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Moisture retention and release characteristics of some soils developed on different parent materials and landforms

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Abstract

Ten soils developed under different landforms and parent materials in a micro-watershed of Wunna catchment were studied for soil properties and also for moisture retention and release characteristics. These soils show considerable variations in physical and chemical characteristics and also in retention and release of soil water. The variation in the amount of water retention of soils on basalt as well as sandstone are attributed to relative proportion of soil separates and type and amount of clay minerals. The water holding capacity of heavy textured soils are more as compared to light textured soils. The plant available water capacity of soils on basalt is relatively higher as compared to soils on sandstone indicating high amount of water storage in the profile during crop growth. The per cent moisture release was maximum between soil matrix suction of 33 kPa and 500 kPa of basaltic soils (73 to 82 %) as well as sandstone soils (65 to 87 %). The percent moisture release decreased nearer to wilting point. The release of soil moisture is gradual between 33 to 1000 kPa matric suction in case of soils on basalt. But in case of sandstone soils, sudden release is observed between 33 to 500 kPa and therefore sandy soils show moisture stress during crop growth. The study indicates that the rate of release of moisture in fine textured soils is more gradual than the relatively coarser textured ones.

Additional key words : Basalt, sandstone, matric suction, micro-watershed.

Introduction

Retention of water by soil colloids against gravitational force is one of the primary functions of soils for sustaining plant growth under conditions of intermittent water supply (Biswas and Nath 1982). Information on the water retention characteristics of soils is necessary to assess water requirement for optimum crop production, soil water management and planning of irrigation schedules (Das *et al.* 1974). The amount of soil water available for crop growth is referred to as plant available water capacity (PAWC). This is determined by storage capacity of soil, depth and distribution of root system (Gardner 1984). The knowledge of PAWC is also helpful to evaluate the soil-site suitability for different crops particularly under rainfed conditions with minimum risk of crop failure (Sehgal 1996). Water retention and release are influenced to a large extent by bulk density, texture, cation exchange capacity and organic matter content (Gajbhiye 1990; Kaushal *et al.* 1996; Rakesh *et al.* 1998). The quantity, nature of clay minerals and amount of clay also play a vital role in the water retention of soils (Ali and Biswas 1971). Such information on water retention and release is lacking in agriculturally potential Wunna micro watershed area. Keeping this in view a study was undertaken to characterize the water retention and release patterns in Wunna micro watershed under different parent materials.

Materials and methods

The study area is a micro-watershed of Wunna catchment (21°12' N latitude and 78°45' E longitude) in Nagpur district of Maharashtra state. The climate is tropical dry sub-humid with well-expressed summer (March to May) and a very mild winter season (November to February). The annual precipitation is 1127 mm (around 90 % is received during June to September), which accounts for about 77 per cent of potential evapotranspiration (1459 mm) and actual evapotranspiration is 829 mm. The soils have surplus moisture (297 mm) from July to October while soil remains dry from March to June. The water supply exceeds the water need (PET) for months from June to September and during the rest of the months the water supply is less than the PET (Fig. 1).

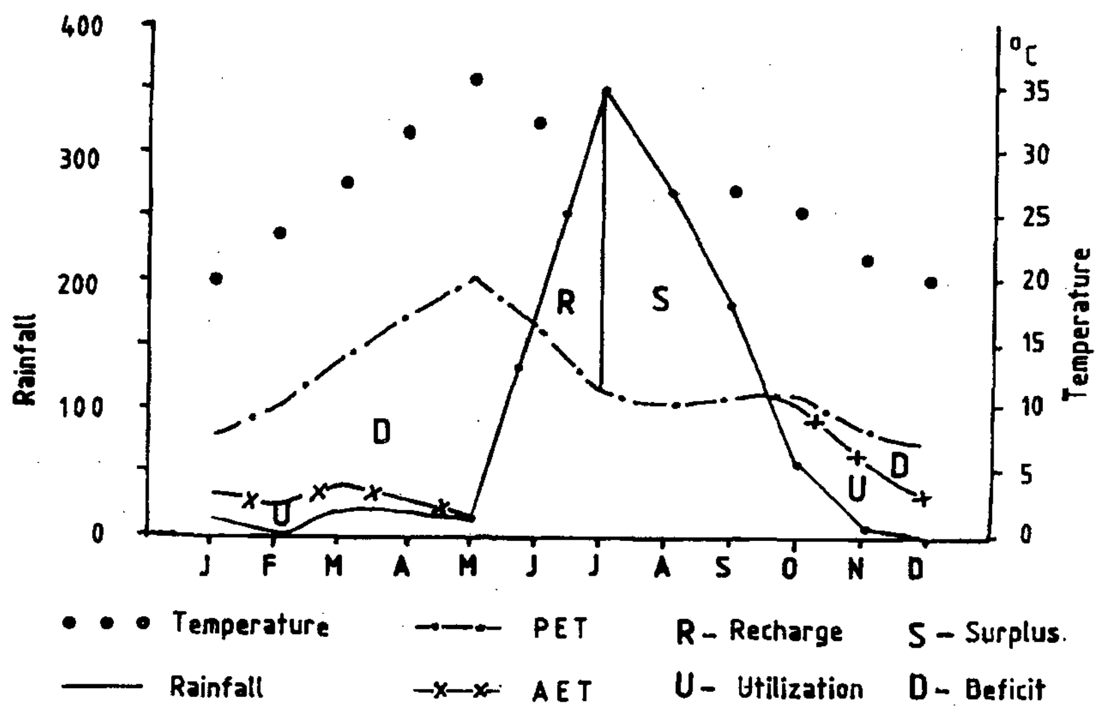


Fig.1. Climatic data and soil water balance

Ten pedons representing various landforms viz. bevelled crest, foot slope, rectilinear slope, concave slope, toe slope (upper sector) and toe slope (lower sector) on basaltic landform and foot slope, back slope, toe slope (upper sector) and toe slope (lower sector) on sandstone transect were exposed and horizon-wise soil samples were collected and processed. Particle size analysis and estimation of organic carbon, cation exchange capacity and exchangeable cations were carried out as per the standard procedures. Soil water retention at 10, 20, 33, 100, 200, 300, 500, 800, 1000, and 1500 kPa were determined by using pressure plate apparatus and tension plate assembly (Richards, 1954). The plant available water capacity (PAWC) was computed using the following expression:

$$\text{PAWC (mm)} = \sum_{Z=0}^{Z=RD} (\text{Wmax} - \text{Wdry})\ \text{BD at Wmax} \times \text{HD}$$

Where,

Wmax = Gravimetric water content at 33 kPa tension

Wdry = Gravimetric water content at 1500 kPa tension

BD = Bulk density at Wmax

HD = Horizon thickness (m)

RD = Total rooting depth taken as 1 m or to a depth of root limiting layer whichever is shallower

Results and discussion

Soil characteristics: The data (Table 1) show considerable variations in physical and chemical properties of soils formed under different parent materials and landforms of the watershed of Wunna catchment. The texture of soils on basaltic transect ranges from clay through clay loam to loam and that of sandy soils ranges from sandy clay to sandy clay loam. The nature of parent materials influences the soil texture. Bulk density of air dry soils on basaltic transect ranges from 1.66 to 1.71 Mg m^{-3} and that of sandstone soils ranges from 1.67 to 1.76 Mg m^{-3}. The organic carbon content in basaltic soils is relatively higher (0.27 to 0.56 %) as compared to those on sandstone soils (0.24 to 0.48 %). Organic carbon content is more in surface horizon and decreases with depth in all profiles. Cation exchange capacity (CEC) of soils derived from basalt was found to be more (11.2 to 50.1 cmol kg^{-1}) as compared to soils developed on sandstone (5.0 to 20.8 cmol kg^{-1}). This variation in CEC is likely due to the amount and nature of clay content. Higher values of CEC of black soils are due to the dominant clay mineral such as smectite and relatively lesser CEC values of sandstone derived soils are due to the presence of kaolinitic minerals as dominant clay minerals in these soils (Chinchmalatpure and Sehgal 2000). The PAWC of soils on basaltic landscape is relatively higher as compared to soils developed on sandstone (Table 3) indicating higher amount of water storage in the profile during the crop season. The PAWC values for the soils on bevelled crest, back slope and rectilinear slope of basaltic transect are less due to shallow depth and comparatively less amount of clay content.

Table 1. Physical and chemical properties of soils

Hori-on	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Bulk density (Mg m^{-3})	Moisture retention (wt/wt)		pH	O.C.. (g kg^{-1})	$CaCO_3$ (g kg^{-1})	CEC [cmol (p+) kg^{-1})]
						33kPa	1500kPa				
Soils on basalt transect											
Pedon 1 (Lithic Ustorthent s) (Bevelled crest)											
Al	0-0.06	52.9	31.7	15.4	1.67	21.2	9.6	6.7	6.5	10.0	17.2
AC	0.06-0.15	73.0	16.4	10.6	1.65	18.2	9.3	7.2	5.0	17.0	11.5
Pedon 2 (Lithic Ustorthents) (Foot slope)											
Al	0-0.10	31.0	44.0	25.0	1.60	30.1	16.4	6.7	5.6	18.0	26.4
Pedon 3 (Lithic Ustorthents) (Rectilinear slope)											
Al	0-0.14	50.8	31.8	17.4	1.60	21.8	14.2	8.1	4.4	52.0	17.0
AC	0.14-0.24	55.2	27.9	16.9	1.52	24.0	15.7	8.0	3.8	45.0	14.9
Pedon 4 (Typic Haplusterts) (Concave slope).											
Ap	0-0.14	13.6	34.9	51.5	1.71	40.7	25.8	7.4	5.3	17.0	47.0
A	0.14-0.28	13.4	37.3	49.3	1.76	39.8	26.4	7.5	3.5	19.0	50.1
Bss1	0.28-0.50	12.0	35.2	52.8	1.76	44.3	28.2	7.5	3.8	30.0	44.1
Bss2	0.50-0.71	13.9	34.2	51.9	1.73	47.2	29.1	7.6	2.9	40.0	45.5
C1	0.71-0.91	36.6	37.3	26.1	1.75	42.2	20.0	7.9	0.8	51.0	28.9
C2	0.91-1.06	25.7	45.5	31.8	1.44	29.8	30.1	8.3	0.2	101.0	31.7
Pedon 5 (Typic Ustochrepts) (Toe slope)											
Ap	0-0.11	46.4	33.1	19.1	1.40	26.7	16.2	8.0	6.0	148.0	23.1
B	0.11-0.34	34.1	29.7	36.2	1.43	28.3	17.3	8.3	5.4	218.0	30.5
BC	0.34-0.65	63.5	14.2	22.3	1.42	21.3	15.6	8.3	4.2	129.0	18.6
C	0.65-0.93	57.3	13.9	28.8	1.44	22.7	15.2	8.2	4.0	154.0	22.8
Pedon 6 (Typic Haplusterts) (Toe slope)											
Ap	0-0.14	15.0	44.1	40.9	1.61	45.9	27.1	7.3	5.6	40.0	38.7
A	0.14-0.43	13.6	42.1	43.3	1.87	47.3	28.7	7.3	5.0	69.0	41.8
Bss	0.43-0.59	12.7	47.8	49.5	1.67	50.9	30.8	7.5	3.8	98.0	39.1
C1	0.59-0.81	39.8	31.3	28.9	1.60	37.0	24.0	7.9	2.3	75.0	31.5
Soils on sandstone transect											
Pedon 7 (Lithic Ustorthents) (Foot slope)											
A	0-0.05	68.9	11.1	20.0	1.66	11.6	5.8	6.7	5.3	10.0	17.2
AC	0.05-0.20	64.1	10.6	25.3	1.68	30.6	12.8	6.6	4.7	10.0	30.8
Pedon 8 (Lithic Ustochrepts) (Back slope)											
A	0-0.12	88.3	4.1	7.6	1.65	2.0	1.0	6.9	1.2	---	6.9
B	0.12-0.30	64.2	7.9	27.9	1.69	10.1	4.9	6.2	2.9	---	12.4
BC	0.30-0.42	74.6	5.5	19.9	1.67	10.3	4.6	5.7	2.9	----	9.8
Pedon 9 (Typic Ustochrepts) (Toe slope- upper sector)											
A	0-0.09	76.5	11.5	12.0	1.68	7.3	1.9	5.7	4.2	---	5.0
B	0.09-0.28	73.1	10.7	16.2	1.67	7.1	2.8	6.0	4.6	---	6.4
BC	0.28-0.50	67.2	10.7	22.1	1.69	6.9	4.5	5.9	2.6	----	10.0
C	0.50-0.66	69.9	9.1	21.0	1.68	13.4	8.2	6.1	1.1	---	9.1
Pedon 10 (Typic Ustochrepts) (Toe slope- Lower sector)											
A	0-.022	66.3	13.1	20.6	1.68	9.9	4.5	6.4	4.0	--	13.3
BA	0.22-0.44	58.4	13.2	28.4	1.68	14.4	7.3	6.1	4.8	--	15.7
B	0.44-0.73	58.5	5.0	36.5	1.83	17.9	10.7	6.6	4.5	---	19.3
BC	0.73-0.94	55.4	9.0	35.6	1.79	19.4	10.0	6.7	2.6	---	19.5
C	0.94-1.15	56.8	8.0	35.0	1.78	18.2	10.6	6.6	1.1	---	18.3

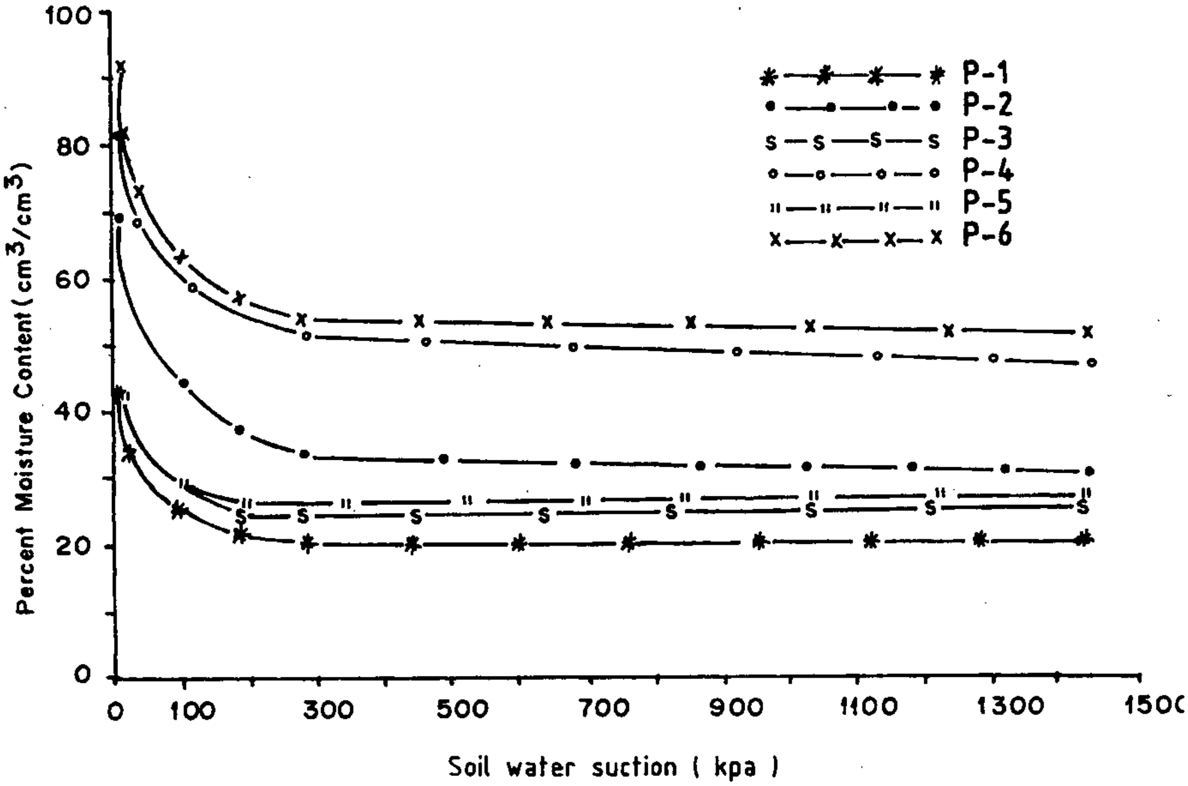
Moisture Retention: The soil moisture content versus matric suction relationship (moisture characteristic curve) indicates the behaviour of the soils for progressive release of moisture on increasing soil-water suctions. The study of moisture retention characteristic curve helps to assess the availability of moisture to plant during the plant growth period. Soils developed on basalt are fine textured with dominance of montmorillonitic clay and retain high amount of moisture at different soil-water suction as compared to relatively coarser textured soils on sandstone having dominant clay mineral as kaolinite (Chinchmalatpure and Sehgal, 2000). Thus it is evident that the texture of the soils, amount and nature of clay influence the water retention in these soils (Table 2). Similar results were also reported by Velayuthum and Raj (1977), Challa and Gaikawad (1987), Diwakar and Singh (1992), Srivastava *et al.* (1998).

Table 2. Regression equations of 33 kPa, 1500 kPa and AWC with soil properties

Regression equation	R^2
Y (33 kPa) = 53.56 – 0.592 X (sand)	90.33
Y (33 kPa) = 4.37 + 0.887 X (silt)	78.38
Y (33 kPa) = 1.15 + 1.019 X (CEC)	86.60
Y (1500 kPa) = 32.61 – 0.372 X (sand)	89.19
Y (1500 kPa) = 2.16 + 0.536 X (silt)	71.24
Y (1500 kPa) = - 0.72 + 0.657 X (CEC)	89.38
Y (AWC) = 20.89 – 0.219 X (sand)	79.75
Y (AWC) = 2.22 + 0.348 X (silt)	77.49
Y (AWC) = 1.877 + 0.361 X (CEC)	69.63

The data (weighted average) (Table 3) on moisture retention showed that moisture retained at 33 kPa in soils on basalt at different topographic positions varies from 32.2 to 77.4 cm^3/cm^3 whereas it varies from 13.2 to 30.7 cm^3/cm^3 in soils on sandstone. The moisture content of these soils at 1500 kPa varies from 15.5 to 47.3 cm^3/cm^3 and 6.2 to 17.7 cm^3/cm^3, respectively for basaltic and sandstone soils. These variations are attributed to the relative proportion of soil separates and type of clay minerals because the water holding capacity of heavy textured soils derived from basalt was observed to be more as compared to light textured soils derived from sandstone (Fig. 2).

The basaltic soils at bevelled crest have sandy loam texture with moisture retention at 33 and 1500 kPa are 32.2 and 15.5 $cm3/cm^{-3}$, respectively (Table 3). The soils at foot slope on basalt, which are loamy in texture, have moisture retention of 48.1 cm^3cm^{-3} at 33 kPa and 26.1 cm^3cm^{-3} at 1500 kPa. The soils at concave slope on basalt, which are clayey in texture, have the moisture retention of 72.9 and 42.9 cm^3cm^{-3} at 33 and 1500 kPa, respectively. The soils on sandstone with texture ranging from sand to sandy clay loam have the moisture retention ranging from 13.2 to 30.7 cm^3cm^{-3} at 33kPa and from



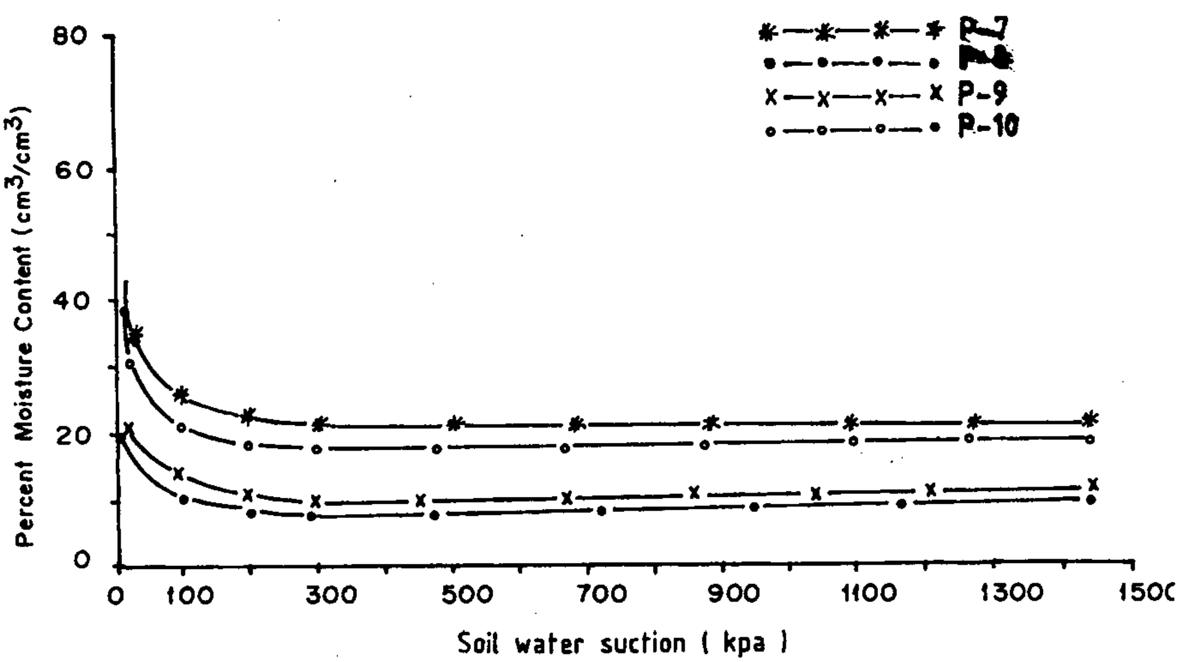


Fig.2 Soil moisture characteristic curve of soils on Basalt and Sandstone

6.2 to 17.7 cm^3cm^{-3} at 1500 kPa. This is relatively less than soils on basaltic parent materials at all landforms.

Table 3. Moisture retention (cm^3cm^{-3}) at different matric suctions (weighted average) and plant available water capacity of soils.

Pedon No.	PAWC (mm)	Soil-water suction (kPa) at									
		10	20	33	100	200	300	500	800	1000	1500
1	21.6	50.7	39.7	32.2	27.6	22.9	20.3	19.2	18.1	16.3	15.5
2	17.2	70.6	58.7	48.1	41.6	33.7	33.3	32.1	28.9	26.2	26.1
3	28.3	52.8	41.2	35.5	28.1	26.3	25.8	24.2	23.2	22.5	21.6
4	217.8	95.6	82.8	72.9	62.8	53.4	52.1	51.4	47.7	43.4	42.9
5	110.8	51.8	37.4	34.3	29.4	26.5	26.0	25.0	22.2	20.8	19.9
6	166.6	98.1	85.2	77.4	65.4	57.9	55.4	53.8	51.5	48.5	47.3
7	20.9	44.0	35.2	30.7	27.2	23.2	22.0	21.2	18.7	18.5	17.7
8	28.1	19.2	15.7	13.2	10.5	9.1	8.6	7.7	7.2	6.7	6.2
9	50.3	21.8	20.9	15.4	14.8	10.6	10.4	9.9	8.5	7.8	7.0
10	126.8	38.7	32.4	28.2	22.0	19.4	18.1	17.5	16.9	16.3	15.4

Moisture release : The per cent release of soil moisture is also affected by the nature of soil properties and relative proportion of soil separates. The maximum per cent i.e. 73 to 82 per cent and 65 to 87 per cent release of moisture from the soils on basaltic and sandstone transects, respectively are mostly from 33 kPa to 500 kPa. The release of moisture from 500 to 1000 kPa is 15 to 24 per cent and 9 to 21 per cent for basalt and sandstone soils, respectively and release of soil moisture decreases nearer to the wilting point. Thus in general, it is observed (Table 4) that the per cent release of soil moisture is maximum between 33 kPa and 500 kPa soil water suction followed by 500 to 1000 kPa and negligible per cent between 1000 to 1500 kPa. With respect to soils, it is also observed that the release of soils moisture is gradual in case of clay soils from 33 to 1000 kPa but in the case of sandy soils sudden release of soil moisture is observed between 33 to 500 kPa and therefore these soils show moisture stress during crop growth (Chinchmalatpure *et al.* 1999). The study therefore indicated that the rate of release of moisture in relatively fine textured soils is more gradual than the relatively coarser textured ones. Similar results were also reported by the Biswas and Mukharjee (1987) and Walia *et al.* (1999).

Table 4. Per cent soil moisture release between different soil-water suctions of soils on basalt and sandstone

Soil-water suction range	Soils on basalt						Soils on sandstone			
Pedon No.	1	2	3	4	5	6	7	8	9	10
33 kPa to 1500 kPa	100	100	100	100	100	100	100	100	100	100
33 kPa to 500 kPa	78	73	82	74	81	79	87	78	65	79
500 kPa to 1000 kPa	18	26	15	24	15	17	9	15	21	11
1000 kPa to 1500 kPa	4	1	2	2	3	3	3	7	13	9

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