Estimation of Soil Erosion using Fallout Radionuclide Cs-137 Technique

S.X. Hushmurodov[1], A.T .Teshayev[2], M.G. Nasirov[3]

Fallout radionuclide techniques have been successfully used to estimate soil erosion and sedimentation in the USA, Europe and Australia using ^{137}Cs and, more recently, introducing the $^{239+240}$Pu technique. Application of environmental radionuclides (^{137}Cs, ^{210}Pb, ^{7}Be, ^{240}Pu, ^{14}C, ^{32}Si, ^{26}Al, ^{36}Cl) techniques for estimation of soil redistribution has received the most attention. ^{137}Cs was distributed globally and deposited as fallout after aboveground nuclear weapons testing during the 1950's to 1970's.

The territory studied was located at the saddle of the Karatepa and Chakilkalyan mountains. The latter are the southwestern spurs of the Zarafshan range and located 2.5 km to the east of the Takhta-Karacha pass (H=1685 meters above sea level) on the Samarkand-Kitab road. The territory was formed by three parallel-stretched hills that were weakly declining in the northern direction: high central (further C) and lower eastern (E) and western (W) (Table 1). To the south, ridges E_g and W_g of the E and W hills adjoin to the eastern - C_E and western - C_w slopes of the northern end of the central hill (C). Between the western – E_w and eastern – W_e slopes of the hills from the northern slope (C_n of hill C), there starts a rather narrow hollow (L). Slopes C_e, C_n and C_w and eastern slope E_e have strong steepness, while the western slope – E_w is less steep, and the eastern slope W_e is more gently sloping. Ridges C_g and E_g are flat with widths of ~20-30 meters. The ridge W_g and western slope W_w merge and slope downward to the northwest plain (R). There is a ground water leakage zone (V, length in meridian direction ~75 m, latitudinal ~25 m, surface level is lower to about ~10 cm relative to adjoining areas) in the northern part of the study territory, in hollow L. The elevation of the territory varies from 1786 m above sea level at the ridge of the C_g hill to 1642 m at the V-zone. Surface soil samples were collected from 17 sites from an area of ~0.5 m^2, to depth of 20 mm depth in increments of 5 mm. Soil probes masses ranged from 1.2 to 1.3 kg/L (specific densities of samples $\rho_s \approx 1.35$ kg/L).

Measurement of ^{137}Cs activity was performed using an analytical equipment complex from STC Radek Ltd, St. Petersburg, Russia. The main part of the complex is a scintillation spectrometer with a NaI(Tl) crystal, 63×63 mm, with a resolution of 6.9% at 661 keV line of ^{137}Cs. The main error in the determination of the spectrometer's sensitivity coefficients does not exceed ±7% (P=0.95). ^{137}Cs activity in the sample is done by single measurement. The spectrometer is calibrated in radionuclide activity units by using a set of standard activities of ^{137}Cs (OMACH) in a density range 0.215-1.770 gr/cm^3, which are manufactured in the shape of Marinelli beakers with volumes of 1 liter.

Values of specific activities and measurement errors are calculated automatically by the MAPC software package. The minimally-detected activity for the spectrometer is 2.3 Bq/kg for a sample density of 1 gr/cm^3 and measurement time of 1 hour. For 3 hours of measurement time the minimally detected activity is 1.3 Bq/kg. Errors in measurement results depending on RN concentration in samples vary within range $\delta A_{Cs,Be}$~10-40% and $\delta A_{Ra,Th,K}$~9-20%. It is notable to say, that attestation precision of standard sources - $\delta A^{et} \approx 7\%$ visibly contribute to errors.

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[1]Shaymonkul X. Hushmurodov, Professor, Department of Nuclear Physics, Samarkand State University, Samarkand, Uzbekistan; [2]Akram T. Teshayev, Ph.D. candidate, Samarkand Agricultural Institute, Samarkand, Uzbekistan; [3]Muhtor G. Nasirov, Professor, Samarkand State University, Samarkand, Uzbekistan. Corresponding author: S.X. Hushmurodov, email: xushmurodov59@mail.ru.

The final stage of the experiment was the estimation of soil erosion and deposition from ^{137}Cs activities. Assuming Cs-137 inventory to be equal to – $\boldsymbol{Q_{ref}}$ = 3.8 kBq/m^2 on a flat ridge with its undisturbed soil cover as a reference, the erosion and sedimentation rates were estimated by the difference between the Cs-137 at the disturbed – $\boldsymbol{Q_{studied}}$ and background – $\boldsymbol{Q_{ref}}$ areas:

1. $Y \approx \frac{(Q_{studied} - Q_{ref})\rho Z_e}{Q_{ref}\Delta T}$

   where $\boldsymbol{\rho}$ = 1350 kg/m^3 – specific soil density, $\boldsymbol{Z_e}$ – depth containing 1-1/e part of Cesium inventory (because inventory of Cs will change exponentially for each layer)
2. $\boldsymbol{\Delta T}$ = 2012 – 1963 – time passed in years.
3. Values of erosion and sedimentation rates

Table 1. ^{137}Cs inventories and erosion rates.

Area	**Site**	**Q, kBq/m^2**	**Y, ton/ha/yr**	**Condition**
Reference		**3.8**		
Ridge	C_g1 - C_g3 E_g3 - E_g5	3.1 2.7 – 3.3	0.6 – 2.4	Erosion
Slopes	C_n1, C_e1, C_w1 C_n2, C_e2, C_w2 E_w1, E_w2, E_w3 E_w5, E_w7 W_e1, W_e3, W_e5 W_e6	3.7 – 3.8 4.2 – 4.4 4.2 – 4.9 5.3 – 6.3 3.3 – 3.7 2.1	0.6 – 0.9 1.5 – 2.1 1.5 – 4.2 5.5 – 8.6 0.6 – 0.7 4.24	Sedimentation Sedimentation Sedimentation Sedimentation Erosion Erosion
Plain	R1, R3, R4 – R6	1.9 – 2.8	11.5 – 48.5	Erosion
Hollow	L1 L2 L3 – L6	2.1 1.3 0.5 – 0.8	4.24 6.7 8.2 – 9.1	Erosion Erosion Erosion
V-zone	V1 – V2	10.2 – 11.7	20.6 – 25.4	Sedimentation
Paths	E_g2R	2.2	3.9	Erosion
Road	E_w4t, E_w5t	2.7 – 3.8	2.4 – 9.1	Erosion
Plough-land	E_g1d, R2d	1.7 – 2.4	3.3 – 5.5	Erosion

The results in Table 1 show that at the plain location (Area #3) the Cs inventory was 1.9 to 2.8 kBq/m^2, which was less than the 3.8 kBq/m^2 measured at the reference point. This indicates that erosion has taken place, and from the model we calculated the erosion rate to be 11.5 to 48.5 ton/ha/yr. At the fifth area measured (V-zone), the cesium inventory was 10.2-11.7 kBq/m^2, which was greater than the 3.8 kBq/m^2 measured at the reference point. This indicates that sedimentation has taken place in this location.

References

Walling, D.E. 1995. Use of Cs and other fallout radionuclides in soil erosion investigations: progress, problems and prospects. IAEA-TECDOC-828, IAEA, Vienna: 39-62.

Lobb, D.A., R.G. Kachanoski, and M.H. Miller. 1995. Tillage translocation and tillage erosion on shoulder slope landscape positions measured using Cs as a tracer. Can. J. Soil Sci. 75: 211-218.