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Gromachenko S. Y., Candidate of Engineering, Senior Lecturer (National University of Water Management and Nature Resources Use, Rivne)

ESTIMATING HYDRAULIC PARAMETERS FOR WATER BALANCE MODELING OF WASTE CONTAINMENT FACILITIES FINAL COVER SYSTEM

The soil-water characteristic curves (SWCCs) and the hydraulic conductivity curves for numerical modeling were worked out based on field data obtained from sensor systems.The performance of final cover storage layer was investigated on both coarse-grained and fine-grained sides of plot area.

Key words:hydraulic parameters, water-balance, waste containment facility, final cover system.

Today the problems of water management and environment recovery have become not only of national but also of international significance. Water capacity potential of any territory is a basis for its economic development, social and environmental well-being[1].

Land disposal of waste, as a method that has potential risk to pollute or degrade its environment, has been and continues to be the most widely-used form for waste management.

On the contrary to an open dump, modern engineered landfills are expected to control fire and spread of litter, limit contact wildlife, minimize or eliminate the release of mobile contaminants to the surrounding environment, and provide acceptable end-of-service land use. From the perspective of environmental protection, release of contaminants to air and groundwater is often considered the most significant issue. If such release occurs, the toxicchemical compoundsinvarious states of aggregation set conditions for air, soil, water bodies and groundwater pollution [2]. To avoid such negative influences, the careful siting and proper design of landfill is required. This can be achieved by construction of an envelope that consists of a top cover and bottom liner that encapsulate the waste and prevent escape of leachate into the environment.

Thus, modern well-constructed landfill is an engineering structure that consists of a composite liner system, leachate collection and removal system, gas collection and control system, and final cover system. Final cover systems are usually multilayered and provide multiple functions, main among those are keeping out infiltration and keeping gases in the waste [3].

On the contrary to conventional final covers, alternative earthen covers generally use unique characteristics of unsaturated flow, the storage capacity of fine-grained soils and moisture-evaporation ability of plants to regulate the cover water-balance elements and thus minimize percolation as a potential leachate. Earthen covers employing capillary or monolayer barrier principle can be effective in minimizing percolation into underlying waste in semiarid and arid regions [4, 5]. They can be constructed in various forms, ranging from a simple design consisting of two layers or more complex designs that include multiple layers of soils with different hydraulic properties.

The key objective of this numerical and field study is to estimate the unsaturated hydraulic properties of an earthen cover that has been in service for over 5 years. The instrumented field cover is located near Omaha, Nebraska (USA) where the soil is expected to undergo freeze /thaw and wetting /drying cycles. These cyclic seasonal stresses are expected to change the hydraulic properties and hence the hydrologic performance of the cover [6].

The field instrumentation and principles of installationthefield-scale sensor systems that measure soil volumetric water content, matric potential and in-situ meteorological characteristics is shown in [7].

Water balance modeling.Calculation Schemes. The importance of hydraulic properties of the final cover was studied by simulating multilayer barriers of the following composition: the calculation scheme #1 (Fig. 1(a)) consisted of 3 materials: a 15 cm (0,5 ft) of top soil, 60 cm (2 ft) of silt and 225 cm (7,5 ft) of silty clay were placed over MSW; the calculation scheme #2 (Fig. 1(b)) consisted of 4 materials: a 15 cm (0,5 ft) of top soil, 60 cm (2 ft) of silt, 60 cm (2 ft) of silty clay and 165 cm (5,5 ft) of clay were placed over MSW.

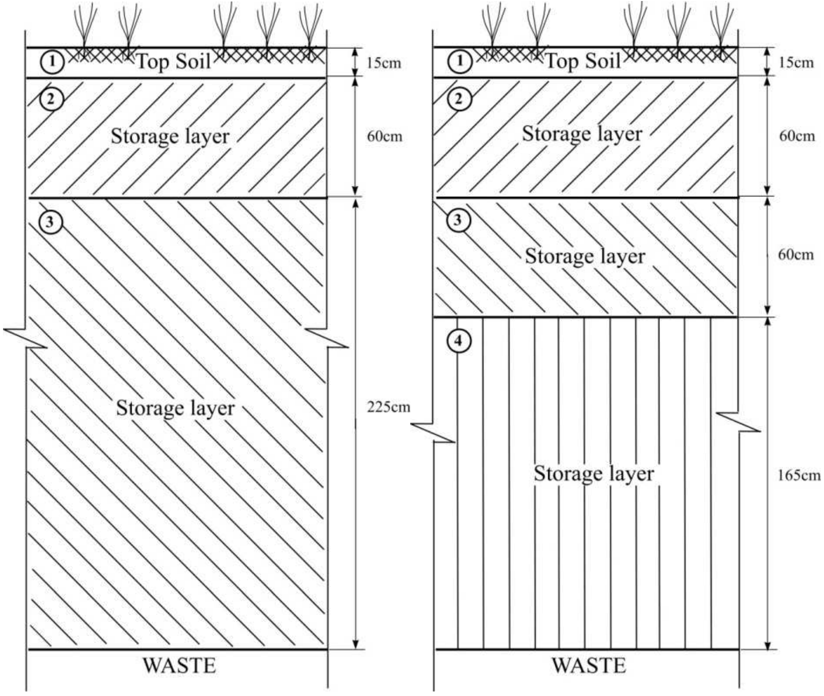

Fig. 1. (a) Three-Material Final Cover Barrier and (b) Four-Material Final Cover Barrier

Hydraulic Functions Development. Properties of six finer-grained soils were used in the simulations. The soil-water characteristic curves (SWCCs) and the hydraulic conductivity curves were worked out based on field data obtained from sensor systems.

For simulation using UNSAT-H the curves were described in terms of the van Genuchten (1) and van Genuchten-Mualem(2) functions [8, 9]:

$$\frac{\theta-\theta_r}{\theta_s-\theta_r}=\left\{\frac{1}{1+(\alpha\psi)^n}\right\}^m ; \qquad (1)$$

$$\frac{K_\psi}{K_S}=\frac{\left\{1-(\alpha\psi)^{n-1}\left[1+(\alpha\psi)^n\right]^{-m}\right\}^2}{\left[1+(\alpha\psi)^n\right]^{m/2}} . \qquad (2)$$

In (1), θ_s = volumetric water content at saturation; θ_r = residual volumetric water content; α, m, n – curve fitting parameters ($m=1-n^{-1}$); K_S = saturated hydraulic conductivity; K_ψ = hydraulic conductivity at matric suction ψ .

For numerical modeling using RZWQM2 the curves were described in terms of the Brooks-Corey (3),(4) relationships [10]:

$$\theta=\theta_r+(\theta_S-\theta_r)\left(\frac{h_b}{h}\right)^{1/b}, \quad h>h_b$$
$$\theta=\theta_S, \quad h\le h_b \qquad (3)$$

$$K_\psi = K_S + \left(\frac{h_{bk}}{h}\right)^{2+b'/b}, \quad h > h_{bk}$$
$$K_\psi = K_S, \quad h \le h_{bk} \tag{4}$$

In (2), θ_s = volumetric water content at saturation; θ_r = residual volumetric water content; h_b= bubbling (air entry) pressure head for SWCC curve; h_{bk}= bubbling pressure for Hydraulic Conductivity Curve; b = curve fitting parameter; K_S= saturated hydraulic conductivity; K_ψ= hydraulic conductivity at matric suction ψ.

Soils used in the simulations cover a wide range of water retention properties and saturated and unsaturated hydraulic conductivities. The three main groups of SWCCs (Fig. 2 (a, b, c)), as well as Hydraulic Conductivity Functions (Fig. 3 (a, b, c)), were developed for numerical modeling conducted.

Groups of SWCCs 1 and 2 were developed for the final cover storage layer to investigate its performance on both coarse-grained and fine-grained sides of plot area. All of the curves shown in Figs. 2 and 3 were obtained by desorption. In the field, both desorption and sorption are important, because cover soils undergo wetting and drying, and both processes affect the ingress and egress of water from a cover [5, 11].

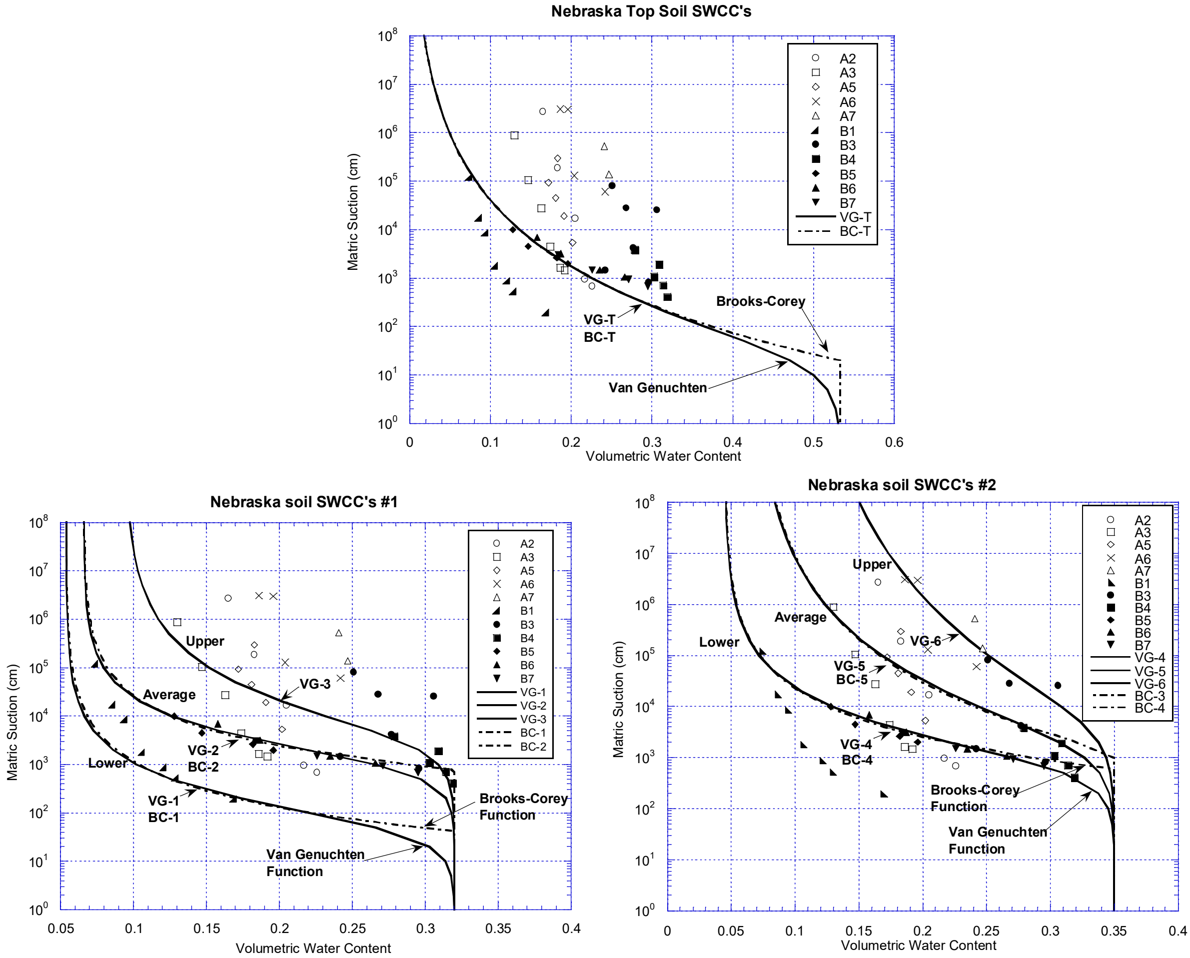

Fig. 2. SWCC's for (a) Top Soil, (b) Storage Layer Case #1 and (c) Storage Layer Case #2

The *first simulation*was performed in accordance with calculation scheme #1 (see Fig. 1(a)). The storage layer of final cover (material #3) was made with silty clay (CL) soil, which hydraulic properties are represented by VG-2 (BC-2) curve (Fig. 2(b)) and VG-2K (BC-2K) curve (Fig. 3(b)). The storage layer made with material #2 consists of silty sand (SM), and hydraulic properties of it are represented by VG-1 (BC-1) curve (Fig. 2(b)) and VG-1K (BC-1K) curve (Fig. 3(b)).

The *second simulation* was also carried out following the calculation scheme #1. Storage layers composition and hydraulic properties were kept the same, with the only difference in hydraulic conductivity function for material #3, as VG-3K (BC-3K) curve ($K_S = 5\cdot10^{-7} cm/\sec$) was used instead of VG-2 (BC-2) curve (Fig. 3(b)).

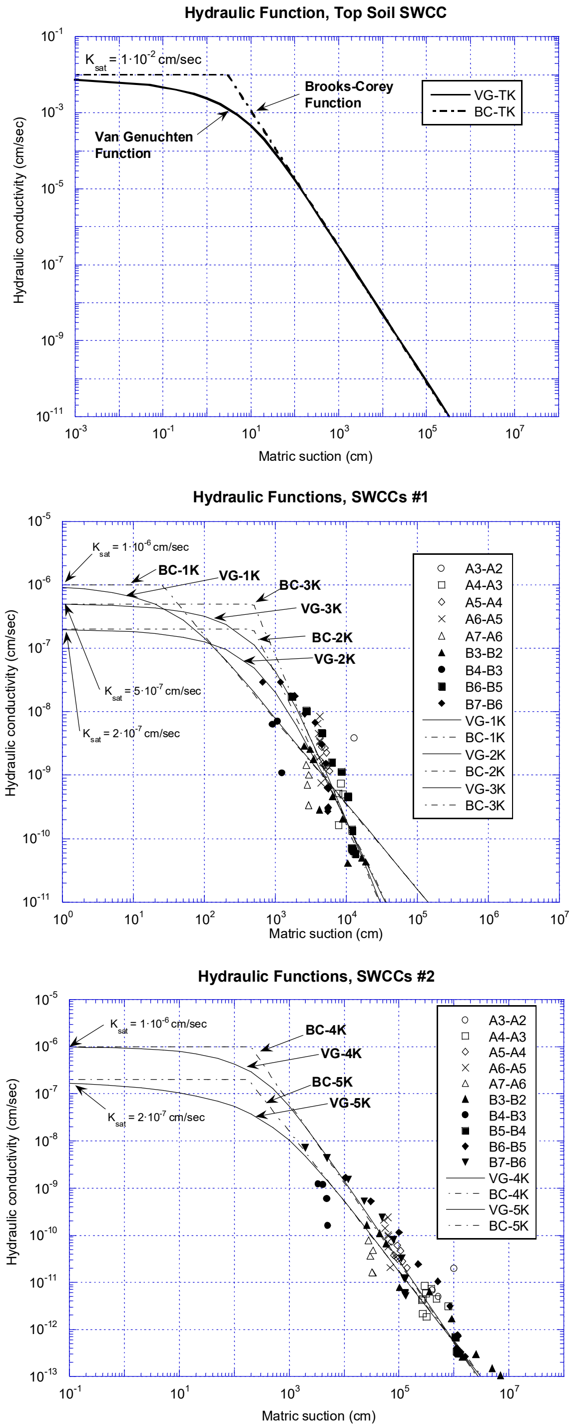

Fig. 3. Hydraulic Functions for (a) Top Soil, (b) Storage Layer Case #1 and (c) Storage Layer Case #2

The calculation scheme #1 was also used for the *third simulation,* but the hydraulic functions for each material were changed. The 3-rd material of storage layer was represented by VG-5 (BC-5) curve (Fig. 2(c)) and VG-5K (BC-5K) curve(Fig. 3(c)). To simulate the hydraulic performance of the second material the VG-4 (BC-4) curve (Fig. 2(c)) and VG-4K (BC-4K) curve (Fig. 3(c)) were used.

The *fourth simulation* was conducted based on calculation scheme 2 (see Fig. 1(b)). Material 4 was described in terms of VG-5 (BC-5) curve (Fig. 2(c))and VG-5K (BC-5K) curve (Fig. 3(c)). Overlaying material 3 is presented with VG-2 (BC-2) curve (Fig. 2(b)) and VG-2K (BC-2K) curve (Fig. 3(b)) that were discussed before. Storage layer composed with material #2 is same as in simulation #1 and represented by VG-1 (BC-1) curve (Fig. 2(b))and VG-1K (BC-1K) curve (Fig. 3(b)).

For every simulation conducted the layer of top soil with constant hydraulic properties (Figs. 2,3(a)) is placed over material 2.

Thus, estimating the cover hydraulic propertiesis the necessary condition for the following water-balance simulations.

Even though, the *final cover thickness* for the simulations may be constant, it is evident that the percolation decreases as the thickness of the storage layer increases. This is because soil-water storage capacity becomes larger, which allows to store more water for a longer period of time without drainage to the underlying layer or out from the bottom of cover. When the storage layer is thicker, the soil water storage curve has a higher peak and greater breadth. The larger and more prolonged soil water storage provided by the thicker fine-grained surface, a greater quantity of water to be removed by evapotranspiration [11].

The moisture content of the soil continually changes – increasing due to infiltration and decreasing due to evaporation. The amount of water that can be stored in a soil depend on its *hydraulic properties* that are mainly determined by the water-physical properties of soil (e.g. dry density, specific gravity, porosity etc.) and factors of ambient environment (freeze /thaw cycles, biota activity etc.).

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Рецензент: д.т.н., професор Рокочинський А. М. (НУВГП)

Громаченко С. Ю., к.т.н., ст. викладач (Національний університет водного господарства та природокористування, м. Рівне)

ВИЗНАЧЕННЯ ГІДРАВЛІЧНИХ ПАРАМЕТРІВ ПРИ МОДЕЛЮВАННІ ВОДНОГО БАЛАНСУ РЕКУЛЬТИВАЦІЙНОГО ШАРУ ОБ’ЄКТУ СКЛАДУВАННЯ ВІДХОДІВ

На основі даних польових сенсорних систем розроблено гідрофізичні залежності для моделювання водного балансу звалища, а також досліджено функціонування рекультиваційного шару в залежності від його гранулометричного складу

Ключові слова: гідравлічні параметри, водний баланс, об’єкт складування відходів, рекультиваційний шар.

Громаченко С. Ю., к.т.н., ст. преподаватель (Национальный университет водного хозяйства и природопользования, г. Ровно)

ОПРЕДЕЛЕНИЕ ГИДРАВЛИЧЕСКИХ ПАРАМЕТРОВ ПРИ МОДЕЛИРОВАНИИ ВОДНОГО БАЛАНСАРЕКУЛЬТИВАЦИОННОГО СЛОЯ ОБЪЕКТА СКЛАДИРОВАНИЯ ОТХОДОВ

На основе данных полевых сенсорных систем разработаны гидрофизические зависимости для моделирования водного баланса свалки, а также исследовано функционирование рекультивационного слоя в зависимости от его гранулометрического состава

Ключевые слова:гидравлические параметры, водный баланс, объект складирования отходов, рекультивационный слой.