Afghanistan Reveals the Source of Atmospheric Nitrogen during North Western Monsoons

AYSE OZLEM GORAL*, AMIR HADJI ALI GHANDI**, AND AHMET CEMAL SAYDAM**

RECEIVED ON 15.04.2014 ACCEPTED ON 17.10.2014

ABSTRACT

Chemical analysis of soil samples collected from Afghanistan have shown that those regions having capability of generating wind-induced dust at northern and south western territories have the capability of supplying nitrates and nitrites in addition to crustal materials. Together with all the other essential elements Afghan soil samples has the potential of controlling so far unexplained phytoplankton bloom and excess nitrate and nitrites during the course of NWM (North Western Monsoons) over the surface waters of Arabian Sea.

Key Words: **Afghan Soil, Nitrate, Nitrite, Dust, North Western Monsoons, Phytoplankton, Arabian Sea.**

1. INTRODUCTION

Until recently Afghanistan was a total mystery for the entire world and it was only possible to establish its normal links with the rest of the world following the UN intervention. Though, it was possible to observe the spread of dust from its ephemeral lakes via satellite-based remote sensing as mentioned by [1] in-situ sampling was practically not viable and still the situation is not encouraging for such scientific activities at Afghanistan. Today, high-resolution satellite based remote sensing technologies that are available to general public via internet has often shown that there exist two regions at Afghanistan that have the potential of generate wind-induced dust. The minor source is placed at southeastern Afghanistan, nestled against the mountains of Tajikistan and the major wind-blown dust originates from its southwestern corner along the border of Pakistan and Iran [1]. It's known that soil dust matrix is transported from land to the oceans, affecting ocean biogeochemistry and hence having feedback effects on climate as mentioned by Jickells, et. al. [2]. It's further known that the bioavailability of iron depends on its solubility therefore during the course of all Iron Enrichment experiments, iron sulfate used as an iron source. Recently, Saydam and Senyuva [3] has shown that the solubility of iron increases when desert origin dust comes into contact with cloud water. The necessity of desert origin dust and its microorganism context are essential ingredients as the reaction mechanism is controlled by the release of oxalate by bacteria and fungi's present within the desert soil. The release of oxalate assists microorganisms to attach themselves onto clay minerals as to form iron oxalate as shown by Chen, et. al. [4]. The next essential step is the photochemical reductive dissolution of adsorbed oxalate through decarboxylation reaction as to form less stable and thus more soluble phase Fe (II) as shown by Sulzberger, and Laubscher, [5]. Saydam, and Senyuva [3] has further shown that, the necessary reducing agent, oxalate, the most abundant dicarboxylic acid and accepted to be formed through chemical oxidation of gas-phase precursors in the aqueous phase of aerosols or assumed to be supplied through industrial activities, is in fact produced by the bacteria and fungi's as an osmosolute when the desert

* Göltaş Cement Inc. Isparta
** Environmental Engineering Department, Hacettepe University, Beytepe, Ankara, Turkey

osmoslute when the desert dust comes into contact with cloud water during its long range atmospheric transport. The oxalate production capacities of *Aspergillus niger* is a well-known process and still used for industrial scale oxalate production [6]. But in cloud production mechanism has not been recognized before and this photochemical reaction process takes place once the desert dust comes into contact with cloud water. Therefore, desert origin dust has the potential of supplying bioavailable iron under specific conditions as explained by [3] and Afghanistan being one of the potential dust sources has always attracted the attention of authors. In fact this specific study stemmed from the conversation with Tajik scientists during a conference where it was mentioned that, Afghan dust is blessed as "heavenly" dust in Tajikistan. Thus it was hypothesized that Afghan soil may have similar properties like Saharan desert dust and may enhance the formation of bioavailable iron as to be called as heavenly dust. In addition as hypothesized by Saydam, [7] we have also checked whether wet dust deposition enhances the phytoplankton bloom over the ocean surface by using satellite derived Chlorophyll and AOD (Aerosol Optical Depth) values.

The potential dust sources located at the northern Afghanistan mainly supply dust towards north and northeast direction since Hindu Kush Mountains of Afghanistan acts as a natural barrier for southerly transport of dust. Whereas, the perennial dust sources in western Afghanistan and eastern Iran emanates from a series of ephemeral/dry lakes and especially during the NEM's period frequent dust pulses originates from southwestern corner of Afghanistan and reaches over the Arabian Sea and eventually settles over the surface waters mostly as dry deposition. All these migration patterns are clearly traced by recent MODIS (Moderate Resolution Imaging Spectroradiometer) TERRA or AQUA satellites and near real time data can also be reached at respective sites available at Internet.

Arabian Sea possesses one of the highest biological productivity and much of this property is directly linked with upwelling of nutrient-rich waters during Southwest Indian Ocean Monsoon as mentioned by Wang, et. al. [8] and Naqvi, et. al. [9]. Thus any changes in the productivity are assumed to be due to the dependence of upwelling on wind intensity. Together with the dust transport emanating from Sahara during the SWM Arabian Sea receives ample amount of bioavailable iron; since solar irradiation that is necessary; is always at or above the threshold level along the path of the synoptic scale atmospheric depression as to initiate the photochemical reaction mechanism that is necessary in the production of bioavailable iron within the cloud droplets as explained by Saydam, et. al. [3]. Mace, et. al. [10] further shown that rain events originating from Sahara; further enhanced by various amino acids. Thus it's possible to suggest that the temporal and spatial variability of bioavailable iron as well as other micronutrient elements such as Zn and Mn and amino acids delivered to the Arabian Ocean, is controlled by the diurnal and latitudinal variations in solar irradiation and the sporadic nature of rain along the path of the synoptic-scale atmospheric depressions. Of course, this does not rule out the upwelling processes and subsequent enrichments of surface waters taking place during the course of SWM.

But, besides this source it is also known that both phytoplankton concentrations and primary productivity rates observed at the northern Arabian Sea are relatively high during both monsoons [11] and possess great inter-annual variability. It is clear that during the SWM, upwelling is responsible from the major phytoplankton blooms that persist until September [12-14]. A less intense phytoplankton bloom develops in the northern Arabian Sea after the NEM. It was proposed that the cool and dry winds cause convective mixing that may entrain nutrient-rich waters to surface layers leading to bloom conditions [15-17]. As expected this bloom develops during the course of NEM's that persists from February till March and all these bloom cases easily be traced by satellite data. In fact such blooms also been observed and reported by Sarangi, et. al. [18-22] via IRS-P4 (Indian Remote Sensing) satellite OCM (Ocean Colour Monitor) data. The successive oceanographic surveys carried out at Arabian Sea could not account for the excess nitrate levels observed at surface layers especially following the NEMs. As reported by Wiggert, et. al. [23] the wintertime convection, mixed-layer nutrient-enrichment scenario is an expected situation since this is typical of the world's oceans. What is atypical for the Arabian Sea is that primary productivity is observed to increase while nutrients accumulate [24-27]. Another interesting feature of the Arabian Sea is the presence of excess nitrite (NO_2) in the upper layers that accumulates during the course of the NEM and needs clarification. Recently, Marra, et. al. [26] concluded that iron does not appear to be at levels that can regulate productivity for the Arabian Sea since it has been surrounded by arid and desert lands thus limitation by nutrients will more likely be caused by nitrogen. Researchers unanimously concluded that nitrate accumulates during the NEM's but the source is still debatable. Several hypotheses were suggested for this and all of them are confined within the broad limitations of nitrogen cycle and still wait for explanation [28]. Thus our approach that illustrates that transport of atmospheric dust enriched with nitrates and nitrites can put a light on this problem once and for all.

2. EXPERIMENTAL

The presence of Turkish armed forces at Afghanistan during the mission of ISAF at 2002 enabled them to assist us in the collection and transport of surface soil samples all around Afghanistan. During the course of their mission it was not possible to lead them to specific places but we have to satisfy with what have been collected for us at those sites delineated with GPS as shown in Table 1 [29]. Sample from Zabol/Iran collected from a city located at southeastern corner of Iran at a location of ($31^0$05' 24''N; $61^0$33' 44''E) at an elevation of 483 meters. This elevation represents the base of this ephemeral lake located at Iran Afghan border. Fig. 1 illustrates the sampling locations at Afghanistan.

As to test the validity of hypothesis put forward by Saydam, et. al. Error! Reference source not found. less

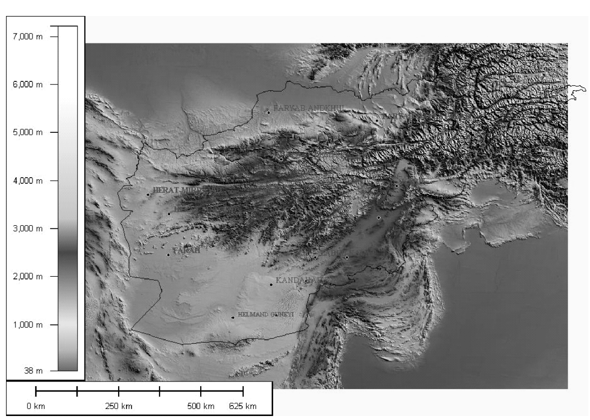

FIG. 1. LOCATIONS OF AFGHAN SOIL SAMPLES SHOWN ON DIGITAL ELEVATION MAP

than 50 micron size Afghan soil samples have been homogenized and 10g samples have been mixed with distilled water and irradiated with 1000 watt tungsten lamp as to imitate the solar radiation for two hours. Dionex IC AS 14 column equipped with AS 14 guard has been used to analyze the aliquots of water samples filtered through 0.45μ filter paper, as to determine their ionic compositions, specifically nitrate, nitrite, sulfate, oxalate and phosphate contents following contact with water as well their pH's. The formation of oxalate as an osmosolute by the bacteria and fungi's that may present within the soil samples, hence its detection was essential as during the photochemical production process of bioavailable iron formation due to presence of reducing agent. Despite this the sensitivity of technique used towards sulfate, and presence of excess sulfate at some samples, often masks detection of oxalate. The overall results were given in Table 1 for each site.

TABLE 1. THE NITRITE, NITRITE, OXALATE SULFATE AND PH LEVELS AT AFGHAN SURFACE SOIL SAMPLES

Region	Lat Lon	NO_3 (mg/g)	NO_2 (mg/g)	C_2O_4 (mg/g)	pH
Faryab-Andkhui	(65 14 N; 36 55 E)	0.412	0.044	-	8,67
Faryab-Daulabad	(68 48 N; 36 30 E)	0.025	0.005	0.006	8,24
Herat-Kemerkalav	(65 52 N;35 12E)	0.021	0.026	0.010	8,67
Herat-Mirdavut	(61 42 N; 34 02 E)	0.086	0.029	0.019	8,32
Herat-Şindand	(62 08 N; 33 43 E)	0.012	-	-	8,53
Farah	(62 06 N; 32 15 E)	2,50	0.9	-	8,42
South of Helmand	(64 03N;30 22 E)	0.112	-	0.030	8,38
Qhandahar-Shakir	(65 37N;30 28E)	0.018	-	0.009	8,37
Qhandahar-Kaji	(65 20 N; 31 23 E)	0.010	-	-	8,49
Qhandahar-Nesaji	(66 28 N;31 35E)	-	26	-	8,88
Zabul-Kalat	(66 58 N;32 07 E)	0.019	0.031	0.012	8,34
Zabul-Tazi	(67 55 N; 32 08 E)	0.018	0.028	0.003	8,07
Gazne	(68 54 N; 33 30 E)	0.099	0.027	0.012	8,65
Kabul	(69 08 N; 34 28 E)	0.008	-	-	9,15

3. RESULTS AND DISCUSSION

The result of the IC analysis as shown in Table 1. indicates two distinct regions, one is the northern territory and the second one is south-western Afghanistan. These two regions deserve special attention due to their ionic compositions and interestingly those two regions coincide with those areas that have the potential of generate wind-induced dust. The sampling sites located at northern Afghanistan, Faryab-Andkhui located at 550 meters elevation possesses 0.4 mg/g nitrate and Faryab-Davulatabad sampling site having an elevation of 1000 meter elevation possesses 0.025mg/g NO_3. These two sampling points represents the northern territories and have the capability of supplying atmospheric dust to northern states, Tajikistan and beyond. We have no further proxy data as to illustrate the impact of dust over these regions.

The essential nitrate source lies at the lower ground located at the south-western corner of Afghanistan surprisingly coinciding with the most remarkable dust generating region especially during the course of NEM's. This area is known to be composed of series of ephemeral/dry lakes and the enlarged Digital Elevation Model of the region further confirms the dried river bed that may have transported the water and sediments from Hindu Kush Mountains as shown in Fig. 2.

The sampling site that has the most enriched nitrate concentration 2.35mg/g NO_3 (Farah) is located at the northern boundaries of this ephemeral lake at 600 meters of elevation and the other one is located at south eastern part (south Helmand region) at 900 meters of elevation having 0.1 mg/g of NO_3. It can be argued that this specific lake although located at 600 meters elevation is located at a place where sediments rich in organic matter may have accumulated during the course of past climatic fluctuations. The location of sampling sites immediately suggests that it may be possible to observe even more elevated nitrate levels provided that the next sampling is being done at the lower basin of this ephemeral lake. In line with this observation it was possible to get soil samples from the Iranian sector of this ephemeral lake basin from Zabol at an elevation of 483 meters [30]. As expected, analysis further confirmed the presence of 3.25mg/g NO_3. The elevation of the Zabol/Iran sampling site represents the base of this lake basin thus may be accepted to represent the average level of nitrate for the entire lower basin. Thus, it is expected that any dust emanating from South Western corner of Afghanistan have the potential of transporting nitrate-enriched soil and the range of nitrate can vary between 2.35-3.25 mg/g. Thus depending on the strength of acting meteorological event it can be assumed that each gram of atmospheric dust have the potential of contributing elevated nitrate levels to the receiving body.

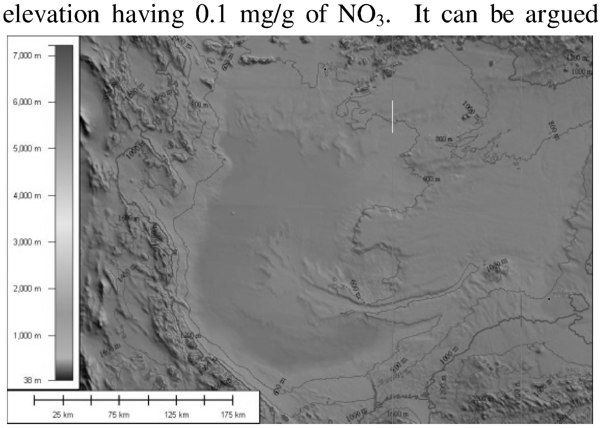

FIG. 2. THE DIGITAL ELEVATION MAP, ILLUSTRATING THE EPHEMERAL DRY LAKE LOCATED AT AFGHAN/IRAN BORDER. THIS BASIN ACTS AS A DUST BOWL AND EXPORTS HUGE AMOUNTS OF DUST ESPECIALLY DURING THE COURSE OF NEM'S WINDS

Despite expectations relatively high nitrate levels have also been observed at higher elevations at 2000 and 2200 meters above sea level at Zabul/Afghanistan region. Close inspection by DEM further confirms that this area is also has the potential of hosting series of small size ephemeral lakes despite its high elevation. Even though elevated levels of nitrate and nitrite Afghan soil suffers from absence of detectable levels of oxalate by IC. This could be due to strong overlapping of oxalate peak with excess sulfate content or simply due to absence of microbial content that is very unlikely for a top soil. Similarly Afghan soil is also lacking phosphate. This property may be explained with highly alkaline characteristics of Afghan soils as they vary between pH's 8.24 and 9.15.

Another interesting property of the Afghan soil is its nitrite content. The dust source region at the south-western part also contains 0.9-mg/g nitrite. But samples collected from Kandahar Nesaji possess abnormally high levels of nitrite reaching to 26 mg/g. This may well be the reason of having excess nitrite in ground water that is unfortunately, often used for drinking purposes.

A highest sulfate level also observed at those sampling points located at around the ephemeral lake and the samples which possesses highest nitrate level also contains the highest sulfate levels.

As to illustrate explicitly the magnitude of the dust emanating from Afghanistan, Iran and Pakistan during the course of NWM's we have used the satellite imageries captured on 20-21 March, 2012, as shown in Fig. 3(a-b) for respective days.

At present it's possible to use models as to predict the amount of dust expected over the entire basin as well as those areas where we do expect to observe wet and dry depositions, in three days advance. The dust model archive that can be reached from (http://www.bsc.es/earth-sciences/mineral-dust-forecast-system/bsc-dream8b-forecast/) also gives us an estimate of the magnitude of dust over the basin for 20 March, 2012 as shown in Fig. 3(c).

Sensors on board various satellites pours down ample amounts of data especially for the atmospheric aerosols for those regions where cloud coverage is not so extensive and Arabian Sea is one of those areas of the world oceans. Recently Giovanni site gave us a possibility to investigate long-term changes in the AOD archive data. Fig. 3(d) illustrates the AOD for the entire Arabian Sea and Northern Indian Ocean for the period July, 2003 till April, 2014. It can be seen that the aerosol concentration over the region reaches its peak levels during summer season but the impact of episodic NEM's can be seen during the course of December-March period for the period covering 2002-2014.

Though episodic, it can be seen that NEM's act as a carrier belt for immense dust pulse triggered from Afghanistan destined towards Arabian Sea where it settles eventually. Though we have no samples as to test the nitrate and nitrite contribution from other dust sources satellite imageries reveals that along its

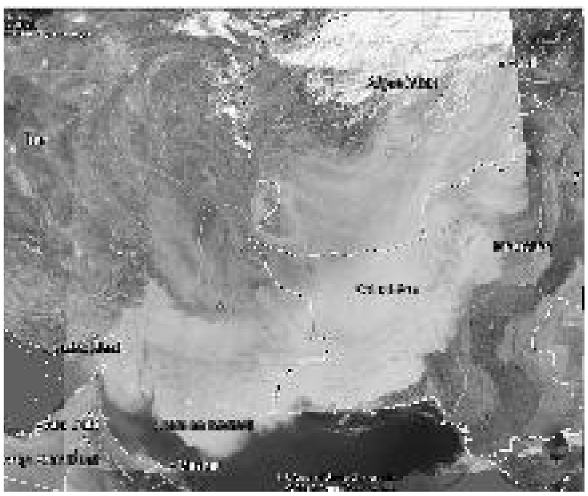

FIG. 3(a). MODIS SATELLITE IMAGERY FOR 20 MARCH 2012 SUPERIMPOSED ONTO GOOGLE EARTH, ILLUSTRATING THE ONSET OF DUST VIA NEM'S FROM SOURCE REGIONS

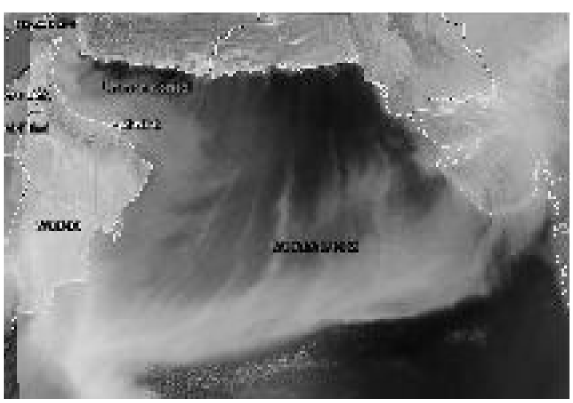

FIG. 3(b). MODIS SATELLITE IMAGERY FOR 21 MARCH 2012 SUPERIMPOSED ONTO GOOGLE EARTH, SHOWING THE IMPACT OF DUST OVER THE ARABIAN SEA

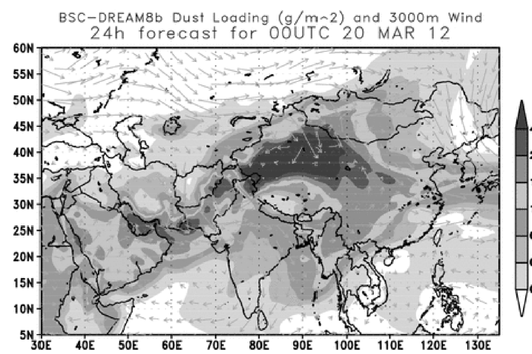

FIG. 3(c). DUST MODEL OUTPUT ILLUSTRATING THE EXPECTED DUST DISTRIBUTION OVER ASIA FOR 20 MARCH, 2012. (BSC-DREAM8B MODEL IN THE EARTH SCIENCES DIVISION OF THE BARCELONA SUPERCOMPUTING CENTER-CENTRO NACIONAL DE SUPERCOMPUTACIÓN (BSC-CNS). THE MODEL PREDICTS THE ATMOSPHERIC LIFE CYCLE OF THE ERODED DESERT DUST AND WAS DEVELOPED AS A PLUGGABLE COMPONENT OF THE NCEP/ETA MODEL)

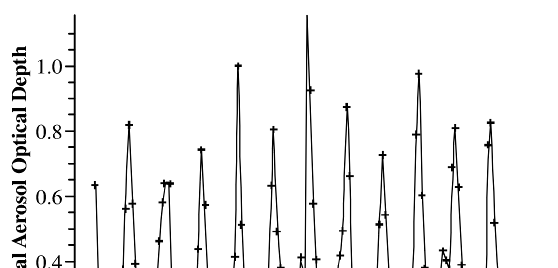

FIG. 3(d). AREA AVERAGED TIME SERIES OF AOD 550NM MONTHLY 1 DEG. FROM JULY, 2002 APRIL, 2014 FOR THE REGION (49.9219E;10.5469N 75.5313E AND 26.7188N) transport route additional sources at Pakistan and Iran also contributes to the dust burden. Unlike SWM's during the course of the NEM's dust settlements takes place often as dry deposition since the region suffers from laciness of clouds during this time period. Thus inspiring from the model estimate as shown in Fig. 3(c) and through the satellite imageries as shown in Fig. 3(a-b), it's possible to suggest that the dust pulse observed during 20-21 March, 2012 have the potential of supplying 1-4 gram of dust per square meter over the entire Arabian Sea and our experimental results shows that each gram of dust possesses 2.35-3.25 and 0.9-26 mg nitrite. Since the analysis of nitrate, nitrite, oxalate and sulfate performed by IC (Ion Chromatography) it can be assumed that the nitrate and nitrite levels present in the dust matrix represents the water-soluble fraction of these nutrient salts.

On 12th -14th December, 2003 yet another but spectacular dust pulse observed in association with the NEM winds as shown in Fig. 4(a-c) for the respective days.

This time we have also used NOAA/Giovanni facility as to illustrate the impact of this dust pulse over the region by using AOD properties as shown in Fig. 5.

As expected during the course of dust transport event AOD reached its peak levels and persisted for about 3 days as it traverse the Arabian Sea in North South direction as shown in Fig. 6, and there were no other significant dust pulse observed till end of December 2003.

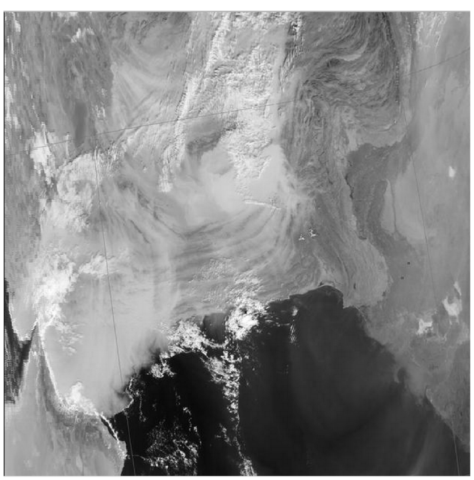

FIG. 4(a). THE ONSET OF DUST PULSE FROM AFGHANISTAN, PAKISTAN AND IRAN DESTINED TOWARDS ARABIAN SEA ON 12TH DECEMBER, 2003. (HTTP://LANCE-MODIS.EOSDIS.NASA.GOV/CGI-BIN/IMAGERY/SINGLE.CGI?IMAGE=CREFL1_143.A2003346062501-2003346063000.2KM.JPG)

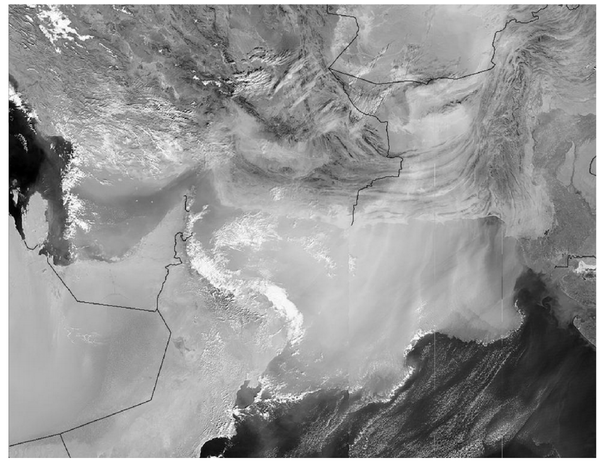

FIG. 4(b). THE SPREAD OF DUST OVER THE NORTHERN ARABIAN SEA ON 13TH DECEMBER, 2003. (HTTP://LANCE-MODIS.EOSDIS.NASA.GOV/CGI-BIN/IMAGERY/SINGLE.CGI?IMAGE=CREFL2_143.A2003347083500-2003347084000.2KM.JPG)

FIG. 4(c). THE SOUTHERN EXTENT OF DUST PULSE OVER THE ARABIAN SEA ON 14TH DECEMBER, 2003. (HTTP://LANCE-MODIS.EOSDIS.NASA.GOV/CGI BIN/IMAGERY/SINGLE.CGI?IMAGE=CREFL1_143.A2003348061500-2003348062001.2KM.JPG).

The chlorophyll a distribution over the region during the course of dust transport event can be illustrated as shown in Fig. 7.

It can be seen that high chlorophyll levels confined to coastal regions and open ocean surface layer suffers from high concentration levels during the time course when dust pulse has traversed the Arabian Sea.

If we continue to trace the development of chlorophyll a level over the Arabian Sea for 19-27 December, 2003 as shown in Fig. 8 we cannot see any detectable major change over the Arabian Sea where the dust has been settled on 12-15th December, 2003.

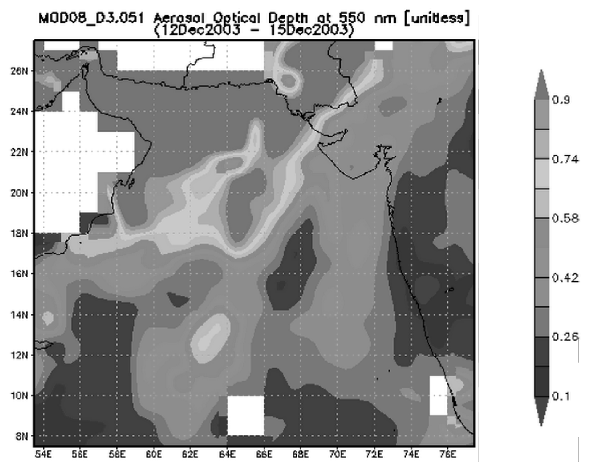

FIG. 5. AERIAL AOD LAT-LON TIME AVERAGED DISTRIBUTION OVER THE ARABIAN SEA DURING 12-15 DECEMBER, 2003.

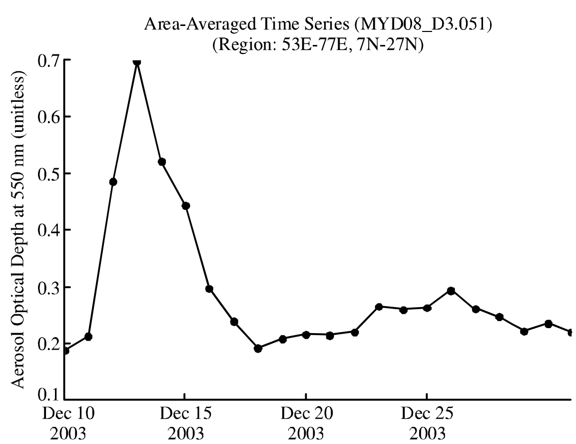

FIG. 6. AOD VALUES AND ITS DISTRIBUTION OVER THE ARABIAN SEA FOR 12-15TH DECEMBER, 2003 BY USING GIOVANNI.

In other words week after the dust transport event still there is not a clear signal from satellite-based sensors that can be related with strong chlorophyll a presence over the sea surface as compared to 1-9 January, 2004 chlorophyll distribution. Fig. 9 represents the chlorophyll a levels for the region during 1-9 January, 2004.

As illustrated in Fig. 9 the chlorophyll a distribution over the Arabian Sea has changed completely. In fact, scientific community misled and still misleading with this time lag. As proposed by [3,7,32], the ocean fertilization has actually taken place during the course of the 12-15th December, 2003 dust transport event. In fact [21] reported that during the course of this specific bloom the dominant species was Trichodesmium, which

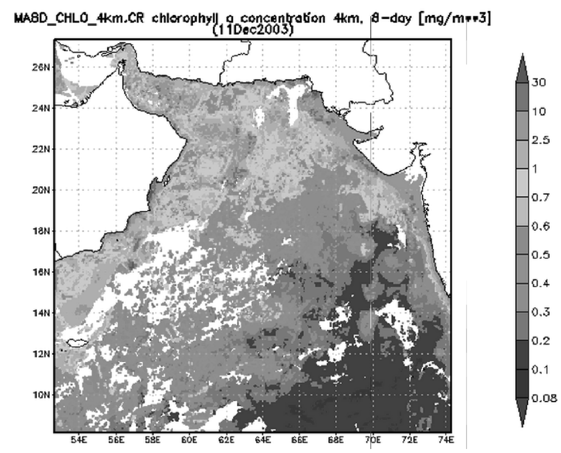

FIG. 7. CHLOROPHYLL A DISTRIBUTION MAP OVER THE ARABIAN SEA DURING 11-15TH DECEMBER, 2003 BY USING GIOVANNI

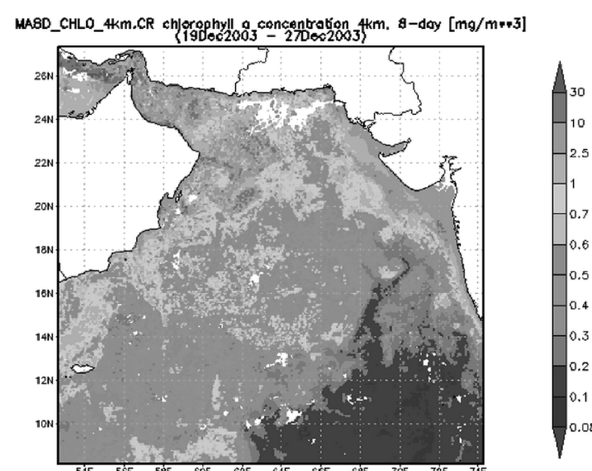

FIG. 8. THE CHLOROPHYLL A DISTRIBUTION OVER THE ARABIAN SEA DURING 19-27TH DECEMBER, 2003 BY USING GIOVANNI

is an important marine cyanobacterium for the tropical and subtropical oceans since it is an excellent N_2 fixator and is likely a major input to the marine and global nitrogen cycle.

As to understand the time lag between the dust deposition (12-15th December, 2003) and the maximum extent of bloom (1-9 January, 2004) we have to investigate the growth curve of Trichodesmium. As reported and as shown in Fig. 10, by Rodriguez and Tung-Yuan [32] it can be seen that following seeding the maximum cell numbers or the steady state is reached after 18-20 days.

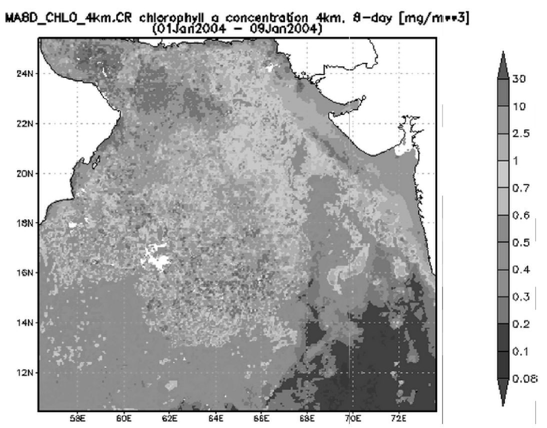

FIG. 9. THE CHLOROPHYLL A DISTRIBUTION OVER THE ARABIAN SEA DURING 1-9 JANUARY, 2004 BY USING GIOVANNI

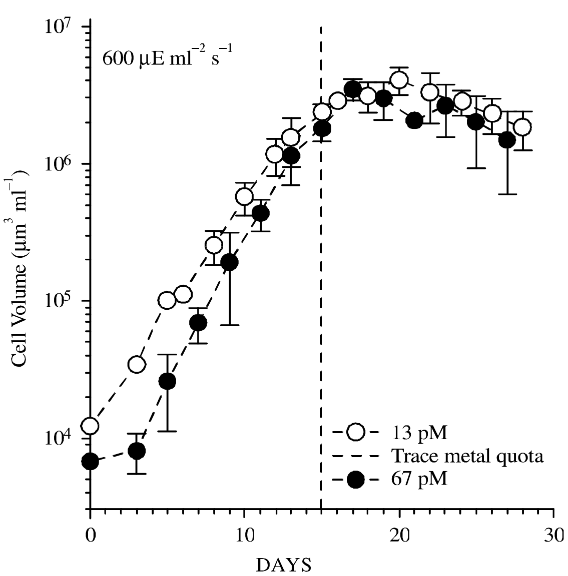

*FIG. 10. THE GROWTH CURVE OF TRICHODESMIUM CULTURES SUBJECTED TO THE LIGHT INTENSITY AT 600ΜE M^{-2} S^{-1}. **ERROR! REFERENCE SOURCE NOT FOUND.***

In line with this growth curve chlorophyll a concentration reached its maximum level and detected by satellite based sensors during the course of 1-9 January, 2004. Close inspection of the areal distribution of chlorophyll levels shows a perfect match with the spread of dust pulse over the Arabian Sea observed on 12-15th December, 2003.

In fact [21] concentrated on this very bloom and supported our dust transport event by illustrating the northerly winds derived from NASA QuikSCAT scatterometer weekly composite wind speed and wind vector but has not mentioned anything about the transport of dust. This is normal since to date there exists few publications that mention dust and algae bloom correlations [3,7,33,34].

Sarangi, et. al. [20-21], and Gabric, et. al. [34], just like all other studies concentrated on the meteorological or oceanographic properties during the course of chlorophyll bloom days without any success since there exists no correlation with the event that has triggered the bloom and the meteorological conditions during the course of the bloom days. The only atmospheric factor that can interfere with the bloom detection is the presence of clouds that can hinder the detection surface parameters by the satellites. These arguments further eliminates possible impact of oceanographic processes like winter cooling convection mixed layer nutrient enrichment or PAR (Photsynthetically Active Radiation) scenarios since as shown above NEM's supplies all necessary nutrients from above and there is no need to seek any other nutrients sources from below. Any argument on PAR is not relevant since at this latitude PAR is always at or above the necessary levels.

Recent example of dust transport took place on 20-21 December 2011. Time series of AOD derived from MODIS satellite images are given in Fig. 11 for 15 December, 2011 till 31 January 2012. It is seen that there was a significant increase in the AOD values for the week that includes 20-22 December 2011 and there was no other significant dust pulse observed till end of January 2012 as shown in Fig. 11.

Same region traced for the phytoplankton bloom following this dust transport event and once again, as expected, 21st December dust pulse reflected itself as elevated chlorophyll levels during the second 8th day average chlorophyll levels as shown in Fig. 12.

Thus, it is possible to suggest that the dust transported by NEM's is responsible from the simultaneous observation of chlorophyll as well as excess nitrate and nitrite levels observed over the surface waters of Arabian Sea. The extent is entirely dependent on the sporadic nature of dust transport and the magnitude of

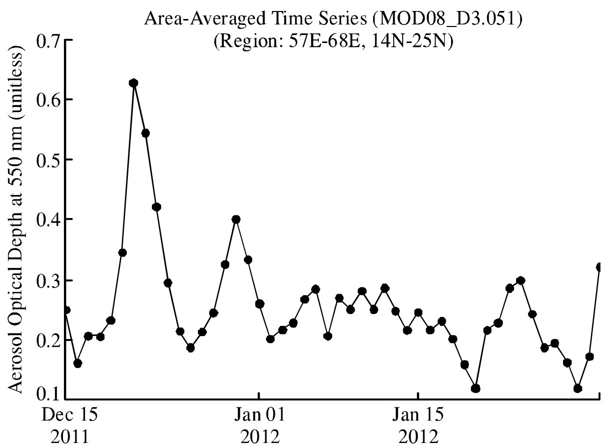

FIG. 11. AOD LEVELS OVER THE ARABIAN SEA DURING THE COURSE OF 15 DECEMBER 2011/31 JANUARY 2012 BY USING GIOVANNI

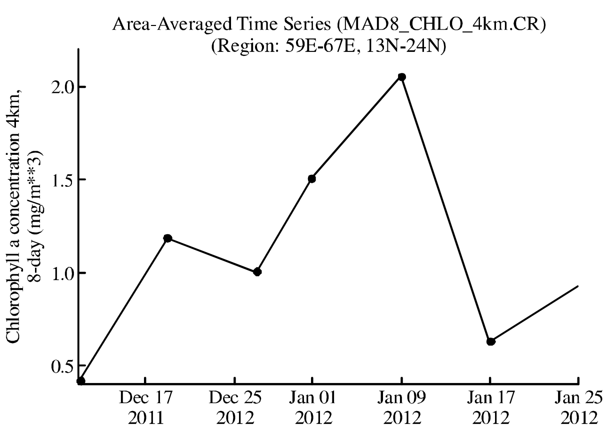

FIG. 12. THE CHLOROPHYLL DISTRIBUTION OVER THE ARABIAN SEA DURING 9TH DECEMBER 2011/25TH JANUARY, 2012 BY USING GIOVANNI

dust being transported during each pulse. [22] study encompassing 2002-2010 satellite derived chlorophyll and AOD data confirms our study. The author has mentioned the impact of aerosols over the ocean somehow influence the productivity but unfortunately just like [36] dust storms and subsequent increase in phytoplankton concentration over the Arabian Sea are linked with general statement "dust storm is carrying nutrients like nitrate, phosphate, iron, etc." without any clear conclusion.

But this study puts a light on the so far unresolved nitrate and nitrite enrichments over the Arabian Sea during the course of NEM's as well as their impact on the surface productivity together with soil properties of Afghan ephemeral lakes.

We have also tested the validity of our hypothesis, this time by using bottom up approach and checked the possible presence of dust pulse stemming from the observed phytoplankton bloom. In line with this we have chosen the phytoplankton bloom observed over the Arabian Sea during the course of 18-25th February, 2008 as shown in Fig. 13.

If our hypothesis is valid then this bottom (sea surface chlorophyll); up (atmospheric dust) approach should also result with an increase in AOD over the Arabian Sea some 15-20 days prior to this bloom, in accordance with the growth curve of Trichodesmium as shown by Rodriguez and Tung-Yuan [32]. Once again we used Giovanni site as to check the presence of dust over the region starting from mid Jan till end of February, 2008 as to see whether there was a corresponding dust pulse event over the region. As shown in Fig. 14, AOD variations over the Arabian Sea has detected the presence of significant increase during 1-3 February, 2008 which resulted with the increase in chlorophyll levels after 15-20 days hence explains the observed bloom during 18-25th February, 2008.

Satellite based sensors also detected this dust transport event on 2-3 February 2008.

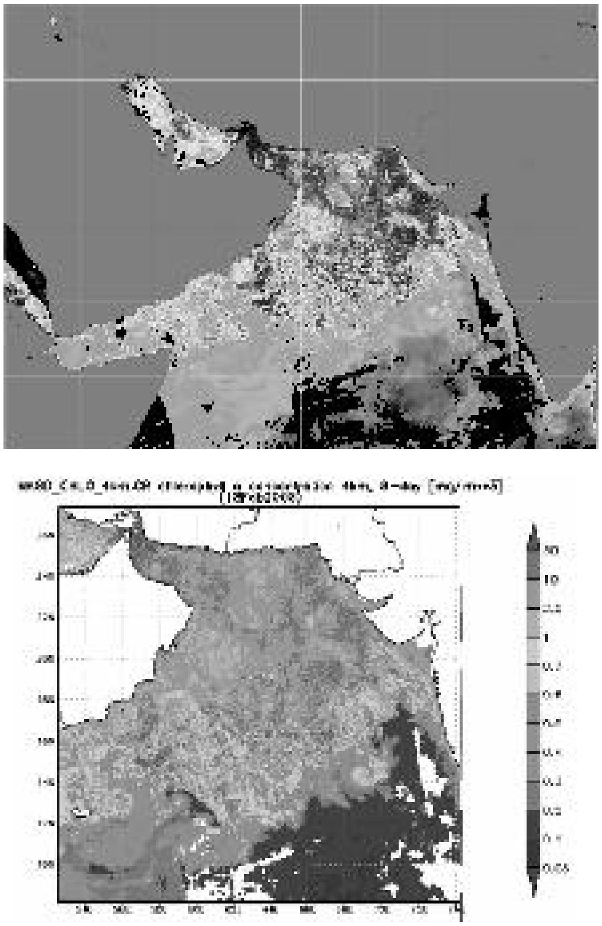

FIG. 13. THE SATELLITE DETECTED CHLOROPHYLL DISTRIBUTION OVER THE ARABIAN SEA DURING 18-25TH FEBRUARY 2008 (LEFT) AND GIOVANNI ILLUSTRATION OF CHL A DISTRIBUTION FOR 18-25TH FEBRUARY, 2005 (RIGHT) (HTTP://OCEANCOLOR.GSFC.NASA.GOV/CGI/L3/A20050492005056.L3M_8D_CHL_CHLOR_A_9KM.PNG?SUB=IMG)

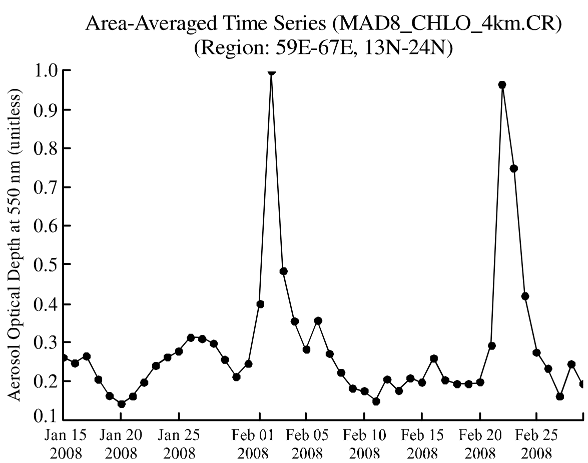

FIG. 14. THE AOD DISTRIBUTION OVER THE ARABIAN SEA DURING 15TH JANUARY-28TH FEBRUARY. 2008 BY USING GIOVANNI

4. CONCLUSIONS

First ever-chemical analyses of the soil samples collected around Afghanistan have shown rather unique properties. First of all Afghan soil can be classified as strongly or very strongly alkaline which makes it very unfavorable for common agricultural activities. But the South Western part that emerges with its extraordinary high nitrate and nitrite concentrations, unfortunately, makes it favourable for the growth of opium. Such high nitrate and nitrite levels at surface topsoil also reflect itself at groundwater hence drinking water in Afghanistan suffers from high levels of nitrite and nitrate levels. Satellite imageries illustrate the significance of the dust pulses that has originated from Afghanistan Pakistan and Iran over the Arabian Sea during the course of NEM's. Satellite imageries further shows that the ephemeral lake located at south-western corner of Afghanistan act as a source of dust during the course of NEM's. Thus each dust pulse that traverse south-western corner of Afghanistan further enriched by surface soils from Pakistan and Iran before they reach and eventually settles over the surface waters of Arabian Sea. Via top down and bottom up approaches we have shown that surface waters that has benefited from the dust deposition enhanced by chlorophyll 15-20 days following the dust settlement in line with the growth cycle of that specific chlorophyll group and vice versa. This approach further explains the presence of excess nitrate (NO_3) and nitrite (NO_2) in the upper

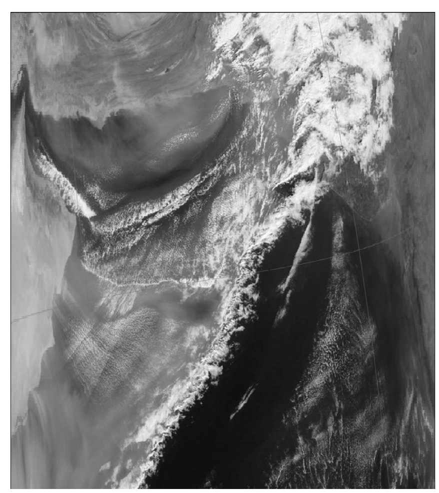

FIG. 15. THE IMPACT OFF DUST OVER THE ARABIAN SEA ON 2/3 FEBRUARY, 2008. (HTTP://LANCE-MODIS.EOSDIS.NASA.GOV/CGI-BIN/IMAGERY/SINGLE.CGI?IMAGE=CREFL1_143.A2008033062000-2008033062500.2KM.JPG)

layers that have accumulated over the course of the NEM, an important issue that has not resolved so far through multi-national oceanographic surveys. This study confirms that the necessary nutrients that is necessary to sustain the observed phytoplankton blooms over the surface Arabian Sea is in fact supplied through the atmosphere. In this pioneering study we have concentrated only on those samples gathered from Afghanistan and Iran but it is clear that those regions that can clearly be identified via satellite based sensors which acts as a dust bowl during the course of NEM's at Pakistan and Iran, should also be investigated with this specific properties in mind. The time lag between the atmospheric seeding and satellite observation of phytoplankton bloom depends on the growth cycle of that specific phytoplankton bloom, 7-10 days for coccolithophores and 15-20 days for cyanobacteriums hence its necessary to investigate the air mass trajectories and associated dust transport that have affected the region accordingly. The broad context of this study is not only confined to the dust sources at this region and the impact of dust deposition should be investigated globally, as mentioned as Cemliania Hypothesis.

It is possible to suggest that this work may offer Afghan (or even to Pakistan and Iran) people the prospect of prosperity since it will be possible to seed the sea with this topsoil, enriched with nitrates and nitrites, which were so far accepted as useless land, and sustain phytoplankton growth over the surface waters of Arabian Sea with possible stabilizing effect on climate.

ACKNOWLEDGMENTS

Authors would like to thank Turkish Armed Forces for their assistance during the collection and transfer of soil samples from Afghanistan. "Analyses and visualizations used in this paper were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC". The Earth Observatory is part of the EOS Project Science Office located at NASA Goddard Space Flight Center "Images are courtesy of MODIS Rapid Response Project at NASA/GSFC and SeaWIFS Project, NASA/GSFC and ORBIMAGE".

REFERENCES

[1] Prospero, J.M., Ginoux, P., Torres, O., Nicholson, S., and Gill, T.E., "Environmental Characterization of Global Sources of Atmospheric Soil Dust Derived from the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) Absorbing Aerosol Product", Reviews of Geophysics, Volume 40, No. 1, pp. 2-31, 2002.

[2] Jickells, T.D., An, Z., Andersen, K.K., Baker, A.R., Bergametti, G., Brooks, N., Cao, J.J., Boyd, P.W., Duce, R.A., Hunter, K.A., Kawahata, H., Kubilay, N., laRoche, J., Liss, P.S., Mahowald, N., Prospero, J.M., Ridgwell, A.J., Tegen, I., and Torres, R., "Global Iron Connections Between Desert Dust, Ocean Biogeochemistry and Climate", Science, Volume 308, No. 5718, pp. 67-71, 2005.

[3] Saydam A.C., and Senyuva H. Z., "Deserts: Can They Be the Potential Suppliers of Bioavailable Iron?", Geophysical Research Letters, Volume 29, No. 11, pp. 11-13, 2002.

[4] Chen, J., Blame, H.P., and Beyer, L., "Weathering of Rocks Induced by Lichen Colonization - A Review", Catena, Volume 39, No. 2, pp. 121-146, 2000.

[5] Sulzberger, B., and Laubscher, H., "Reactivity of Various Types of Iron(III) (hydr) Oxides Towards Light-Induced Dissolution", Marine Chemistry, Volume 50, Nos. 1-4, pp.103-115, 1995.

[6] Strasser, H., Burgstaller, W., and Schinner, F., "High-Yield Production of Oxalic Acid for Metal Leaching Processes by Aspergillus Niger", FEMS Microbiology Letters, Volume 119, No. 3, pp. 365-370, 1994.

[7] Saydam, A.C., "Can We Predict Harmful Algae Blooms", Harmful Algae News, Volume 15, pp. 5-6, 1996.

[8] Wang, Z., Dimarco, S.F., Al-Kharusi, L.H., Belabbassi, L., and Ingle, S., "How a Seven-Year Ocean Observatory is Influencing Our Understanding of Physical and Biological Processes in Northern Arabian Sea?", August Fall Meeting Abstracts, Volume 1, pp. 07, 2012.

[9] Naqvi, S.W.A., Bange, H.W., Gibb, S.W., Goyet, C., Hatton A.D., and Upstill-Goddard, R.C., "Biogeochemical Ocean-Atmosphere Transfers in The Arabian Sea", Progress In Oceanography, Volume 65, Nos. 2-4, pp. 116-144, 2005.

[10] Mace, K.A., Kubilay, N., and Duce, A.R., "Organic Nitrogen in Rain and Aerosol in The Eastern Mediterranean Atmosphere an Association with Atmospheric Dust", Journal of Geophysical Research Atmosphere, Volume 108, No. 4320, 2003.

[11] Marra, J., Dickey, T.D., Ho, C., Kinkade, C.S., Sigurdson, D.E., Weller, R.A., and Barber, R.T., "Variability in Primary Production as Observed From Moored Sensors in The Central Arabian Sea in 1995", Deep Sea Research Part-II: Topical Studies in Oceanography, Volume 45, Nos. 10–11, pp. 2253-2267, 1998.

[12] Garrison, D.L., Gowing, M.M., Hughes, M.P., Campbell, L., Caron, D.A., Dennett, M.R., Shalapyonok, A., Olson, R.J., Landry, M.R., Brown, S.L., Liu, H., Azam, F., Steward, G.F., Ducklow, H.W., and Smith, D. C., "Microbial Food Web Structure in the Arabian Sea: a US JGOFS Study", Deep Sea Research Part-II, Topical Studies in Oceanography, Volume 47, Nos. 7-8, pp. 1387-1422, 2000.

[13] Gundersen, J.S., Gardnera, W.D., Richardsona, M.J., Ian, D., and Walshb, I.D., "Effects of Monsoons on the Seasonal and Spatial Distributions of POC and

Chlorophyll in the Arabian Sea", Deep-Sea Research Part-II, Volume 45, Nos. 10-11, pp. 2103-2132. 1998.

[14] Latasa, M., and Bidigare, R.R., "A Comparison of Phytoplankton Populations of The Arabian Sea During The Spring Intermonsoon and Southwest Monsoon of 1995 as Described by HPLC-Analyzed Pigments", Deep Sea Research Part-II: Topical Studies in Oceanography, Volume 45, Nos. 10–11, pp. 2133-2170, 1998.

[15] Gardner, W.D., Gundersen, J.S., Richardson, M.J., and Walsh, I.D., "The Role of Seasonal and Diel Changes in Mixed-Layer Depth on Carbon and Chlorophyll Distributions in the Arabian Sea", Deep Sea Research Part-II, Topical Studies in Oceanography, Volume 46, Nos. 8-9, pp. 1833-1858, 1999.

[16] Sarangi, R.K., Chauhan, P., Mohan, M., Nayak, S.R., and Navalgund, R.R., "Phytoplankton Distribution in the Arabian Sea Using IRS-P4 OCM Satellite Data", International Journal of Remote Sensing, Volume 22, No. 15, pp. 2863-2866, 2001.

[17] Wiggert, J.D., Jones, B.H., Dickey, T.D., Brink, K.H., Weller, R.A., Marra, J., and Codispoti. L.A., "The Northeast Monsoon's Impact on Mixing, Phytoplankton Biomass and Nutrient Cycling in The Arabian Sea", Deep Sea Research Part-II: Topical Studies in Oceanography, Volume 47, No. 7, pp.1353-1385, 2000.

[18] Sarangi, R.K., Chauhan, P., and Nayak, S.R., "Phytoplankton Bloom Monitoring in the Offshore Water of Northern Arabian Sea Using IRS-P4 OCM Satellite Data", Indian Journal of Marine Sciences, Volume 30, No. 4, pp. 214-221, 2001.

[19] Sarangi, R.K., Chauhan, P., and Nayak, S.R., "Assessment of Resourcesat-1 AWiFS Data for Marine Applications", NNRMS Bulletin, Department of Space, pp. 73-75, Bangalore, September, 2004.

[20] Sarangi, R.K., Chauhan, P., and Nayak, S.R., "Inter-Annual Variability of Phytoplankton Blooms in the Northern Arabian Sea During Winter Monsoon Period (February-March) Using IRS-P4 OCM Data", Indian Journal of Marine Sciences, Volume 34, No. 2, pp. 163-173, 2005.

[21] Sarangi, R.K., "Observation of Algal Bloom in the Northwest Arabian Sea Using Multisensor Remote Sensing Satellite Data", Marine Geodesy, Volume 35, No. 2, pp. 158-174, 2012.

[22] Sarangi, R.K., "Spatiotemporal Variability of MODIS-Aqua-Derived Aerosol and Its Impact on Surface Chlorophyll-A in the Indian Coastal and Offshore Waters", Journal of Applied Remote Sensing, Volume 7, No. 1, pp. 73501-73501, 2013.

[23] Wiggert, J.D., Murtugudde, R.G., and McClain, C.R., "Processes Controlling Interannual Variations in Wintertime (Northeast Monsoon) Primary Productivity in The Central Arabian Sea", Deep Sea Research Part-II, Volume 49, pp. 2319-2343, 2002.

[24] Barber, R.T., John, M., Robert, C., Bidigare, L.A., Codispoti, D.H., Zackary, J., Mikel, L., Ralf, G., and Sharon, L.S., "Primary Productivity and its Regulation in the Arabian Sea during 1995", Deep Sea Research Part-II, Topical Studies in Oceanography, Volume 48, Nos. 6-7, pp. 1127-1172, 2001.

[25] McCarthy, J.J., Garside, C., and Nevins, J.L., "Nitrogen Dynamics during the Arabian Sea Northeast Monsoon", Deep Sea Research Part-II, Topical Studies in Oceanography, Volume 46, Nos. 8-9, pp. 1623-1664, 1999.

[26] Marra, J., and Barber, R.T., "Primary Productivity in the Arabian Sea: A Synthesis of JGOFS Data", Progress in Oceanography, Volume 65, Nos. 2-4, pp. 159-175, 2005.

[27] Wiggert, J.D., Hoodb, R.R., Banse, K., and Kindle, J.C., "Monsoon-Driven Biogeochemical Processes in the Arabian Sea", Progress in Oceanography, Volume 65, Nos. 2-4, pp. 176-213, 2005.

[28] Bange, H.W., Wajih, S., Naqvi, A., and Codispoti, L.A., "The Nitrogen Cycle in The Arabian Sea", Progress in Oceanography, Volume 65, Nos. 2-4, pp. 145-158, 2005.

[29] Göral, A.Ö., "The Study of the Some Aspects of Afghan Soil Samples", M.Sc. Thesis, Institute of Science, Department of Environmental Engineering, Hacettepe University, Ankara-Turkey, 2004.

[30] Ezzati, R., "Atmosferik Tasinıma Giren Degisik Kaynakli Topraklarin Bitki Gelisimine Etkilerinin Arastirilmasi", Ph.D. Thesis, pp. 137, Turkish, 2009.

[31] Guerzoni, S., Chester, R., Dulac, F., Herut, B., Loÿe-Pi, M., Measures, C., Migon, C., Molinaroli, E., Moulin, C., and Rossini, P., "The Role of Atmospheric Deposition in the Biogeochemistry of the Mediterranean Sea", Progress in Oceanography, Volume 44, No. 1, pp. 147-190, August, 1999.

[32] Rodriguez, Irene, B., and Tung-Yuan, H., "Diel Nitrogen Fixation Pattern of Trichodesmium: The Interactive Control of Light and Ni", Scientific Reports, Volume 4, No. 4445, March, 2014.

[33] Saydam, A.C., and Polat, I., "The Impact of Saharan Dust on the Occurrence of Algae Bloom", Proceedings of EUROTRAC Symposium'98, pp. 656-663, 1999.

[34] Gabric, A.J., Cropp, R., Ayers, G.P., McTainsh, G., and Braddock, R., "Coupling between Cycles of Phytoplankton Biomass and Aerosol Optical Depth as Derived from Seawifs Time Series in the Subantarctic Southern Ocean", Geophysical Research Letters, Volume 29, No. 7, pp. 1-16, USA, April, 2002.

[35] Das, B., and Mishra, A.K., "Effect of Dust Storm on Phytoplankton Productivity in Arabian Sea", Journal of Remote Sensing & GIS, Volume 4, No. 3, pp. 33-44, 2013.