Long-term effects of pesticides and chemical fertilizers usage on some soil properties and accumulation of heavy metals in the soil (case study of Moghan plain’s (Iran) irrigation and drainage network)

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ABSTRACT: This research has been done in Moghan’s irrigation and drainage network (Ardabil- Iran) in order to evaluate long term effects of pesticides and chemical fertilizers usage on soil properties and heavy metals accumulation. In this research, with complete understanding about the network and Moghan plain, we selected an area about 20000 ha of network level and appointed 5 stations on that, then we collected soil samples from 0-30 cm depth both in summer and winter and at least we compared the obtained results with the results of control soil (pasture soil) which was adjacent to the network. In this study, some factors such as EC, pH, nitrogen percentage, organic matter, soil texture, bulk density, soil hydraulic conductivity and also concentrations of some heavy metals such as cadmium, arsenic, mercury and ... were measured using recommended reference methods. The results showed that soil physical characteristics such as bulk density were changed in long-term and it was increased compared to control soil. The heavy metals accumulation in soil were highly affected and the concentration of some metals such as cadmium has reached a limit beyond the standard for agricultural purposes. The results also showed that fortunately the concentration of other metals is not beyond the standard. In this context, given the state of the soil and gained results, considering pesticides and fertilizers management is essential and it requires planning to reduce or replace pesticides and fertilizers usage in this region.

Keywords: pesticides and fertilizers, pollution, soil characteristics, heavy metals, irrigation

INTRODUCTION

Moghan plain is one of the most fertile plains in country. It is also one of the agricultural major hubs in national and international scale and therefore it is very important to maintain its soil quality and fertility. Due to environmental and health effects of heavy metals accumulation, transfer to crops and entry to human food chain, and the lack of standards in the type and amount of consumed fertilizers and pesticides in country, and also lack of adequate studies on the effects of their indiscriminate usage, this research is necessary with the aim of evaluating the long term effects of pesticides and fertilizers usage on the fate and accumulation of some heavy metals in soil and also on some soil’s physical-chemical characteristics. Abbasisade et al. (2009) conducted a research based on lead and cadmium pollution in soil resulted from the consumption of sewage sludge. Statistical analysis showed that the mean lead concentration in 50 and 100 Mg/ha treatments, which were fertilized for more than three years, were significantly higher than the control sample. Also the mean concentration of cadmium was significantly higher than the control sample in all treatments which were fertilized over two years. The results showed that the residual and cumulative sewage sludge increases the cadmium and lead concentrations in soil. With unbalanced use of fertilizers, especially extravagance in nitrogen and phosphate fertilizers, in addition to increase in nitrate and cadmium concentration, the concentration of vitamin C is reduced. This is also a serious threat for soil health and
reduces qualitative and quantitative yield of crops (Atouyi et al., 2011). Linn et al. (1993) describe the behavior of pesticides in soils by physical, chemical and biological processes including absorption and desorption, evaporation, chemical and biological degradation, uptake by plants, runoff and leaching. Gimeno-Garcia et al. (1996) examined the role of mineral fertilizers and pesticides application on heavy metals concentrations in paddy soils. Results showed that the presence of cadmium, cobalt, copper and zinc impurities in super phosphate fertilizer, and lead and nickel impurities in copper sulphate and iron sulphate fertilizers, increases the concentrations of these metals in soil. Wong et al. (1996) investigated the heavy metal contamination of soil and crops caused by traffic, sewage and chemical fertilizer. The results showed that although the annual average of traffic is low in agricultural areas, however higher concentrations of copper, lead, cadmium and zinc are detected in areas which are close to commercial centers. Continuous application of fertilizers has increased heavy metal concentrations in soil, root and other organs of products. Carbonel et al. (2011) conducted a research to investigate the effects of municipal waste composts and mineral fertilizers on soil properties. The results showed that municipal waste composts increased the amounts of copper, lead and zinc in soil while NPK fertilizers increased the amount of cadmium and nickel concentrations on one hand and decreased mercury concentration on the other hand in soil. Olawoyin et al. (2012) reviewed the dangers of high concentrations of heavy metals (in soil) on human health. They stated that the accumulation of heavy metals in soil and enhancement of their concentration over the standards can increase significantly the risk of cancer, especially in children.

Rezayinezhad et al. (2001) conducted a study based on the investigation of organic matter effects on soil chemical properties. The results showed that organic fertilizers significantly increased the organic matter content, extractable zinc, copper, lead and iron (by EDTA), Absorbable phosphorus and potassium, and the percentage of total nitrogen in soil. Ahmad Abadi et al. (2013) investigated the application effects of compost, vermicompost and sewage sludge on some soil physical properties. The results showed that their application caused a significant increase in soil porosity, moisture content at field capacity and wilting point, and soil’s water holding capacity and also it caused a significant reduce in soil’s bulk density in comparison with control treatment. In this regard, the effect of sewage sludge and compost was greater than vermicompost. Zhong et al. (2007) examined the long term effects of inorganic fertilizers on biochemical properties of paddy soils. After 13 years of continuous fertilization, the potential nitrification and urease activity in Nitrogen application treatments and phosphatase acid and dehydrogenase activity in phosphorus application treatments were higher than the lack of their application. Good correlation of Dehydrogenase activity with the concentrations of hydrolysable phosphorus and nitrogen and rice production shows that dehydrogenase activity can be a useful indicator of soil’s fertility improvement. Chirinda et al. (2010) conducted a study on the effects of organic and inorganic fertilization on soil properties and crop production. The results showed that in organic farming systems, microbial activity and the rate of production can be increased through the inclusion of crops. However the inoculation time of these products is vital. Zhengchao et al. (2013) concluded a research based on the long-term effects of organic and inorganic fertilizers on the amount of organic carbon and total nitrogen in semi-arid farm lands of wheat in China. The results showed that the use of fertilizers increases the winter wheat grain and crop biomass, furthermore significant correlation between wheat biomass and soil organic carbon and total nitrogen in the 0-20 cm of soil was observed. The amount of soil’s organic carbon and total nitrogen in 0-30 cm of soil was higher than other layers and it showed a decreasing trend up to 50 cm depth.

MATERIAL AND METHODS

The studied area of Moghan’s irrigation and drainage network is located in Moghan plain (between 47° 25′ to 48° 25′ of north latitude from the equator and 39° 25′ to 39° 42′ of east longitude from the Greenwich meridian). Irrigation is done using Moghan’s irrigation networks and the use of nitrogen and phosphate fertilizers, Topik, 2-4-D and Granstar herbicides in wheat and barley fields, Folicur, Tilt, Alto, Altocombi, Ridomil, Mancozeb, Acosinbrand and Benomyl fungicides and copper components and Dursban, Samicidin, Omite and Nissoru pesticides in maize, cotton, tomato and soybean fields is common in the studied area. Initially we selected 5 stations in irrigation and drainage network (in a range of 20000 ha). Not only the stations are representative of area (it means that they are similar to region in terms of soil properties and environmental characteristics), but also they have been cultivated during the past years. Four points were selected as control sites in pastures (Lands without cultivating and using fertilizers and pesticides). For this purpose, soil samples were taken two times during the year (in farming season and non-farming season) from 30 cm depth of each station and then heavy metals and pesticides measurements were done with Atomic absorption spectrometer and poison measurement device respectively. Then Physical and chemical properties of soil, including soil texture (hydrometer), hydraulic conductivity (falling load) and soil bulk density (bulk density), Ec, pH, nitrogen percent and organic matter (Walky-black) were measured.
RESULTS AND DISCUSSIONS

**EC and pH**

Control region’s EC is lower than the network’s lands (Figure 1). This enhancement in EC of these lands (especially in summer) is due to salt accumulation in irrigation water and also fertilizers and pesticides usage. However due to high expenditures and low efficiency of irrigation in Moghan’s irrigation network, which leaches soils and transfers salts to drains and insignificant accumulation of salts in soil, EC values do not differ significantly in soil between farming season and non farming season. pH variations in cultivated lands in summer and winter in compared with control soil is not significant and so long term use of fertilizers and pesticides do not have any significant effect on soil’s pH (Figure 2).

![Figure 1. Soil’s EC](image1)

![Figure 2. Soil’s pH](image2)

**Organic matter and N percentage**

OM% results showed that the amount of organic matter in control area is lower than network’s lands (Figure 3). This rate is also higher in summer than in winter. High concentration of organic matter in the network can be caused by plantation in consecutive years and remaining of crop residues at network level and also addition of manure as soil amendments. It is worth noting that soil organic matter, has a significant role in the uptake and storage of heavy metals and pesticides in soil and can increase their survival in the soil environment. Results showed that the average N percentage in control soil is lower than network’s lands (Figure 4). The presence of N in control soil (according to lack of fertilizer usage in this lands) can be caused by natural resources. The maximum amount of N in network lands is in summer which results from using nitrogen fertilizers and its reduction in winter could be attributed to the high solubility of nitrogen fertilizers and their leaching to drainage (surface and underground) and so exiting from root zone. Results show that despite the enhancement of nitrogen compounds concentrations in network’s soil, this increase is not sharp and significant and the major reason for this is the changes in soil nitrogen compounds due to natural and biological processes that lead to the conversion of different forms of nitrogen compounds to each other and volatility from soil level in different forms (water soluble, N₂ gas, etc.).

![Figure 3. Soil’s OM%](image3)

![Figure 4. Soil’s N%](image4)

**Bulk density and hydraulic conductivity**

Although soil bulk density does not show any significant difference between summer and winter, however the bulk density of the network has increased significantly compared to the control soil (Fig. 5). The reason for this increase is mainly due to the implementation of long-term tillage and fertilizer applications which can affect the

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physical properties of soil and increase the amount of soil bulk density compared to control soil. Mean comparison of hydraulic conductivity (Figure 6) showed no significant difference between two seasons. Hydraulic conductivity values were higher in control soil in comparison with network soil. The reduction of hydraulic conductivity values in network soil can be due to the implementation of long-term tillage and fertilizer applications in Moghan’s network. It should be noted that soil texture at all stations is silty clay.

Figure 5. Soil bulk density
Figure 6. Soil hydraulic conductivity

Cadmium and Selenium

Cadmium concentration is increased about 100 ppb in summer than in winter (Figure 7). Comparing the results of two seasons with the results of control soil also showed egregious difference between cadmium concentration in control soil and cultivated lands in Moghan’s irrigation network. Comparing results with standards show that average cadmium concentration in Moghan’s network soil is higher than Sweden standard and in most cases it is exceeding the standard of Sweden and Germany. Since the main source of cadmium in agricultural lands is phosphate fertilizers, so we need to reduce their consumption and replace them with fertilizers which have less cadmium impurities (Rahmani, 2011). Egregious differences are observed in selenium concentrations between control soil and cultivated soils of Moghan’s irrigation network (Figure 8). Comparing results with standards shows that despite increased selenium concentration in network soil, this concentration is in permitted limit and do not restrict cultivating in these soils. The main cause of cadmium and selenium high concentrations in cultivated soil is the indiscriminate use of pesticides and fertilizers which with containing these elements leads to their accumulation in soil.

Figure 7. Cadmium concentration
Figure 8. Selenium concentration

Arsenic and Mercury

Arsenic concentrations in the network show significant enhancement, especially in the summer, than in the control area, this increase results from pesticides and chemical fertilizers usage for consecutive years in network’s soils (Figure 9). In the case of mercury, comparing the results of two seasons with control area (Figure 10) showed that mercury concentrations in the control soil is very low (below the detection limit (ppb 10)) which indicates a lack of this element in natural soil of region. Resources survey indicate that the main source of Mercury are toxins and pesticides which enter the soil during long term uses and thus they are absorbed into clay minerals (as a result of ion exchange processes) and accumulate in the soil. According to results and comparing them with proposed
standards shows that despite increased concentrations of these elements in network’s soil, their concentration is in permitted limit and do not restrict cultivating in these soils.

**Toxins**

The amount of this factor is below the detection limit (10ppb) of device, both in control soil and in network soil in winter (Figure 11). But its amount is higher in summer. Due to the natural conditions of the region and the nature of used pesticides it can be concluded that consumed pesticides during growing season are removed from soil due to natural processes and chemical and biological reactions and so their remains are reduced to the immeasurable extent. In this context it is necessary to note that despite the low half-life and persistence of pesticides in the soil environment which leads to their departure from soil in different ways (such as evaporation, biodegradation, absorption by plants), some elements and compounds of these materials, including heavy metals, remain in the soil and cause soil pollution by heavy metals in consecutive years.

In recent years, agricultural producers in our country (Iran) have increased the consumption of fertilizers per unit area instead of using knowledge for producing more. Unfortunately, paying subsidies to inorganic fertilizers in Iran has intensified their irregular uses. Considering the adverse effects of inorganic fertilizers on resources and food security, items such as development of integrated management systems, biological nitrogen fixation in soil, using compost and vermicompost, observing proper crop rotation, improving soil texture, returning crop residues to soil and preventing burning them, using no-till systems specially in arid regions should be institutionalized in the country (Miraki et al. (2011)). Considering the results, it is observed that indiscriminate uses of pesticides and fertilizers cause negative effects on the soil of study area such as heavy metals accumulation in soil and changes in physical and chemical properties of soil. In this respect, attention and applying following strategies to mitigate and prevent continued contamination of soil is recommended:

Planning to move toward organic agriculture with minimal use of pesticides and fertilizers
Providing necessary trainings to farmers in order to make optimum use of agricultural inputs, so that lead to improved management of the farming. In this context it is necessary to note the following:
Increasing the efficiency and pesticides and fertilizers usage and reducing the amount of their losses
Timely use of pesticides and chemical fertilizers to have greatest effect on the product and less waste and pollution in the environment.
Refrain from using fertilizers and pesticides out of the growing season
Using inputs based on desired soil and crop pattern, using chemical testing of soil
Modifying fertilizing practices to increase uptake and reduce losses.

Given that in some zones of Moghan’s network the concentration of cadmium is beyond the standard, soil careful monitoring to determine the scope and extent of contamination is necessary. Also, given that the main source of cadmium is phosphate fertilizers so special attention seems to be necessary in using these fertilizers.

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