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E. J. MESU*, L. E. VAN ENGERS*

GROUND WATER POLLUTION BY WASTE-TIPS

The relation between tipping technique and leachate amounts has been discussed. Tipping techniques preventing an excessive pollution of ground water have been described and the main factors responsible for leachate pollution given. The paper is illustrated by the appropriate numerical data.

1. AMOUNTS OF LEACHATE

It is clear that as long as tipped waste does not have immediate contact with ground water it can be polluted only by the leachate coming from the tipping-area.

Therefore the amount of leachate should be reduced to a minimum and, if possible, eliminated entirely.

The amount of leachate chiefly depends on the precipitation-surplus (the difference between precipitation and evaporation) and on the moisture-content of the tipped waste.

The moisture-content of the tipped waste can be controlled to some degree by avoiding the tipping of large amounts of waste matter with high water-content (non-dehydrated sludge from water-treatment plants, industrial sludges, etc.). The precipitation-surplus — that for Holland amounts to appr. 160 mm annually — is rather difficult to control. It should be borne in mind that the average 160 mm was calculated from the monthly precipitation-surplus data: 8 months have a precipitation-surplus of appr. 320 mm in total, and 4 months a shortage of appr. 160 mm in total. Considerable amount of precipitation that penetrated into the tipping area during dry season are not available to evapo-transpiration process.

In view of the above it can be expected that the amount of leachate exceeds remarkably the precipitation-surplus and would amount to appr. 250 mm annually.

*E.J. Mesu, L.E. van Engers—engineers, Stichting Verwijdering Alvalstoffen, Amersfoort, Utrechtseweg 223, Holland.

In order to prevent infiltration of highly polluted percolation-water two entirely different tipping-techniques have been developed.

The first technique [3], known as "Rotte Deponie", can be applied to practically uncompact waste tipping in layers appr. 2–3 m thick.

Aerobic processes, occuring in these layers due to a relatively high content of oxygen, are associated with high temperature which allows the evaporation of infiltrated rain water. During the first six months much organic matter is decomposed into H_2O and CO_2, hence the formation of CH_4 and H_2S (when the anaerobic processes prevail in the waste) is considerably lower.

After 6 months, originally loose waste is getting compact, while the next waste layers are consecutively added until final height of the tipping site is reached. Although theoretically this technique is much attractive its application, however, rises many objections due to the possible presence of rats, insects and birds as well as to the danger of fire and waste blowing away. This technique demands probably more space and is difficult to modelling. As far as we know even in Germany this technique is almost not applied either.

In the second technique, originated in the USA and in England, the waste should be best possibly compacted and kneaded by means of appropriate machins (compactors, heavy bulldozers). According to this technique the waste is pushed upward in thin layers against the tipping-front in order to make the waste-water impermeable and to help the outflow of surplus water from the surface. For this reason the top of the tipping-layer should be slightly sloping. Despite those precautions, however, precipitation-water will penetrate into the tipped waste.

In general, the tipped waste certainly has a water-absorbing ability. From SVA research [3] it appeared that in the winter-period it takes appr. 4 months before leachate comes out from a waste-layer 2 m thick. In this research no effort was made to achieve the ideal degree of compactness, nor to construct a sloping surface of the waste layer.

The SVA results, have been confirmed by foreign research (Fungaroli a.o. [2]).

Thus it may be assumed that the addition of the next tipping layer 2 m thick, performed within 4 months will result in a 4 month delay in the expected discharge of leachate. This assumption has been verified experimentally. Two test-plots, 100 m^2 each, were isolated from the tipping area in Tilburg. The formation of first 8 m high tip, started in June 1972, lasted for about 2 month. At the end of 1973 no leachate was observed. On the other test-plot the tipping up to a height of 6 m was completed within a longer period of time (in appr. half a year). Within one year appr. 20 mm of leachate, i.e. 2.7% of the precipitation has been discharged. Similar testes have been also performed in Ambt-Delden. In these tests the waste layers appr. 2 1/2 m thick were piled at appr. 6 month intervals, until the tip height of appr. 10 m was reached. The amount of leachate was also very low till the end of 1973 (3–7% of the precipitation).

A temporary increase in leachate observed any time a new waste layer was

Table 1

Pollutant loads of the leachetes from waste-tips

Stopień skażenia wyciekami ze składowisk

Waste-tip location	Parameters											
	pH	Conductance µs	COD mg/dm³	BOD mg/dm³	N-Kjeld. mg/dm³	N-N amm. mg/dm³	Cl^- mg/dm³	P total mg/dm³	SO^{2-} mg/dm³	Fe mg/dm³	Vol. acid. mg HAC/dm³	Hardness meq/dm³
HOLLAND												
Delden [4]	5.3–6.5	14350–44500	18600–74100	7700–43000	310–3125	190–2300	1114–3730	0.5–2.8	80–1470	900–3850	6400–20900	94–210
Tilburg [5]	5.8	12500	27000	14300	500	365	950	3.5	535	530	6200	100
Rotteme-ren [6]												
(a)	8.0	60400	215	5	4.8	0.4	22100	0.3	2590	< 0.05	< 10	82
(b)	7.1	14000	310	16	21.1	3.2	2975	0.9	2550	17.4	< 10	67
(c)	9.0	4000	285	62	40.0	24.2	750	0.8	507	1.5	14	5.4
(d)	7.5	88500	440	24	48.0	29.0	27700	1.1	4225	21.3	12	106
GERMANY												
(e) [7]	7.1–8.2	7700–9000		105–236		270–310	880–1640	0.48–0.92	369–558	0–6.5		
(f) [7]	7.3–7.7	3810–4940		70–88		138–190	500–600	0.22–0.68	1.65–30.0	8.0–88.8		
(g) [7]	7.5			1376		2144			324	3.79		
(h) [8]	7.45–7.65	11800–23800		15000–46000		600–3000	1700–2250		200–400	160–400		64–82
(i) [8]	7.2–8.6	3700–9800		800–2500		600–2200	1300–1850	0.82–9.1	190–270	55–210		
(j) [8]	6.2–7.8	2300–3800		6700–10300		65–110	340–1010	0.91–2.58	170–220	76–115		35–45
USA												
(k) [9]	6.49	2290		1880		18	225		50	578		
(l) [10]	5.6			32400		845	2240		630	305		

(a) Coal ash; (b) Deironed slag; (c) Slag from Den Haag; (d) Slag from Alkmaar; (e – 1) Precise information on tip location not available.

(a) popiół; (b) szlaka; (c)żużel z Hagi; (d) żużel z Alkmaar; (e – l) brak dokładnych informacji na temat lokalizacji skadowiska added [11] suggests that a substantial part of the total amount of leachate is due to water pressed out by consecutive waste layers tipped.

It seems moreover, that the 100 m^2 area of each test-plot, separated from the normal waste-tip, can be too small to come to definite conclusions. It is quite possible that some water-conducting openings allowing the penetration of leachate to soil apart from the test-plots were formed.

In order to check this hypothesis a test-plot consisting of 5 succesive 100 m^2-catch--plots, each with its own drainage leading into a control sump, was set up in the waste-tip in Maarsbergen at the end of 1973.

From the tests a tentative conclusion may be drawn, namely that a waste-tip pulled up of compact layers gives little or no percolation water in course of waste--tipping, provided that the final height is reached in a possibly short time. In order to prevent water leakage from the completed waste-tip the following precautions are necessary:

1. The top of the tipping-plot should be slightly sloped;
2. Local depressions should be avoided;
3. The waste should be covered with at least 0.80 m layer of soil;
4. The soil-cover of the tipping-site should be planted and/or seeded as soon as possible with not deeply rooted plants to prevent the penetration of roots into the waste;
5. The covering layer should be trenched or drained in order to stimulate the superficial drainage.

Eventually the top of the waste-tip can be covered with an impervious layer (e.g. synthetic foil), with black earth on it. This method, though seems to be quite efficacious, is rather expensive one. In order to avoid the damage of the foil, an appr. 0.30 m. layer of sand should be put on the upper waste-layer and followed by the foil, next by draining layer of appr. 0.30 m coarse sand or fravel and finally by 0.8–1.0 m black earth. It should be mentioned that a first consultation with representatives of the synthetic material industry took place at the end of 1973 to consider the possibilities of spraying an impermeable layer of synthetic foam on tipping-sites.

2. THE COMPOSITION OF LEACHATE

Although the amount of leachate can be reduced considerably, nevertheless it should be taken into account from the hygienic reasons.

It is certainly the case when the waste is not covered with an impermeable layer and/or when considerable amount of waste with a high moisture-content is produced. The pollution degree of leachate depends on:

a) the composition of the tipped waste;

b) the tipping-height, and hence on waste-leachate contact period;

c) the waste compactness, related also to the storage and the water-waste contact time;

d) the amount of leachate;

e) the age of the tipping-site.

The differences between the literature data and results of our investigations concerning the pollution degree should be attributed to a great extent to the factors presented above. Nevertheless, sampling and analysis techniques (especially the analysis of heavy metals) exert also a great influence. Thus a more advanced standarization is desirable. Under the present circumstances it is difficult to compare the results of various tests and definitely risky to draw any resonable conclusions.

The differences in pollutions degree of a number of leachates are shown in Table 1.

Some differences between W.German and Dutch results cannot be explained by the factors already mentioned. It is not clear namely why in W.Germany the leachate is almost always alkaline while in Holland low pH values are always stated. This would be possible if in W.Germany waste higher coal-ashes contents were stated for the leachates coming from incinerating slag characterized by high pH values. The different COD-contents can be explained neither.

It should be noticed that some american data are in better correspondence with the Dutch data than with the W. Germany ones. From the national and foreign research it follows also that the leachate pollution degree is gradually diminishing. Obviously the putrescible organic matter and soluble salts are responsible for it (Table 2).

Table 2

Effect of the tipping-site age on the quality of the leachate

Wpływ wieku składowiska na jakość wycieku

Site age	Parameters, mg/dm^3				
	COD	Cl^-	Fe	SO_4^{2-}	$N-NH_4^+$
5 months*	—	—	—	1321	694
17 months*	—	1710	—	606	458
31 months*	—	573	—	930	42
1 year**	37 600	2160	—	850	492
2 years**	46 500	2690	2065	959	700
3 years**	30 400	2165	1700	850	675
4 years**	20 100	1940	1225	—	512
2 years***	39 680	1697	5500	680	—
6 years***	8 000	1330	6.3	2	—
17 years***	40	135	0.6	2	—

(*) After Min. of Housing and Local Government [12].

(**) From SVA reports, Delden.

(***) After Hughes and Cartwright [11].

3. GROUNDWATER POLLUTION BY LEACHATE

The leachate discharged from the tipping-site enters the ground or surface water. This happens also when the top of a tipping-site is impermeable or is being made impervious. The leachate emerging at the foot of a tipping-site cannot be simply drained away to nearby surface-water because of its high pollution degree. Pumping it back (on the tipping-site itself) is of little use. The tip being made as impermeable as possible, the great part of leachate would flow of from the surface and enter the surface water. Thus its purification via treatment plant is the only solution. However, from the research by Knoch and Stegmann [9] it appears that this treatment certainly cannot be sufficient enough from the hygienic point of view. The research performed by the SVA started in 1973, seems also to confirm this conclusion. The reason is, that the collection of the leachate is not appropriate thus the groundwater pollution by the leachate should be determined. No influence of this pollution can be found in the ground water at a distance of 300 to 500 m from the pollution source at ground water flow-rate < 1.00 m/24 hrs and in prevailing types of soils (Table 3.)

Where big fissures, cracks or karsts take place in the soil (hardly ever appearing in Holland) the pollution can be manifested at much greater distance and at unexpected places. This subject was widely studed in international literature [5, 8, 18, 19]. Similar results were obtained from the SVA research conduced near the tipping-site in Delden (Table 4).

Investigations performed by the "Institute for Land and Water Management Research" at old tipping-sites (Beverwijk, Kampen, Ede) as well as by the Advisary Office Arnhem (tipping-site-Oss) show analogical results [6, 15]. Finally, it should be emphasized that experiments on ground water pollution, conducted by other authorities have shown the some results [15, 17].

Considering that the Dutch soil practically always consists of fine structured and granulated material, that the flow-rate seldom exceeds 0.30 m/24 hrs, and that pollution which is manifested at a distance of 300 to 500 m from the pollution

Table 3

Selfpurification of the leachate in soil [11]

Samooczyszczanie wycieku w gruncie

Item	Type of soil							
	"Silty clay"					"Silty Sand"		
Percolation distance, m	0	0,9	1,4	4,5	5	10	100	200
COD mg/dm^3	39680	96	52	—	7	8200	348	68
CL^- mg/dm^3	1697	309	94	17	7	287	269	64

Table 4

Ground water pollution by the tipping-site of Delden [4]

Zanieczyszczenie wody gruntowej przez składowisko w Delten

Parameters		Unpolluted ground water		Leachate		Polluted ground water*	
		min	max	min	max	min	max
Depth 3—4 m							
COD	mg/dm³	48	97	18600	74100	40	60
amm N	mg/dm³	0.17	1.43	190	2300	0.41	9.5
Cl^-	mg/dm³	46	89	1114	3730	255	529
P	mg/dm³	0.05	0.15	0.5	2.8	0.05	0.16
SO_4^{2-}	mg/dm³	94	194	80	1470	6	26
Fe	mg/dm³	1.8	40.0	900	3850	4.0	28.3
Conductability	μs	477	622	14350	44500	1492	2285
Depth 6—7 m							
COD	mg/dm³	27	36	18600	74100	46	52
amm N	mg/dm³	0.09	0.75	190	2300	0.1	5.0
Cl^-	mg/dm³	39	52	1114	3730	726	900
P	mg/dm³	0.05	0.12	0.5	2.8	0.06	0.2
SO_4^{2-}	mg/dm³	16	50	80	1470	0	44
Fe	mg/dm³	1.6	8.6	900	3850	4.1	7.3
Conductability	μs	568	622	14350	44500	2790	3230

* At the distance of 12 m from the waste-tip.

source by a small increase in the Cl-content, one can came to conclusion that the leachate discharged from tipping site is relatively pollutant-free; provided that the tipping takes place above groundwater level. It is important to know what processes are responsible for this intensive purification of the leaking water in the soil. Neverless, the possibility of the delayed occurance of pollution from the source can not be excluded in the future.

Much research in this field has been conducted in W.Germany. Golwer, Matthes and Schneider [5] have distinguished three zones in the soil a reduction zone under and in the vicinity of a tipping site, a transitional zone adhearent the tipping--site, and finally — an oxidation zone. The reduction zone is characterized by the absence of dissolved oxygen due to advanced nitrate and sulphate reduction and to the presence of Fe^{2+} and ammonium ions. In this zone organic matter is oxidized by microbiological activity, nitrate and sulphate acting as hydrogen acceptors. The formation of havy metal sulphides is observed with iron sulphide being prevailing. All these sulphides being practically insoluble the metalions are to a high degree retained under the tipping-site. In the transition and oxydation zones the precipitates of iron hydroxide, manganese-hydroxide and other hardly dissolving components (e.g. Cu,Pb,Zn,As, etc. fluorides, phosphates and $CaCO_3$) are formed.

Apart from this precipitation and microbial decay the adsorption of cations on clay, humus hydroxide as well as on bacteria slime plays a pronouced role. The latter factor is of particular importance in case of soil complexes with a slight adsorption ability (sandy soils, cristalline soils). The bacterial slime is continually regenerated through the breakdown of the organic matter. For this reason certain chemical wastes should be tipped together with municipal waste (with high content of organic matter).

To verify the hypothesis the investigations on the tipping-site in Rijssen were conducted in 1973. The precipitates of iron and manganese carbonates and sulphides were found in the experiment; other characteristic phenomena being not observed due to not sufficiently aged tipping-site.

FINAL REMARKS

From the so-far performed investigation it follows that further research should be concerned with the tipping of certain chemical wastes in order to find out whether the same phenomena will occur in this case.

ZANIECZYSZCZENIE WÓD GRUNTOWYCH PRZEZ WYSYPISKA ŚMIECI

W pracy omówiono zależność między sposobami składowania odpadków a ilością zanieczyszczonego odcieku pochodzącego ze składowiska, stanowiącego potencjalne zagrożenie dla wód gruntowych. Autorzy nie zalecają, ze względu na higienę i zagrożenie pożarowe, techniki składowania polegającej na tworzeniu 2-3-metrowych nie ugniecionych warstw odpadków, ulegających następnie półrocznemu aerobowemu rozkładowi i ugnieceniu. Znacznie korzystniejsza jest metoda składowania polegająca na ugniataniu odpadków przez buldożery na stokach wysypiska. Zwartość tak utworzonych warstw oraz spadek ich powierzchni uniemożliwiają infiltrację wód opadowych oraz powstanie większych ilości zanieczyszczonego odcieku. Ilości te nie przekraczają 2,7-7% wód opadowych.

Autorzy podali sposoby rekultywacji hałd wysypiskowych zabezpieczające wody gruntowe przed nadmiernym zanieczyszczeniem. W dalszej części pracy omówiono czynniki wpływające na ilość zanieczyszczeń w odcieku oraz przedstawiono odpowiednie dane pochodzące z kilkunastu wysypisk holenderskich. Scharakteryzowano także strefy i przebieg samooczyszczania się odcieku oraz oceniono efektywność tego procesu w gruncie, zależnie od typu gleby. Scharakteryzowano stopień zanieczyszczenia wód gruntowych zawartymi w odcieku zanieczyszczeniami.

VERUNREINIGUNG DER GRUNDGEWÄSSER DURCH MÜLLDEPONIEN

Zwischen den verschiedenen Methoden der Müllablagerung und der Sickerwassermenge besteht unzweifelhaft eine enge Beziehung was ohnehin eine Gefährdung der Grundgewässer darstellt. Aus hygienischer Sicht und wegen der bestehenden Brandgefahr, befürworten die Verfasser die Rottedeponie nicht. Auf der Rottedeponie werden die Abfälle in 2- bis 3-m hohen Schichten ohne sie zu verdichten abgelagert, was in einem Zeitraum von etwa 6 Monaten die aerobe Rotte begünstigt. Erst nach Ablauf dieser Zeit wird der Müll verdichtet.

Die Verdichtung des Mülls unmittelbar nach seiner Lieferung mit Hilfe von Kompaktoren scheint vorteilhafter zu sein. Durch gute Verdichtung der einzelnen Schichten ist die Versickerung der Niederschläge sowie die Entstehung grösserer Sickerwassermengen wesentich kleiner. Die gemessesen Sickerwassermengen betrugen in einem Fall nur 2,7 bis 7% der Niederschlagsmenge.

Die Verfasser formulieren Methoden und Richtlinien zur Rekultivierung von Mülldeponien, die u.a. das Grundwasser vor einer übermässigen Verunreinigung schützen sollen. Im weiteren Teil des Beitrages sind die Ursachen der verschiedenen Sickerwasserkonzertrationen untersucht worden. Die entsprechenden Zahlewerte stammen aus mehreren holländischen Mülldeponien. Hierbei sind die Zonen der Verunreinigung, das Selbstreinigungsvermögen des Sickerwassers sowie dessen Verlauf im Boden (je nach Bodenart) charakterisiert und beurteilt worden. Weiterhin ist auch der Verunreinigungsgrad der Grundgewässer mit Inhaltsstoffen der Sickerwässer analysiert worden.

ЗАГРЯЗНЕНИЕ ГРУНТОВЫХ ВОД МУСОРНЫМИ СВАЛКАМИ

В работе обсуждены зависимости между способами захоронения отбросов и количеством загрязненного оттека из мусорного полигона. Этот оттек представляет собой потенциальную опасность для грунтовых вод. Техника захоронения, заключающаяся в образовании не умятых слоев мусора толщиной 2—3 м, подвергаемых затем — в течение полутора года — аэробному разложению и уминанию, не рекомендуется по гигиеническим и противопожарным соображениям.

Гораздо выгоднее представляется метод складирования, состоящий в уминании отбросов бульдозерами на склонах свалочного полигона. Состав образованных таким образом слоев, а также склон их поверхности предотьращаю проникновение осадков и возникновение более значительных количеств загрязненного оттека. Эти количества не превышают 2,7-7% воды от осадков.

Излагаются способы освоения отвалов, защищающие грунтовые воды от чрезмерного загрязнения. В дальнейшей части работы обсуждены факторы, влияющие на количество загрязнений в оттеке, о приведены соответствующие данные о свыше весятке отвалов в Голландии. Охарактеризованы также зоны и процесс самоочистки оттека. Кроме того, оценена эффективность этого процесса в грунтовой среде в зависимости от типа почвы. Обсуждена также степень загрязнения грунтовых вод веществами, находящимися в оттеке.

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