In The Name Of God

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Title of the Thesis:

EFFECTS OF INDUCED SAND-DUST STORM ON PERIPHYTON PRODUCTIVITY (AUTOTROPHIC INDEX, AFDM AND CHLOROPHILL *a*) IN ARTIFICIAL STREAMS

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This thesis is dedicated to my dear family, especially my father and mother

Abstract

During the last years, dust storms frequencies and intensities have increased significantly in Iran. Mineral aerosols carried by dust storm are normally rich in key nutrients and organic content and can have significant impact upon medium enrichment and the biogeochemical cycles in aquatic environments. In this context, in two experiment (10 and 22 day), we studied the role of aeolian dust on various aspects of productivity of a periphyton community in artificial streams. Increasing stream suspended solid catchment development increasing primary production via nutrient enrichment and reduction in shading by reduces light penetration. In aquatic ecosystem, nutrient and water current are major constraints on phytoplankton production in the open ocean, in freshwater streams the effect of shading is important. We measured dry mass, ash-free dry mass and chlorophyll *a* content in a series of artificial streams exposed to a gradient of dust concentration (T_1=2.5, T_2=10 and T_3=40g.m^{-3}). We also determined autotrophic index (AI) and fine sediment index (FSI) in the periphyton community. Exposure to aeolian dust initiate a dose-dependent reaction in which low content of dust provoke growth but at high concentration inhibits the growth of the periphyton community. At high sediment load (40 g.m^{-3}), algal photosynthetic efficiency showed a quick decrease after two days of exposure which continued until the end of experiment. Results of this experiment demonstrated that with an increase in fine sediment, chlorophyll *a* decreased but the non-living fraction of periphyton as represented by AI, increased. The most of Cyanophyceae family died after the exposed to dust texture. The Species of the family Bacillariophyceae (Diatoms) Showed quite different behavior, So that Were present in the streams after the Exposure of dust texture.The Species of the family Chlorophyceae Showed an intermediate behavior**.** A predominance of diatoms over the other phytoplankton classes occurred after the enrichment by aeolian dust.

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Chapter 1

Introduction

1-1- Dust storm in the Earth system

Dust storms, one type of dust event, are in most cases the result of turbulent wind, which raise large quantities of dust from desert surfaces and reduce visibility to less than 1 km (Miller *et al*., 2008). Dust storm can be transported over thousands of kilometers and may reach concentrations to reduces visibility to few hundred meters. When heavier mineral particles are blown by wind sand-dust flux or sandstorm is formed. In arid and semi-arid parts of the world excessive mineral aerosol carried by air parcels is a common climatic incident with well known environmental side effects. Both dust and sand storms are known to have profound effects on human health and on the environment. Dust storms are also a source of trace elements, for example, Al, Fe, Si, Cu, Mn, Ni, V, Zn, Cd, Pb, Ag, and Cr Among these, Co, Cu, Fe, Zn, Mn, Ni, and V constitute essential micronutrients for phytoplankton growth (e.g. Subba Rao and Yeats 1985).

In some studies it has been shown that in streams, sediment transport is highest during dust storms (Downes *et al*., 2002). It is known that during dust events fine sediments, deposited as well as suspended solids, alter the physical and chemical characteristics of rivers. Moreover, a sudden increase in the amount of suspended solid in a small body of freshwater can affect biotic structure and ecosystem functioning (Crowe and Hay, 2004). Some authors have studied the effects of soil use and catchment geology on deposition, turbidity and particle size in rivers (e.g., Owens and Walling, 2002; Boer *et al*., 2005), whereas others have assessed the impacts of solids on the biota (Oihana, 2009). Increase in the sediments as a result of dust storm have significant impacts on both invertebrates and fish because of abrasion (NewCombe and MacDonald, 1991). Such an increase in sediment and suspended solids can also affect aquatic habitats by destroying their microhabitats (e.g. Wood and Armitage, 1997), or by reducing the connectivity between epibenthos and hyporheos (Waters, 1995). Siltation can also have profound impacts on primary producers, and thus can be especially detrimental in areas where primary production is the main basis of food webs (Ryan, 1991).

The effects of sediments on periphyton communities are complex and can include, reduction in light (e.g. Wood and Armitage, 1997), abrasion (NewCombe and MacDonald, 1991), and reduction of hard substrata available for establishing periphyton colonies (Biggs, 1995). Heavy siltation can also have profound impacts on primary producers, and thus can be especially detrimental in areas where primary production is the main basis of food webs (Ryan, 1991). Studies have focused on both the effect of suspended (Davies-Colley *et al*., 1992; Parkhill and Gulliver, 2002) and deposited sediments (Graham, 1990; Yamada and Nakamura, 2002). Decreased light availability can reduce photosynthetic activity (Van Nieuwenhuyse and La Perriere, 1986; Davies-Colley *et al*., 1992) and affect algal community composition (NewCombe and MacDonald, 1991). Most rivers in developed areas are affected simultaneously by many stresses, from pollutants to water withdrawal and changes in channel form. This makes it difficult to discern the effects of each impact (Downes *et al*., 2002). Artificial channels are one of the best ways to assess the impacts of single stressors, because their design makes it possible to isolate particular effects from complex influences (Shriner and Gregory, 1984).

Studies based on dust accumulation in Northern Mesopotamian plain have shown that during the late Holocene Iran and the surrounding areas had much drier climate compared to present time (Morteza *et al*., 2008). However, there are recent reports on a sudden increase in frequencies and intensities of dust storm in Iran (Hadi *et al*., 2011). These dust storms have affected human health and the environment in the western and southern provinces of Iran such as Kermanshah, Illam and Khuzestan Provinces up to southeastern in Sistan and Baluchistan Provinces (Misconi *et al*., 2010). In these areas dust storms are well known for their direct burial effects upon vegetation cover and sever fertility loss and loss of storage capacity of soil water when top soil is blown up and soil organic matter is lost. However, little is known about enhancement of vegetation cover structure, floristic composition and possibly a seral successional community type associated with dust storm in both aquatic and terrestrial habitats. Given the importance of the problem of aeolian dust of natural and anthropogenic origin, we hope this work will fill gaps in the regional studies of dust storms in Iran. The purpose of this work is to provide basic information on the type of the dust storm damages on the periphyton communities and facilitate further assessment for an environmental impact assessment of dust-sand storm in the area.

1-1-1- Dust from the perspective of ecology

Dust is fine particulate material that is removed from the land surface by wind erosion and is small enough to be suspended in the atmosphere (Bagnold, 1941; Toy *et al*. 2002). Dust emissions vary with climate, as shown by paleo-studies (eg Clark *et al*. 2002), and also with land use. Environmental scientists are increasingly recognizing dust as both a major environmental driver and a source of uncertainty for climate models (Tanaka and Chiba 2006; Neff *et al*. 2008). Wind erosion and dust emissions can cause substantial impacts, not only to human health (through respiratory problems), but also to basic ecosystem processes, at scales ranging from individual plants or even smaller up through local and regional scales to a global scale, representing biogeochemical connectivity across continents (Peters *et al*. 2007; Okin *et al*. 2009). Wind transports soil material through three mechanisms (Figure 1-1) that are roughly differentiated based on the soil particle diameter (these categories overlap): surface creep for soil particle diameters > 500 µm, saltation for diameters ranging from 20–500 µm, and suspension for diameters < 20 µm (Bagnold 1941; Toy *et al*. 2002; Goudie and Middleton 2006). All three processes redistribute soil and associated nutrients and organic material at different spatial scales (Field *et al*. 2009).

Wind driven surface creep and saltating particles dominate the mass movement of soil on a local scale (Stout and Zobeck 1996). In contrast, suspended dust particles can be transported over long distances and can be moved at regional, continental, and even global scales (Chadwick *et al.* 1999; Prospero *et al.* 2002; Goudie and Middleton 2006). Most of the horizontal aeolian sediment transport occurs close to the soil surface, decreasing sharply with height (Shao *et al*. 1993). A small fraction of this flux can become suspended and thus be available for long-distance dust transport, as reflected in a vertical flux that is linearly related to horizontal flux (Gillette *et al*. 1997). Because soil nutrients (nitrogen, phosphorus) and organic matter are often associated with smaller soil particles, soil fertility in dust source areas becomes depleted while sink areas are concomitantly enriched (Li *et al*. 2007).

Wind erosion rates and dust emissions at a specific location are influenced by various factors, such as microscale wind gradients and atmospheric relative humidity (Toy *et al*. 2002). Wind speed is related to the amount of energy available to move sediment, and much aeolian research focuses on the "threshold friction velocity" wind speed at which particles of a given size under a given set of field conditions begin to detach from the soil surface (Gillette *et al*. 1980). Atmospheric relative humidity controls soil moisture at the soil surface, especially in arid and semiarid regions during rainless periods (Ravi *et al*. 2004), because soil moisture in particles at the soil surface is typically at equilibrium with atmospheric moisture. This is important because soil moisture influences the interparticle forces that, in turn, influence the threshold velocity, resulting in a clear, but complex relationship between atmospheric relative humidity, particle size, and soil erodibility (Ravi *et al*. 2004). Wind erosion may be interactive with water erosion, although few studies have specifically addressed this issue (Field *et al*. 2009). Collectively, these complex relationships need to be considered in terms of their relative role in affecting aeolian processes at all scales.

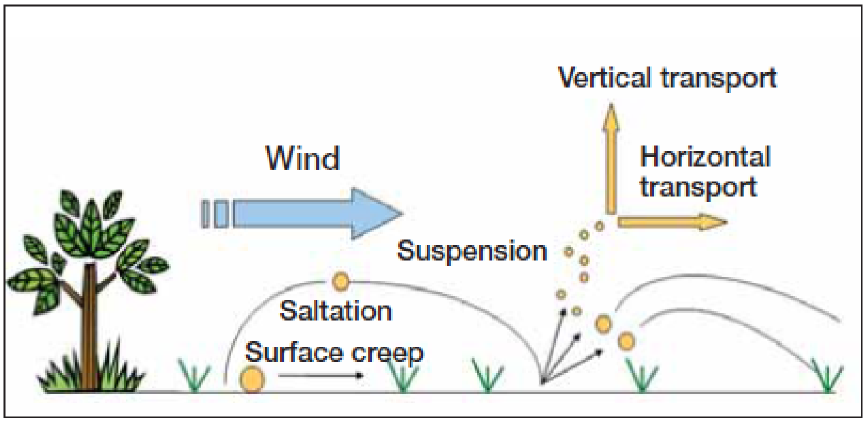

Fig. 1. 1. How wind erosion works. Saltation occurs when the shear velocity of the wind exceeds the threshold shear velocity of the soil; suspension of dust-size particles occurs when saltating particles sand-blast the soil surface, overcoming the strong interparticle forces between fine particles (Field, 2010).

Erosion resistance is determined by the strength of the soil and the presence of surface protectors, such as rocks, plant litter, and physical and biological soil crusts (Gillette *et al*. 1980; Okin *et al*. 2006). Rocks and plant litter too large to be moved by wind offer the greatest soil protection. Physical soil crusts created by the binding together of silt and clay particles when wetted and then dried protect soils, except when crusts are subjected to disturbance. Biological soil crusts, composed of cyanobacteria, lichens, and moss, stabilize soils by excreting mucilaginous material that binds soil surface particles together, thereby increasing soil aggregate size and increasing soil resistance to the shearing forces of wind (Belnap and Gillette 1997). The type, cover, and arrangement of vegetation have the strongest influence on the ability of the wind to reach the soil surface. The patchy and dynamic nature of vegetation in dryland regions results in aeolian transport being highly heterogeneous in both space and time. The amount of material that is moved depends on the size of unvegetated gaps upon which the wind can act (generally excluding rocky or gravelly areas, referred to as desert pavement, and areas covered by physical or biological soil crust) and the height and density of the vegetation, which controls the size of the protected area downwind of individual plants (Breshears *et al*. 2009). Many of the factors that drive wind erosion are, of course, greatly affected by soil surface disturbances. Grazing cattle crush biological and physical soil crusts and decrease vegetative cover (Nash *et al*. 2004), thereby increasing wind erosion (Neff *et al*. 2008).

There are important feedbacks between the vegetation and aeolian flux in deserts. Aeolian flux controls the redistribution of sediment and the loss of dust and dust-borne nutrients, thus affecting the amount and distribution of vegetation on the land surface. The amount and distribution of vegetation, in turn, affect the degree and spatial patterns of aeolian flux. This feedback can occur in most environments, including those with relatively high vegetation cover, and is responsible for cascading land-degradation phenomena caused by local or regional disturbance events (Peters *et al*. 2007). At the same time, dust emitted by desert regions, particularly those that have experienced substantial disturbance, can have critical consequences for downwind ecosystems.

In summary, greater dust emissions, including more frequent and larger dust storms, are likely to occur from dryland regions as temperatures increase and more dryland areas are trampled, cleared of vegetation, plowed, and/or converted from perennial to annual plants. These increasing emissions will result in degraded soils and plants at the dust source, as well as in impacts to human and ecosystem health during transport and at deposition points. Avoiding the potentially severe consequences of this future scenario will require a new approach to the management of dryland regions. We need to identify the chronic and acute sources of dust that have potentially large impacts at local, regional, and global scales (Peters *et al*. 2007). We also need to better understand how the timing, type, and intensity of different land uses affect dust production. The overarching challenge for ecologists and other environmental scientists, land managers, and policy makers will be to work together to manage vulnerable areas in ways that reduce excess dust production to the fullest extent possible (Okin *et al*. 2009).

1-1-2- Dust accumulation versus dust deposition

In aeolian dust literature, there is considerable confusion concerning the distinction between dust deposition and dust accumulation. Usually, no consequent discrimination is made between these terms. Most studies dealing with the settling of dust pretend to present deposition data, whereas in reality, they deal with accumulation. There is a clear physical difference between deposition and accumulation: deposition refers to the amount of sediment that impacts on a unit surface in a unit time, whereas accumulation is the amount of sediment that remains at a unit surface at the end of a particular time interval. Deposition (or sedimentation) thus corresponds to the sediment flux component directed perpendicularly to the surface, whereas accumulation is the sum of that component and the component directed perpendicularly from the surface. In plain words, accumulation is the sum of deposition and erosion. It can be positive or negative, depending on which component – deposition or erosion – is largest (Goossend, 2001).

1-1-3- Source regions for dust emissions

Deserts are main sources for dust storm around the world. The Sahara is the world's largest desert, and plays a significant role in the atmospheric global circulation (Cuesta *et al*., 2009). The Sahara is the world's most significant source of mineral dust in the atmosphere (Tanaka & Chiba, 2006). The importance of dust to global biogeochemical cycles raises several questions about the magnitude, distribution, and variation in dust fluxes across the Earth; this has led to numerous attempts to quantify the contributions of dust sources around the globe. Dust from land disturbed by humans or extreme climatic events, such as drought, may constitute a substantial fraction – perhaps one-third to one-half – of the total atmospheric dust loading (Tegen and Fung 1995). The largest and most persistent sources are located in the Northern Hemisphere, model assessments indicate that global fluxes are dominated by the large deserts of North Africa, Asia, and the Middle East (Tanaka and Chiba 2006).

1-1-4- Future dust storm activity

The nature of future dust activity will depend on three main factors: anthropogenic modification of desert surfaces (Mahowald and Luo, 2003); natural climatic variability and changes in climate brought about by global warming. With regard to the first of these, increasing human pressures include disturbance of desert surfaces by vehicular traffic, removal of vegetation cover for wood supply, grazing and crop production, and desiccation of lakes and soil surfaces by inter-basin water transfers and ground water depletion (see, for example, Pelletier, 2006). Natural climatic variability will doubtless continue as it has in the past, but global warming has the potential to cause major changes in dust emissions. The IPCC (2007) suggests that under many scenarios many dryland areas will suffer from lower rainfall levels and increased amounts of moisture deficits because of higher rates of evapotran spiration. If this is the case then it is conceivable that dust storm activity could increase, though this is to a certain extent dependant on how wind energy levels may change (an area about which there is great uncertainty).

1-2- Impacts of dust on the environment and humans

Much of the current interest in dust storms relates to their possible role in the Earth System (Goudie and Middleton, 2006). Dust loadings may affect air temperatures through the absorption and scattering of solar radiation, may affect cloud formation (Toon, 2003) and convectional activity (Wong and Desler, 2005), influence sulphur dioxide levels in the atmosphere, either by physical absorption or by heterogeneous reactions (Adams *et al*., 2005), and influence marine primary productivity and thus atmospheric carbon dioxide levels (Ridgwell, 2003). Bar-Or *et al*. (2008) believe that though the albedo effect, dust may have had a significant impact on the speed of ice-sheet retreat. They also suggest that dust radiative forcing may have emphasised the asymmetry of glacial cycles. A modern study of how dust causes important area of research has been to identify the role of dust in biogeochemical cycles and in soil formation (X. Yang et al., 2008; Y.Q. Yang et al., 2008). The global dust cycle plays a major role in the delivery of iron to the oceans (Mahowald et al., 2005), together with nutrients such as phosphorus (Pulido-Villena et al., 2008) and nitrates (Chen and Chen, 2008). Dust fertilization could be an important control of the productivity of marine phytoplankton (Han et al., 2008).

1-2-1- Dust impacts upon marine ecosystems

Recent advances in remote sensing technologies have dramatically increased knowledge of long distance dust transport paths over the oceans (Herrmann *et al*., 1996) and it is now becoming widely accepted that dust deposition may have significant impacts upon marine ecosystems (Jickells and Spokes, 2001). Modelling studies by Kumar et al. (1995) and Mahowald et al. (1999) suggest that the increased dust activity during glacial times would have resulted in 10–50 times more iron being deposited in the Southern Ocean. Also, Calvo *et al*. (2004) used long chain n-alkanes data to show that there were increases in diatom activity associated with increased aridity the last three glacial periods. There is even evidence of a possible link between phytoplankton abundance and atmospheric CO_2, and temperature, with high dust periods being associated with low atmospheric CO2 and lower temperatures (Watson *et al*., 2000). Mineral fragments are relatively insoluble in surface ocean waters, and settle largely unaltered through the water column, to be