UPGRADING SMALL MUNICIPAL DUMPSITE INTO AN ENVIRONMENTALLY SUSTAINABLE LANDFILL RATIONALLY - REAL CASE STUDY

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ABSTRACT

Many positive characteristics distinctive for disperse type sanitary landfills can be preserved within certain physically controlable settings when old municipal open dumpsites are to be remediated and upgraded. This can be done in the way that the resultant landfill interferes with the environment very much in accordance with a sustainable development ideal. At the same time, investments and operational costs can be reduced when compared with other investment opportunities. Sound geotechnological assessment is needed in order to avoid any hazzards connected with the application of leachate recirculation technology.

Key words: sustainable landfills, low cost landfills, landfill slope stability analysis, leachate recirculation.

AJDOVŠČINA LANDFILL SITE DESIGN, TECHNOLOGY AND OPERATIONAL PRACTICES

The waste disposal technology applied in Ajdovščina landfill is not a new. At the first glance it may look similar to the former 'dump and cover' way of landfill. The operator's idea namely was to imitate some selected features typical of many disperse type landfills (like the low degree of input compaction, utilization of large quantities of sanitary cover in the form of the free of charge local soils derived from excavations, abundant final capping with some permeable, fertile soils), together with the related positive impacts on the environment (relatively low contaminant levels of the untreated leachate already during the operational phase, fast mineralization of the waste, posibility to recirculate and accumulate large quantities of water in a short time making use of the highly porous landfill body) and on the social environment (relatively low cost of the waste disposal). Unacceptable and hazardous conditions coupled with negligence were often observed on the open dumpsites, not to mention adverse impact they imposed to the surroundings during the time they were active and soon after their closure, because the concept of engineered barriers did not apply to them. This is the most probable reason responsible for their positive characteristics being overlooked so easily (at least until recently). Ajdovščina landfill absolutely differs from the 'open dumps', since it belongs to the containment, controled category of waste disposal sites, which is the same category to which, e.g., dry entombment landfill belongs.

The science of hydrogeology is another pool from which the ideas for the Ajdovščina low cost, sustainable landfill design and technology have been derived. Hydrogeology in relation to waste disposal has always been considered only from the aspects of landfill siting and the risk for groundwater to become contaminated by the leachate. From this aspect, very reliable data about the effectiveness of the geological clay barrier underneath the Ajdovscina landfill to attenuate and/or prevent subterranian transport of dissolved pollutants exist. However, the landfill body itself, is a geological body of antropogenic origin from the recent quaternary age. It has its own structure and texture, and its own unsaturated and saturated zones with the related permeabilities and storage capacities. Hydrogeological methods of research were applied to the already existing landfill body in order to acquire quantitative data on the hydrogeological parameters. This was done using the same methodologies employed when exploring ordinary geological bodies, which are often much larger, more heterogenous and more difficult to investigate and understand. The purpose of the hydrogeological measurements was/is to provide data for the calculation of different water balance scenarios and to make use of the landfill body volume of pores and voids for transient leachate water storage during the peakflow hydrological conditions consequently preventing the possible escape of excess contaminated water into the environment.

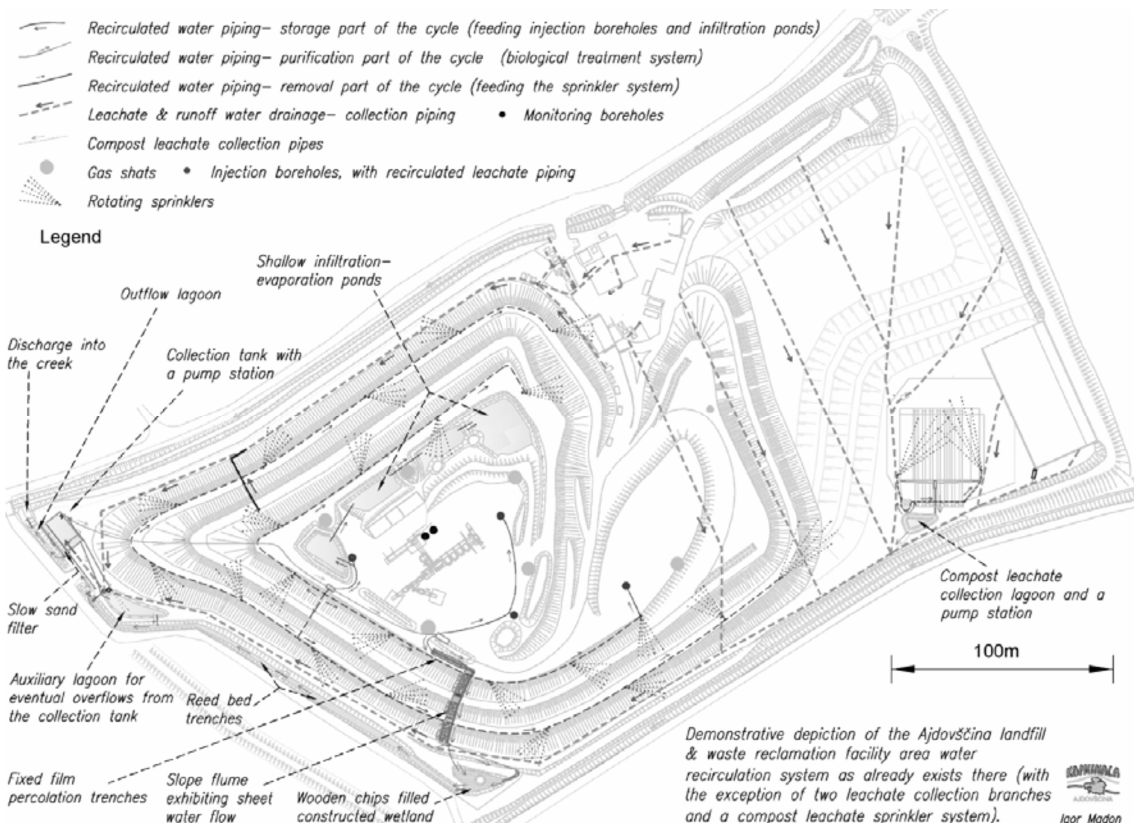

Figure 1.: Ajdovščina landfill and waste reclamation facility area water recirculation system. Demonstrative situation. Gas shafts are also depicted.

Some 35 years ago, when a location for the actual MSW landfill was chosen by the Ajdovščina municipality council, science was not involved at all. By chance, however, the site appeared to be geologically an ideal one. Below the thick clay layer underneath the Ajdovščina landfill there is nothing but a dry, marly flysch aquiclude. Oddly enough, if new landfill had to be erected somewhere in such a geological environment today, it is still very much possible that applicative hydrogeological science would be ignored and an artificial synthetic liner be requested to be laid down on the bottom of it. Such conservative approach seems sometimes to be preferred by the designers in the name of protecting the environment, which is however a false perception. Such stance rather appears to be in collision with the sustainable development principles. Namely, limited resources would be wasted for no environmental benefit, at the same time being lost to protect the environment where really needed.

Geotechnical aspects have been considered as well, because many differences exist between the Ajdovscina sustainable, low cost landfill and the ordinary, dry entombment type of a landfill, such as 1) loose compaction of the disposed off waste rather than a dense one, 2) considerable water fluxes into the whole landfill body (particularly during the peakflow hydrological conditions) rather than weak percolation through the waste body within the active cell only and 3) accelerated rate of biodegradation and the resulting fast settlement rate and not vice versa. It was found that the applied method of landfilling allows the application of plots of ground within the young, just a few years ago closed, still settling parts of the landfill to be used for different waste treatment related purposes, even for setting up outdoor facility for mechanical treatment of the MSW, refuse-shreding, sorting and similar waste materials processing, sparing the environmentaly sensible space.

Many simple and low cost solutions and technologies were implemented at the Ajdovščina landfill site and waste reclamation center there, deliberately making good use of relative advantages the location is offering. Simple-technology units are usually just constituent parts of some larger, interconnected, complex and more advanced environmental systems which were systematically designed exploiting multidisciplinary knowledge. Here is a compilation of such a systems:

- water recirculation system used for leachate and polluted run-off water removal by means of evapotranspiration and equalization of uneven fluxes throughout the hydrological year (the later implemented by performing infiltration from the shallow ponds constructed on the surface of the old parts of the landfill and by performing injection of recirculated water into the wells and utilizing packers in order to distribute the water uniformly accros the landfill body), as well as to accelerate the rate of waste mineralization (Figure 1.),
- gravitationally driven biological water purification system, chiefly designed for purposes of adequate abatement of nitrogen, TOC, turbidity and iron; it is an auxiliary, low-flowrate, parallel branch to the water removal circuit, diverging part of the water out of the landfill complex disposing it of into a nearby creek; purpose of the system is to flush persistent compounds into the environment at low concentrations, thus preventing them to infinitely accumulate within the water circuit which would happen if the water was continually taken out only by means of

evaporation; such compounds happen to be non-degradable, non-volatile and very soluble, like e.g. the chloride ions),

- composite system for disposal of biodegradable monofractions of waste and wastewater treatment plant derived sludge which reasonably exploits sinergies which exist when landfill and compost (biodegradable waste pre-treatment) facilities are operated jointly,
- low cost gas collection and treatment system.

GEOTECHNOLOGICAL CONSIDERATIONS AND THE RELATED APPLICATIONS

Landfill slope stability in the context of the implemented leachate recirculation technology

In order to clarify any concerns related to leachate recirculation technology and the eventual slope instability in the Ajdovščina landfill case, an appropriate stability analyses based on a sound geotechnical judgement were performed, i.e.:

- realistic minimum shear strength parameters values of the Ajdovščina disposed off MSW were acquired in situ by performing backward slope stability analyses on an artificially prepared water saturated slope, using Bishop's method of slope stability calculation and utilizing Galena 5.0. software,
- subsequently, forward slope stability analyses were run (including by considering unrealistic, total saturation conditions) using the most conservative (i.e., minimum) parameters values derived from backanalyses as well as using realistic parameters values derived from dr. Kolsch's large volume tension and shear tests[1] and making use of his waste mechanics theory,
- additionally, water balance calculations were chequed once again in order to prove that large scale saturation of the landfill body can not occur at all.

The experimental slope was prepared on the top floor of the landfill by excavating 15 m long, 5.5m deep and 1 m wide trench into the two years old, loosely compacted waste parallelly and nearby to the foothill of a 5m high screening berm made from fairly compacted clayey soil (see the setting around the failure surfaces 1 and 2, Figure 2.). The zone of the supposed sliding body was systematically watered from the infiltration pond until the condition of full saturation was attained (zone of perched subsurface water was formed). Buildup of the water column was monitored in the 6 nearby boreholes penetrating the whole body of the landfill. As predicted, the leachate level on the bottom of the level remained to be almost unaffected. The trench need not to be watered separately, since it was readily filled up by the water deriving from the infiltration pond, percolating through the waste layer and oozing out of the trench sidewall (Figure 2.). The berm was continually wetted, too, using the already installed drip irrigation system there (perforated pipes) in order to increase the weight pressing on the sidewall of the trench and to decrease cohesion of the clayey soil within the body of the berm itself. Water was pumped out of the trench intermittently (once per week) in order to expose the slope to dynamical stresses. At the same time, convergence measurements were performed between the two trench opposite walls, on the level of one meter above the ground, on three crossections (approximately once per three weeks) in order to assess magnitude of deformation before the eventual collapse would have happened. However, in spite of the efforts, the slope did not brake down. Thus, back calculated slope stability analysis could not have given us the actual values for shear strength parameters. Cohesion – angle of shear resistance curve(s) apparteining to the defined factor(s) of safety were acquired instead. For the lowest factor of safety (FoS = 1), 17 kPa value for cohesion and 24° for the angle of shear resistance were derived. This would mean that the actual shear parameters values are bigger, probably much bigger, but certainly not smaller than these minimum acquired ones.

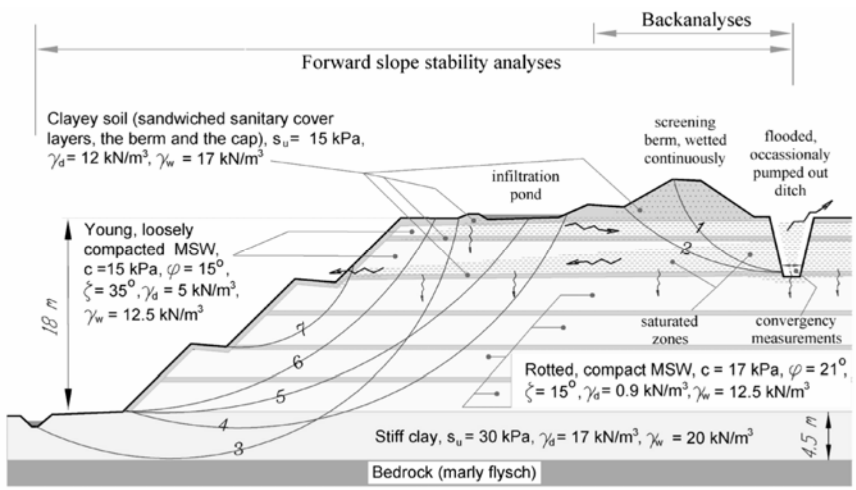

Figure 2.: Demonstrative crossection accross the Ajdovščina landfill depicting geometrical setting for running slope stability analyses. Material shear strength properties for MSW used for forward analyses were derived from two sources, i.e. 1) from backward slope stability analyses and 2) by realistical estimation based on prof. Kolsch’s large volume tension and shear experiments and considering the related waste mechanics theory. The later shear parameter values are demonstrated in the picture together with the correspondent materials unit weights.

Convergence measurements in the lower part of the trench demonstrated relatively small cumulative deformations during the course of four months after the trench excavation. Deformations clearly have not reached the maximal values yet, but the slowdown is obvious (see Figure 3.). Tension tests performed on large scale samples of MSW[1] demonstrated that large specific elastoplastic deformations ($\varepsilon \approx 30$ ppt) have to be achieved before the whole tensile strength (~fibrous cohesion) of the material would be activated. Considering geometry of the potential slip body above the failure surface No. 1 (behind the trench sidewall Figure 2.) and considering the deformations already achieved (as well as those yet to be expected regarding to the trends which can be approximately predicted from the Figure 3.), the fibrous cohesion did not appear to be activated in full yet at all. By another words, the actual cohesion of the landfilled MSW in Ajdovščina landfill is much greater than is the minimal cohesion value derived from the back analysis there.

Tensile strength deriving from fibrous fractions and foils within the MSW expressively contributes to the overall shear strength of the burried waste. Waste mechanics theory and practice which considers this essential fact was developed by prof. Kolsch in Braunschweig University and is recommended to be used in practice by the German Society of Geotechnics. Fibrous cohesion is a strength parameter which is not a constant of the material, but rises linearly with the applied normal stress instead (similarity with the frictional part of the shear strength is obvious). Total cohesion which characterises MSW thus consists from the ordinary cohesion (which is independent from the normal load, usually very small) and the fibrous cohesion (which is usually very large in the range of loads normally encountered in the landfills). The internal angle of tensile stress 'ξ', derived from large volume tension tests is the coefficient needed for the calculation of fibrous cohesion, i.e. $c_{fibrous} = \sigma \cdot tg\xi$. By another words, the fibrous cohesion is increasing with depth of the landfilled waste. When the waste management activity called 'mechanical-biological pretreatment of the MSW' will become implemented to the full in order to fullfull the requirements imposed by the regulations, the cohesive strength of the residual MSW to be landfilled will decrease considerably. Dramatic failures of landfills largelly occured just in locations where reinforcing fibrous materials for some reason appeared to be almost absent or due to the long-lasting subsurface smouldering fires[2], weakening the shear strength along the potential sliding planes and at the same time providing voids for water percolation there.

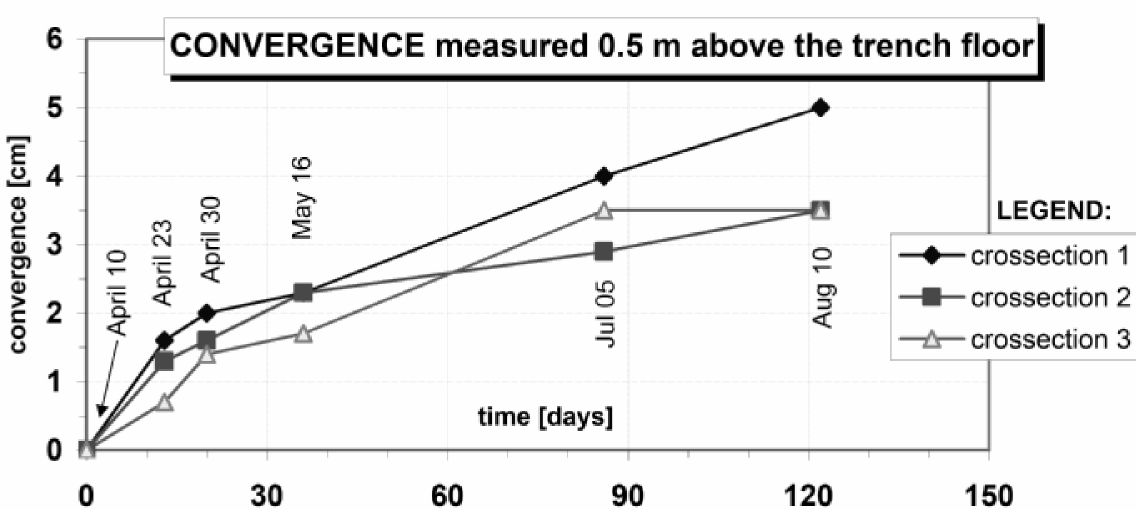

Figure 3.: Convergence measured in the trench from Fig. 3 in the period of four months from the time it was excavated. Measurements will proceede for at least some more months before the trench will be refilled with the material.

Considering very reliable geotechnical parameters data derived from laboratory experiments performed on high-volume samples [~4 m^3] of well defined different types of MSW[1], slope stability analyses were carried out on one demonstrative side slope of the

Ajdovščina landfill as well as on the already presented experimental slope at the top of the landfill.

Phreatic surfaces were considered in two ways: 1) realistically and 2) extremely conservatively, i.e.:

Ad 1): Realistic phreatic surface was drawn on basis of measurements from the boreholes during the high waters conditions implementing intense leachate recirculation.

Ad 2): Unrealistic, extremely conservative phreatic surface, coincident with the surface of the landfill itself; this would be the worst, only theoretically possible scenario, i.e., as if the buildup of the pore water pressure appeared into existance as a continuous water column from the botom to the top of the landfill.

Results from all of the forward stability analyses are compiled in the Table 1. From the results derived from the performed slope stability analyses it can be concluded that the Ajdovščina landfill operator can proceede with the activities related to the leachate recirculation technology already in use for some years now. After all, loosely compacted, 20 m high heap of waste can not become throughout saturated with water in no reasonable way.

Table 1: Values of the calculated Factors of Safety (FoS's) related to the seven failure surfaces depicted in Figure 2., and four combinations of the input data sets using two methods of strength parameters values selection and two ways of phreatic surfaces considerations.

Failure Surface Number → Conservativeness in regard to the selection of shear strength parameters values and in regard to the position of the phreatic surface ↓	**1**	**2**	**3**	**4**	**5**	**6**	**7**
I	2.10	2.66	1.44	1.69	2.30	2.69	3.74
II	1.35	2.10	1.10	1.29	1.54	1.52	1.99
III	1.72	2.37	1.10	1.13	1.51	2.05	3.03
IV	1.00	2.21	0.76	0.70	1.35	0.75	1.26

I …. Realistic shear strength parameter values + realistic phreatic surfaces

II …. In situ derived conservative shear strength parameter values + realistic phreatic surfaces

III …. Realistic shear strength parameter values + complete saturation of the sliding body

IV…. In situ derived conservative shear strength parameter values + complete saturation of the sliding body

Settlement of the landfill in the context of the utilization of the closed parts of the landfill for other waste management purposes

The waste disposed off in the Ajdovščina landfill is not dense, since heavy, efficient compactors were never used. Originally, compaction was not practised because of the lack of financial means. Now, loose compaction happens to be integrative part of the technology in order to make good use of many short and long term environmental benefits which can be win from the porous waste body, at the same time reducing operational and capital costs.

Settlement appears to be much biger in loosely compacted landfills and those practising leachate recirculation than in other types of landfills. Additionally, settlement rate is much faster there. This facts too, can be perceived as beneficial, since some of the compaction job is done by the settlement process itself instead of by using the machine and the area can be reutilised relatively quickly. Secondary settlement, also called creep is the one which is important. It occurs due to gradual changes in the particulate structure of the material, including as a consequence of biodegradation processes taking place within the body of waste.

How much the surface of certain closed part of the landfill will settle from a given time onward it depends on very many factors. After all, the lower layers of waste can already be relatively old and mineralized, which is the case in the large portions of the Ajdovščina landfill. Another characteristic fact regarding the closed part of the Ajdovščina landfill is, that during the course of remediation of the old dump in 2003 some 20 thousands m^3 of the already partly mineralized waste appeared to be transposed from the peripheral parts of the dump to its central part, where some 2 hectares of the surface area already reached the design height, which means, that part of the landfill was capped and closed down.

In the remediated and closed part of the Ajdovščina landfill there was no need to wait for the settlement to calm down for more than two years due to already mentioned reasons. The settlement rate decreased from 35 cm/year in 2005 to some 13 cm/year in 2006 and it remained almost the same in 2007. However, the settlement rate regression trendline can not be drawn reliably yet, so the predicton about the final settlement value could not have been elaborated (which is not a too much important issue, anyway). Which is really important is the fact that the settlements appear to be very uniform. It is because such favorable geotechnical circumstances that a semimobile outdoor plant for mechanical treatment of MSW and similar waste materials processing could have been placed in this particular closed area of the landfill in the years 2005 and 2006. The plant is intended to be upgraded with some additional machines in the years to come. Some similarity with separation plants which operate within the frame of quarry facilities is obvious – namely, mineral processing plants, too, often appear to be placed in some old, already exploited parts of the quarry.

The machinery and the sorting cabin are supported by the steel frame construction. The structure can be fast dismantled if needed (similar mode of proceeding as scaffold dismantlement). The uprights with base plates are screwed on the reinforced concrete pad foundations. The pad foundations are of small dimensions since the bearing capacity of the MSW is large, as can be derived by its high shear strength parameters values. The differential settlements are so small and so slow (see Figure 4.), that the levels need to be adjusted only once per year, which is done by laying additional steel plates of the proper thickness under the existent base plates.

CONCLUSIONS

Small municipal company in western Slovenia managed to transform its open dump into a landfill for non-hazardous waste in a limited amount time and despite of the shortage of available resources. The operator utilized a pretty unorthodox approach in order to be successful. This means the applied technology and mode of operation should assure the cost of operation would not be excessive and the residents would not be charged with some over-inflated waste disposal fees. Such type of a landfill can be called 'sustainable, low cost sanitary landfill'.

Interestingly, socio-economic issues have been highly ignored until recently through out the developed world, although social sensitiveness and economic performance already represent two of the three main original pillars supporting the entire concept of sustainable development. Quite the opposit, environmental concerns have had an absolute priority in regard to the design and operation of sanitary landfills, sometimes leading to technologically sophisticated and expensive solutions just in order to acquire relatively trivial environmental benefits. Such deviations could have thrived due to relative ease in obtaining funding into the sector in certain cases and because the waste management related ideas have not yet solidified.

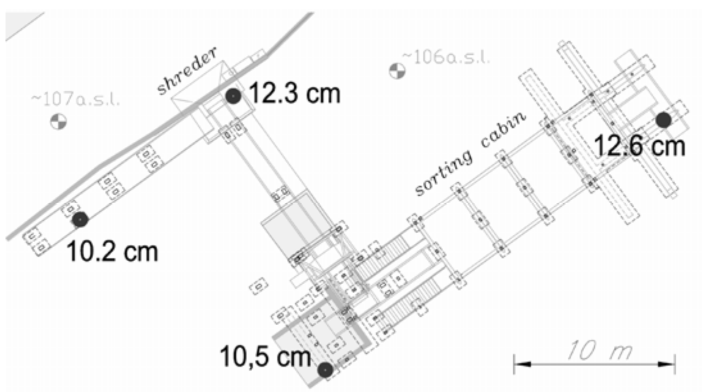

Figure 6.: Situation of the pad foundations on the top of the 20 meters high Ajdovščina MSW landfill bearing the outdoor waste processing plant and its steel frame supporting construction. The depicted values in centimeters represent settlements originating between April 2006 (i.e., the time when the plant was erected) and May 2007. Only the values for four foundations which are lying the most appart from each other are presented. As can be seen, differential settlements are on the order of 2 cm/year only. This is happening just few years after the closure of this part of the landfill.

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