Env. Biodiv. Soil Security **Vol.1**, pp.109- 128 (2017)

Review Article

Environmental Nanoremediation under Changing Climate

Hassan El-Ramady[1]*, Tarek Alshaal[1], Ahmed El-Henawy[1], Neama Abdalla[2], Hussein S. Taha[2], Mohammed Elmahrouk[3], Tarek Shalaby[4], Tamer Elsakhawy[5], Alaa El-Dein Omara[5], Samia El-Marsafawy[5], Nevien Elhawat[6], Said Shehata[7], Dirk Selmar[8] and Éva Domokos-Szabolcsy[9]

[1] *Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh Uni., Kafr El-Sheikh, Egypt (alshaaltarek@gmail.com, aelhenawy@yahoo.com)*

[2] *Plant Biotechnology Department, Genetic Engineering Division, National Research Center, Dokki, Giza, Egypt (E-mails: neama_ncr@yahoo.com; hussein.taha2@yahoo.com)*

[3] *Horticulture Dept., Faculty of Agriculture, Kafrelsheikh Uni., Kafr El-Sheikh, Egypt (E-mail: threemelmahrouk@yahoo.com)*

[4] *Horticulture Dept., Faculty of Agriculture, Kafrelsheikh Uni., Kafr El-Sheikh, Egypt and College of Agricultural and Food Sciences, King Faisal University, Al-Hassa 31982, Saudi Arabia (E-mail: tashalaby@yahoo.com)*

[5] *Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center, Egypt (E-mails: dr_megahed120@yahoo.com; alaa.omara@yahoo.com; drelsakhawyg@gmail.com; samiaelmarsafawy797@hotmail.com)*

[6] *Biological and Environmental Science Department, Faculty of Home Economics, Al-Azhar University, Cairo, Egypt (E-mail address: adel.nevien@yahoo.com)*

[7] *Vegetable Crops Department, Faculty of Agriculture, Cairo University, Giza, Egypt (E-mail: said_shehata2@ysahoo.com)*

[8] *Applied Plant Science Dept., Institute for Plant Biology, TU Braunschweig, Braunschweig, Germany (E-mail: d.selmar@tu-bs.de)*

[9] *Plant Biotechnology Dept., Debrecen Uni., Böszörményi Útca. 138, 4032 Debrecen, Hungary (E-mails: domokosszabolcsy@gmail.com)*

MANY global problems threaten our life on the Planet including climate changes, environmental pollution, food and soil security, energy crisis, etc. This environmental pollution has not only mainly serious risks and stress involving the human health and safety of the entire ecosystem but also the quantity and quality of crops productivity worldwide. Due to the great gap between the global food production and the global consumption, there is a crucial need to cultivate these contaminated lands sooner or later. Therefore, the removing of pollutants from soils and waters should be performed in frame of sustainable remediation and sustainable energy production accordingly. Depending on many factors (source and kind of pollutants, land use and the economics of water and soil resources, etc) many strategies should be addressed for the sustainable and integrated management of polluted lands. Nanoremediation is a promising strategy in controlling pollution and management. Three major applications of nanoremediation could be characterized including detection of pollution using nanosensors, prevention of pollution, purification and remediation of contamination. Further studies also concerning the impact of changing climate on the nanoremediation process in the agroecosystems should be considered. Thus, this review will focus on the evaluation of environmental nanoremediation and its strategy in polluted lands under climate changes. Using of nanotechnology in pollution control as well as the environmental pollution and its sustainable management also will be highlighted.

Keywords: Environmental nanoremediation, Climate change, Pollution, Crop production, Environmental stress.

* Corresponding author e-mail: ramady2000@gmail.com

DOI : 10.21608/jenvbs.2017.1550.1009

Introduction

Climate changes are a great challenge facing the human kind as well as other living things. The production of crops and other agricultural features are extremely susceptible to changes in climate. So, these global changes will be caused major shifts in crop distribution due to climate changes in the future. Moreover, it has been estimated that climate changes are likely to reduce yields and/or damage crops in the 21st century in different parts of the world (Qiao et al. 2017). Therefore, the effects of climate changes on agriculture include global warming (Salawitch et al. 2017), sea level rise (Cazenave et al. 2017; Jevrejeva et al. 2017; Marzeion et al. 2017; Marcos et al. 2017), melting of arctic ice (Copland et al. 2017; Matishov et al. 2017; Pope et al. 2017) and frequent occurrence of extreme events such as flooding and droughts (Aslam et al. 2017; Chen et al. 2017; Debortoli et al. 2017; Jangra et al. 2017; Omambia et al. 2017; Nally et al. 2017).

The polluted environments including water, soil and air also could be considered an emerging issue (Belal and El-Ramady 2016; Plekhanova et al. 2017). These pollutants could be resulted from different sources including traffic (Patton et al. 2016; França et al. 2017), industrial activities (Zheng and Shi 2017; Wang et al. 2017), mining activities (Campos-Herrera et al. 2016; Strzebońska et al. 2017) and agricultural activities (Slabe-Erker et al. 2017; Shukla et al. 2017). The polluted lands suffer from the high concentration of toxic pollutants destroying the agroecosystems (Stiborova et al. 2017; Saha et al. 2017a). This toxic level of pollutants prevents the sustainable management of these lands (Saha et al. 2017a; Stiborova et al. 2017). So, an international collaboration between different countries should be established concerning the global pollution (Günther and Hellmann 2017).

Removing of pollutants from soils and waters could be linked with both the sustainable remediation as well as sustainable energy production (Kovacs and Szemmelveisz 2017; Zheng and Shi 2017). Many strategies for the sustainable and integrated management of polluted lands should be addressed depending on several factors e.g., type of pollutants and their level, the purpose of land use after remediation, soil characterization and its topography, climate , cropping patterns and the availability of resources and their economics (El-Ramady et al. 2017; Saha et al. 2017a). Furthermore, a great debate concerning using of lands for crop food production (under growing global population) or energy crop production was and still for ages (Paschalidou et al. 2016). Therefore, a global and holistic strategy in facing the main three threats including hunger, lack of energy and pollution of environment as well as climate changes should be established (Paschalidou et al. 2016; Alshaal et al. 2017; Delev 2017).

Concerning environmental nanoremediation, nanoparticles are the most important strategy for the remediation of these contaminated environments. This remediation for different environments using nanoparticles/nanomaterials is called nanoremediation (Kuppusamy et al. 2016; El-Ramady et al. 2017). This nanoremediation could be performed in the presence of nanoparticles/ nanomaterials using plants or phyto-nanoremediation (Shalaby et al. 2016; Martínez-Fernández et al. 2017), microbes or microbial nanoremediation (Patil et al. 2016; Davis et al. 2017) or animal or zoonanoremediation (Belal and El-Ramady 2016; El-Ramady et al. 2017). Therefore, there is an urgent need for the environmental pollution control under a sustainable management (Pandey et al. 2016; El-Ramady et al. 2017; Prashanthi et al. 2017). Several applications of nanomaterials/nanoparticles have been used in many sectors including sustainable crop production, reduction of nutrient losses, suppression disease and enhancement of crop yield (Shalaby et al. 2016; Davari et al. 2017; Kaphle et al. 2017). The nanoremediation for sustainable crop production in polluted lands should be managed in a proper way before the expansion in such polluted lands for the agricultural production (Patil et al. 2016; El-Ramady et al. 2017). This currently resulted from the difficulty in measuring the sustainability of crop production in such polluted lands as well as lack in evaluating techniques for the performance of phytoremediation in frame of bioeconomy (Shalaby et al. 2016; Mishra et al. 2017; Shivlata and Satyanarayana 2017; Verma et al. 2017).

Therefore, the aim of this review was to evaluate the environmental nanoremediation under climate changes conditions and the strategies of polluted lands for sustainable crop production. Nanotechnology and its using in pollution control, as well as the environmental pollution and its sustainable management also will be highlighted.

Climate change: more than a global issue

Climate changes could be defined as the changes in climate variables or elements (temperature, precipitation, humidity, wind, pressure, etc), which could be identified and its properties for a long period or for decades or an even longer time scale (Najjar et al. 2017). It is acceptable to define the climate as the study of weather or climatic variables for a long time (usually over a 30-year interval). The climate and its changes have been investigated from many fields including agriculture, water, soil, energy, etc. The topic of climate change is considered nowadays one of the hottest issues worldwide and studies about it in ascending level. This concern could be noticed from many published books (more than 133 books), by Springer till August 14, 2017about the impact of climate changes on soil, water and agriculture.

Concerning climate change and its effects on soils, globally different soil and water resources are at risk from loosing of access, degradation and scarcity, which will lead to increase the pressure on the global and environmental security. So, it is stated by the President of the World Bank (Jim Yong Kim) that "*fights over water and food are going to be the most significant direct impacts of climate change in the next 5 to 10 years*". Furthermore, it should save our soils to save our planet as stated by Australia's first National Advocate for Soil Health Jeffrey and his colleague Achurch (2017). Concerning some climate change issues, McCarl (2017) is also stated that, it could improve or maintain soil condition and its health including (1) the direct and indirect soil-related effects of extreme events, a warming world and associated changes in precipitation and other climate attributes, (2) soil-related effects of actions to adapt to climate change and (3) soil-related effects of climate change mitigation efforts in terms of sequestration enhancement and more general greenhouse gas emission control (Fig. 1 and 2).

From these previous publications, it is clear that climate change is penetrated all our life. Agriculture sector is considered the main source of global food and water security. This sector accounts for 24 % of greenhouse gas (GHG) emissions (carbon dioxide, methane, nitrous oxide). Therefore, the mitigation and adaptation to climate changes may be reconciled in climate-smart agriculture proposals in these previous two different responses (Torquebiau 2016). So, the European Union has a great challenge about the integration of agriculture into the frameworks and strategies of global climate change mitigation policy. This challenge includes (1) a reduction in GHG emissions, (2) a wide need for technological mitigation options, (3) the mitigation of climate change should be at national and global level and (4) the agriculture sector should contain multilateral commitments to limit emission leakage (Fellmann et al. 2017).

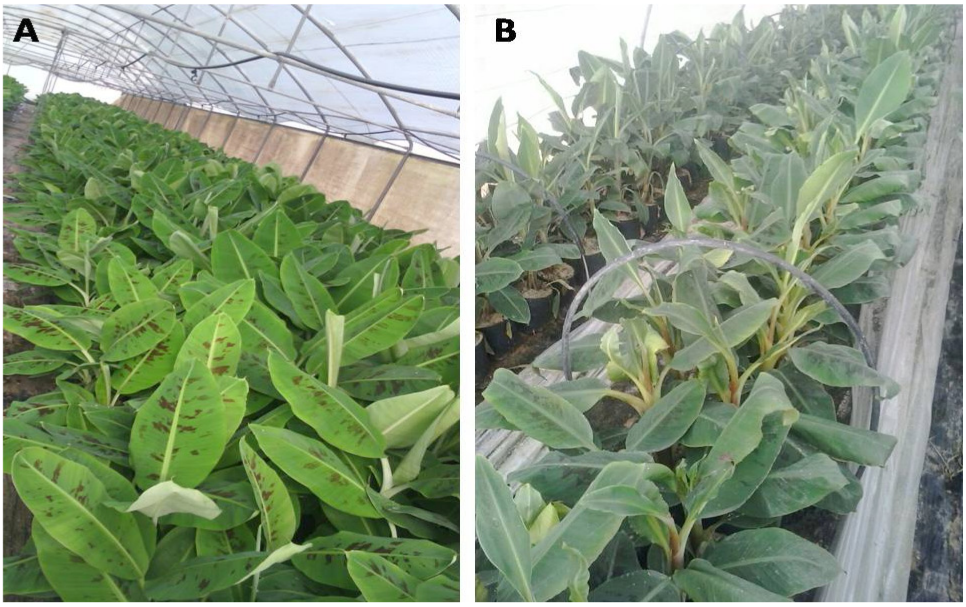

Fig. 1. Effect of low temperature (6 ±2 ^{O}C) on growth of banana seedlings during January (2017) in greenhouse in El Nubaria (Beheira Governorate, Egypt), where (A) normal growth and (B) abnormal plants with spear shaped leaves, narrow blade, needle edges and pale color (Photos by Elmahrouk).

Fig. 2. Effect of low temperature (4 ±2 ^{O}C) on growth of banana plants during January (2017) in open field in El Nubaria (Beheira Governorate, Egypt), where (A) normal and healthy field, (B), (C) and (D) stages of cooling effect caused vegetative burn (E) open field of mother banana plants burned and (F) open field of the first generation of banana plants burned. This change in climate has been caused a loss by several million dollars this year in Egypt for the farmers of banana (Photos by Elmahrouk).

Therefore, the impact of climate changes on agriculture and food security should be addressed to the global level. The relationship between agriculture and climate change is complicated, where the agricultural practices impact and influence by climate changes. Nearly all agricultural production and practices depend on climatic elements and these practices could control the global change in climate. The adaptation and mitigation of the changes in climate should be faced by both developed and developing countries as well as there is no nation away from these climate changes all over the world.

Environmental pollution and abiotic stress

Environmental pollution is considered one of the most important global issues, which threatens our life (Shankar and Shikha 2017). This global threat is manifested day by day including soil, water, air and ecosystem pollution (Figs. 3 and 4). These environmental pollutions could be considered as a source of abiotic stress on the environment. Concerning the air pollution, it is the major threat to human health as reported by World Health Organization (WHO; Venkatesan 2016). Regarding soil and water pollution, they are also a real threat for human health (Chen et al. 2016a; Islam et al. 2017). Environmental pollution includes different forms such as organic and inorganic pollutants but the most important and new types are electronic wastes (Awasthi et al. 2016; Li et al. 2017) and nanoparticle or nanomaterial pollutants (Li et al. 2016a; El-Ramady et al. 2017). The common pollutants include the heavy metals (Li et al. 2016b; Chen et al. 2016b; da Silva et al. 2017), persistent of organic pollutants (Wilson et al. 2016; Saha et al. 2017b), environmental persistent of pharmaceutical pollutants (Huber et al. 2016; Łukaszewicz et al. 2017), polycyclic aromatic hydrocarbons (Kenessov et al. 2016; Wei et al. 2017), volatile organic compounds (Pantoja et al. 2016; Yu et al.

2017) and environmental xenobiotics (Witczak et al. 2016; Hashmi et al. 2017). Developing and developed countries suffer from problems resulting from environmental pollution. So, new methodologies should be developed to detect and monitor not only well known pollutants but also different new contaminants (Lodeiro et al. 2016; Hashmi et al. 2017). Different pollutants should be removed from different environments including soil, water, air and ecosystem within various technologies of remediation.

Fig. 3. Effect of soil alkalinity (pH: 8.7) and salinity of irrigation water (2500 ppm) on growth and fruits of Citrus sinensis in Wadi El-Natrun (Beheira Governorate, Egypt), where (A) normal plant, (B) fall leaves from the end of new branches (C) some branches drop all their leaves and (D) all branches drop all their leaves. A distinguished change in salinity of soil and water has been recorded due to changes in climate during last few years causing a loss by several million dollars in Egypt (Photos by Elmahrouk).

Year by year and day by day, enormous pollutants or xenobiotic compounds have been increased in ecosystems considerably. Environmental pollution nowadays is considered a major human and environmental problem (Noguera-Oviedo and Aga 2016; Hashmi et al. 2017). This environmental pollution can be defined as any discharge of material or energy into natural resources (i.e., water, land, air, forest, etc) causing or may cause acute (through short-term) or chronic (through long-term) damage to the universe (da Silva et al. 2017). Several sources of pollution or many synthetic substances represent these sources including (1) the natural activities (geological erosion and saline seeps), (2) the human activities (e.g., construction and mining), (3) industrial activities, (4) agricultural activities (e.g. fertilizers, pesticides) (5), acidic deposition, (6) radioactive fallout, and (7) pharmaceuticals (Adki et al. 2014).

Fig. 4. Effect of soil alkalinity stress (pH: 8.9) and salinity of irrigation water (2500 ppm) on the growth of mango production in El-Khatatba (Minufiya Governorate, Egypt), where (A) normal plant, (B) burned the leave edges by soil salinity and (C) pale yellow leaves caused by water salinity. A distinguished change in salinity of soil and water has been recorded due to changes in climate during last few years causing a loss by several million dollars in Egypt (Photos by Elmahrouk).

Concerning soil pollution, it is very important to monitor and remediate different toxic pollutants in soils because of the global food safety (Kenessov et al. 2016; Saha et al. 2017c). Due to the complexity and dynamics of soils, it is represented as the sink and/or the source of contaminants, which can be found in exchanging with air, water and the biosphere (Kenessov et al. 2016). Hence, the soil properties can be used as a good indicator for soil pollution such as soil basal respiration (Romero-Freire et al. 2016), soil data (Chen et al. 2016c), soil microbial communities (Azarbad et al. 2016), etc (Saha et al. 2017d). In order to quantify soil pollutants, four requirements are necessary i.e., (1) estimation the spatial and temporal trends of pollutant concentrations, (2) development of the efficiency of the technology of soil remediation, (3) determination the pollution source and the soil map for polluted areas and (4) verification that soil quality fulfills the standards of safety (Kenessov et al. 2016; Saha et al. 2017c).

It is well established that, the management of natural resources (soil, water, air, forests, fisheries, etc.) should be performed under the umberella of sustainable utilization. Because these natural resources are the main source for our life and support this life with essential food, feed, fibre, and fuel (Akhtar et al. 2016; Shalaby et al. 2016). As mentioned above, the envoronmental pollution is a serious problem and its managment should be achieved under the umbrella of sustainability. This management depends on the type of pollution and its level. Therefore, soil, water and air pollution should be managed in frame of the sustainability. The best solution for sustainable pollution management is to prevent this pollution first or reducing or managing it (Ullwer et al. 2016). Regarding the soil pollution management, it is a great challenge and target several years ago for all countries. Many practices have been performed in dealing with this management depending on the type and level of pollution. Recently, many best management practices in dealing with soil pollution have been published including these issues, the outdoor shooting ranges (Fayiga and Saha 2016; Rodríguez-Seijo et al. 2016), pesticides (Ouyang et al. 2016), cement plant wastes (Cutillas-Barreiro et al. 2016), mining and smelting (Lei et al. 2016), heavy metals (Cutillas-Barreiro et al. 2016; Liao et al. 2016a) and agricultural pollution (Babin et al. 2016; Domínguez et al. 2016). Therefore, it could be sustained soil in general through recycling of nutrients, the cleaning of air and water, as well as climatic cycles, where these previous issues represent the fundamental factors in the management of the natural resources as well (Akhtar et al. 2016).

Therefore, soil pollution could be considered an emerging threat to agriculture due to the abiotic stress on plant or crop production (Saha et al. 2017d). Environmental pollution varies widely due to several complex interactions of pollutants at both extracellular and intracellular levels. Inorganic pollutants can reduce the uptake of water and nutrient in rhizosphere as well as reducing the rate of several nutrient cycling processes and thus impacting on nutrient use efficiency (Saha et al. 2017e). Several impacts of soil pollution on agroecosystems have been recorded including (1) losses of crop productivity and crop diversity, (2) decline in nutrient use efficiency, (3) reduce the quality of food including vegetables, fruits and grains, (4) contamination of food with toxic compounds like heavy metals, (5) rejection of export consignment, (6) increase soil hardness or compaction, (7) decrease in available soil moisture content, (8) waterlogging due to poor infiltration, and (9) impacts on soil fertility parameters (Saha et al. 2017e). The close relationship between environmental pollution and abiotic stress has been documented in several studies in field (e.g., Alshaal et al. 2017; Balakhnina and Nadezhkina 2017; Giron-Calva et al. 2017; Hasanuzzaman et al. 2017) or in *in vitro* studies (e.g., Leung 2017). So, several publications have been issued about the pollutants in the environment such as arsenic (Gupta and Chatterjee 2017), cadmium (Zaborowska et al. 2017), copper (Kashulina 2017), mercury (Sarkar et al. 2017), nickel (Plekhanova et al. 2017) or trace elements (Hasanuzzaman et al. 2017; Saha et al. 2017c; Shankar and Shikha 2017).

Therefore, it could be concluded that, natural resources including soil, water, air and forests are fundamental for maintaining environmental sustainability for human communities. Sustainable development issues have significant concerns in rural areas, particularly under pressures of economic development, poverty reduction and environmental protection. As well known, all steps or technical analyses just suggest any forward movement toward sustainable development must be achieved, although there is no definite agreement concerning sustainable development. Sustainable management of soil, water and air pollution is not easy issue but it should be planned and this sustainability will be only achieved by improving the use efficiency of these natural resources. Environmental pollution represents a great and serious threat facing the environment due to the real stress on the natural resources. Therefore, this threat should be faced even in single and/or multiple pollutants. A global collaboration among countries should be established to overcome the common threats.

Environmental nanotechnology and pollution control

Nanotechnology, which emerged in 1980s, could be defined as a science of understanding and controlling of matter at dimensions between 1 and 100 nm (National Nanotechnology Initiative 2009). This science has been played an important role in addressing different effective and innovative solutions to many different environmental challenges (Patil et al. 2016; Centonze and Manacorda 2017; Di Sia 2017; Singh 2017). Nanoremediation also can help in lowering down the pollutants and their generation in the environment. Three major applications of nanoremediation could be characterized including detection of pollution using nanosensors, prevention of pollution, purification and remediation of contamination (Kaur et al. 2017). Therefore, nanoremediation can be used in developing cost-effective and specific methods in remediation of soils, water, air and groundwater. Several nanoparticles have been used successfully in nanoremediation such as iron nanoparticles (Fe^0), ZnO and TiO_2 nanoparticles, magnetic nanoparticles, ferritin nanoparticles, polymeric nanoparticles, and bioactive nanoparticles (Kaur et al. 2017).

Therefore, a new branch is already emerged calling environmental nanotechnology, which deals in general with different remediation methods using the application of nanoparticles. This reflects the recent increasing efforts in using this branch of nanotechnology in different environmental sectors (Patil et al. 2016; Auty 2017; Iavicoli et al. 2017). Due to the intensive urbanization and human activities, pollution has become one of the most important environmental challenges. So, the environment will not suffer from new pollutants resulting from different advanced technologies but also the environmental ability for self remediation will be decreased (Mehndiratta et al. 2013). Therefore, an urgent need to find the suitable solutions in order to reduce these pollutant levels. Hence, nanotechnology is not only considered an emerging solution for cleaning environment but also for combating pollution through preventing pollutants formation or reducing the release of these pollutants (Mehndiratta et al. 2013; Kaur et al. 2017).

On the other hand, remediation can be defined as the science of reduction or removal of pollutants in soil, sediments, air, water and environments using physical, chemical and biological methods. This remediation can be achieved using nanoparticles or nanomaterials. These nanoparticles have a several benefits owing to their high surface area and small size. These nanoparticles/ nanomaterials have a great diversity in their types that can be used for the remediation purpose including carbon nanotubes, dendrimers, nanoscale zeolites, bimetallic particles, enzymes and metal oxides (Mehndiratta et al. 2013; Kaur et al. 2017). Therefore, nanotechnology offers a new generation of nanomaterials for environmental remediation. This remediation has cost effective solutions in challenging the problems of the environmental cleanup from pollutants (El-Temsah et al. 2016). For example, some nanoparticles can be used in remediation of soil or waste water or groundwater pollution because these nanomaterials have the following characterizations (1) the very small size of these nanoparticles can make the injection of them into very small spaces easy and remain active for a long time, (2) the large surface area can help to a high enzymatic activity, (3) the movement of these nanoparticles can be transported with the flow of water and is controlled by gravitational sedimentation, (4) and these nanoparticles can be adsorbed on the solid matrix (Araújo et al. 2015; Guan et al. 2015; Liu et al. 2015; Louie et al. 2016; Zhao et al. 2016; Dasgupta et al. 2017; Kaur et al. 2017).

In general, remediation methods can be classified into three methods, physical, chemical and biological. Concerning the physico-chemical and engineering methods, they are very expensive requesting the digging up of polluted and disposal of the wastes to a landfill in soils, leading to pollution elsewhere as well as the handling and transport of hazardous materials within the environment (Adki et al. 2014). Regarding bioremediation processes, it is involved the removal of hazardous pollutants using microbes (microbial remediation), plants (phytoremediation) and animals (zooremediation). Regarding zooremediation, it has been accounted as a tool for removal of pollutants from aquatic ecosystems. Due to the ethical or human health concerns, animals are rarely considered for bioremediation initiatives (Gifford et al. 2006). Many studies have been published regarding the suitable solutions of nanotechnology in controlling the pollution such as Wang et al. (2016), Patil et al. (2016), Devi and Ahmaruzzaman (2016), Ibrahim et al. (2016), Subramanian et al. (2016) and El-Ramady et al. (2017).

The using of plants and their associated microbes in cleaning up different pollutants from soils and water is a promising technology calling phytoremediation (Ma et al. 2016). Several researchers have been studied phytoremediation process and its strategies including phytoextraction, phytostabilization, phytofiltration, phytovolatilization, etc. (El-Ramady et al. 2015a, b; Agnello et al. 2016; Ji et al. 2016; Liao et al. 2016b; Luo et al. 2016; Ma et al. 2016; Mitton et al. 2016; Shah et al. 2016; Wan et al. 2016; Ansari et al. 2017; Bauddh et al. 2017). It is also reported that, phytoremediation of contaminated environments using nanoparticles (e.g., nano-Au, Ag, CuO, ZnO and C_{60}) have been performed, where these nanoparticles can be absorbed and translocated by plants either as nano- or in their ionic form (Tripathi et al. 2015, 2016; Mustafa and Komatsu 2016; Singh and Lee 2016; Khan et al. 2016; Patil et al. 2016; Martínez-Fernández et al. 2017). Concerning the microbial remediation, it is recently reported that, a developed strategy was established using genetically modified microbes in detoxifying and degradation of environmental pollutants (Chandra 2015).

Therefore, doubtless, the global deterioration of natural resources i.e. soil, water and air by releasing of toxic substances from the continuous anthropogenic activities is nowadays a serious problem across the world. This poses numerous issues relevant to the global ecosystem and human health. The great challenge now is how all countries can maintain the sustainability of the environment. The control of pollution can be achieved using the emerging applications of nanotechnology, but more control is needed with many regulations depends on the nature and size of used nanoparticles. Thus, environmental nanoremediation will not only specifically detect the pollutants but also convert them into non-toxic form upon reaction with it.

Environmrntal nanoremediation under climate change

As mentioned before, the environmental remediation involoved the removal or clean up of pollutants/contaminats from different environemntal compartments (e.g., soil, groundwater, air, sediment and water) which are the main natural the most areas suffer from these pollutants. Therefore, the remediation processes mainly are subjected for human health and envirnment protection, which based on the asessment of different ecological risks (Ingle et al. 2014). One of the most important strategies in remediating soil, ground- and waste water is nanoparticles/nanomaterials. Thus, using of these nanoparticles in cleaning the environment from pollutants is called nanoremediation. Many studies have been published concerning the benefits of nanoremediation or nanotechnology for environmental clean-up including heavy metals removing from soils (Ingle et al. 2014; Araújo et al. 2105; Jain et al. 2015; Fajardo et al. 2015; Jain et al. 2016; Gillies et al. 2016; Gil-Díaz et al. 2016a; Martínez-Fernández et al. 2017), using plants in clean up (Ghormade et al. 2011; Capaldi Arruda et al. 2015; Gil-Díaz et al. 2016b; Martínez-Fernández et al. 2017), remediation of waste water (Hamza et al. 2016; Peeters et al. 2016; De Luca and Ferrer 2017; Shekarriz et al. 2017; Xue et al. 2017) degradation of pesticides in soil and water (El-Temsah and Joner 2013; Gomes et al. 2014; El-Temsah et al. 2016; Kaushik and Djiwanti 2017).

Nanoremediation of soils, as a promising strategy in minimizing the entry of pollutants in plant parts, can be performed using nanoparticles such as zero-valent iron nanoparticles (nZVI), ZnO, TiO_2, carbon nanotubes, fullerenes and bimetallic nano-metals. These nanoparticles have four missions in soil nanoremediation including (1) reducing the soil heavy metal concentration in leachates to acceptable level, (2) immobilization of soil heavy metals (e.g. Cr VI, Pb II, As III and Cd) in polluted soils (Mallampati et al. 2013; El-Ramady et al. 2017), (3) remediation the redox potential enhancing the convert of some soil heavy metals (like Cr VI) to less toxic forms and (4) degradation of organic contaminants (e.g. DDT, chlorinated organic solvents, carbamates, etc) (Abhilash et al. 2016; Saha et al. 2017f). Therefore, an integrated soil management through nanoremediation should be addressed. The proper management strategy depends on many parameters including (1) soil properties and type, (2) pollutants type, level, and their mode of toxicity expression, (3) climate area and climatic factors, (4) crops, and cropping system, (5) management of nutrients, water and organic matter, (6) the purpose of land use during and after remediation process, and (7) economics considerations (Saha et al. 2017f). Concerning climatic factors, these factors include particularly distribution pattern of precipitation or rainfall and magnitude, humidity, temperature, etc. These previous climatic factors could control and impact on degradation, transformation, mobility and fate of pollutants in the soil profile.

Regarding climate changes and environmental nanoremediation, the changing in climate could impact on all processes in soils including nanoremediation process (**Fig. 5**). As well known, all soil processes and factors are totally controlled by the climatic factors. For example, any change in soil moisture or temperature will be followed by changes in fate and behavior of all nutrients or elements or pollutants. This distinguished impact of climate change on soil remediation could be also involved water and air remediation as well (Mitra et al. 2017). It is reported that, changes in temperatures and precipitation patterns are predicted to be significantly altered by 2100 (Melillo et al. 2014; Phelan et al. 2016). Together, the individual and interactive impacts of these previous two stressors could impact on many components of terrestrial ecosystems including soil processes and plant community diversity (Porter et al. 2013; Phelan et al. 2016). It could be noticed that, a few publications have been issued regarding the influence of climate changes on environmental pollution and nanoremediation (e.g., Phelan et al. 2016; Alshaal et al. 2017; Kolokytha et al. 2017; Niinemets et al. 2017).

Some important information about climate changes through the following sentences (more details in Alshaal et al. 2017; Niinemets et al. 2017):

(1) Water and food security are the key challenges under climate change as both are highly vulnerable to continuously changing climatic patterns. So, any degradation, transport, mobility and sorption and bioavailability of nanoparticles or pollutants is totally controlled by factors including soil pH, soil texture or clay content, cation exchange capacity, pollutant level and type, nutrient and water management and soil organic matter (Phelan et al. 2016).

(2) Studies have predicted that the average global temperature may increase by 1.4–5.8 °C and there would be substantial reduction in fresh water resources and agricultural yield by the end of the 21st century (Misra 2014).

(3) According to the report of IPCC (2008), it could be predicted that the climate change over the next century will affect rainfall pattern, river flows and sea levels all over the world as well as agriculture yield will likely be severely affected over the next hundred years due to unprecedented rates of changes in the climate system (Thornton et al. 2011).

(4) – In arid and semi-arid areas, the expected precipitation decreases over the next century would by 20% or more as well as the accelerated increase in the greenhouse gases (GHGs) concentration in the atmosphere is a major cause for climate change (El-Ramady et al. 2013).

(5) Higher temperatures and increased variability of precipitation would, in general, lead to an increased irrigation water demand, even if the total precipitation during the growing season remains the same.

(6) As a result of increased atmospheric CO_2 concentrations, water-use efficiency for some crops would increase, which would increase the ratio of crop yield to unit of water input (water productivity). However, in hot regions, such as Egypt, the ratio may even decline as yields decrease due to heat stress (IPCC 2007)

(7) The increase modifications in both temperature and precipitation patterns globally induce major environmental alterations in different agroecosystems including soils and aquatic ecosystems (Niinemets et al. 2017).

(8) The modifications in global temperature will impact on the distribution of ice, thereby altering the timing of peak productivity, while changes in precipitation strongly alter water table depth with pollutant modifications in light distribution, temperature, and water chemistry, collectively altering the balance between primary production, organic matter consumption, and decomposition.

(9) The fate, behavior, oxidation and degradation of different pollutants in agroecosystems are totally controlled by the global warming and climate changes beside different soil characters particularly soil organic matter, which could impact upon increase of soil microbial activity and others.

(10) The impact of human activities on agroecosystems under global climate changes should include different environmental nanoremediation in particular pollutants originating from various rural and urban land use activities.

(11) Further studies concerning impact of climate changes on environmental nanoremediation should include predicting and identification the impact of climate changes on the fate, behavior, bioavailability and toxicity of pollutants as well as how the pollutants alter agroecosystem responses to these global climate change (Niinemets et al. 2017).

Therefore, it could be concluded that, promising results have been obtained from the application of nanotechnology for the remediation of contaminants. Furthermore, nanoremediation also can provide us with a way in purifying soil, air and water resources by using nanoparticles/nanomaterials as a catalyst and/or sensing systems. Groundwater remediation for drinking and reuse is a promising field, which can be achieved by using nanomaterials such as zero-valent iron and carbon nanotubes. However, there are still some open questions remaining concerning the potential risks and human health associated with this use of nanomaterials in the environment under changing climate. Concerning the

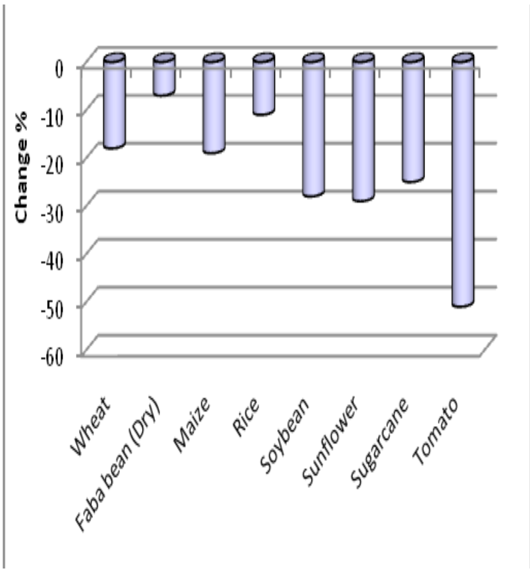

Fig. 5. Change percent in crop productivity under climate change as compared with current conditions in Egypt. More than 50 % of the crop production of tomato will be lost under climate change in Egypt. Current crop productivity (2015) was obtained from Bulletin of the Agricultural Statistics, September 2016, Economic Affairs Sector. Ministry of Agriculture and Land Reclamation.

sustainable crop production from polluted lands using nanoremediation, there are many economic, social and ecotoxicological considerations and some strategies regarding minimizing the potential risks for human health should be kept in mind. Furthermore, restoration soil functionality and growth of plants monitoring in polluted lands are necessary before any field recommendations for application of nanoremediation. Concerning nanoremediation under changing climate, this type of remediation for soil, water, air, etc.., still needs further investigations to draw the complete portrait about this global issue. The relationship among pollutants, water, soils, nanomaterials and the environment under climate changes was and will still the crucial global issue worldwide.

Conclusion

As mentioned above, nanoremediation can be considered an interesting approach in dealing with both environmental health and safety terms whereas, there is not fully understanding concerning the behavior of nanoparticles/ nanomaterials on the large scale. Therefore, the use of nanoparticles/nanomaterials for remediation should be followed after further safety and appropriate researches. Furthermore, the polluted lands represent a real threat for the environment espeacilly in case of the dangerous contaminants but on the other hand these polluted soils may offer a real opportunity for the multiple cropping in both the production of foods and the biorefineries for the bioeconomy. Further studies are needed in dealing with nanremediation including (1) the biotoxicity of nanomaterials/ nanoparticles (e.g., the mobility and biogeochimstry of these nanoparticles in particular under the field conditions), (2) the investigation of local environmental conditions and their effects on the fate, transport and transformation of nanoparticles/nanomaterials, and (3) study the antagonistic or synergistic effects of nanoparticles and microbial activities in soils.

Acknowledgements

Authors thank the outstanding contribution of STDF research teams (Science and Technology Development Fund, Egypt) and MBMF/DLR (the Federal Ministry of Education and Research of the Federal Republic of Germany), (Project ID 5310) for their help. Great support from this German-Egyptian Research Fund (GERF) is gratefully acknowledged.

References

Abhilash P. C., V. Tripathi, S Adil Edrisi, R. Kant Dubey, M. Bakshi, P. K. Dubey, H. B. Singh and S. D. Ebbs (2016). Sustainability of crop production from polluted lands. Energ. *Ecol. Environ.* **1**(1), 54–65. DOI: 10.1007/s40974-016-0007-x

Adki V. S., J. P. Jadhav and V. A. Bapat (2014). At the cross roads of environmental pollutants and phytoremediation: a promising bio remedial approach. *J. Plant Biochem. Biotechnol.* (April–June 2014) **23**(2),125–140. DOI: 10.1007/s13562-013-0250-6

Agnello A.C., M. Bagard, E.D. van Hullebusch, G. Esposito, D. Huguenot (2016). Comparative bioremediation of heavy metals and petroleum hydrocarbons co-contaminated soil by natural attenuation, phytoremediation, bioaugmentation and bioaugmentation-assisted phytoremediation. *Science of The Total Environment,* **563–564,** 693-703.

Akhtar F., Lodhi, S.A., Khan, S.S. and Sarwar, F. (2016) Incorporating permaculture and strategic management for sustainable ecological resource management. *Journal of Environmental Management* **179,** 31-37. http://dx.doi.org/10.1016/j.jenvman.2016.04.051.

Alshaal, T., El-Ramady, H. AH Al-Saeedi, T Shalaby, T Elsakhawy, AE-D Omara, A. Gad, E Hamad, A. El-Ghamry, A. Mosa, Amer, M. and N. Abdalla (2017) the rhizosphere and plant nutrition under climate change. In: M. Naeem et al. (Eds.), *Essential Plant Nutrients,* DOI 10.1007/978-3-319-58841-4_11, pp: 275 – 308.

Springer International Publishing, A.G. Ansari, A.A., S.S. Gill, R Gill, Lanza, G.R. and Newman, L .(2017) *Phytoremediation: Management of Environmental Contaminants,* Vol. 5. DOI 10.1007/978-3-319-52381-1, Springer International Publishing AG.

Araújo, R., Meira Castro, A. C. and Fiúz, A. (2015)The use of nanoparticles in soil and water remediation processes. *Materials Today: Proceedings* **2** (1), 315 – 320. Doi: 10.1016/j.matpr.2015.04.055.

Aslam, Z., Khattak, J. Z. K. and Ahmed, M. (2017) Drought Tolerance in Cereal Grain Crops Under Changing Climate. In: M. Ahmed, C.O. Stockle (Eds.), *Quantification of Climate Variability, Adaptation and Mitigation for Agricultural Sustainability,* DOI 10.1007/978-3-319-32059-5_9, pp: 181 – 209. Springer International Publishing Switzerland.

Auty, A.R. (2017) Quantifying environmental and personal risks of nanotechnology for industry. *Current Opinion in Biotechnology,* **46,** 150-155.

Awasthi, A. K. Zeng, X. and Li, J. (2016) Environmental pollution of electronic waste recycling in India: A critical review. *Environmental Pollution,* **211,** 259-270.

Azarbad H, van Straalen, N. M., Laskowski, R. Nikiel, K. Röling,W. F.M. and Niklinska, M. (2016) Susceptibility to additional stressors in metal-tolerant soil microbial communities from two pollution gradients. *Applied Soil Ecology* **98,** 233–242. http://dx.doi.org/10.1016/j.apsoil.2015.10.020.

Babin N., Mullendore, N. D. and Prokopy,L. S. (2016) Using social criteria to select watersheds for non-point source agricultural pollution abatement projects. *Land Use Policy* **55,** 327–333. http://dx.doi.org/10.1016/j.landusepol.2015.06.021.

Balakhnina, L.T.I. and Nadezhkina, E.S. (2017) effect of selenium on growth and antioxidant capacity of *triticum aestivum* during development of lead-induced oxidative stress. *Russian Journal of Plant Physiology,* **64** (2), 215–223. DOI: 10.1134/S1021443717010022.

Bauddh, K., Singh, B. and Korstad, J. (2017) *Phytoremediation Potential of Bioenergy Plants.* DOI 10.1007/978-981-10-3084-0, Springer Nature Singapore Pte Ltd.

Belal, E. and El-Ramady, H. (2016) Nanoparticles in water, soils and agriculture. In: S. Ranjan et al. (Eds.), *Nanoscience in Food and Agriculture 2, Sustainable Agriculture Reviews* 21, DOI 10.1007/978-3-319-39306-3_**10,**Springer International Publishing Switzerland

Campos-Herrera, R., Martín, J A R., Escuer, M. García-González, M. T., Duncan, L. W. and Gutiérrez , C. (2016) Entomopathogenic nematode food webs in an ancient, mining pollution gradient in Spain. *Science of The Total Environment,* **572,** 312-323

Capaldi Arruda, S. C. C., Silva, A. L. Galazzi,D. R. M. Azevedo,R. A. and Arruda, M. A. Z. (2015) Review nanoparticles applied to plant science: A review. *Talanta* **131,** 693–705. http://dx.doi.org/10.1016/j.talanta.2014.08.050

Cazenave A., Champollion, N ., Paul,F. and Benveniste, J. (2017) integrative study of the mean sea level and its components. *Space Sciences Series of ISSI* Vol. **58,** DOI: 10.1007/978-3-319-56490-6, Springer International Publishing AG

Centonze, F. and Manacorda, S. (2017) *Historical Pollution: Comparative Legal Responses to Environmental Crimes*. DOI 10.1007/978-3-319-56937-6, Springer International Publishing AG

Chandra, R. (2015) *Advances in Biodegradation and Bioremediation of Industrial wastes*. CRC Press of Taylor and Francis Group. ISBN-10: 1498700543; ISBN-13, 978-1498700542

Chen, H., Teng, Y. Lu, S., Wang, Y., Wu, J. and Wang, J .(2016a) Source apportionment and health risk assessment of trace metals in surface soils of Beijing metropolitan, *China. Chemosphere,* **144,**1002-1011.

Chen, L., Wang, G., Zhong, Y. and Shen, Z. (2016c) Evaluating the impacts of soil data on hydrological and nonpoint source pollution prediction. *Science of the Total Environment* **563–564,** 19–28. http://dx.doi.org/10.1016/j.scitotenv.2016.04.107.

Chen, M., Qin, X., Zeng,G. and Li, J. (2016b) Impacts of human activity modes and climate on heavy metal “spread” in groundwater are biased. *Chemosphere,* **152,** 439-445. http://dx.doi.org/10.1016/j. *chemosphere.* 2016.03.046 .

Chen, W.Y., Suzuki,T. and Lackner, M. (2017) *Handbook of Climate Change Mitigation and Adaptation.* DOI 10.1007/978-3-319-14409-2, Springer International Publishing Switzerland.

Copland, L., Mortimer,C., White, A., McCallum, M.

R. and Mueller, D. (2017) Factors Contributing to Recent Arctic Ice Shelf Losses. In: L. Copland, D. Mueller (Eds.), *Arctic Ice Shelves and Ice Islands, Springer Polar Sciences,* DOI 10.1007/978-94-024-1101-0_10, pp: 263 – 285. Springer Science + Business Media B.V.

Cutillas-Barreiro L.,Pérez-Rodríguez, P., Gómez-Armesto, A., Fernández-Sanjurjo,M. J., Álvarez-Rodríguez, E. Núñez-Delgado,A. , Arias-Estévez M. and Nóvoa-Muñoz J. C. (2016) Lithological and land-use based assessment of heavy metal pollution in soils surrounding a cement plant in SW Europe. *Science of the Total Environment* **562,** 179–190. http://dx.doi.org/10.1016/j.scitotenv.2016.03.198.

da Silva C.P., da Silveira E.L., de Campos S.X. (2017) Environmental pollution by heavy metals in the Sao Joao River basin, southern Brazil. *Environ Earth Sci* **76,**554. DOI 10.1007/s12665-017-6890-4.

Dasgupta, N., Ranjan,S. and Ramalingam, C. (2017) Applications of nanotechnology in agriculture and water quality management. *Environ Chem Lett,* DOI 10.1007/s10311-017-0648-9.

Davari, M.R., Kazazi, S.B. and Pivehzhani,O.A. (2017) Nanomaterials: Implications on Agroecosystem. In: R. Prasad et al. (Eds.), *Nanotechnology,* DOI 10.1007/978-981-10-4573-8_4, pp: 59 – 71. Springer Nature Singapore Pte Ltd.

Davis, A.S., Prakash,P. and Thamaraiselvi, K. (2017) Nanobioremediation Technologies for Sustainable Environment. In: M. Prashanthi et al. (Eds.), *Bioremediation and Sustainable Technologies for Cleaner Environment, Environmental Science and Engineering,* DOI 10.1007/978-3-319-48439-6_2, pp: 13 – 33. Springer International Publishing AG.

De Luca, A. and Ferrer,B.B. (2017) Nanomaterials for Water Remediation: Synthesis, Application and Environmental Fate. In: G. Lofrano et al. (Eds.), *Nanotechnologies for Environmental Remediation,* DOI 10.1007/978-3-319-53162-5_2, Springer International Publishing AG.

Debortoli N. S., Camarinha, P. I. M., Marengo, J. A. and Rodrigues,R. R. (2017)An index of Brazil's vulnerability to expected increases in natural flash flooding and landslide disasters in the context of climate change. *Nat Hazards* **86,** 557–582. DOI 10.1007/s11069-016-2705-2.

Delev, K. (2017) climate change and water as a resource will cause serious security implications around the globe. In: O. Nikolov, S. Veeravalli (Eds.), Implications of Climate Change and Disasters on Military Activities, NATO Science for Peace and Security Series C: *Environmental Security,* DOI 10.1007/978-94-024-1071-6_22, pp: 137 – 142. Springer Science + Business Media B.V.

Devi, Th. B. and Ahmaruzzaman, M. (2016) Bio-inspired sustainable and green synthesis of plasmonic Ag/AgCl nanoparticles for enhanced degradation of organic compound from aqueous phase. *Environ Sci Pollut Res*, DOI: 10.1007/s11356-016-6945-1

Di Sia, P. (2017) Nanotechnology Among Innovation, Health and Risks. *Procedia - Social and Behavioral Sciences*, **237**, 1076-1080.

Domínguez, M. T., Alegre, J. M., Madejón, P., Madejón, E., Burgos, P., Cabrera, F., Marañón, T. and Murillo,J. M. (2016) River banks and channels as hotspots of soil pollution after large-scale remediation of a river basin. *Geoderma* **261,**133–140. http://dx.doi.org/10.1016/j.geoderma.2015.07.008.

El-Ramady, H., T. Alshaal, M. Abowaly, N. Abdalla, H.S. Taha, A.H. Al-Saeedi, T. Shalaby, M. Amer, M. Fári, É. Domokos-Szabolcsy, A. Sztrik, J. Prokisch, D Selmar, EAH Pilon-Smits, M Pilon (2017) Nanoremediation for Sustainable Crop Production. In: S. Ranjan et al. (Eds.), Nanoscience in Food and Agriculture 5, *Sustainable Agriculture Reviews* **26,** DOI 10.1007/978-3-319-58496-6_12, pp: 335 – 363. Springer International Publishing AG.

El-Ramady, H.R., El-Marsafawy, S.M. and Lewis, L.N. (2013) Sustainable Agriculture and Climate Changes in Egypt. In: E. Lichtfouse (Ed.), *Sustainable Agriculture Reviews,* **12,** 41 DOI 10.1007/978-94-007-5961-9_2, Springer Science + Business Media Dordrecht 2013 .

El-Ramady, H., Abdalla,N., Alshaal, T., Elhenawy,A. S., Shams, M. S., Faizy, S. E.-D. A., E. B. Belal, S. A. Shehata, M. I. Ragab, M. M. Amer, M. Fari, A. Sztrik, J. Prokisch, D. Selmar, E. Schnug, E. A. H. Pilon-Smits, E., El-Marsafawy, S. M. and Domokos-Szabolcsy, E. (2015a) Giant reed for selenium phytoremediation under changing climate. *Environ Chem Lett,* **13** (4), 359-380. DOI: 10.1007/s10311-015-0523-5.

El-Ramady, H., Abdalla,N., Alshaal, T., Fári, M., Prokisch,J., Pilon-Smits, E. A. H. and Domokos-Szabolcsy, É. (2015b) Selenium phytoremediation by giant reed. In: Eric Lichtfouse, Jan Schwarzbauer, Didier Robert (Eds.), *Environmental Chemistry for a Sustainable World* Vol. 6 (Hydrogen production and remediation of carbon and pollutants), Springer Science + Business Media B.V. DOI 10.1007/978-3-319-19375-5_4, pp: 133-198.

El-Temsah, Y. S. and Joner, E. J. (2013) Effects of nano-sized zero-valent iron (nZVI) on DDT degradation in soil and its toxicity to collembola and ostracods. *Chemosphere* **92,** 131–137. . http://dx.doi.org/10.1016/j.chemosphere.2013.02.039.

El-Temsah Y. S., A. Sevcu, K. Bobcikova, M. Cernik and E. J. Joner (2016). DDT degradation efficiency and ecotoxicological effects of two types of nano-sized zero-valent iron (nZVI) in water and soil. *Chemosphere* **144,** 2221–2228. http://dx.doi.org/10.1016/j.chemosphere.2015.10.122.

Fajardo, C., M. Gil-Díaz, G. Costa, J. Alonso, A. M. Guerrero, M. Nande, M. C. Lobo and M. Martín (2015). Residual impact of aged nZVI on heavy metal-polluted soils. *Science of The Total Environment,* **535,** 79-84. http://dx.doi.org/10.1016/j.scitotenv.2015.03.067.

Fayiga A. O. and Saha, U. K. (2016) Soil pollution at outdoor shooting ranges: Health effects, bioavailability and best management practices. *Environmental Pollution* **216,** 135-145. http://dx.doi.org/10.1016/j.envpol.2016.05.062.

Fellmann, T., Witzke, P., F. Weiss, B. Van Doorslaer, D., Drabik, I., Huck, Salputra, G., Jansson, T. and Leip,A. (2017) Major challenges of integrating agriculture into climate change mitigation policy frameworks. *Mitig Adapt Strateg Glob Change,* DOI 10.1007/s11027-017-9743-2.

França, F. C.S.S., Albuuerque,A. M.A., Almeida, A. C., Silveira, P. B., Filho, C.A. Hazin, C. A. and Honorato, E.V. (2017) Heavy metals deposited in the culture of lettuce (*Lactuca sativa* L.) by the influence of vehicular traffic in Pernambuco, Brazil. *Food Chemistry*, **215,** 171-176.

Ghormade V., Deshpande, M. V. and Paknikar,K. M. (2011) Perspectives for nano-biotechnology enabled protection and nutrition of plants. *Biotechnology Advances* **29,** 792–803. Doi:10.1016/j.biotechadv.2011.06.007.

Gifford, S., Dunstan, R.H., O'Connor, W., Koller, C.E., MacFarlane, G.R. (2006) Aquatic zooremediation: deploying animals to remediate contaminated aquatic environments. *Trends Biotechnol* **25**,60–65.

Gil-Díaz, M., Gonzalez, A., Alonso, A. and Lobo, M.C. (2016b) Evaluation of the stability of a nanoremediation strategy using barley plants.

Journal of Environmental Management **165,** 150-158. http://dx.doi.org/10.1016/ j.jenvman. 2015.09.032.

Gil-Díaz, M., S. Diez-Pascual, Gonzalez, A., Alonso, J., Rodríguez-Valdes, E., Gallego, J. R. and Lobo,M. C. (2016a) A nanoremediation strategy for the recovery of an As-polluted soil. *Chemosphere* **149,** 137-145. http:// dx.doi. org/ 10.1016/j.chemosphere.2016.01.106.

Gillies G., Mackenzie, K. Kopinke,F.D. and Georgi,A. (2016) Fluorescence labelling as tool for zeolite particle tracking in nanoremediation approaches. *Science of the Total Environment* **550,** 820–826. http://dx.doi.org/10.1016/j.scitotenv.2016.01.009.

Giron-Calva, P.S., Li,T. and Blande, J.D. (2017) Volatile-Mediated Interactions between Cabbage Plants in the Field and the Impact of Ozone Pollution. *J. Chem Ecol* **43,**339–350. DOI 10.1007/s10886-017-0836-x.

Gomes, H. I., Fan, G., Mateus, E. P., Dias-Ferreira, C. and Ribeiro, A. B. (2014) Assessment of combined electro–nanoremediation of molinate contaminated soil. *Science of the Total Environment* **493,**178–184. http://dx.doi.org/10.1016/j.scitotenv.2014.05.112.

Guan, X., Sun, Y., Qin, H., Li, J., Lo, I.M., He, D., Dong, H. (2015) The limitations of applying zero-valent iron technology in contaminants sequestration and the corresponding countermeasures: the development in zero-valent iron technology in the last two decades (1994-2014). *Water Res.* **75,** 224-248.

Günther, M. and Hellmann, T. (2017) International environmental agreements for local and global pollution. *Journal of Environmental Economics and Management,* **81,** 38-58.

Gupta, D.K., Chatterjee, S. (2017) *Arsenic Contamination in the Environment: The Issues and Solutions.* DOI 10.1007/978-3-319-54356-7, Springer International Publishing AG.

Hamza R.A., Iorhemen, O.T. and Tay, J.H. (2016) Occurrence, impacts and removal of emerging substances of concern from wastewater. *Environmental Technology & Innovation* **5,**161–175. http://dx.doi.org/10.1016/j.eti.2016.02.003.

Hasanuzzaman, M., Nahar, K., Rahman, A., Al Mahmud, J., Hossain, M.S. MK Alam, H Oku, Fujita, M. (2017) Actions of Biological Trace Elements in Plant Abiotic Stress Tolerance. In: M. Naeem et al. (Eds.), *Essential Plant Nutrients,* DOI 10.1007/978-3-319-58841-4_10, Springer International Publishing AG.

Hashmi, M.Z., Kumar, V. and Varma, A. (2017) Xenobiotics in the Soil Environment: Monitoring, Toxicity and Management. *Soil Biology Series* Vol. **49,** DOI 10.1007/978-3-319-47744-2. Springer International Publishing AG.

Huber, C., M. Preis, P. J. Harvey, S. Grosse, T. Letzel and P. Schroder, (2016) Emerging pollutants and plants e Metabolic activation of diclofenac by peroxidases. *Chemosphere* **146,** 435-441.

Iavicoli I, V Leso, DH Beezhold, AA Shvedova (2017) toxicological implications, and occupational risks. *Toxicology and Applied Pharmacology,* **329,** 96-111.

Ibrahim, R.K., Hayyan, M., AlSaadi, M.A., Hayyan, A., Ibrahim, S. (2016) Environmental application of nanotechnology: air, soil, and water. *Environ Sci Pollut Res Int.* DOI: 10.1007/s11356-016-6457-z

Ingle, A. P., A. B. Seabra, N. Duran, and M. Rai (2014) Nanoremediation: a new and emerging technology for the removal of toxic contaminant from environment. In: Das S. (Ed.) *Microbial Biodegradation and Bioremediation,* pp: 233-250. DOI: http://dx.doi.org/10.1016/B978-0-12-800021-2.00009-1. Elsevier Inc.

IPCC (2007) Fourth Assessment Report: Climate Change 2007. *Working Group II: Impacts, Adaptation and Vulnerability*. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3s3-5-1.html

IPCC (2008) Climate change and water, Intergovernmental panel on climate change technical report IV. June 2008.

Islam, M.A., D. Romic´, M.A. Akber, and M. Romic, (2017)Trace metals accumulation in soil irrigated with polluted water and assessment of human health risk from vegetable consumption in Bangladesh. *Environ Geochem Health,* DOI 10.1007/s10653-017-9907-8.

Jain R., D. Dominic, N. Jordan, E. R. Rene, S. Weiss, E. D. van Hullebusch, R. Hubner and P. N. L. Lens (2016) Higher Cd adsorption on biogenic elemental selenium nanoparticles. *Environ Chem Lett,* DOI: 10.1007/s10311-016-0560-8.

Jain, R., N. Jordan, D. Schild, E.D. van Hullebusch, S. Weiss, C. Franzen, F. Farges, R. Hübner, P.N.L. Lens (2015) Adsorption of zinc by biogenic elemental selenium nanoparticles, *Chemical Engineering Journal* **260,** 855 – 863. Doi: http://dx.doi.org/10.1016/j.cej.2014.09.057

Jangra, S., A Mishra, D. Kamboj, N. R.Yadav, and R C. Yadav. (2017) Engineering Abiotic Stress Tolerance Traits for Mitigating Climate Change. In: S.K. Gahlawat et al. (Eds.), *Plant Biotechnology: Recent Advancements and Developments,* DOI 10.1007/978-981-10-4732-9_3, pp: 59 – 73. Springer Nature Singapore Pte Ltd.

Jevrejeva, S., A. Matthews and A. Slangen, (2017). The twentieth-century sea level budget: recent progress and challenges. *Surv Geophys* **38,** 295–307. DOI 10.1007/s10712-016-9405-z.

Ji, X., S. Liu, J. Huang, E. Bocharnikova. and V. Matichenkov, (2016) Monosilicic acid potential in phytoremediation of the contaminated areas. *Chemosphere,* **157,** 132-136.

Kaphle, A., P.N. Navya, A. Umapathi, M. Chopra, and Daima, H.K. (2017) Nanomaterial Impact, Toxicity and Regulation in Agriculture, Food and Environment. In: S. Ranjan et al. (Eds.), *Nanoscience in Food and Agriculture 5, Sustainable Agriculture Reviews* **26,** DOI 10.1007/978-3-319-58496-6_8, pp: 205 – 242. Springer International Publishing AG.

Kashulina, G.M. (2017) extreme pollution of soils by emissions of the copper–nickel industrial complex in the kola peninsula. *Eurasian Soil Science,* **50** (7),837–849. DOI: 10.1134/S1064229317070031

Kaur, J., T. Pathak, A. Singh, and K. Kumar, (2017) Application of Nanotechnology in the Environment Biotechnology. In: R. Kumar et al. (Eds.), *Advances in Environmental Biotechnology,* DOI 10.1007/978-981-10-4041-2_9, Springer Nature Singapore Pte Ltd.

Kaushik, S. and Djiwanti, S.R. (2017) Nanotechnology for Enhancing Crop Productivity. In: R. Prasad et al. (eds.), *Nanotechnology,* DOI 10.1007/978-981-10-4573-8_11, Springer Nature Singapore Pte Ltd.

Kenessov, B., J. A. Koziel, N. V. Bakaikina, and Orazbayeva,D. (2016) Perspectives and challenges of on-site quantification of organic pollutants in soils using solid-phase microextraction. *Trends in Analytical Chemistry,* http://dx.doi.org/10.1016/j.trac.2016.04.007.

Khan, M. N, M. Mobin, Z. K. Abbas, K. A., AlMutairi and Siddiqui, Z. H. (2016) Role of nanomaterials in plants under challenging environments. *Plant Physiology and Biochemistry, Biochemistry* http://dx.doi.org/10.1016/j.plaphy.2016.05.038 .

Kolokytha, E., Oishi,S., Teegavarapu, R.S.V. (2017) *Sustainable Water Resources Planning and Management Under Climate Change.* DOI 10.1007/978-981-10-2051-3, Springer Science + Business Media Singapore.

Kovacs, H. and Szemmelveisz, K. (2017) Disposal options for polluted plants grown on heavy metal contaminated brown field lands– A review. *Chemosphere,* **166,** 8-20.

Kuppusamy, S., T. Palanisami , M. Megharaj , K. Venkateswarlu, and Naidu, R. (2016) In-Situ Remediation Approaches for the Management of Contaminated Sites: A Comprehensive Overview. In: P. de Voogt (Ed.), *Reviews of Environmental Contamination and Toxicology* Vol. **236,** DOI: 10.1007/978-3-319-20013-2_1, pp:1–115. Springer International Publishing Switzerland .

Lei K., E. Giubilato, A. Critto, H. Pan and C. Lin (2016). Contamination and human health risk of lead in soils around lead/zinc smelting areas in China. *Environ Sci Pollut Res,* DOI: 10.1007/s11356-016-6473-z.

Leung, D.W.M. (2017) Potential of Plant Tissue Culture Research Contributing to Combating Arsenic Pollution. In: D.K. Gupta, S. Chatterjee (Eds.), *Arsenic Contamination in the Environment,* DOI 10.1007/978-3-319-54356-7_9, Springer International Publishing AG .

Li ,A., R. Lin, C. Lin, B. He, T. Zheng, L. Lu and Y. Cao (2016b). An environment-friendly and multi-functional absorbent from chitosan for organic pollutants and heavy metal ion. *Carbohydrate Polymers* **148,**272–280.

Li, J., Ge, Z., Liang, C. and An, N.(2017) Present status of recycling waste mobile phones in China: a review. *Environ Sci Pollut Res* **24**,16578–16591. DOI 10.1007/s11356-017-9089-z.

Li Y, P Li, H Yua and Y Bian (2016a). Recent advances (2010–2015) in studies of cerium oxide nanoparticles' health effects. *Environmental Toxicology and Pharmacology* **44,** 25–29.

Liao C., W. Xu, G. Lu, F. Deng, X. Liang, C. Guo and Z. Dang (2016b). Biosurfactant-enhanced phytoremediation of soils contaminated by crude oil using maize (*Zea mays* L). *Ecological Engineering* **92,** 10–17.

Liao, G., Q. Wu, R. Feng, J .Guo, R. Wang, Y. Xu, Y. Ding, Z. Fan and Mo, L. (2016a) Efficiency evaluation for remediating paddy soil contaminated with cadmium and arsenic using water management, variety screening and foliage dressing technologies. *Journal of Environmental Management* **170,** 116-122. http://dx.doi.org/10.1016/j.jenvman.2016.01.008.

Liu W., Tian, S., Zhao, X., Xie, W., Gong, Y., Zhao, D. (2015) Application of stabilized nanoparticles for in situ remediation of metal-contaminated soil and groundwater: a critical review. *Curr. Pollut. Rep.* **1** (4), 280-291.

Lodeiro, C, Capelo, J. L., Oliveira, E. and Nuñez , C. (2016) Pollutant toxic ions and molecules: a global pollution problem: trends in detection and protection. *Environ Sci. Pollut Res,* DOI: 10.1007/s11356-016-6685-2

Louie S.M., Tilton, R.D. and Lowry, G.V. (2016) Critical review: impacts of macromolecular coatings on critical physicochemical processes controlling environmental fate of nanomaterials. *Environ. Sci. Nano* **3,** 283-310.

Łukaszewicz, P., J. Maszkowska, E. Mulkiewicz, J. Kumirska, P., Stepnowski, M. Caban, (2017)Impact of Veterinary Pharmaceuticals on the Agricultural Environment: A Re-inspection. In: *Reviews of Environmental Contamination and Toxicology,* DOI 10.1007/398_2016_16, Springer International Publishing Switzerland

Luo J., S. Qi, X. W. S. Gu, J. Wang and X. Xie (2016) Evaluation of the phytoremediation effect and environmental risk in remediation processes under different cultivation systems. *Journal of Cleaner Production,* Vol. **119,** 25 – 31.

Ma, Y., M. Rajkumar, C., Zhang and H. Freitas, (2016) Beneficial role of bacterial endophytes in heavy metal phytoremediation *Journal of Environmental Management* **174,** 14-25. DOI:10.1016/j.jenvman.2016.02.047.

Mallampati, S.R., Mitoma, Y., Okuda, T., Sakita, S. and Kakeda, M. (2013) Total immobilization of soil heavy metals with nano-Fe/Ca/CaO dispersion mixtures. *Environ Chem Lett* **11,** 119–125.

Marcos, M., B. Marzeion, S. Dangendorf, A. B. A. Slangen, H. Palanisamy and L. Fenoglio-Marc (2017) Internal variability versus anthropogenic forcing on sea level and its components. *Surv Geophys* **38,**329–348. DOI 10.1007/s10712-016-9373-3.

Martínez-Fernández, D., M. Vítková, Z. Michálková, and M. Komárek, (2017). Engineered Nanomaterials for Phytoremediation of Metal/Metalloid-Contaminated Soils: Implications for Plant Physiology. In: A.A. Ansari et al. (Eds.), *Phytoremediation,* DOI 10.1007/978-3-319-52381-1_14, pp: 369 – 403. Springer International Publishing AG .

Marzeion, B., N. Champollion, W. Haeberli, K. Langley, P. Leclercq and Paul, F. (2017) observation-based estimates of global glacier mass change and its contribution to sea-level change. *Surv Geophys* **38,**105–130. DOI: 10.1007/s10712-016-9394-y.

Matishov, G. G., S. L. Dzhenyuk, and D. V. Moiseev, (2017)climate and large marine ecosystems of the arctic. *Herald of the Russian Academy of Sciences* **87** (1), 30–39. DOI: 10.1134/S1019331617010087.

McCarl, B.A. (2017) Economics, Energy, Climate Change, and Soil Security. In: D.J. Field et al. (Eds.), *Global Soil Security, Progress in Soil Science,* DOI 10.1007/978-3-319-43394-3_17, pp: 195 – 205. Springer International Publishing Switzerland .

Mehndiratta, P., A. Jain, S. Srivastava, and N. Gupta, (2013). Environmental Pollution and Nanotechnology. *Environment and Pollution;* **2** (2),49 – 58. http://dx.doi.org/10.5539/ep.v2n2p49.

Melillo, J.M., Richmond, T.C. and Yohe, G.W. (2014) Climate change impacts in the United States: the

Third National Climate Assessment. *U.S. Global Change Research Program,* 841 pp. doi: 10.7930/J0Z31WJ2. Available online at: http://www.globalchange. gov/nca3- downloads-materials Accessed on 19 Aug. 2017

Mishra, J., Singh, R. and Arora, N.K. (2017) Plant Growth-Promoting Microbes: Diverse Roles in Agriculture and Environmental Sustainability. In: V. Kumar et al. (Eds.), *Probiotics and Plant Health,* DOI 10.1007/978-981-10-3473-2_4, pp: 71 – 111. Springer Nature Singapore Pte Ltd.

Misra, A.K. (2014) Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment.* **3**(1), June 2014, Pages 153-165.

Mitra, S., Sarkar, A. and Sen, S. (2017) Removal of chromium from industrial effluents using nanotechnology: a review. *Nanotechnol. Environ. Eng.* **2,**11 DOI 10.1007/s41204-017-0022-y

Mitton,F. M., M. Gonzalez, J. M. Monserrat and K. S. Miglioranza, B. (2016) Potential use of edible crops in the phytoremediation of endosulfan residues in soil. *Chemosphere*, **148,** 300-306.

Mustafa, G. and Komatsu,S. (2016)Toxicity of heavy metals and metal-containing nanoparticles on plants. *Biochimica et Biophysica Acta (BBA) - Proteins and Proteomics,* **1864** (8), 932-944.

Najjar S., Bhatia,U. and Ganguly,A. R. (2017) Climate Adaptation: Introduction. In: S. Shekhar et al. (Eds.), *Encyclopedia of GIS,* DOI 10.1007/978-3-319-17885-1, pp: 174 – 179. Springer International Publishing AG.

Nally R. M., Horrocks,G. F. B. and Lada,H. (2017) Anuran responses to pressures from high-amplitude drought–flood–drought sequences under climate change. *Climatic Change* **141,** 243–257. DOI 10.1007/s10584-016-1890-z .

National Nanotechnology Initiative (2009) What is Nanotechnology? Available: http://www.nano.gov/html/facts/whatisNano.html (accessed 19.04.14).

Niinemets, Ü., A. Kahru, P. Nõges, A. Tuvikene, A. Vasemägi, Ü. Mander, T. Nõges (2017) Environmental feedbacks in temperate aquatic ecosystems under global change: why do we need to consider chemical stressors? *Reg Environ Change* DOI 10.1007/s10113-017-1197-2.

Noguera-Oviedo, K. and Aga, D. S. (2016) Lessons learned from more than two decades of research on emerging contaminants in the environment. *Journal of Hazardous Materials,* **316,**242-251.

Omambia, A.N., C. Shemsanga and I. A. S. Hernandez, (2017) Climate Change Impacts, Vulnerability, and Adaptation in East Africa (EA) and South America (SA). In: W.-Y. Chen et al. (Eds.), *Handbook of Climate Change Mitigation and Adaptation,* DOI 10.1007/978-3-319-14409-2_17, pp: 749 – 799. Springer International Publishing Switzerland.

Ouyang, W., W. Huang, P. Wei, F. Hao and Y. Yu, (2016) Optimization of typical diffuse herbicide pollution control by soil amendment configurations under four levels of rainfall intensities. *Journal of Environmental Management* **175,** 1-8. http://dx.doi.org/10.1016/j.jenvman.2016.03.026.

Pandey, V. C., O. Bajpai, and N. Singh, (2016) Energy crops in sustainable phytoremediation. *Renewable and Sustainable Energy Reviews,* **54,** 58-73.

Pantoja, L. D. M., R. F. do Nascimento, and A. B. de A. Nunes, (2016) Investigation of fungal volatile organic compounds in hospital air. *Atmospheric Pollution Research,* http://dx.doi.org/10.1016/j.apr.2016.02.011.

Paschalidou, A., Tsatiris, M. and Kitikidou,K. (2016) Energy crops for biofuel production or for food? - SWOT analysis (case study: Greece). *Renewable Energ*y **93,** 636-647.

Patil, S. S., U. U. Shedbalkar, A. Truskewycz, Chopade, B.A. and Ball, A.S.(2016) Nanoparticles for environmental clean-up: A review of potential risks and emerging solutions *Environmental Technology & Innovation* **5,** 10–21. http://dx.doi.org/10.1016/j.eti.2015.11.001 .

Patton, A.P., R. Laumbach, P. Ohman-Strickland, K. Black, S Alimokhtari, P. J. Lioy and H. M. Kipen (2016) Scripted drives: A robust protocol for generating exposures to traffic-related air pollution. *Atmospheric Environment*, **143,**290-299.

Peeters, K., G. Lespes, T. Zuliani, J. Scancar and R. Milacic, (2016). The fate of iron nanoparticles in environmental waters treated with nanoscale zero-valent iron, FeONPs and Fe_3O_4NPs. *Water Research* **94,** 315e327. http://dx.doi.org/10.1016/j.watres.2016.03.004.

Phelan, J., S. Belyazid, P. Jones, J. Cajka, J. Buckley, C. Clark, (2016) assessing the effects of climate change and air pollution on soil properties and plant diversity in sugar maple–beech–yellow birch hardwood forests in the northeastern united states: model simulations from 1900 to 2100. *Water Air Soil Pollut* **227,** 84 DOI 10.1007/s11270-016-2762-x.

Plekhanova, I.O., A.P. Zarubinab, and Plekhanov, S.E. (2017) Ecotoxicological assessment of nickel pollution of soil and water environments adjacent to soddy–podzolic soil. *Moscow University Soil Science Bulletin,* **72** (2), 71–77. DOI: 10.3103/S0147687417020065.

Pope, S., Copland, L. and Alt, B. (2017) Recent

Changes in Sea Ice Plugs Along the Northern Canadian Arctic Archipelago. In: L. Copland, D. Mueller (eds.), Arctic Ice Shelves and Ice Islands, *Springer Polar Sciences,* DOI 10.1007/978-94-024-1101-0_12, pp: 317 – 342. Springer Science + Business Media B.V.

Porter, E.M., Bowman, W.D., Clark, C.M., Compton, J.E., Pardo, L.H. and Soong, J.L. (2013) Interactive effects of anthropogenic nitrogen enrichment and climatic change on terrestrial and aquatic biodiversity. *Biogeochemistry,* **114,** 93–120.

Prashanthi, M., Sundaram, R., Jeyaseelan, A., Kaliannan, T. (2017) Bioremediation and Sustainable Technologies for Cleaner Environment. *Environmental Science and Engineering Series,* DOI 10.1007/978-3-319-48439-6, Springer International Publishing AG.

Qiao, J., Yu,D., Wang,Q. and Liu, Y. (2017) Diverse effects of crop distribution and climate change on crop production in the agro-pastoral transitional zone of China. *Front. Earth Sci.* DOI 10.1007/s11707-017-0665-9 .

Rodríguez-Seijo A., Lago-Vila,M. and Andrade,M. L., Vega,F. A. (2016) Pb pollution in soils from a trap shooting range and the phytoremediation ability of *Agrostis capillaris* L. *Environ Sci Pollut Res,* DOI: 10.1007/s11356-015-5340-7.

Romero-Freire, A., Sierra Aragón, M., Martínez, F.J., Garzón and Martín Peinado,F.J. (2016) Is soil basal respiration a good indicator of soil pollution? *Geoderma* **263,**132–139. http://dx.doi.org/10.1016/j.geoderma.2015.09.006.

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya, M.L., Kundu, S. and Patra, A.K. (2017a) Industrial Activities in India and Their Impact on Agroecosystem. In: J.K. Saha et al., Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable World* **10,** DOI 10.1007/978-981-10-4274-4_9, Springer Nature Singapore Pte Ltd.

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya, M.L., Kundu, S. and Patra, A.K. (2017b) Organic Pollutants. In: J.K. Saha et al., Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable* World **10,** DOI 10.1007/978-981-10-4274-4_5, Springer Nature Singapore Pte Ltd.

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya, M.L., Kundu, S. and Patra, A.K. (2017c)Impacts of Soil Pollution and Their Assessment. In: J.K. Saha et al., Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable World* **10,** DOI 10.1007/978-981-10-4274-4_3, Springer Nature Singapore Pte Ltd.

Saha, J.K., Selladurai, R., Coumar,M.V., Dotaniya, M.L., Kundu, S. and Patra, A.K. (2017d) Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable World* **10,** DOI 10.1007/978-981-10-4274-4, Springer Nature Singapore Pte Ltd.

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya, M.L., Kundu, S. and Patra, A.K. (2017e) Major Inorganic Pollutants Affecting Soil and Crop Quality. In: J.K. Saha et al., Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable World* **10,** DOI 10.1007/978-981-10-4274-4_4, Springer Nature Singapore Pte Ltd.

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya,M.L., Kundu, S. and Patra, A.K. (2017f) Remediation and Management of Polluted Sites. In: J.K. Saha et al., Soil Pollution – An Emerging Threat to Agriculture. *Environmental Chemistry for a Sustainable World* **10,** DOI 10.1007/978-981-10-4274-4_12, Springer Nature Singapore Pte Ltd.

Salawitch, R.J., Canty, T.P., Hope, A.P.,Tribett, WR. and Bennett, B. F. (2017) Paris Climate Agreement: Beacon of Hope. DOI: 10.1007/978-3-319-46939-3, Springer International Publishing.

Sarkar, P.K., Halder, A., Polley, N. and Pal, S.K. (2017) Development of Highly Selective and Efficient Prototype Sensor for Potential Application in Environmental Mercury Pollution Monitoring. *Water Air Soil Pollut* **228,** 314. DOI 10.1007/s11270-017-3479-1.

Shah, G., Jan, M., Afreen,M., Anees, M., Rehman, S., Daud, M. K., Malook, I. and Jamil,M. (2016) Halophilic bacteria mediated phytoremediation of salt-affected soils cultivated with rice. *Journal of Geochemical Exploration,* doi:10.1016/j.gexplo.2016.03.011

Shalaby, T., Bayoumi, Y., Abdalla,N., Taha, H., Alshaal, Shehata, T., S., Amer, M. Domokos-Szabolcsy, É. and El-Ramady, H. (2016) Nanoparticles, soils, plants and sustainable agriculture. In: S. Ranjan et al. (eds.), *Nanoscience in Food and Agriculture 1, Sustainable Agriculture Reviews* **20,** DOI: 10.1007/978-3-319-39303-2_10, Springer International Publishing Switzerland

Shankar, S., Shikha (2017) Management and Remediation of Problem Soils, Solid Waste and Soil Pollution. In: R.L. Singh (ed.), Principles and applications of environmental biotechnology for a sustainable future, *Applied Environmental Science and Engineering for a Sustainable Future,* DOI 10.1007/978-981-10-1866-4_5, Springer Science + Business Media Singapore.

Shekarriz, M., Ramezani, Z. and Elhami,F. (2017) Preparation and characterization of ZSM5-supported nano-zerovalent iron and its potential application in nitrate remediation from aqueous solution. *Int. J. Environ. Sci. Technol.* **14,**1081–1090. DOI 10.1007/s13762-016-1213-y

Shivlata, L. and Satyanarayana, T. (2017)Actinobacteria in Agricultural and Environmental Sustainability. In: J.S. Singh, G. Seneviratne (eds.), *Agro-Environmental Sustainability*, DOI 10.1007/978-3-319-49724-2_**9,** pp: 173 – 218. Springer International Publishing AG.

Shukla, K., Kumar, B., Agrawal, R., Priyanka, K., Venkatesh, M. and Anshumali (2017) Assessment of Cr, Ni and Pb Pollution in Rural Agricultural Soils of Tonalite–Trondjhemite Series in Central India. *Bull Environ Contam Toxicol,* **98,** 856–866. DOI 10.1007/s00128-017-2085-7

Singh, J. and Lee, B.K. (2016) Influence of nano-TiO_2 particles on the bioaccumulation of Cd in soybean plants (*Glycine max*): A possible mechanism for the removal of Cd from the contaminated soil. *Journal of Environmental Management,* **170,**88-96.

Singh, N.A. (2017) Nanotechnology innovations, industrial applications and patents. *Environ Chem Lett* **15,**185–191. DOI 10.1007/s10311-017-0612-8

Slabe-Erker, R., Bartolj,T., Ogorevc, M., Kavaš, D. and Koman, K (2017) The impacts of agricultural payments on groundwater quality: Spatial analysis on the case of Slovenia. *Ecological Indicators,* **73,** 338-344.

Stiborova, H., Kolar, M., Vrkoslavova, J., Pulkrabova, J ., Hajslova, J., Demnerova, K. and Uhlik,O. (2017) Linking toxicity profiles to pollutants in sludge and sediments**.** *Journal of Hazardous Materials,* 321, 672-680.

Strzebońska, M., Jarosz-Krzemińska, E., Adamiec, E. (2017) Assessing Historical Mining and Smelting Effects on Heavy Metal Pollution of River Systems over Span of Two Decades. *Water Air Soil Pollut* **228,** 141. DOI 10.1007/s11270-017-3327-3.

Subramanian, V., Semenzin, E., Hristozov, D., Zabeo, A., Malsch, I., McAlea, E., Murphy, F., Mullins, M., van Harmelen, T., Ligthart, T., Linkov, I. and Marcomini,A. (2016) Sustainable nanotechnology decision support system: bridging risk management, sustainable innovation and risk governance. *J. Nanopart Res,* **18,** 89 DOI: 10.1007/s11051-016-3375-4

Thornton, P.K., Jones, P.G., Ericksen, P.J. and Challinor,A.J. (2011)Agriculture and food systems in sub-Saharan Africa in a 4 °C+ world. Philos. Trans. R. Soc. A: *Math. Phys. Eng. Sci.,* **369** (1934), 117-136

Torquebiau, E. (2016) Climate Change and Agriculture Worldwide. DOI 10.1007/978-94-017-7462-8, *Springer Netherlands, Dordrecht, Heidelberg, New* York, London.

Tripathi, V., Fraceto,L. F. and Abhilas, P. C. (2015) Sustainable clean-up technologies for soils contaminated with multiple pollutants: Plant-microbe-pollutant and climate nexus. *Ecological Engineering,* **82,** 330-335

Tripathi, V., Edrisi, S. A. and Abhilash,P. C. (2016) Towards the coupling of phytoremediation with bioenergy production. *Renewable and Sustainable Energy Reviews* **57,** 1386–1389. http://dx.doi.org/10.1016/j.rser.2015.12.116

Ullwer, J., Campos,J. K. and Straube, F. (2016) Waste and pollution management practices by German companies. *IFAC-Papers On Line,* **49** (2), 102-107. DOI: 10. 1016/j.ifacol.2016.03.018

Venkatesan P (2016). WHO report: air pollution is a major threat to health. The Lancet Respiratory Medicine, 4 (5): 351

Verma SK, P Trivedi, AK Gupta, RK Verma (2017). Aromatic Plant–Microbe Associations: A Sustainable Approach for Remediation of Polluted Soils. In: J.S. Singh, G. Seneviratne (eds.), Agro-Environmental Sustainability, DOI 10.1007/978-3-319-49727-3_5, pp: 85 – 103. Springer International Publishing AG

Wan X., M. Lei and T. Chen (2016). Cost–benefit calculation of phytoremediation technology for heavy-metal-contaminated soil. Science of The Total Environment, 563–564: 796-802.

Wang C., X Du and Y. Liu (2017). Measuring spatial spillover effects of industrial emissions: A method and case study in Anhui province, China. Journal of Cleaner Production, 141: 1240-1248

Wang P., E. Lombi, F.-J. Zhao and P. M. Kopittke (2016). Nanotechnology: a new opportunity in plant sciences. Trends in Plant Science, http://dx.doi.org/10.1016/j.tplants.2016.04.005

Wei, R., Ni, J. and Chen, W. Yang (2017)Variation in soil aggregate–size distribution affects the dissipation of polycyclic aromatic hydrocarbons in long-term field-contaminated soils. *Environ Sci Pollut Res,* DOI 10.1007/s11356-017-9919-z.

Wilson, J., Berntsen, H. F., Zimmer, K. E. Verhaegen, S. Frizzell, C., Ropsta,E. and Connolly,L. (2016) Do persistent organic pollutants interact with the stress response? Individual compounds, and their mixtures, interaction with the glucocorticoid receptor. *Toxicology Letters* **241,**121–132. http://dx.doi.org/10.1016/j.toxlet.2015.11.014.

Witczak, A., Pohoryło,A. and Mituniewicz-Małek, A (2016) Assessment of health risk from organochlorine xenobiotics in goat milk for consumers in Poland. *Chemosphere*

148, 395-402. http://dx.doi.org/10.1016/j.chemosphere.2016.01.025.

Xue, X., Cheng, R., Shi,L., Ma, Z. and Zheng, X. (2017) Nanomaterials for water pollution monitoring and remediation. *Environ Chem Lett* **15,** 23–27. DOI 10.1007/s10311-016-0595-x.

Yu S, P-K., Lee, S-T. Yun, S.I. Hwang, and G. Chae, (2017) Comparison of volatile organic compounds in storm water and groundwater in Seoul metropolitan city, South Korea. *Environ Earth Sci.* **76,**338. DOI 10.1007/s12665-017-6666-x.

Zaborowska, M., Kucharski, J. and Wyszkowska, J. (2017)Brown Algae and Basalt Meal in Maintaining the Activity of Arylsulfatase of Soil Polluted with Cadmium. *Water Air Soil Pollut,* **228,** 267. DOI 10.1007/s11270-017-3449-7.

Zhao, X., Liu, W., Cai, Z., Han, B., Qian,T. and Zhao, D. (2016) An overview of preparation and applications of stabilized zero-valent iron nanoparticles for soil and groundwater remediation. *Water Research* **100,** 245-266. http://dx.doi. org/10.1016/j.watres. 2016.05.019.

Zheng D. and Shi,M. (2017) Multiple environmental policies and pollution haven hypothesis: Evidence from China's polluting industries. *Journal of Cleaner Production,* **141,** 295-304.

(*Received* 23/8/2017;
accepted 2/10/2017)