temperature °C	Year	Temperature °C	Year	Temperature °C
1982	25.03	1992	24.35	2002	25.87	2012	25.67
1983	24.38	1993	25.19	2003	25.72	2013	25.84
1984	25.36	1994	25.59	2004	25.70	2014	26.09
1985	25.58	1995	25.10	2005	25.44	2015	25.49
1986	25.40	1996	25.27	2006	25.33	2016	25.94
1987	25.11	1997	24.98	2007	25.78	2017	25.25
1988	25.48	1998	25.49	2008	25.85	2018	26.59
1989	25.13	1999	26.09	2009	25.95	2019	25.78
1990	25.33	2000	25.25	2010	27.14	2020	25.39
1991	25.22	2001	26.09	2011	25.05	2021	25.82
Average	25.2	*Average*	25.3	*Average*	25.8	*Average*	25.8

Year	Precipitation mm	Year	Precipitation mm	Year	Precipitation mm	Year	Precipitation mm
1982	32.48	1992	143.18	2002	123.31	2012	78.09
1983	157.69	1993	118.11	2003	74.77	2013	137.01
1984	55.48	1994	132.85	2004	124.43	2014	85.96
1985	100.75	1995	154.33	2005	116.12	2015	72.08
1986	102.36	1996	80.60	2006	118.90	2016	142.56
1987	71.07	1997	70.34	2007	96.45	2017	74.52
1988	111.20	1998	74.44	2008	138.23	2018	102.36
1989	165.43	1999	100.82	2009	65.58	2019	114.77
1990	101.45	2000	139.61	2010	56.54	2020	105.62

Continue Table 1

1991	98.69	2001	72.56	2011	71.80	2021	67.23
Total	996.60	*Total*	1086.84	*Total*	986.13	*Total*	980.20
Average	99.66	*Average*	108.68	*Average*	98.61	*Average*	98.02

3.2 Geologic datasets

The deposits from the Tertiary and Quaternary are covering the area. The Middle Miocene Marmarica Formation is belonging to Tertiary and represents the main constituents of the plateau. The three measured stratigraphic sections (Fig. 3) have Miocene thickness ranges between 22m and 39m. These sections indicate that the plateau is composed of fossiliferous limestone ($CaCO_3$ about 95.35%), chalky limestone ($CaCO_3$ about 96.8%), argillaceous limestone ($CaCO_3$ about 75%), marl ($CaCO_3$ about 66%), and shale intercalations ($CaCO_3$ about 10%). These different rocks are indirect contact with wastewater (Fig. 4) which immersed the plateau. Consequently, there is a set of possible chemical reactions that can result from this contact between rocks and wastewater, and this will be dealt later within the following sections.

3.3 Chemical and bacteriological datasets

The water samples were collected from different forms of wastewater that are spreading above the plateau where the influent sample represents the initial wastewater. The wastewater overflow and seepage express about the water after passing over the plateau rocks, but they are still in continues reactions.

Also, samples are collected from groundwater where the deep and shallow wells are represented. These wells are belonging to the Middle Miocene (deep wells) and Pleistocene (shallow wells) aquifers. The groundwater chemistry can reflect the reactions between constituents of the water that infiltrate to the aquifer and interact with the aquifer matrix as a result to rock-water interactions. The chemical analyses of the wastewater (influent, effluent, seepage, and overflow, samples from 1 to 5, Fig. 7) show disparity in the constituents' concentrations (Table 2, Fig. 6). For example, the TDS values are ranging between 3539 and 9509 mg/l, chloride ranges between 1640 and 5000 mg/l, and sodium between 1200 and 3000 mg/l.

The data reveal the general concentrations increasing in all samples than the initial wastewater (samples 1 and 2).Quite contrast, the values of COD, BOD and TOC, as well as CFU and MPN data show the highest records in influent and effluent samples, while other wastewater samples have lower values (Table 2, Fig. 6).

On the other hand, the chemical analyses of the groundwater (deep and shallow wells, samples from 6 to 10) have TDS values range between 3680 and 11471 mg/l, chloride values between 1900 and 6000 mg/l, and sodium between 1120 and 2600 mg/l.

The most important obtained results of the groundwater are the existence of NO_3 (1.4 to 11.2 mg/l), viable bacteria(CFU: 16 to 70, MPN: 9 to 22), as well as the records of COD (70 to 125mg/l), BOD (15 to 40mg/l), and TOC (90 to 192mg/l), (Table 2, Fig. 6).

The last-mentioned data represents the pollution indicator and clarify the penetration of the wastewater to the plateau rocks till depth 125 m (the deepest groundwater well). The different spreading wastewater forms (Fig. 7) above the plateau are thought to affect on surface and subsurface plateau rocks and cause the groundwater contamination.

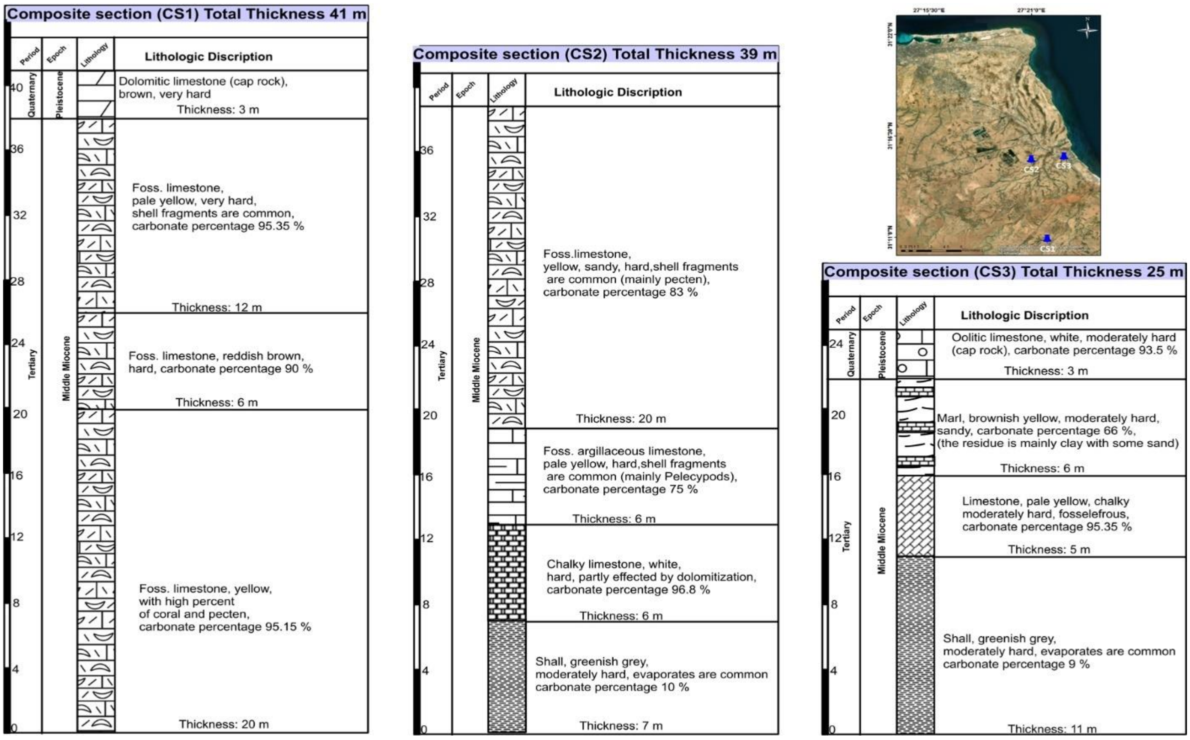

Fig. 3. Graphical representation of the three measured stratigraphic sections representing the main rocks of the study area

3.4 Hypothetical salts combinations and possible reactions with the Marmarica plateau

It is assumed that the strong acid ions (Cl^- and SO_4^{2-}) form a chemical bond with the alkali metals (Na^+ + K^+) and the rest of the acid radicals' combine with the alkaline earth's (Ca^{2+} and Mg^{2+}). Therefore, the chemical results of the studied water samples reveal the possibility of five groups of the salts combinations.

The obtained hypothetical salts combinations and their assemblages are shown in (Table 3).The two wastewater samples that were collected from influent and effluent (samples nos. 1 and 2) are showing assemblage (I) that represents the initial water status. This water is discharging over the plateau and reacts with its rocks and soil as well as infiltrate to the groundwater. This result is clear from the existence of hypothetical salts (assemblages V and VI in wastewater) which resulted from the reactions with plateau and form the advanced water status. The last two assemblages are characterizing with the presence of $MgCl_2$ and $CaCl_2$. Also, the assemblage(VI) indicates that an ion exchange processhas been occurred and the wastewater had an enough residence time that permit to rock-water interaction. These two chloride salts reflect the effect of marine salts combinations (marine facies) which are dominant in plateau rocks. The studied groundwater samples show salts combinations belonging to assemblages (IV and V) where $MgCl_2$ (marine facies) is also existed. The two bicarbonate salts ($Ca(HCO_3)_2$ and $Mg(HCO_3)_2$) reflect the effect of leaching and dissolution processes of terrestrial salts (meteoric water) by local precipitation, while the SO_4 salt as ($MgSO_4$) characterizes groundwater affected by evaporate deposits and or due to the effect of leaching and dissolution processes of terrestrial salts (Table 3). These salts can still in continues reactions with plateau rocks and soils.

The studied geological sections indicate that the plateau is composed mainly of limestone ($CaCO_3$). The expected reactions and equations that can be resulted from the rock-water interactionsare tabulated in (Table 4). The most important results of review those equations are showing the hazard that may affect the plateau due to wastewater discharge. Also, the equations indicate the release of CO_2 gas through many reactions; this result has a direct impact on the environmental pollution and climate change.

Table (2): Analytical data of wastewater forms as well as deep and shallow groundwater wells.

Sample No.	1	2	3	4	5	6	7	8	9	10
Type	Wastewater influent	Wastewater effluent	Wastewater overflow	Wastewater seepage	Wastewater seepage	Deep groundwater wells >100 m			Shallow groundwater wells <50m	
pH	10.6	9.2	9.3	7.29	10.2	9.6	9.3	9.4	8.4	8.4
TDS	3539	3540	9509	6984	8943	3680	6499	7250	6068	11721
Ca^{+2}	42	63	126	244	505	67	63	84	126	589
Mg^{+2}	64	64	281	391	409	133	179	205	179	665
Na^{+}	1200	1200	3000	1850	2150	1120	2067	2333	1867	2600
K^{+}	46	46	50	42	49	24	62	71	32	62
CO_3^{-2}	36	27	45	20	18	27	27	27	54	36
HCO_3^{-}	549	494	302	476	73	210	192	128	329	146
SO_4^{-2}	236	193	856	456	775	304	705	836	510	1695
Cl^{-}	1640	1700	5000	3744	5000	1900	3300	3630	3135	6000
NO_3^{-}	26	15.4	16.8	28	11.2	5.6	7	5.6	11.2	1.4
COD	260	120	68	63	50	120	125	91	70	110
BOD	450	22	30	50	36	15	30	30	40	22
TOC	170	140	78	95	140	192	90	180	170	135
Total count (cfu) [1]	1100	280	42	42	108	70	60	16	20	70
MPN[2]	280	84	6.2	6.2	16	9.4	22	15	16	9

(1) cfu: A colony-forming unit 2) MPN: Most Probable Number of bacteria /100 ml
The depths of deep wells nos. 6, 7 and 8 are: 125, 100, and 110 m respectively, belonging Middle Miocene aquifer.
The depths of shallow wells nos. 9 and 10 are: 30 and 25 m respectively, belonging Pleistocene aquifer.

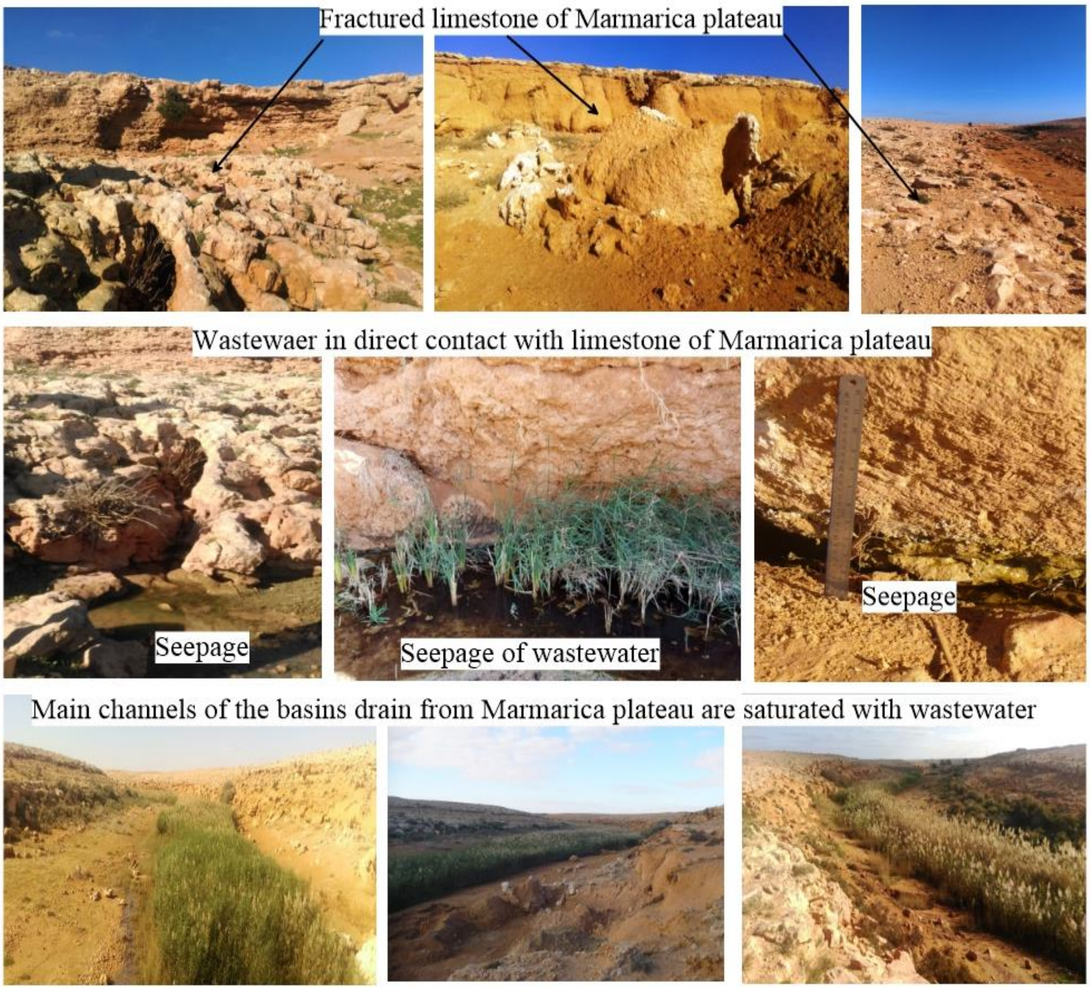

Fig. 4. Field photos show the effect of wastewater on plateau rockswhere they are in a direct contact.

Table (3): Hypothetical salts combinations of different wastewater forms and groundwater samples.

Sample no.	Water types	Hypothetical salts combinations					Assemblages
		1st	*2nd*	*3rd*	*4th*	*5th*	
1	Influent	NaCl	Na_2SO_4	$NaHCO_3$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	I (Initial status)
2	Effluent	NaCl	Na_2SO_4	$NaHCO_3$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	
3	Overflow	NaCl	$MgCl_2$	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	V (Advanced status)
4	Seepage	NaCl	$MgCl_2$	$CaCl_2$	$CaSO_4$	$Ca(HCO_3)_2$	VI (Advanced status)
5	Seepage	NaCl	$MgCl_2$	$CaCl_2$	$CaSO_4$	$Ca(HCO_3)_2$	
6	Deep well	NaCl	$MgCl_2$	$MgSO_4$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	IV (Intermediate status)
7	Deep well	NaCl	$MgCl_2$	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	V (Advanced status)
8	Deep well	NaCl	$MgCl_2$	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	V (Advanced status)
9	Shallow well	NaCl	$MgCl_2$	$MgSO_4$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	IV (Intermediate status)
10	Shallow well	NaCl	$MgCl_2$	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	V (Advanced status)

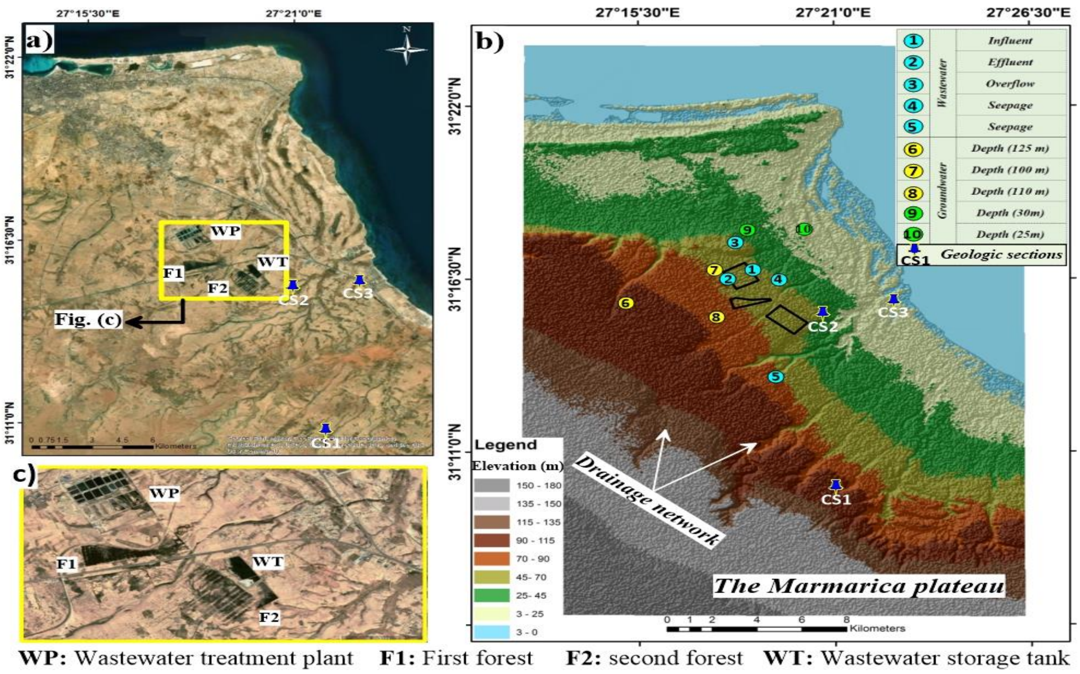

Fig. 5. Spatial distribution of the collected water samples and measured geological sections. a) Landsat 8 (LC8) shows the infrastructures of the wastewater plant with the forests. b) The illustration of all collected water samples overlay the TIN (triangulated irregular network, represents a classification of DEM). c) Focusing of the wastewater plant (Landsat 8).

Table (4): The expected reactions between the wastewater and, rocks and soil of Marmaica plateau

Hypothetical salts combinations in the studied water	Type of reaction	Expected equations for possible reactions that can be occurred between the wastewater and, the Marmarica plateau
NaCl	Direct reactions with plateau rocks and soil ($CaCO_3$)	*Cation exchange process* $Ca\ Mg\ (CO_3)_2 + 2NaCl$ Colloid ⇌ $2Na$ Colloid $+ Ca\ (Mg)Cl_2 + CO_2\uparrow$
Na_2SO_4		*Cation exchange process* $Ca\ Mg\ (CO_3)_2 + Na_2SO_4$ Colloid ⇌ $2Na$ Colloid $+ Ca\ (Mg)SO_4 + CO_2\uparrow$
Ca $(HCO_3)_2$	Indirect reactions	*Leaching and dissolution process* $CaCO_3 + CO_2 + H_2O \rightarrow Ca + 2HCO_3$ $2HCO_3 \rightarrow H_2O + CO_2\uparrow$
		Leaching and dissolution process $CaCO_3 + H_2O \rightarrow Ca\ (OH)_2 + CO_2\uparrow$

3.5 Change detection of land use /land cover (LULC)

The monitoring of the plateau surface during the period of 1990 to 2021 shows land use changes where the wastewater plant start existing in 2000 as small building. Then the plant is extended, and two tree forests were appeared (Fig. 8). In this regard, expanding along from the year of 1990 to 2021 which means more pumping of wastewater to the plant and forests above the plateau. This continuous pumping led to the existing of wastewater in different forms (overflows, and seepages). The wastewater overflows are occurred when the soil is fully saturated. Therefore, the wastewater also can infiltrate to the groundwater through the overflow pathway and through the excess quantities pumped into the forests daily. The recent LULC map of 2021 [22-23] reveals the same mentioned results with more details about the wastewater tanks and the tree forests. 3.6 Thematic **3.6GIS data layers**

The structural lineaments are representing the faults and/or joints that affected the plateau rocks. These lineaments were obtained through the investigation of the Landsat image as well as the shaded relief map and the geological map [24]. The analyses of these lineaments indicate that the plateau was affected by two sets of faults with trends NE-SW and NW-SE (Fig. 9). The first trend (NE-SW) is dominant one than the other NW-SE.

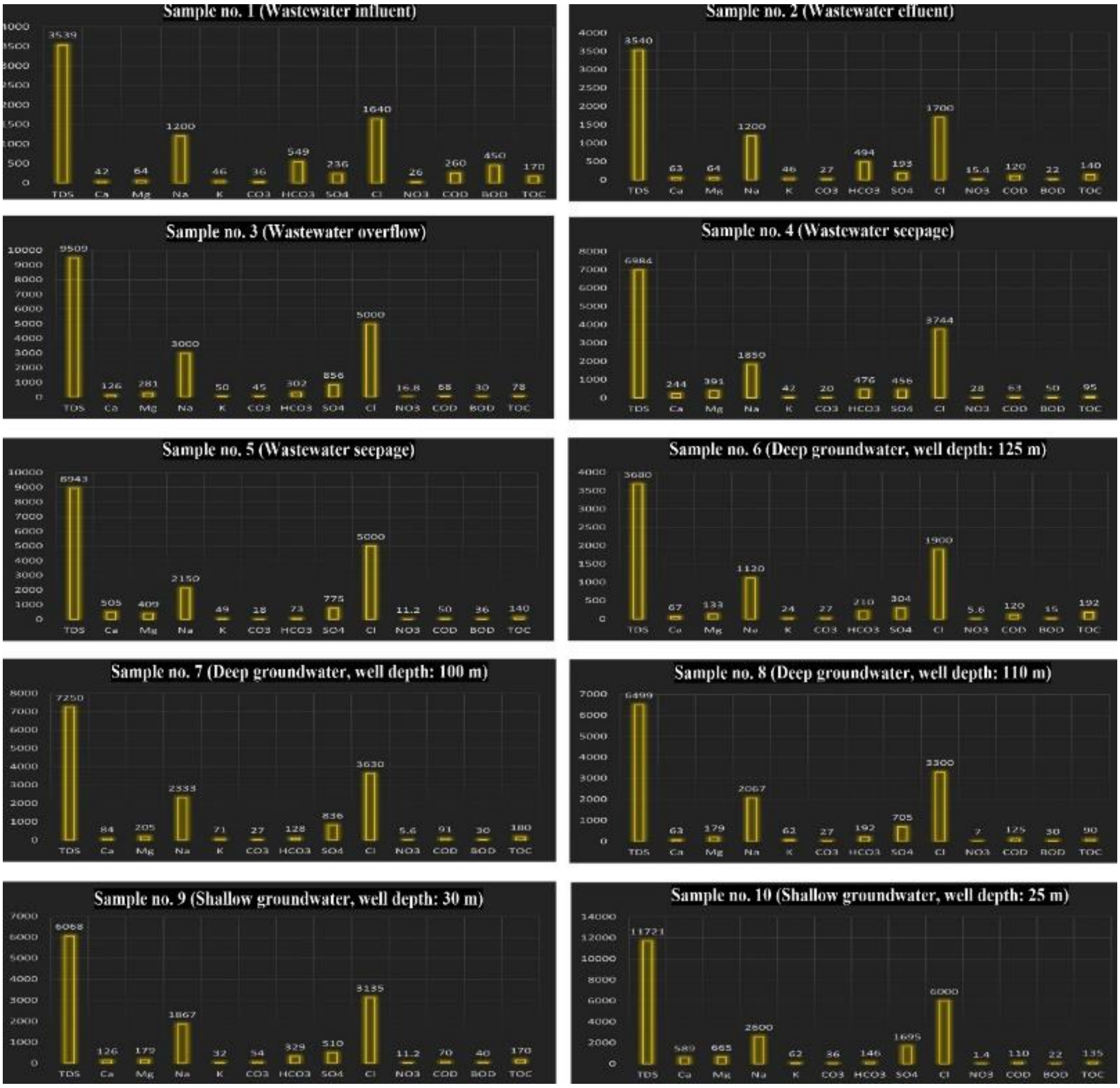

Fig. 6. Graphical representation of the obtained chemical and bacteriological data.

The lineaments density is recorded throughout the fieldworks where they are existed over the Middle Miocene rocks of the plateau. Also, the plateau rocks are recorded highly affected by cracks and joints (fractures as appear in the field photos). The overlaying of these structural lineaments above the shaded relief map reflects that drainage lines are structurally originated and controlled. These lineaments facilitate the penetration of wastewater to the subsurface plateau rocks and can increase the interactions between them where they can be considered as week zones for erosions. Also, they have an important role for groundwater recharge (from rainwater) and contamination (from wastewater). On the other hand, the flow accumulation data layer (extracted from DEM analyses) shows the main drainage networks affecting the plateau. This drainage represents the surface water path of both rainwater and wastewater and provides the chance for reactions with plateau rocks (Fig. 10a). Additionally, the slope layer represents an important factor extracted from DEM analyses to identifying the surface-groundwater interactions [25]. This is due to that surface slope affects the runoff (accumulation and speed) as well as infiltration capacity. The Marmarica plateau has a general gentle slope where the values are ranging between 1 and 5 degrees (Fig. 10b). Only the drainage networks show a moderate slope range between 8 and 20 degrees. It is obvious that the gentle slops areas generate a good chance for rocks-water interactions and increase the capability of the infiltration rates.

Fig. 7. Field photos show the spreading of wastewater above the plateau with different forms (influent, effluent, seepage, overflow, and lacks).

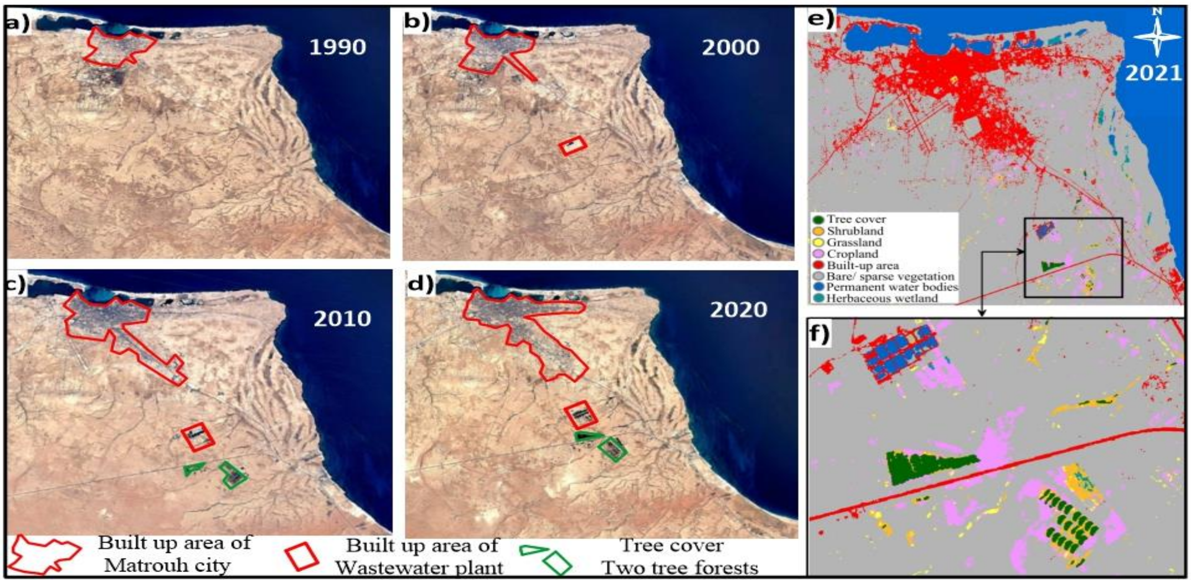

Fig. 8. Change detection through satellite images: a) Year of 1990, b) Year of 2000, c) Year of 2010, d) Year of 2020. e) and f) Land use/land cover map (LULC) that was created with a spatial resolution 10 depending on combination of both Sentinel-1 and Sentinel-2 data [23].

4 Discussion

The idea of "scientific policy" can be explained as combining the attainment of both scientific facts and hypotheses on the real ground in decision-making processes and policies applied to various problems, particularly environmental challenges. In the present study, the obtained datasets of climate, geology, water chemistry, bacteriological analyses, land use/land cover, and thematic layers, provided the basic scientific knowledge needed to overcome a specified environmental problem. The current study represents an integrated approach where the satellite platforms were employed to provide data alongside the chemical and bacteriological analyses to investigate the hazards of wastewater on the Marmarica plateau. The interpretation of the climate datasets for 40 years (rainfall and temperature) reveals that climate change is thought to have occurred and is affecting the study area where the increasing trend of temperature is associated with a decreasing trend of rainfall amounts (Table 1, Fig.2). This change can lead to environmental deterioration. The investigations of the geological sections indicate that the plateau is mainly composed of carbonate rocks (limestone, marl, and dolomitic limestone), where $CaCO_3$ is the main constituent of these rocks (Fig. 3). Therefore, many chemical reactions can occur between $CaCO_3$ and wastewater. These reactions can affect the plateau through the dissolution of itsrock constituents and represent a hazard to the environment. The CO_2 gas is also noticeable as a result of these expected reactions (Table 4).The emission of CO_2 gas has a direct impact on the environment and plays an important role in increasing climate change, both locally and globally. With regards to the initiative of a "science-based target"[26], Net-Zero Emissions can be reached when anthropogenic reductions over a specific period balance greenhouse gas emissions [27]. The Paris Agreement states that reducing CO emissions alone will not be enough to achieve the goal of reducing global warming by 1.5°C. Net-Zero emissions might therefore be regarded as the best option for future climate change mitigation. According to [28], however, the Parties are urged to increase their emission reductions and link their climate action commitments with the 2015 Paris Agreement in order to take mitigation action. In this context, the current study focuses on the local emissions that can be produced by wastewater reactions with plateau and can even contribute to an increase in greenhouse gases inadvertently. The reactions between wastewater and the plateau are believed to have started before the year 2000, as the changes detected reflect the appearance of the treatment plant (Fig. 8) around this date. Therefore, reactions continued for a long time. The current study is the first to use a chemical approach to express these reactions on the surface and subsurface. This method used chemical analyses of wastewater and groundwater to identify hypothetical salts (Table 3), which can then react with wastewater (influents, effluent, seepage, and overflow, Figs. 4 and 7), releasing CO_2.To confirm that the area has a specific condition permitting rock-water interactions, thematic data layers were investigated. The plateau is highly fractured, has a gentle slope, and is crossed by many drainage lines (which represent water accumulation, Figs. 9 and 10). These conditions increase the contact time between wastewater (particularly the overflow form) and rocks and provide the chance for groundwater contamination and recharge. The existence of NO_3, bacteria, as well as the obtained values of COD, BOD and TOC confirms that the groundwater is contaminated by wastewater (Fig. 6, Table 2).

Generally, the data reveal that the surface rocks and soils of the plateau were saturated (partly or fully) with wastewater, which led to occurrence of overflow and seepage (surface reactions). Also, the wastewater reached the groundwater along the faults and/or joints, which indicate the occurrence of contact with plateau subsurface rocks (subsurface reactions). Therefore, it is believed that the Marmarica plateau is highly influenced by wastewater plant operation, and it is now at risk because this water is spreading over its surface and also into its subsurface. Also, this status affects the environment negatively through groundwater contamination, soil, and air pollution, and contributes to the release of greenhouse gases.

Recommendation

According the forementioned data and investigations, this research introduces a set of suggestions and recommendation as follows:

a)It highly recommended to protect this unique landscape (the Marmarica plateau) through stop pumping of wastewater on its surface and to tree forests.

b)Establishment of a new wastewater plant with capacity 150,000 m^3/day instead of the current one (25,000 m^3/day). The location of the new one should be selected and isolated carefully.

c)The analyses confirm that the groundwater is chemically and bacteriologically contaminated, therefore it should be treated before any use

d)Launching a warning and educating the local communities about this situation and its riskson their health.

e)Installing a set of portable wastewater treatment systems around the current plant that offer a flexible solution for quick management, particularly in the summer season (where 80,000m^3 are pumped). These portable systems represent urgent solution where their effluent should be the downstream areas (low elevation) and used for main roads afforestation.

f)Finally, it essential to inform the decision makers with the hazards of the unplanning constructions and land use changes over the unique landscape and desert areas which cause environmental pollution. These hazards are also including greenhouse gases release and climate change effects at a time where the whole world seeks to reach Net-Zero emissions.

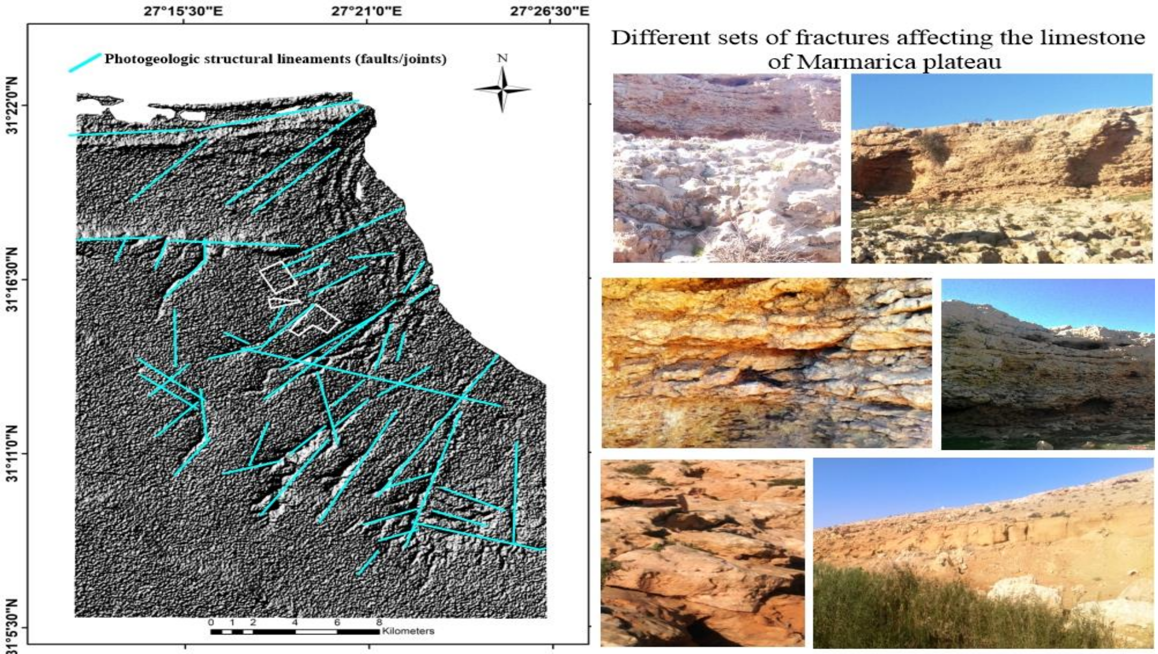

Fig. 9. Photogeological structural lineaments overlay the hilly shaded relief map, showing the main faults affecting the plateau, supported by photos of the recorded fractures.

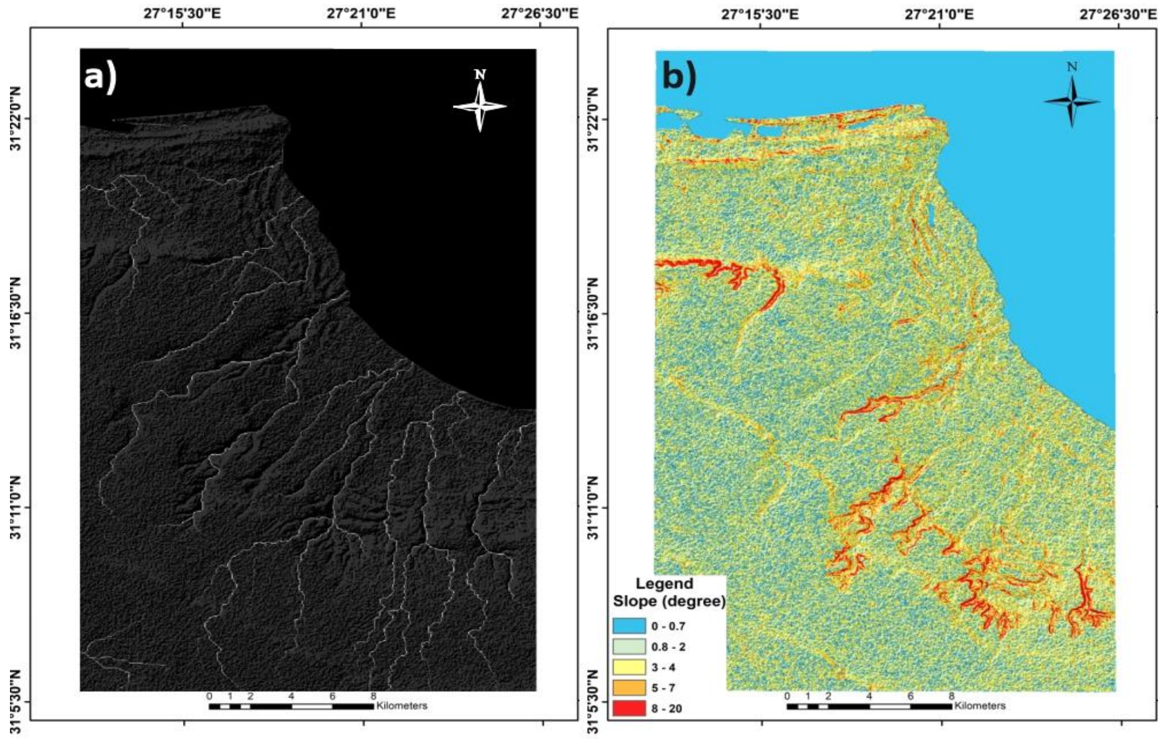

Fig. 10. Thematic GIS data layers express about the surface of the plateau. a) Flow accumulation layer. b) Surface slope data layer.

5. Conclusions

An integrated approach was used to understand and monitor the hazards of unplanned wastewater plant constructions above the carbonate plateau, which included chemical and bacteriological analyses of water, geological and remote sensing datasets from a coastal area, and field investigations. The chemical and bacteriological datasets indicated that the spreading wastewater can react with plateaus (soils and rocks) and also infiltrate to cause groundwater contamination, even in deep wells. Also, the current study introduces the first chemical attempt to express the reactions that may have occurred between wastewater and rocks. The obtained chemical data from the represented water samples (surface and subsurface) were converted to hypothetical salts, whereas the rocks were expressed through their main chemical constituents ($CaCO_3$, 95%). These chemical reactions and their equations indicate the possibility of rock dissolution and the subsequent release of CO_2(agreenhouse gas). On the other hand, the research pays attention to the effects of land use and land cover changes and how they can lead to environmental problems. The long-time change detections (1990–2021) show the expanding of the built area over the plateau with continued wastewater discharge, which led to surface and subsurface contamination. In this regard, the satellite platforms were employed to provide data regarding the following: climate (high resolution '0.05°' gridded precipitation data using new satellite observational techniques), land use and cover, slope, structural lineaments, water flow accumulation, and elevations. The integration between environmental chemistry and remote sensing data was very useful to introduce an effective approach regarding the factors controlling wastewater management strategies in an arid environment. The study pays attention to raising awarenessregarding the environmental hazards of unplanned constructions and land use changes over the unique landscape, which causes contamination in different spheres. These hazards also include greenhouse gas releases and climate change effects at a time when the whole world seeks to reach net-zero emissions. The authors believe these integrated environmental chemistry studies should be carried out before any construction leads to changes in land use and affects the ambient environment.

6. Conflict of interest

There are no conflicts to declare

7. Funding sources

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