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SUSTAINABLE REDEVELOPMENT OF HAZARDOUS WASTE LANDFILLS – THE HAZARDOUS WASTE LANDFILL OF SOVJAK (RIJEKA, CROATIA) AS CASE STUDY

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Sustainable landfill redevelopment is a concept that proposes restoration of a degraded environment, social benefits for the community and economic benefits for possible investors. In the scope of this study a conceptual framework for sustainable redevelopment is presented and applied as a post project analysis in the case of the hazardous waste landfill of Sovjak. A comparative representation of the results obtained by the introduction of the concept of sustainable redevelopment is provided. The comparison of the achieved results shows that sustainable redevelopment will provide social benefits to a community living in close proximity to the hazardous waste landfill; threats to human health are eliminated, property values are restored, and the project presents social progress, economic growth and the possibility of employment. Furthermore an overview of the present state of the environment influenced by the hazardous waste landfill of Sovjak is described. Emphasis here is given to contamination of groundwater, due to the specific karst terrain in which the landfill is located, and its threat to human health.

Key words: sustainable redevelopment, hazardous waste landfill, groundwater contamination, karst area

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Održiv razvoj u saniranju odlagališta otpada je koncept koji nameće obnovu narušenog okoliša, društvenu dobrobit i gospodarske beneficije za potencijalne ulagače. U ovom radu predstavljen je održiv razvoj kao koncept i primijenjen na rezultate dobivene analizom odlagališta opasnog otpada Sovjak. Usporedba dobivenih rezultata ukazuje da je uvođenjem pojma održivog razvoja sanacija odlagališta opasnog otpada dobila novu značajku. Održivi razvoj pruža boljitak zajednici koja živi u bliskoj okolici odlagališta opasnog otpada; prijetnje javnom zdravlju bi time nestale, cijene nekretnina bi porasle. Projekt predviđa i društveni napredak, gospodarski rast i povećanje stope zaposlenosti. Rad pruža pregled trenutnog stanja okoliša i utjecaj opasnog otpada na odlagalište

Sovjak. Naglasak je stavljen na zagađivanje podzemnih voda upravo zbog specifičnosti krškog terena na kojem se nalazi te kao takav predstavlja prijetnju ljudskom zdravlju.

Ključne riječi: održiv razvoj u saniranju odlagališta otpada, odlagalište opasnog otpada, podzemne vode, krš

INTRODUCTION

Sustainable remediation relates to undertaking projects that deliver social progress, protect the environment, use natural resources prudently and maintain economic growth and employment (SULFANET, 2007). One of the most sustainable concepts is recognizing which materials are 'suitable for use' and that, in any case, should not be considered waste. Whether a project is sustainable can only be judged in the context of a project. Beyond that, it is the balance between social benefits, environmental impacts and the cost of the project that defines whether something is sustainable. Redevelopment can also provide resources for long term monitoring and maintenance, environmental remediation, and restoration of the ecological balance, provide financial rewards for the developer and benefits for the community. Former and abandoned landfills sites may also provide areas for necessary or desirable services in densely developed urban areas.

The method in this particular case study is applied to the closed hazardous waste landfill of Sovjak near Rijeka, Croatia. The complexity in this case lies in the particular geographic area in which the landfill is located. The landfill is situated in a karst pit and is at present contaminating the groundwater. The hazardous waste landfill of Sovjak was used from 1955 to 1990 when it was closed. The landfill was used for disposing of various hazardous materials predominantly from the local refinery; acid tar, produced as a by-product from the production of lubricants, motor oils, and similar products, where sulphuric acid was used in the process of acid kerosene refinement. After 1966, the refinery commenced the process of the industrial modernization of its production facilities and the landfill was used to store other industrial wastes. This included acetylene sludge from shipyards, coke coal tar, waste oils and bunkers from repairing shipyards, tank bottoms from refinery and power plants, various spent solvents, cutting oils, waste lube oils, oily wastewaters from various sources and damaged and dangerous goods from the Customs Services. No tracking system for waste depositing was ever implemented and no pre-treatment was ever performed on the industrial wastes stored in the landfill of Sovjak. According to the tender documentation we can presume that there are at least 250.000 m^3 of hazardous waste at the site.

All studies regarding the hazardous waste landfill of Sovjak were conducted on the basis of solely site remediation. Remediation techniques were chosen on basis of environmental preservation and cost effectiveness. Little or no consideration was given to the social aspect of the remediation of the contaminated site. All conducted studies based their social benefits on the environmental restoration of the site, removal of the active source of harm to human health, and increase of property value for the county in which the site is located. The concept of sustainable

remediation in this case would have to cover, in addition to the hazardous waste landfill of Sovjak, the adjacent landfill of Viševac. Taking in consideration both landfills, the total available surface, of approximately 90000 m^2, would be large enough to proceed with a sustainable remediation landfill project.

CASE STUDY

Site Description of the Hazardous Waste Landfill of Sovjak

The hazardous waste landfill of Sovjak was used from 1955 to 1990 when it was closed. According to a topographic map from 1966 the surface elevation in the landfill was 303.5 m. No measurements were taken prior to this and the depth of the original pit is not known. According to statements from the local population it was at least 30 m deep with two deeper pockets at the bottom of the pit that would have increased the total volume of the landfill. From calculations based on these estimations the pit has a minimum volume of 92.000 m^3 and a maximum volume of 150.000 m^3 (not taking into account the unknown volume of pockets at the bottom of the pit) (ECOINA, 1999).

The maximum rainfall is expected in the autumn, of about 200 mm/m^2, and the minimum in the summer season, of approximately 65 mm/m^2. These data are relevant to the calculation of the seepage of contaminated water into the ground at the site location.

Because of the specific area where there are multiple winds blowing from different directions, wind monitoring has to be referenced to micro locations at the site. After monitoring the effect of temperature on site it was concluded that it does not influence the degradation of the organic substances present. That is influenced solely from precipitation (ECOINA, 1999).

The hydrological aspects of the location are characterized by the lack of surface waters. This is a direct consequence of the porous type rock, a geological characteristic of the area, which allows the water to pass through except in the discharge area near the coast. In the ground the conditions of flow are complex and diverse. The horizontal speed of water is great, according to measurements taken, from 1 to 10 cm/s in kilometric distances. With heavy rain fall the flow of water intensifies. Water quality measurements were taken in periods of low, medium and high waters and results indicate a constant negative effect on the groundwater flow in the area.

According to existing data the level of underground water flow on the site is 10–20 m above sea level, that is, at the depth of 270–280 m. Tests were preformed by releasing dye at Klanjska Rječina, located about 10km north of the landfill, and this proved the connection with groundwater flow across the sites to the coastal area in the city of Rijeka.

The flow of groundwater at the location is confined to an area of about 6000 ha. Taking into account the same amount of rain water, the flow produces about 5 million m^3 at the sources near the coast. If an assumption is made that the site filters approximately 50.000 m^3/year we get a factor of dilution of 1/1000. This is a sim-

plified analysis but it indicates the potential pollution of ground water as a consequence of dumping chemicals into the landfill. If the pollution is present in 100 mg/l (ppm) it should result in concentrations of 100 µg/l (ppb) in the groundwater, which is below the level of detection (ECOINA, 1999).

Karst in the Context of the Case Study

The area of interest in this case study is the Adriatic drainage basin which spreads from the Slovenian boundary on the north toward the south to the Zrmanja River. There are several drainage systems, and the first to the north, and the one of interest in this case study is the catchment area of the spring in the city of Rijeka. This is the largest and most valuable drainage system in the northern Croatian coastal zone. The city of Rijeka, which is the largest Croatian port, with a population of approximately 200.000, owes its development in this region to the abundance of potable water, which is discharged from the above karst drainage basin. On a drainage surface of approximately 465 km^2 an average of up to 3000 mm of rainfall is deposited, unfortunately unevenly distributed within the seasons. The drainage basin gives about 2600 l/s of water to the water supply in the zone of permanent discharge and about 1400 l/s in the intermittent spring Riječina. The water potential of this drainage basin is the basis of the present and future water supply of the northern Croatian littoral area and the northern Adriatic Islands (BIONDIĆ, 2000).

METHODS

A post project analysis has shown that by applying only the methods specified in the project documentation, restoration would be achieved solely in an environment restoration plan. By introducing the concept of sustainable remediation, the results show a holistic approach that covers all three components crucial to a redevelopment project, the ecological and environmental, the economic and the social component.

Methods Proposed For Project Site Remediation

All remediation technologies proposed by the project have undergone an analytical process which determined the best possible solutions; the combination chosen has the best practical application, according to previous experiences, and minimizes the detrimental effects on the environment.

All possible remediation technologies considered are ex situ methods and represent the final solutions for the materials located in the landfill. Besides the treatment of the waste, the location will also need to be treated, in particular the ground and rocks surrounding the pit; this would prevent the material that can not be extracted from liquefying and draining into the ground. In total, six solutions were chosen for the landfill remediation and five for the remediation of the surrounding rocks and ground. The actions chosen below represent the best possible remedies (DAMES & MOORE, 1998)

Remediation techniques to be used for the hazardous waste landfill of Sovjak are

- Waste water treatment
- Removal of hazardous waste with dredgers
- Stabilization of extracted materials using lime
- Use of stabilized material as part of the cover layer in the Viševac landfill

Remediation techniques to be used for soil and rock remediation are

- Fill the remaining pockets with concrete to stop the material from draining into the ground
- Use inert type materials to fill the pit
- Cap the surface with a surface layer

Sustainable Remediation

Sustainable redevelopment is promoted through a strategy composed of three broad elements:

- Identify and characterize (potential redevelopment sites)
- Prioritize, provide incentives; and publicize (redevelopment opportunities) and;
- Facilitate (redevelopment project) (THE DUTCH FOUNDATION FOR SUSTAINABLE LANDFILLING, 2008)

To be sustainable, a landfill redevelopment project must be protective of the environment and preferably restore or at least enhance the ecosystem compared to the existing degraded state created by landfill activities. The economic and social components of sustainable redevelopment are strongly interrelated. No matter how profitable a redevelopment project might be, if there are no social benefits, the project is not viable. Furthermore, social (and environmental) benefits may drive an economically non-advantageous redevelopment project. The social and environmental benefits of a redevelopment project can justify a municipality providing financial incentives to a private developer for the project to move ahead. Financial incentives from a municipality could include an establishment of a private/public partnership or some other type of cost sharing (SULFANET, 2007)

Without public acceptance, any landfill redevelopment plan is at risk. An integrated community communications plan that addresses the technical, environmental, economic and social aspects should be an integral part of any landfill redevelopment program. A public awareness raising campaign and communication plans are crucial for achieving public acceptance (SULFANET, 2007).

RESULTS AND DISCUSSION

According to the tender documentation we can presume that there are at least 250.000 m^3 of hazardous waste at the site. A visual examination of the pit reveals that the walls are black indicating that the volume of waste has varied over the years. The blackened area is 1.5 m above the current level of waste in the landfill.

This leads to the conclusion that a part of the liquid hydrocarbons from the surface have drained into the ground through the fractures in the walls of the pit and that the current volume of waste is less than 250.000 m^3. It can therefore be concluded that approximately 100.000 m^3 of dangerous waste has drained into the ground.

Examination works at the site included drilling of soil at both Viševac and Sovjak landfills, taking water samples, gas monitoring (Viševac) and laboratory analyses of the collected samples.

From an examination of the site (1987) it was determined that the waste had formed four separate layers. The surface layer was around 1m thick and it floated on a layer of waste waters about 2m thick. Below the water there could be found a layer of soft tar approximately 8 m deep and then a formation of acid tar that closed the pit from below.

The four separate layers can be distinguished by their physical and chemical characteristics and for that reason the four layers are to be considered as four separate units (ECOINA, 1999).

Tab. 1. Results of a test performed at the Sovjak landfill in 1987

Layers	Depth %	Water %	Sulphur %	pH	Energy Value
Oil	0–1 m	12–15	2,2	3,9	40 MJ/kg
Water	1–3 m	100	–	6,6	–
Soft tar	3–11 m	25–35+	4–6	<1–2,5	9–25 MJ/kg
Acid tar	11 m+	–	7–9	1	25 MJ/kg

Another examination was undertaken in 1997. This consisted of drilling in three separate locations to an approximate depth of 18 m (first layer of acid tar) (ECOINA, 1999).

Tab. 2. Results of a test performed at the Sovjak landfill in 1997

Layers	Depth %	Water %	Sulphur %	pH	Energy Value
Oil	0,05–0,1 m	4	1	5,3	39 MJ/kg
Water	1–(3–6) m	100	–	6–11	–
Soft tar	(3–6)–11 m	14–24	0,6–1,2	6–11	22-36 MJ/kg
Acid tar	11 m+	1–8	2,6–3,3	3–4	22-24 MJ/kg

The significant difference from the tests of 1987 is the thinning of the surface layer indicating that liquid hydrocarbons have drained into the ground.

In 2002 new samples were taken to monitor the state of the hazardous waste landfill of Sovjak (ČISTOĆA, 2003).

Tab. 3. Results of a test performed at the Sovjak landfill in 2002

Layers	Depth
Oil	0 – (0,05 – 2,5) m
Water	0 – 3,5 m
Soft Tar	3,5 – 11 m
Acid Tar	11 m +

The state of the landfill in 2002 is very different from that found in 1997. The greater difference represents the reappearance of the liquid layer of hydrocarbons in the estimated amount of 2000–6000 m^3. The structure of the new layer of hydrocarbons differs from that of 1987, for the new layer has a high viscosity characteristic that was not present in the sample taken in 1987. The water layer in 1987 was acidic, while the sample taken in 1997 showed the water to be mildly acid with tendencies to turn alkaline, while the sample taken in 2002 showed the water to be alkaline (ECOINA, 2003). The new state could require a modification in the remediation techniques chosen for the site. The new layer of hydrocarbons could be used as alternative fuel in thermo energetic complexes.

From the results presented it was proven that due to the karst terrain in which the landfill is located, the chemical composition, and the degradation of the waste, the landfill is indisputably affecting the environment. In particular, it contaminates the groundwater and consequently causes harm to human health.

A number of factors are important in understanding and interpreting these results. The studies conducted on the hazardous waste landfill took into account scientifically all relevant factors; emphasis was placed on the chemical composition of the waste in the landfill and on the specific karst terrain in which the landfill is situated. Air pollution was taken in consideration in the early stages of site remediation before the hydrocarbons seepage in the ground, wind pattern were taken in consideration on the macro and micro scale; quantities of rainfall were established in the summer and winter period. Groundwater flows were analyzed and tests to establish flow patterns were conducted; the depth of the water table was established, as were the direction of water flow and the velocity of aquifers at low, medium and high water tables. The state of the pit itself prior to a landfill was mostly ascertained from the statements of the local population.

However, all the studies were conducted solely on the basis of site remediation. Remediation techniques were chosen on basis of environmental preservation and cost effectiveness. Little or no consideration was given to the social aspect of the remediation of the contaminated site. All conducted studies based their social benefits on the environmental restoration of the site, the removal of the active source of harm to human health, and increase of property value for the county in which the site is located.

Social Benefits – Hazardous Waste Landfill Sovjak

Redevelopment of an old and abandoned landfill site provides opportunity for significant profits for the developer by virtue of the reduced property values and prime locations associated with these sites in urban areas. Community benefits from landfill redevelopment can include provision of necessary or desired services or amenities, creation of jobs, direct and indirect generation of revenue, and aesthetic enhancements. Furthermore, financial incentives and cost and risk sharing through public/private partnership may be required to promote landfill redevelopment where there are desirable environmental and/or community benefits but financial returns alone do not provide sufficient motivation for privately funded redevelopment. Potential incentives may include grants, loans, financial guarantees, providing indemnification to developers, and other types of public/private partnership for cost and risk sharing (SULFANET, 2007).

However, a consideration of sustainable redevelopment comprising three components (environmental, economic and social), will change the approach to site remediation of the hazardous waste landfill of Sovjak drastically. The primary emphasis should be on the possibility of waste re-use. One of the studies did imply that the hydrocarbons present in the pit could be re-used as an energy source. The idea was presented to the Croatian oil company 'INA', but was rejected. According to the literature, no offers to other possible users were made (ČISTOĆA, 2003).

Emphasis should be placed on site re-assessment and a new plan of action should be set in motion. The first thing that should be taken into account is the possible uses for the site after remediation. This will influence the decisions taken on methods for site remediation. Obviously, this plan of action must also take into account the active landfill of Viševac. The remediation of both landfills will provide a greater area for development and with no more active or closed landfills the value of the property and the attractiveness of the community will increase.

The economic calculations on this subject were done on basis of site remediation. For the landfill of Sovjak and the remediation of the ground and rock a cost of approximately $22 million was estimated; and an additional $5 million sum is needed for the remediation of the landfill of Viševac. Part of the cost would be covered by the contributors that used the landfill in the 35 years the landfill was in use. The amounts would be stipulated by establishing a monetary value for percent of waste and defining a lump sum based on records of waste contributions to the landfill of Sovjak. The rest would be covered by government grants and possible credits from various projects. Part of the costs, not including the ones provided by the landfill contributors, could be covered by investors, land development companies and stakeholders. Cost-benefit analysis, considering social benefits and environmental boundaries, should be done and the best option taken as a possible and realistic plan for the landfill remediation (DAMES & MOORE, 1998).

Considering all the factors, the problem of the hazardous waste landfill of Sovjak will be solved with maximum emphasis on environment remediation and restoration, with minimum economic strain on the community while maximizing the ben-

efits the community would get from closing both landfills; this implies improving the quality of life, removing active threats to human health, new possibilities of employment, and new contents to the community.

CONCLUSION

This article has attempted to demonstrate the importance and significance of site restoration for the hazardous waste landfill of Sovjak and give a new perspective for site remediation through the model of sustainable landfill redevelopment. Unlike other projects foreseen for the hazardous waste landfill of Sovjak, this principle would attempt to achieve sustainable development while providing social, environmental and economic benefits for the community. Sustainable landfill redevelopment is a project which shows that investment in landfill restorations can be incremental as compared with the mere site remediation projects that were used so far for landfills.

Further calculation would have to be made but the principle of sustainable redevelopment demonstrated a clear and indisputable advantage over the simple ecological site remediation that has been planned. An indisputable fact is that the site will be subject to environmental remediation and restoration; the social and economic benefits should be ramified on the basis of the options received for land use after the site has been cleaned and restored.

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SAŽETAK

Održivi razvoj u saniranju odlagališta otpada – studija slučaja odlagališta opasnog otpada Sovjak (Rijeka, Hrvatska)

I. Ribić

Zatvoreno odlagalište opasnog otpada Sovjak locirano je u prirodnoj vrtači krškog područja u razvijenoj urbanoj zoni općine Viškovo. Nalazi se na visini od oko 300 metara i približno isto toliko iznad razine podzemnih voda, s obzirom na karakter kraškog područja i raspukline u stjenovitim naslagama, za pretpostaviti je da postoje povlašteni putevi migracije oborinskih voda iz odlagališta u podzemlje. Prvih godina jama se koristila za odlaganje kiselog gudrona, a kasnije i za odlaganje drugog industrijskog opasnog otpada.

Pretpostavlja se da se u jami Sovjak nalazilo otprilike 250.000 m^3 opasnog otpada, a prema zacrnjenu bočnih stijenki može se zaključiti da je dio otpada zajedno sa oborinskim vodama dreniran direktno u podzemlje putem fraktura i raspuklinama na stjenkama jame. Pretpostavlja se da je oko 100.000 m^3 opasnog otpada infiltrirano u podzemlje.

S obzirom da je općina Viškovo svojim razvojem kao rubno područje grada Rijeke dosegla izgrađenost do neposredne blizine odlagališta, te takoreći ne postoji potreban šumski zaštitni pojas koji bi odjeljivao odlagalište od urbane zone. Imajući u vidu gustoću naseljenosti predmetne općine kao i potencijalnih razvoj na kraškim površinama potrebno je odrediti metodu sanacije koji bi omogućila razvoj općine na ekonomskom, ekološkom i društvenom aspektu.

Metodom održivog razvoja saniranja odlagališta opasnog otpada projekt sanacije dobiva novu perspektivu. Održivi razvoj pruža boljitak zajednici koja živi u bliskoj okolici odlagališta opasnog otpada; prijetnje javnom zdravlju bi time nestale, cijene nekretnina bi porasle. Projekt predviđa i društveni napredak, gospodarski rast i povećanje stope zaposlenosti.