ENVIRONMENTAL PROBLEMS IN VERTISOL SOILS: THE EXAMPLE OF THE HARRAN PLAIN

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Ayse Dilek Atasoy*
Harran University, Department of Environmental Engineering, 63300 Sanliurfa, Turkey

ABSTRACT

The SEA (Southeast Anatolian) Project region has an intensive agricultural production, an increasing population and gradually raising food consumption related to population. The basic aim in agriculture is to get crops in high quality and quantity to compensate for the increasing necessities. Therefore, the soil of Harran Plain is used very intensively in agriculture. A huge amount of fertilizers and chemicals is used in agricultural activities, which causes high environmental risks in the area. This study aims at investigating certain physical and chemical properties of the soil in Harran Plain that impact the fate of pollutants in the environment. The soil samples were taken from a profile excavated in the Harran soil series. The soils from 0-27 cm, 27-40 cm, 40-55 cm, 70-85 cm and 85-100 cm layers were air-dried, sieved (2 mm) and analyzed for the bulk density, moisture, particle size distribution (soil texture), cation exchange capacity (CEC, organic matter, pH and lime content. All analyses were made in three replicates. Soil samples typically reflect vertisol soil properties. The impact of soil properties of Harran Plain on the pollutant movement, as well as sorption and salinity were discussed in detail. Hence, the results of the study can be helpful for authorities to develop effective management strategies for the Harran Plain.

KEYWORDS:
Vertisol, pedoturbation, pollution, salinity, sorption, Harran Plain.

INTRODUCTION

Population growth and the accompanying industrial, commercial and agricultural development is producing multiple potential sources of contaminants from manure and artificial fertilizers, landfills, accidental spills, and domestic or industrial effluent discharges. Among these sources, agriculture-related activities are well-known as non-point source pollution, which may deteriorate the groundwater quality in small to large watersheds, especially due to uncontrolled use of fertilizers and various carcinogenic pesticides [1]. Soil and groundwater quality in an area is a function of physical and chemical parameters of soil.

Turkey is currently engaged in a large integrated water resources development project in its semi-arid South-eastern region. Commonly referred to by its Turkish acronym SAP, the Southeastern Anatolia Project includes 22 dams in the upper Euphrates-Tigris Basin, and aims to provide irrigation for 1.7 million hectares of land by 2015 [2]. The use of uncontrolled and huge amount of fertilizers during agricultural activities may deteriorate soil and groundwater quality. Hence, the information on the physical and chemical properties of the soil should be necessary to determine the fate of specific pollutants in the environment, and to determine the effective management and control strategies.

Vertisol soils are dominant in Harran Plain [3]. The vertisols’ order of mineral soils is characterized by a high content (>30%) of sticky or swelling and shrinking type clays to a depth of 1 m, which, in dry seasons, causes the soils to develop deep, wide cracks. A significant amount of material from the upper part of the profile may slough off into the cracks [4]. Vertisols are found mostly in arid to semi-arid environments, and where the average soil temperatures are higher than 8 °C. Vertisols are generally reddish-brown soils. Micromorphological studies have shown that, in addition to widespread opaque volcanic minerals, dark-colored iron and manganese forming under anaerobic conditions may contribute to this coloring [5].

Carbonate nodules in vertisols may have a homogeneous distribution, or they may have deposits on the surface or subsurface horizons, depending on the soil’s age. Their productivity and plant nutrient levels are generally good [3]. However, vertisols’ fine texture and marked shrinking and swelling characteristics make them less suitable than other soils for crop production, and for building foundations and highway bases [4].

The main process in the formation of vertisols is pedoturbation [6]. Materials, continuously spilling through cracks, move from the upper horizons to lower ones throughout the profile. In vertisols, horizons are interconnected, and it is difficult to establish clear boundaries be-
between them. In addition to causing the horizons to intermingle, pedoturbation also causes the transport of soil particles within the profile during different periods. This study aimed at determining certain physical and chemical characteristics of soils (sampled from different horizons in a profile) from Harran soil series, and discussing the eventual soil problems which come from vertisol soil characteristics and environmental pollution of Harran plain.

MATERIALS AND METHODS

Study Area

Soil samples were taken from a soil profile excavated in Harran soil series on May 23, 2004. The location of the soil profile is at 7 km south of the Agricultural Faculty of Eyyubiye Campus, in the directions of the village of Ugurlu (coordinates: K: 37° 0.2’266”-D: 38° 52’633”).

The elevation is 375 m in the area. The plain has a semi-arid climate with almost no precipitation between June and September. The long-term mean annual temperature is 18 °C, the highest annual mean temperature is 31.4 °C in July, and the lowest annual mean temperature is 5.8 °C in January. The highest temperature in the thirty-year period was 46.7 °C, recorded in 1980, and the lowest was -15.1 °C, recorded in 1979. The annual mean relative humidity is 57 %, the annual mean precipitation is 284.2 mm. The average wind speed (bofor) is 1.1, and the direction of the fastest-blowing wind is easterly [7]. Cotton is the dominant crop in the area. The location map of the Harran plain and the general appearance of the soil profile are presented in Fig. 1 and Fig. 2, respectively.

FIGURE 1 - Location map of the Harran Plain [7].

FIGURE 2 - General appearance of the soil profile.
Soil Analysis

Soil samples were taken from 5 different depths in the profile excavated in the Harran soil series: 0-27 cm, 27-40 cm, 40-55 cm, 55-70 cm, 70-85 cm, and 85-100 cm. Air-dried and sieved (<2 mm) samples were processed for basic soil characteristics. Soils were examined for bulk density, moisture, particle size distribution (soil texture), cation exchange capacity (CEC), organic matter content, pH, and lime content. All soil analyses were carried out in 3 parallels, and the averages were reported.

Bulk density was determined in unspoiled samples using cylinder method, and moisture was measured using gravimetric method. Soil texture was determined using Bouyoucos hydrometer method. CEC and organic matter were measured using sodium acetate method and modified Walkley-Black method (wet combustion), respectively [8]. Soil pH was measured in a 1:1 (w/v) soil to 0.01 M CaCl₂ solution mixture. Lime content was determined using calometric method [9].

RESULTS AND DISCUSSION

Soil Properties

Horizon characterization for the soil profile (0-100 cm) was conducted in the field. The morphological characteristics of the soils are given in Table 1. The physical and chemical properties of the soil samples are shown in Table 2. The general soil properties of the horizons are found to be quite similar with each other. The Bw1 horizon has a greater bulk density than the other horizons (1.54 Mg/m³).

Bulk densities are higher in horizons with high clay content. Moisture was 21 % in Bw1 horizon, and 20 % in the others. Clay content in the profile was found to be 64 % in the BSSS horizon, and 60 % in the Ap horizon. All horizons belong to the “clay” texture class. Vertisols generally contain high clay content throughout the profile.

Smectite is the dominant clay mineral in vertisols [4]. However, other clay mineral types were encountered at different levels. High levels of smectite increase the volume by 25-50 % as it gets wet and dry, causing deep cracking. Vertisols formed on basalt contain the best crystallized smectite. Kaolinites and other clay minerals were also encountered in vertisols [10]. CEC of the soil samples ranged from 27.12 to 32.53 cmol/kg. The CEC was higher in the Ap horizon. CEC values of vertisols ranged from 25 to 80 cmol/kg, and base saturation levels were generally high. The lowest organic matter content was found to be 0.8 % in the BW2 and BSSS, horizons, and the highest organic matter content was 1.1 % in the Bw1 horizon. Organic matter contents in vertisols generally did not exceed 1-2 %.

The average soil pH was found to be approximately 7.5. The pH values of vertisols found in Southeast Anatolia ranged between 6.0-8.5 [3]. Lime content was 18.20 % as the highest value in BSSS horizon. Vertisols contained secondary CaCO₃ in the form of powdery accumulations or concretions.

Dark-colored or heavy-textured soils containing low levels of organic matter, which are commonly found in arid and semi-arid regions, are grouped in the vertisol order. Many soil series in the region, including the Harran series, belong to the vertisol order. Because of their high smectite

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Boundary</th>
<th>Moist color</th>
<th>Moist consistency</th>
<th>Texture</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap</td>
<td>0-27</td>
<td>Smooth</td>
<td>5 YR 4/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Massive aspect, crust formation at 0-2 cm, there were some roots.</td>
</tr>
<tr>
<td>Bw1</td>
<td>27-40</td>
<td>Smooth</td>
<td>5 YR 3.5/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Medium angular blocky, there were no roots</td>
</tr>
<tr>
<td>BW2</td>
<td>40-55</td>
<td>Smooth</td>
<td>5 YR 4/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Medium semi-angular blocky, there were no roots.</td>
</tr>
<tr>
<td>BW3</td>
<td>55-70</td>
<td>Smooth</td>
<td>5 YR 4/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Weak semi-angular blocky, there were no roots.</td>
</tr>
<tr>
<td>BSSI</td>
<td>70-85</td>
<td>Smooth</td>
<td>5 YR 4/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Weak semi-angular blocky, slickensides were determined, there were no roots.</td>
</tr>
<tr>
<td>BSSS</td>
<td>85-100</td>
<td>Smooth</td>
<td>5 YR 5/4</td>
<td>Friable and plastic</td>
<td>Clay</td>
<td>Weak semi-angular blocky, slickensides and lime nodules were determined, there were no roots.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horizon and depth (cm)</th>
<th>Bulk density (Mg/m³)</th>
<th>Moisture (%)</th>
<th>Soil texture ( % clay, % sand, % silt)</th>
<th>Texture class</th>
<th>CEC (cmol/kg)</th>
<th>Organic matter (%)</th>
<th>pH</th>
<th>Lime content %</th>
<th>CaCO₃ ( %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap (0-27)</td>
<td>1.30</td>
<td>20</td>
<td>60 16 24</td>
<td>Clay</td>
<td>32.53</td>
<td>1.0</td>
<td>7.6</td>
<td>17.10</td>
<td></td>
</tr>
<tr>
<td>BW1 (27-40)</td>
<td>1.47</td>
<td>21</td>
<td>62 16 22</td>
<td>Clay</td>
<td>27.57</td>
<td>1.1</td>
<td>7.6</td>
<td>16.30</td>
<td></td>
</tr>
<tr>
<td>BW2 (40-55)</td>
<td>1.49</td>
<td>20</td>
<td>63 17 20</td>
<td>Clay</td>
<td>28.65</td>
<td>0.8</td>
<td>7.5</td>
<td>17.25</td>
<td></td>
</tr>
<tr>
<td>BW3 (55-70)</td>
<td>1.39</td>
<td>20</td>
<td>60 20 20</td>
<td>Clay</td>
<td>27.12</td>
<td>1.0</td>
<td>7.5</td>
<td>17.10</td>
<td></td>
</tr>
<tr>
<td>BSSI (70-85)</td>
<td>1.44</td>
<td>20</td>
<td>64 13 23</td>
<td>Clay</td>
<td>30.50</td>
<td>0.8</td>
<td>7.5</td>
<td>18.20</td>
<td></td>
</tr>
<tr>
<td>BSSS (85-100)</td>
<td>1.54</td>
<td>20</td>
<td>62 18 20</td>
<td>Clay</td>
<td>28.88</td>
<td>0.9</td>
<td>77.5</td>
<td>16.50</td>
<td></td>
</tr>
</tbody>
</table>
content, their most significant feature is cracking, as a result of buckling during the droughty period. Vertisols in the region are generally dark reddish-brown soils. Micromorphological studies have shown that, in addition to widespread opaque volcanic minerals, dark-colored iron and manganese forming under anaerobic conditions may contribute to this coloration [5].

Clay content generally does not vary with depth, or it increases very slightly throughout the profile. Coarse prismatic structure occurs after cracking, forming the typical cracks in vertisols. These cracks are approximately 10 cm in width, and may be about 1 m in depth. Because of the seasonal swelling and buckling, these coarse-structured units lead to the slipping of some soil particles over others, and the formation of shiny and slippery slicken-sides in the soil (Fig. 3).

Vertisols’ hues generally ranged between 2.5 YR (yellow-red) and 10 YR. Carbonate nodules in vertisols generally exhibited a homogenous distribution throughout the profile. However, they may also have accumulations on the upper and in subsurface horizons, depending on soil moisture. Vertisols are suitable for cotton agriculture in Southeast Anatolia. Their productivity and plant nutrient levels are generally good. In a study on a vertisol located in Harran Plain, it was determined that Fe-oxyhydroxides as well as silicate clays had a significant effect on phosphorus adsorption-desorption [5].

Soil samples taken from different profiles excavated in the Harran Plain typically reflect vertisol soil properties. All horizons were reddish-brown, and soils were heavy, with friable and plastic aggregates when moist. They have high clay content and low organic matter and contain lime (CaCO₃) throughout the profile. Several environmental problems -expecting in these soils are listed below under subheadings.

Vertical Movement of Pollutants through Pedoturbation

Deep cracks form in vertisol soils in Harran plain because of the high clay content (Figs. 4a and 4b). Soil particles on the surface may go deep through these cracks as spillage, during rainless period. Therefore, adsorbed pollutants on the upper soil particles may pass through these cracks to lower horizons. Just as pollutants may drift horizontally to non-target areas, they may also be moved vertically to subsoil by pedoturbation. With regard to this typical characteristic of Harran soils, adsorbed pesticide molecules or heavy metals on the upper soil particles may reach the lower depths of the soil. Thus, in addition to moving horizontally within the soil, pollutants may reach the groundwater via the lower horizons because of this peculiar feature of the vertisol soil.

Components, such as sunlight and oxygen, decrease through the subsoil. Hence, the degradation period of organic pollutants is longer in the lower horizons compared to topsoil. The degradation period increases in the subsoil with downward transport of adsorbed pollutants on the soil particles, and negative effects of the chemicals occur in the soil environment. This movement, which occurs frequently in vertical direction, induces the groundwater contamination. The extent of groundwater pollution by contaminants increased over the years. Furthermore, soil ero-
sion, which is a major problem in the region, accelerated transport of sorbing pollutants. In areas with high rainfall, water movement and chemical transport is much faster than in low rainfall areas. However, many other factors, such as properties of particular chemicals, soil type, climate, and vegetation affect the movement of chemicals through the soil and groundwater [11].

Salinity and Drainage Problems

Salts found naturally within the soil move into surface water and groundwater with precipitation in the rainy areas. Therefore, there are generally no saline deposits in the soils of humid regions. In regions with arid climates and little rainfall, uncontrolled irrigation causes accumulation of salts in the soil. Infiltration rate of water is very low in poorly drained soils [12]. Excessive irrigation on these soils still reduces the infiltration, causing the rise of groundwater level. Water evaporates in a short time remaining the salts in the soil, because of high evapotranspiration. Consequently, salinization problem, limiting the agricultural improvement and decreasing the crop production, occurs in the soil environment. Even the high-quality water of the Euphrates River brings approximately 1.1 tons of soluble salt to a 10-decares area, every year [13].

Harran Plain has semi-arid climate with almost no precipitation between June and September, and poorly drained soils because of high (≥60 %) clay content. Indications of intensive saline deposits have been observed on the low part of the plain, after excessive irrigation (Fig. 5, Fig. 6). Low infiltration rate of water in vertisol soils and high evapotranspiration invite salinization on the topsoil. Salt deposits pass through the cracks in the soil and accumulate in the lower horizons. In this way, salinization in the Harran plain soils diffuses increasingly from lower horizons to the topsoil. This situation limits the amendatory applications against the problem. Even surface drainage systems cannot solve the problem, because the salt layer continues throughout the soil profile from topsoil to subsoil. Thus, the danger arises that the Harran plain soils, which have been quite plentiful for numerous civilizations, may become barren. Salinization will pose a significant problem, because of the regional climate and the dominant vertisol soil properties.

The regional climate and soil properties have important acts on the salinization problem. On the other hand, incorrect agricultural applications contributed the growing up of salinization on different areas. The danger of salinization is somewhat reduced by the presence of a humid climate. However, over many years, one can expect a reduction in quality of this irrigation water by the use of high amounts of fertilizers and in the absence of a proper drainage and disposal system [12].

Sorption of Organic and Inorganic Pollutants

The dominant clay type in the Harran Plain is known as smectite of the 2:1 type [14]. The high clay content of Harran plain soils, which was found in A_{p} and B_{w2} horizons at levels of, respectively, 60% and 63%, is thought to be an important factor in the adsorption of pesticides and heavy metals. It was determined that Fe-oxyhydroxides as well as silicates affected phosphorus adsorption-desorption at significant levels in a study carried out on a vertisol soil in Harran Plain, [3]. Similarly, in soils, clay and metal oxide surfaces and organic matter are the dominant materials responsible for the sorption of organic contaminants [15].

Organic matter content is low and exists homogeneously in all horizons of Harran soils. Adsorption generally occurs between clay surfaces instead of on the organic matter, and adsorption tendency of contaminants is thought to be at a high level because of the high clay content. Therefore, pollution risk of groundwater and/or surface water becomes an important issue with the contaminant transport. Endosulfan is widely used insecticide in the Southeast Anatolian region and adsorbed highly by the Harran soils [16]. The crystal lattice structure of clayey soil plays an important role in endosulfan adsorption, and that clays are more effective than organic matter. Maximum adsorption of alpha and beta endosulfan occurred in, respectively, clayey soil, compost soil, and red soil [17].
Physical adsorption occurred between endosulfan and clay minerals, and endosulfan molecules cannot adhere firmly to soil particles because of the physical van der Waals force. Desorption occurs between the physically bonded chemicals. Desorption of organic pollutants from soil caused groundwater contamination, and, thus, residual endosulfan was found in the groundwater samples taken from wells in the plain [16].

Adsorption-desorption tendency and transport of organic and inorganic pollutants in the soil cause important environmental problems. Therefore, the pollutants carried to different areas may have negative effects for living organisms both in the soil and in the water. The long-term application of chemicals lengthens the reduction period of these chemicals in the soil by degradation, leading to continuous accumulation. As the concentrations of contaminants in water and soil environments increase, the use of the natural resources becomes more restricted, and significant health problems occur. The source and delivery control of pollutants is directly related to management options and mitigation strategies [18].

CONCLUSION

Basic soil properties of samples, taken from different depths of a profile in the plain, revealed vertisol soil characteristics. Certain environmental problems that may result from conditions peculiar to vertisol soils were generally expressed above. Vértisolos in Harran plain may cause greatly increased yields of food crops with improved soil management practices. When the SEA Project goes into full operation, there will be a great increase in agricultural activities which means that the soil of Harran Plain will be used intensively. Soil characteristics and environmental properties, such as climate, topography, and vegetation, are the major factors that control the movement of pollutants in soils. Nature of the pollutant is another factor on the transport of different pollutants, necessary precautions must be taken immediately:

- Control techniques for soil erosion should be advanced;
- Different amendments in improving physical properties of vertisol soils should be investigated.

REFERENCES


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CORRESPONDING AUTHOR

Ayse Dilek Atasoy
Harran University
Environmental Engineering Department
Osmanbey Campus
63000 Şanlıurfa
TURKEY

Phone: +90-414-3440020/1116
Fax: +90-414-3440031
E-mail: adilekatasoy@hotmail.com
adilek@harran.edu.tr