特別研究会“土壌中の物質移動現象の新たな展開”について。

1．はじめに

去る1987年7月18日，土壌物理研究会主催，農業土木試験場と農業土木学会土壌物理研究部会後援による特別研究会が開催された。本研究会は恒例のシンポジウムと異なり，海外からのゲストスピーカーを含め，英語を会議用語として使用するという，一種の国際研究集会であった。本研究会としてこの種の経験は，1977年の第19回シンポジウム以外には見あたらないので，会の内容と状況を記録にとどめ，今後の参考に供したい。なお，特別研究会英文タイトルは，

A special meeting on the new aspects of transport phenomena in soils であった。

2．プログラム

- Openning Speeches :
  - S. Nakagawa (Director General of National Research Institute of Agricul tural Engineering)
  - N. Nakano (President of Research Association of Soil Physics, Japan)
- Morning session : Effects of macropores on water and solute movement in soils.
  - R. Hatano and T. Sakuma ; Significance of the interpedal macropores in the movement of water and solute in heavy clayey soils.
  - Ir. J. Bouma ; Characterizing water and solute movement in heavy clay soils.
- Comments by H. Inoue snd H. Narioka on the morning session.
- Afternoon session : “Flow of solutes in soils”
  - B. P. Warkentin ; Contaminant transport in solis--an Overview.
  - T. Tabuchi ; Percolation loss of nitrogen in flooded rice fields.
- Comments by S. Otoma on the afternoon session.
- General discussion : The chairman was Dr . T. Woodhead.

3．参加者について

プログラムに紹介したボーマ氏，ワーケンチン氏そしてウッドヘッド氏は，特に日程を都合して当研究会に参加してもらったものである。また，乙間氏は，今回の研究会のテーマに深い関係を持った研究を手がけておられる方として，国立公害研究所からの御推薦を頂いただいてご招待したものである。会場に参加した人々も数名の外国人を始め，北海道から沖縄まで幅広くおられたのも本研究会の特徴であった。

4．講演要旨

Morning session

The Significance of the Interpedal Macropores in the Movement of Water and Solutes in Heavy Clayey Soils.

Ryusuke Hatano and Toshio Sakuma
Hakkaido University

Most theoretical analyses of the material transport phenomena in the soil-plant-atmosphere system have been made on the assumption of the existence of homogeneous Soil profiles. Heavy clayey soils, however, have heterogeneous profiles which are characterized by coarse and dense prismatic or blocky : peds and very coarse interpedal macropores. Consequently, we are not able to adapt the methods of analyses of homogeneous soil profiles to the heavy clayey soils. This report attempts to evaluate the role of interpedal macropores in the movement of water and solutes in heavy clayey soils, based on the idea that the heterogeneous soil system can be regarded as a cluster of homogeneous fractions.

The water infiltration experiment in a Pseudogley soil indicated an extremely irregular distribution of percolating water. That is, the soil water suction in the deeper part of the Cg horizon just above the impermeable layer decreased more rapidly than that in the upper part of the Cg horizon. We consider that such a phenomenon is due to bypass flow when most infiltration water moves into a part of the interpedal macropores. We have therefore developed a simulation model that consists of the following four submodels : 1) vertical infiltration into the peds ; 2) bypass flow ; 3) lateral water absorption into the peds through the macropore walls ; 4) accumulation of water in the bottom of the macropores.

With regard to solute transport, its irregularity was also observed in breakthrough experiments using Cl^- in undisturbed soil cores with shrinkage cracks. Breakthrough curves are characterized by a very rapid increase of concentration during the initial stage a significant tailing during the later stage. Since breakthrough curves failed to fit to the fundamental diffusion-dispersion transfer equation consisting of diffusion-dispersion term and mass flow term, we considere the possibility of a source-sink term. The source-sink term was evaluated by a graphical method assuming that pore water was divided into two phases : a mobile phase a stagnant phase. Consequently, we concluded that the rapid increase in the initial stage of the breakthrough curve was caused by the bypass flow, while the tailing in the later stage was caused by the interdiffusion between the mobile phase and the stagnant phase. Furthermore, when the initial salt concentration of the soil solution was low, solute transport through the mobile phase was accelerated owing to the salt sieving effect which occurs in the interpedal micropores and the decrease of sink volume in the stagnant phase.

Heavy clayey soils are characterized by such very poor physical properties as high bulk density, high stickiness and poor permeability. We therefore considered that physical improvements in drainage, for example the breaking up of the subsoil, are indispensable for the utilization of such heavy clay soils as upland fields. As we have already suggested, however, macropores generated by the breaking up of the subsoil are considered to be effective in not only helping rapid drainage but also in increasing the retentivity of the subsoil layer, owing to water absorption of peds from water which has accumulated in the bottom of the macropores. The plant roots which elongate preferentially through the macropores can effectively utilize water and nutrients which exist there. In this sense, it can be said that the interpedal macropores developed in subsoil layer play an important role in providing favorable conditions for water and nutrient supply to plant roots.

Characterizing Water and Solute Movement in Hervy Clay Soils.

J. Bouma
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Porosity patterns in heavy clay soils are highly variable : shrinkage upon drying and swelling upon wetting create a constantly changing pattern of macropores, notally cracks between peds. Water movement is highly influenced by these cracks and the talk to be presented will focus on different procedures that can be used to adequately represent these changing conditions. These procedures are unique in that they emphasize the use of both physical and morphological techniques.

Many standard soil physical techniques for measuring hydraulic conditions don't work in clay soils. Measurement of water-tables in unlined augerholes (3) and of pressure heads in the soil matrix (6) may yield unrepresentative results when macropores are intercepted. Alternative procedures can be defined after considering macropore-patterns to be obtained with morphological techniques. The same is true for obtaining optimal sampling volumes (2). An important aspect of the hydrology of clay soils is bypass flow, which is movement of free water along vertical macropores through an unsaturated soil matrix. Techniques were developed to measure bypass flow (4,1) and data obtained can be used in simulation models, bylowering effective rainfall (5, 8). Detailed simulations considering a single shower can also be made. This includes consideration of lateral infiltration from the macropores into the adjacent unsaturated soil matrix (7). Such models require data on the total vertical area along which bypass-flow occurs. This area can be obtained with morphological techniques. Formation of horizontal cracks upon can have a major drying amajor effect on the unsaturated, upward flux water from the watertable to the root zone. A staining technique was developed to allow quantification of the air-filled horizontal cracks as a function of the pressure head (1,8).

So far, studies discussed covered the physical behaviour of specific structural conditions at a fixed point in time. Dynamic characterization of the flow system in time is still very difficult because small changes in be continued. Physical processes have to be characterized primarily by physical methods. However, morphological techniques are crucial when defining specific physical boundary conditions of the flow system.

Refernces.

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Afernnoon session

Contaminant Transport in Soils--an Overview

B. P. Warkentin

Contaminant transport in soils is usually described by models, because this is the best way to deal with complex systems. Models attempt to predict the distribution of the contaminant in space and time. The more a model represents the nature of soil, the more complex it becomes. Increased complexity often does not mean increased predictive power. Prediction of the actual paths of contaminant transport through soils is not yet possible. Simple models, with estimates of soil parameters, serves well in predicting relative movement of classes of contaminants. Complex models allow study of processes, aid in understanding the systems, and allow study of how variation in specific combinations of characteristics affect transport. Because of the nature of variability in soils, stochastic models based on probability of certain values of soil properties at certain points are seen to be more useful than deterministic models that describe mechanisms.

The models for contaminant transport in unsaturated soils are based on transport equations that have terms for mass or advective flow, diffusion and ／ or dispersion, and retardation due to sorption, degradation or volatilization. Each of these terms depends upon soil properties that vary in time and space. Examples are distribution of organic matter on a micro scale, pore - size distributions, or changes in soil particle coatings. Average parameters may be valid for some uses but not for others.

The nature of variability of soils in the field must be part of our mathematical descriptions of natural processes. In man-made materials we attempt to increase uniformity ; in nature the rule is diversity and variability.

Typically, in ten cores taken in a field, one will show that a contaminant has moved to 3 meters, 2 will show the contaminant at 30 cm and 7 will show no contaminant below 5 cm. Our task is to describe that produces such a distribution.

It is usually desirable that the soil interacts with contaminants in such a way that transport is restricted. This may involve sorption of the contaminant, or biological degradation. Sorption may be a simple exchange reaction, or involve physical-chemical reactions that are poorly understood and generally called "specific adsorption. " In either case there is a limit to the soil's ability to retain contaminants ; and soils must be managed in such a way that their "buffer capacity" for attenuation of contaminants is not exceeded.

Degradation is generally considered to occur only at the soil surface, although microorganisms have beem found at depth . It may be possible to make conditions suitable for biological degradation at depth.

A particular example of contaminant transport in soil that depends upon reactions not well

understood arises in schemes for ultimate disposal of high level nuclear wastes.
The wastes are contained in metal canisters, with swelling clays filling the remainder of the cavity in solid rock a thousand meters below the surface. When the canisters fail, the clay is the second line of protecition. The canisters have a temperature of several hundres degrees centigrade, while the pore water in the rock is saline and is under a hydraulic gradient. The problem is to predict movement of radioactive elments in the clay over several hundred years under a temperature gradient, with a swelling pressure modified by temperature and pore water. The diffusion process is modified by exchange and by changes in pore size distribution of the clays due to swelling and shrinking. A simple macroscopic diffusion coefficient is an imprecise average; bulk water has a different diffusion coefficient from film water on clays. Fluxes due to temperature, pressure and solute gradients are poorly understood, and need further investigation by soil physicists.

Percolation Loss of Nitrogen in Flooded Rice Fields

Toshio Tabuchi
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1. Introduction

Excess percolation causes fertilizer loss of nitrogen and groundwater pollution. Finally it flows out to rivers and lakes. If the concentration of nitrogen and phosphorus increase in lake water, the lake will be eutrophicated. Many kinds of plankton grow abnormally in the lake and the lake water change to like a green paint. It becomes undesirable to use the water for drinking and irrigation. In some cases fish culturing will have a great damage due to the dead water by the decrease of dissolved oxygen. Accordingly percolation loss of nitrogen should be controlled.

2. Difference between flooded rice fields and upland fields

There is a great difference between the percolation loss of nitrogen of flooded rice fields and that of upland fields. In flooded rice fields, surface soil is saturated and oxygen is little; reduced condition. Then NH_4 is main form of nitrogen.

Contrary to this, in upland fields soil is unsaturated and oxygen is abundant. Then NH_4 changes to NO_3, which flows out from soil easier than NH_4. Furthermore there are many kinds of crops which need large quantity of fertilized nitrogen in upland. Accordingly, nitrogen loss is larger in uplands than in flooded rice fields.

3. Saturated type and unsaturated tyre

There are two types of rice fields. In saturated type, soil is saturated and little oxygen condition. In unsaturated type, surface soil is saturated but subsoil is not saturated and water pressure is negative.

In saturated type the concentration of nitrogen in percolating water of 40 cm depth was less than 2 mg／ℓ and its main form was NH_4 and organic nitrogen.

In unsaturated type main form of nitrogen of percolating water was NO_3 and NH_4 was little (Furuhata 1979). Usually percolation loss in this type is larger than in saturated type.

4. Inflow and outflow of nitrogen

In rice fields not only outflow of nitrogen but also inflow of nitrogen exists. Inflow consists of irrigation water and rainfall. Outflow consists of surface outflow and percolation.

Inflow and outflow of nitrogen were measured in 58 fields in Japan. Both outflow and inflow are in the wide range. In some rice fields inflow is larger than outflow. We call this type of rice fields as a absorber type. On the other hand, rice fields where outflow is larger than inflow are outflow type. Outflow type should be changed to absorber type by percolation control and improvement of water management and fertilizer application.

5. Nitrogen removal in flooded fields

Flooded rice fields have a function of nitrogen removal by denitrification. If NO_3 flows into flooded reduced condition, it will be removed by denitrification. Lots of rice fields remove nitrogen in the process of natural water flow from upland to lowland. From the viewpoint of environment as well as food production, rice fields should be conserved in Japan.

5. 質疑応答

質疑応答は，午前の部のコメンテーター，井上久義氏（農土試），成岡市氏（東京農大）および午後の部のコメンテーター乙間末広氏（国立公害研）によって事前に準備されていたもの以外に，各発表者に対しても活発に行なわれた。特に，ゲストスピーカーのボーマ氏，ワーケンチン氏に対しては会場から果敢な質問が発せられ，日本人スピーカーやコメンテーターに対してボーマ氏，ワーケンチン氏，ウッドヘッド氏から熱心な質問が繰り返し出され，よくかみ合った議論が進んだ。

総合討論では，ウッドヘッド氏を座長として討議を行ない，立派に長い弁説を振るわれた人，何度か英語で質問していたがついに面倒になって日本語に切り換えた人などいろいろであったが，発言者が絶えることなく，1時間があっという間に過ぎ去った。

最後に，本セミナーの実質的ディレクターであった岩田進午氏から示唆に豊んだまとめの発言をいただいて，散会となった。

（文責　宮崎　毅）