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REFLECTIONS ON GROUNDWATERPOLLUTION BY TIPPING OF SOLID WASTES

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ABSTRACT

In the following paper is stated that groundwater-pollution caused by waste-tips is of very little significance. That is when is token that the waste is never dumped in open surface-water nor below the groundwater-table and that the subsoil does not contain gravel-layers nor bear "karst"-phenomena or open fissures.

Besides it appears that the leachate from a tip contains most pollution during the first years after tipping and that after two or these years this pollution diminishes gradually.

The microbial breakdown of the waste and the herewith formed products play a big role in the purification-processes in the soil. Organic material is needed for the development of this microflora. This induces to the opinion to combine the tipping of certain types anorganic (chemical) waste with urban waste (high organic content) rather than to tip it separately.

INTRODUCTION

Often air-, water- and soilpollution are mentioned in one breath, as if they were comparable matters. This, without distinguishing that air and water are consumptive goods, whereas this is not the case with the soil – at least not for man and animal. The original topsoil under a tip does not serve anymore as food-store for plants. As a matter of fact, the vegetation withdraws the food from the topsoil down to at most two metres.

So, if the topsoil under a tip is polluted, this has not any influence on the plant-growth.

Not until, as a result of this soilpollution, the groundwater and, through this, the surface- and drinking water are polluted, can there be question of disturbance of the original environment.

So, the question whether a refuse-dump causes soil-pollution is hardly relevant and must be replaced by the question whether a refusedump causes groundwaterpollution.

Such groundwaterpollution can only originate when:

a. the refuse is dumped into the groundwater, contaminating this water directly,
b. the percolationwater from a tip comes into contact via the soil with the groundwater and mixes with it.

As concerns the first case: this is so plausible that when one should really worry about groundwaterpollution, it is really inconceivable that tipping in open water still takes place and even is still admitted by responsible authorities. It is to be hoped that the law on the disposal of solid wastes, which still will take some time before being operative, will contain prohibiting orders for this.

THE QUANTITY OF PERCOLATION-WATER

In the following only groundwaterpollution will be discussed as far as it is a result of tipping solid wastes above the groundwatertable.

As remarked before, groundwater can only be polluted when the percolation-water reaches this groundwater. A first possibility to prevent groundwaterpollution is to take care that no percolationwater originates. For this there are several techniques, such as covering the subsoil with an impermeable layer, compressing the dumped wastes to a highdegree together with filling the tip quickly up to the final height, covering the top of the dump with a impermeable layer, etc. These systems, however, all have more or less great financial and technical consequences, and none of them are literally and figuratively guaranteed waterproof.

If wastes with a high water-content are tipped (e.g. sludge from sewage-plants or from industry) the quantity of percolation-water will increase considerably. It would lead too far afield for the scope of this discussion to study the systems for limitation of percolation-water too deeply. Here may suffice the statement that, if one or more of these systems is emplaced, the quantity of percolation-water – under Dutch climatological circumstances – has to be reduced to at least 10% of the annual precipitation.

POLLUTION OF PERCOLATION-WATER

The degree of groundwater-pollution is determined not only by the quantity of percolation-water that reaches the groundwater per time-unit, but also by the degree of pollution of the percolation-water. In theory it ought to be

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TABEL 1

		Delden	Tilburg	Emscher-bruch (1)	Braun-schweig (2)	U.S.A.		
						I (3)	II (4)	III
COD	mg/l	40.000	25.230	2.230	12.000	7.150	39.700	30.300
pH		5,5-6,2	5,6	6,8-7,8	6,8-7,8	5,6	n.v.	n.v.
NO_2	mg/l	0	<0,03	0	0	n.v.	n.v.	n.v.
NO_3	mg/l	0	<1,0	20	0	n.v.	n.v.	n.v.
NH_4-N	mg/l	600	360	45	900	845	n.v.	480
Org.N	mg/1	n.v.	n.v.	20	n.v.	550	n.v.	465
Cl	mg/l	4.000	890	615	n.v.	2.240	1.700	2.350
SO_4	mg/l	1.000	440	69	n.v.	630	680	730
P	mg/1	6,0	n.v.	1,4	n.v.	n.v.	n.v.	29
Conductivity	µS	30.000	10.000	7.900	n.v.	n.v.	n.v.	n.v.
Fe	mg/l	2.300	575	n.v.		305	5.500	2.640

TABEL 2

Hughes en Cartwright (1972)

	2 yr. old	6 yr. old	17 year old
COD	39.680	8.000	40
Cl	1.697	1.330	135
Fe	5.500	6,3	0,6
SO_4	680	2	2

Min. of Housing and Local Government (1961)

	after 5 months	after 17 months	after 31 months
NH_4-N	694	458	42
Cl	n.b.	1.710	573
SO_4	1.321	606	930

Delden (SVA)

	after 1 year	after 2 years	after 3 years
COD	37.600	46.500	30.400
Amm. N	492	700	675
Cl	2.160	2.690	2.165
pH	5,6	5,4	5,5
SO_4	850	959	850
Gel. verm.	21.500	31.100	23.450
Fe	n.b.	2.065	1.700
PO_4	n.b.	7,8	0,56

possible to give a forecast of this pollution, when it is known how much and what kind of wastes has been dumped and how much precipitation penetrates into the dump, but unfortunately we still know practically nothing of the chemical composition of refuse and definitely nothing of the leachable part of it. The only thing we know is that refuse contains practically everything that our society produces and consumes. Moreover the expectation that in future we may perhaps calculate to a certain extent the composition of percolation-water, is considerably reduced by the statement that the composition of percolationwater, originating from various dumps shows enormous differences, without a reasonable explanation for it can be given. In some cases these differences may be traced back to differences suchas in sampling, in age of the tip, in composition of the tipped waste, in climatological circumstances, etc., but this is not always the case.

Table I shows a number of analyses of percolation-water. Especially the differences in C.O.D. and pH are surprising and it is remarkable that the Dutch analyses correspond more with the American than with the German ones.

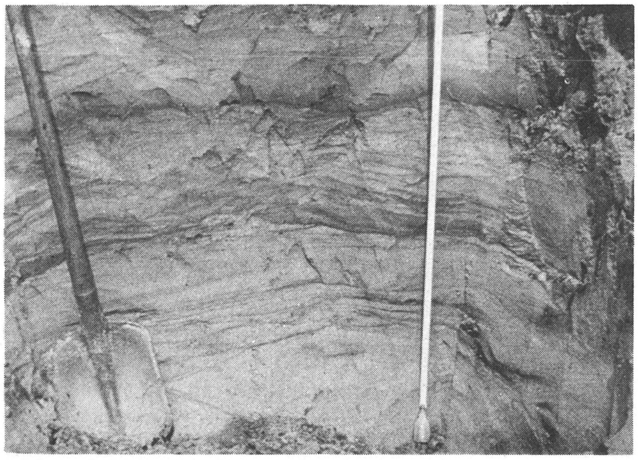
As concerns the heavy metals, there is not any reasonable relation to be fixed with the foreign analyses. Generally speaking, no heavy metals are found in Germany in percolation-water, which is undoubtedly caused by the higher pH found there. Also the Fe-content in German percolation-water is only one percent and sometimes even less than one promille from what is found in Delden. Probably this is also connected with the differences found of the pH. Besides, a correct analysis of the content in heavy metals in this heavily polluted water is not so simple, and great differences in analysis-results must often be blamed to differences in the preparation of the sample to be analysed. Standard regulations and standardised preparation of these samples would be very desirable (Fonds, van den Eshof, 1973) In any case the percolation-water coming from the refusedump in Delden is very heavily polluted and as such it would be a good starting-point for studying eventual pollution of the groundwater.

But before discussing groundwater-pollution something must be said about the pollution of percolation-water in its dependance on time.

It appears from own observations, as well as from observations in other countries that the percolationwater-pollution decreases in proportion as the tip gets older.

As table 2 shows, evidently the heaviest leaching occurs during the first years, naturally from the easier soluble compounds. The picture of Delden is not yet as striking as the other cases, but still there clearly was a top about two years after the tipping of the waste.

At the moment the pollution has returned to the level of the first year, and the trend of a further decrease is obviously continuing.



FIGUUR 1

TABEL 3

		groundwater, pure	groundwater polluted	"pure" percolation water
COD	mg/l	20	70	40.000
amm. N	mg/l	0,7	1,5	600
Cl	mg/l	65	450	4.000
tot. P	mg/l	⟨0,05	⟨0,05	6,0
Sulfate	mg/l	40	10	1.000
Conductivity	µS	600	2.400	30.000
Fe	mg/l	10	10	2.300
Hg	µg/l	0,1	⟨0,1	⟨0,5
As	µg/l	21	1,5	160
Pb	µg/l	65	⟨5	20
Cu	µg/l	26	7	45
Zn	µg/l	70	80	30.000
Cd	µg/l	⟨1	⟨1	⟨1
Cr	µg/l	50	5	120
Ni	µg/l	20	5	1.050
Co	µg/l	20	5	10

THE POLLUTION OF GROUNDWATER

Since 1970 "Stichting Verwijdering Afvalstoffen" has carried out considerable research on the pollution of groundwater, especially at the controlled tip in the community of Ambt-Delden. Tipping was started there in 1969 on soil consisting of fine to coarse sand, in which appear locally thin and interrupted loam-layers. The original humous topsoil has been removed down to appr. 0.40 cm. above the average highest groundwatertable and this soil is used to cover the refuse.

The groundwater-flow moves from east to west, with a slope of appr. 15 cm/100 m. and at a rate of appr. 3 to 4 m. monthly.

At the downstream-side of the dump, at a distance of 5-12 m. from the dump's toe there are a number of filter-tubes, from which the groundwater can be sampled at various depths down to 15 m. At a depth of 15 m. there is a thick loamy-layer, extending under the entire area of Twente, and which can be expected to be practically impermeable. Possible groundwater-pollution, therefore, must be found in one or more filter-tubes.

It is surprising, that we can hardly recover anything of the pollution carried along by the percolation-water, as table 3 shows. This would lead to the supposition that we are measuring at a spot along which no groundwater contaminated with percolationwater flows. This, however, is obviously not the case, as appears from the still greatly increased Cl^- content in the filters. $C1^-$ is an ion, which remains mobile under practically all circumstances and forms an ideal tracer for contamination-research.

Although we are dealing with groundwater that is contaminated with percolation-water yet, the quality of that groundwater, with the exception of the Cl^- content is hardly influenced. The C.O.D. is highly reduced, also the ammonium-nitrogen; the sulphate-content is even lower than in the up-stream groundwater and the most remarkable thing is that the content of heavy metals is lower in the downstream groundwater than upstream!

One should – just ignoring the Cl^- content – almost be tempted to say that when one wants to have clean water one should start a waste-tip!

Moreover these observations don't stand alone. By order of the S.V.A. a geo-electric research was carried out by the Adviesbureau Arnhem, a research that was repeated by the "Dienst Grondwaterverkenningen TNO" in November 1972 and again in August 1973.

From these surveys, which among other things served to determine in what direction the pollution had made the greatest progress, pollution is not found at a distance of more than 30 m. from the tip. The surveys of the "Dienst Grondwaterverkenningen TNO" in August '73 did not show any progress of the pollution-line with regard to the surveys in 1972.

Research at a tip in Tegelen, which in 1971 came into publicity, because large quantities of cyanide should have been tipped there, showed a cyanide-content just beside the tippingsite, which even though it might be slightly raised, had hardly exceeded the limit of determinability.

Research at a dump near Exloo (Csengo) showed the following pollution just near the dump:

conductivity	µS 771
Cl^-	mg/l 120
Ammonium	mg/l 0,86

Also in foreign literature similar observations are made. Hughes and Cartwright (1972) give the following surprising results:

Percolationwater after having passed through

		silty clay			silty sand				
distance:		0	0,90	1,40	4,50	5 m	10	100	200 m
COD	mg/1	39.680	96	52	–	7	8200	348	68
Cl	mg/l	1.697	309	94	17	7	287	269	64

On the other hand Exler (1972) found a Cl^- contamination caused by the presence of a waste tip at a distance of 3000 m from this tip (appr. 239 mg/l).

As Cl^- can only be reduced to an acceptable content through dilution, the Cl^- content is dependent on the available quantity of groundwater, with which the percolation-water is diluted. In addition Exler found that this Cl^- load progressed to 3000 m in an ever narrowing area. This area was at 3000 m distance appr. 100 m wide. Exler's result differs greatly from what was found elsewhere, but one must take into account that at the spot of his research the soil consisted of fluvioglacial deposits with much gravel. A soilanalysis showed that alle grain-sizes from fine sand to stones from 10 to 20 cm occurred. Moreover the speed of flow of the groundwater there was appr. 5 – 10 m/day, which is much higher than in normal circumstances in Holland. This kind of soil is most unsuitable as a site for a tip.

From the bare fact, that up to the present, under reasonable circumstances and when certain precautions are observed, never any groundwater-polution of any significance has yet been found may, however, not be concluded that this pollution will never occur. As far as the reassuring results are only based on observations, this may not be considered as a basis to recommend tipping of waste, and in no case tip waste containing noxious components. Quite rightly several authors (a.o. Schrammeck (1973) have made a stand against such conception.

The observations in themselves are therefore not sufficient. Only an explanation of the observed phenomena will be a basis for the decision to either tip the waste or not.

In looking for this explanation one naturally tries to find what the purifying function of the soil is, what underlying processes can be found and to which degree these processes can be influenced either favourably or un favourably.

In the first place dilution in the groundwater plays an important rôle. Per time-unit, however, dilution does not influence the absolute quantity of the leached and polluting components. In the second place dispersion and diffusion must be mentioned. In literature these physical processes generally are treated as being of slight significance.

The third purifying action of the soil is based on filtration of the solid components, and eventually also bacteria from the percolation-water. This action is of restricted significance, as was shown by Knoch and Stegmann (1971) filtering percolationwater through a virus-filter.

A fourth possibility for purifying the polluted water is the adsorption-capacity of clay and humus with regard to cat-ions. Through this the heavy metals can – in as far as they appear as cat-ion in the solution – be kept to a very great amount within a limited distance from the dump. In this connection also the phenomenon phosphate-fixation should be mentioned, to which some clays offer possibilities. A special form of adsorption can also be operative for the cat-ion's K and NH4. In certain cases they are - just as phosphate – built into the crystal-lattice. Especially on the heavy clay-soils this can take place in important amounts.

Finally precipitation in insoluble form of the contaminating components must to be mentioned. One should consider that at the bottom of the waste dump an anaerobic and highly reducing environment develops. This implies that the sulphate-ion is reduced to sulphide through microbial action. As is known, sulphide forms insoluble compounds with practically all metal-ions, which presumably, precipitate directly under the dump forming thin layers in the soil.

Not only does sulphide form practically insoluble compounds, this is also the case with carbonate. When there is sufficient organic matter in a tip Co_2 is formed and so carbonate.

With these "tools" present, the risk of heavy metals in solution is almost reduced to nil, as these compounds are fixed to stay in the soil under the dumping-site.

This theory, or perhaps rather hypothesis about precipitation is difficult to judge on its merits so far as one has not the opportunity to follow in practice what is really happening under a dump. It seldom happens that this opportunity presents itself, but last summer between Markelo and Rijssen a dump was partly moved away for the construction of the motorway E-8.

This opportunity was used to study the subsoil, which consisted of moderated coarse pleistocene sand.

Fig. 1 clearly shows that some layers are formed, the upper one greenish, the lower one black. These layers have been analyzed and, indeed, in them considerable more metals than in the un-coloured material have been found. But, there is the question whether these metals were present in the material earlier. Per annum e.g. the Fe_2O_3- content could increase by some tenths of promilles, and the tip inquestion has only been used since appr. 6 years; then the contents of some percents – as found – are far too high to have been precipitated in this short time.

However this may be, in comparable soilprofiles on which no dump had been situated such coloured layers have never found. Analysis of these layers did show a striking similarity between the number of milli-equivalents of anions and the number of milli-equivalents of cat-ions (see table 4).

TABEL 4

	anions (milli-equivalents)				cations (milli-equivalents)				
	CO_3^{2-}	S^{2-}	SO_4^{2-}	Sum	Ca^{2+}	$Fe^{2+}(Fe^{3+})$	Mn	Mg	sum cations
green band	4,6	afw.	afw.	4,6	1;39	0,81	0,21	0,88	3,29
black band	40,8	7,6	afw.	48,4	24,1	27,6	1,41	1,42	54,5

This does show that the theory of sulphide – and carbonateforming, and as a result precipitation of metals is not due to a fiction. Besides clear indications are given for this in the handbook "Minerals, Solutions Equilibria" (Garrels, Christ, 1965). It needs mentioning here, that the research and the studying of the data from this waste-dump have not yet been completed. Shortly and individual report will appear, which is to be drawn up by S.V .A. and Stiboka.

A marginal note is that the anions, the sulphide and the carbonate must always be present to make precipitation possible. However, they can only be present when sulphur as well as carbon are present and also the microflora that enables the conversion into sulphide and carbonate. This implies that organic matter, that is to say domestic waste must be dumped and no excess of chemical anorganic wastes which would influence the microflora unfavourably. The logical result of this would be that when in future chemical anorganic waste matter will have to be tipped, it is preferable to do this in dosed quantities and mixed with the normal domestic waste.

So called "Sonderdeponieën" as are constructed in West-Germany and where exclusively anorganic wastes are tipped are potentially more dangerous than the normal controlled tips, where the anorganic wastes are treated together with the domestic waste.

CONCLUSION

In the foregoing it was assumed that the waste is not dumped into the groundwater or into open water, but always above groundwatertable. The percolationwater coming free at the sole of the dump then can be the only cause of subsoilwater-pollution.

The percolation of water can be considerably reduced in quantity through technical measures. If one does not or cannot trust this reduction and has to assume that an essential quantity of pollution penetrates into the soil then it appears that mainly as a result of adsorption, precipitation and dilution the groundwater at some distance from a dumping place is hardly polluted.

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COD (Chemical Oxygen Demand) indicates the quantity of oxygen, used during oxidation with potassiumdichromate, by substances dissolved in the water. The COD is a measure for the pollution of the water with organic material.