Remediation of degraded sites by means of mature biostabilized waste: environmental risk analysis

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Abstract

The aim of this study is investigate the use of RBM (Italian acronym of Mature Biostabilized Waste) for environmental remediation of degraded sites. This case study is a limestone ex-quarry, used in the 1980s for the disposal of municipal solid waste but not totally filled. The actual situation of the landfill and an environmental remediation scenario will be studied and compared by a tier 2 risk assessment. The tools used in this paper are the softwares ROME release 2.1 and LandSim release 2.5.

The results show that in the remediation scenario by use of RBM, both the Cancer Risk (CR) and the Hazard Index (HI) decreas. The results of LandSim's simulations show that the risk for the groundwaters turns out also attenuated.

1. Introduction

Coherently with EU principles, the Italian legislation on waste has long been oriented to the creation of a system of "integrated management" aimed to achieve the dual result of the economic valorization of the resource waste and to protect environmental quality.

The present work has as main objective the environmental recovery of an abandoned quarry. Because in the basin, which is the main body of the landfill, the waste has been laid just about regularly, occupying almost uniformly only a part of the volume available, in accordance with the provisions of DC 296/02[1] [1], in the present study has been evaluated the feasibility of using RBM for the regularization of the geomorphology of the quarry.

[1] *"The wet fraction Mature (RBM), can be used as a coating material of waste, even stabilized but not matured, with a depth not exceeding 15% of the waste to be coated, or for land reclamation, environmental remediation, etc.., in the latter case, after the acquisition under Articles. 27 and 28 of Decree 22/97, to identify the maximum amount that can be used in a specific situation. "*

It was therefore drawn up a risk analysis first on the current scenario of the site contamination and then the post environment recovery scenario.

2. Report

2.1 Site classification

The site under study corresponds to a former quarry located in the city of Giovinazzo (near Bari) in an area of predominantly agricultural use. Subject to the inherent morphological constraint related to the quarry itself, it discloses no further geomorphological elements relevant to the present work. The area has been used for about a decade as storage for municipal solid waste (MSW), as effect of interim orders and/or extraordinary emergency order, not saturating the entire volume of the basin (Fig. 1). Recently the site has been affected by uncontrolled and illegal storage of various kinds of waste.

In the area of interest groundwater is in pressure, 110-120 m from the ground level.

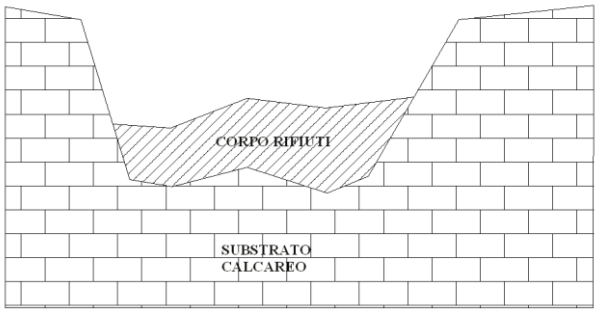

Fig.1 – *Schematic diagram of the current scenario of the site*

The results of the characterization plan allow the classification of the site as potentially contaminated because it was found exceeding the TCC (threshold concentration of contamination) in the subsoil and groundwater compared to Table 1. B of the Italian Legislative Decree 152/06.

2.2 Methodologies and software

The Risk Analysis (RA) is a scientific and systematic methodology to assess the state of contamination in environmental matrices in terms of quantification of the current risks and/or potential for humans and the environment.

For carcinogenic substances the risk (CR) is the probability of incremental cases of cancer during lifetime, caused by exposure to a substance, as compared to the usual conditions of life. For non-

carcinogenic substances, however, the Hazard Index (HI) expresses how much the exposure to the substance exceeds the tolerable or reference dose.

Therefore it was carried out a site-specific RA of Level 2 for the current scenario and for the supposed scenario of environmental rehabilitation by the use of RBM, following the specific guidelines issued by APAT [2] and [3]. The scenario of remediation (Fig. 2) provides for the filling of the former quarry with RBM and then a final cover consisting of two layers of drainage material with a layer of compacted material and a layer of topsoil on top for the renaturalization of the area.

As operational support at this stage the code ROME vers.2.1 of APAT for the health risk analisys, and the software LandSim vers.2.5 of Golder Associates for the receptor-groundwater resource were used, although the water appears to have been impacted at the hydrological upstream of the site, and a direct impact on this matrix due to the leachate from the landfill is to be excluded.

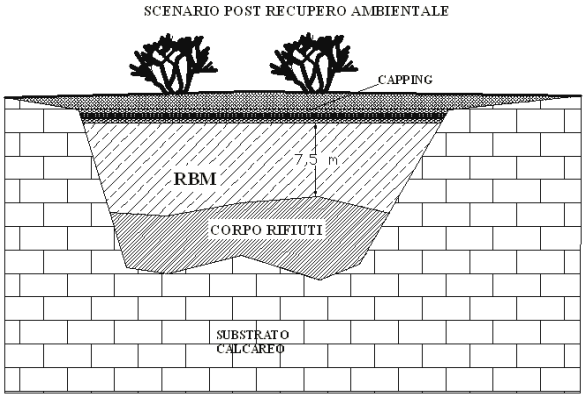

Fig.2 – *Schematic diagram of the supposed post environmental recovery scenario with RBM*

Thus a conceptual model of the site (CMS) was formulated. For the health risk analysis off-site agricultural workers are the only sensitive targets.

With regard to the present scenario it is assumed that the receptor interacts with the site in terms of contamination detected in the environmental characterization, according to the exposure pathways to be active in CMS: inhalation of dust or vapors from soil surface and inhalation of vapors from deep soil in outdoor environments.

For the CMS in the post recovery scenario, the presence of multilayer surface capping and the underlying layer of RBM eliminates virtually the possibility that the receptor can interact directly with the contaminated matrix. The active route of exposure compared to the current scenario, therefore, are those for outdoor inhalation of vapor phase contaminants from the surface soil and deep soil. Among the selected index contaminants is canceled the contribution of heavy metals (except mercury), as pollutants which can evaporate at room temperature.

In order to quantify the additional risk that might arise from the use of RBM, has been developed further RA which was similar to the previous scenario but with the use of filling natural terrain instead of RBM.

2.3 Characterization of a RBM sample

The sample was drawn from a characterized biocell of the biostabilisation plant operated in the basin BA/2.

A primary factor in the characterization of the RBM is the biological stability, considered as the measure of the decomposition degree of organic matter contained in readily biodegradable organic matrix [4]. Because of its indirect measurement, in this experiment was determined by the Dynamic Respiration Index (DRI) applying the method A of technical specification UNI/TS 11184:2006 [5].

In order to develop an RA in the post-recovery scenario, it was also determined on the sample of RBM all the investigated contaminants in the plan for site characterization, both for the waste of the landfill and for soil samples.

For the sample tested biostabilisation rejection was not found any excess in respect of Table 1 with the TCC Tab.1 Col. B of the Legislative Decree 152/06.

2.4 Results and discussion

The results of risk analysis are presented in graphic design made on the basis of the output of the software and ROME vers.2.1 LandSim vers. 2.5.

2.4.1 Health risk analisys

The current scenario is characterized by a total carcinogenic risk (CR) (sum of partial risk for each route of exposure for each index contaminant) of 4.98 E^{-07}, a value less than the legal limit of reference equal to 10^{-5} ([6] [7]).

The dominant contribution is due to PCBs that contribute with a CR equal to 4.67 E^{-07} (value not far below the limit of 10^{-6} set for individual risk) to about 93% of the total CR in particular according to the exposure route outdoor inhalation of vapor from deep soil.

Under the same conditions, the Hazard Index (HI) assumes a value of 5.83 E^{-01}, also not far from the limit of 1, caused mainly by light hydrocarbons and mercury as contaminants, and the surface and deep soil vapors inhalation in outdoor environments as route of exposure.

However as regards the supposed post recovery scenario, the total carcinogenic risk (CR) goes down of approximately two orders of magnitude, going to 4.81 E^{-09}. The significant CR decrease is mainly attributable to the route of exposure vapor inhalation from deep soil in outdoor

environments, as can be seen in Fig.3. In the post-remediation scenario, unlike the current one, the CR is entirely due to the concentration of PCBs (CRTOT = CRPCB) in deep soil (waste).

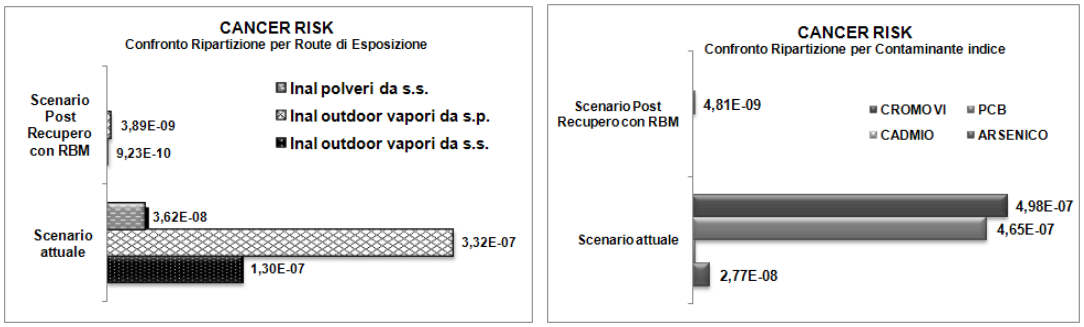

Fig. 3 – *Carcinogenic risk (CR) divided by route of exposure and index contamination*

The graphs in Figure 4 are related to non-carcinogenic risk (HI). For the HI, in the post recovery scenario in the quarry there is a reduction of about two orders of magnitude (5.83 E^{-01} to 2.21 E^{-03}) and are canceled the contributions of some active index contaminants in the current state of contamination of the site.

As already mentioned, in order to quantify the incremental risk resulting in the use of RBM in the environmental restoration project has been designed with the software ROME further RA examination of the recovery scenario similar to the previous but by employing natural soil, a matrix free of contamination. As can be seen from the summary graphs shown in Figure 5 only negligible alteration of the risk rising from natural ground to RBM was found.

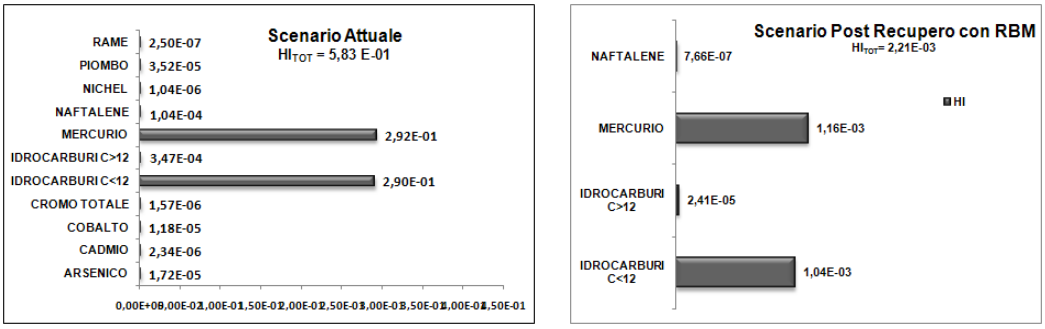

Fig. 4 – *Non-carcinogenic risk (HI) divided in index contaminant*

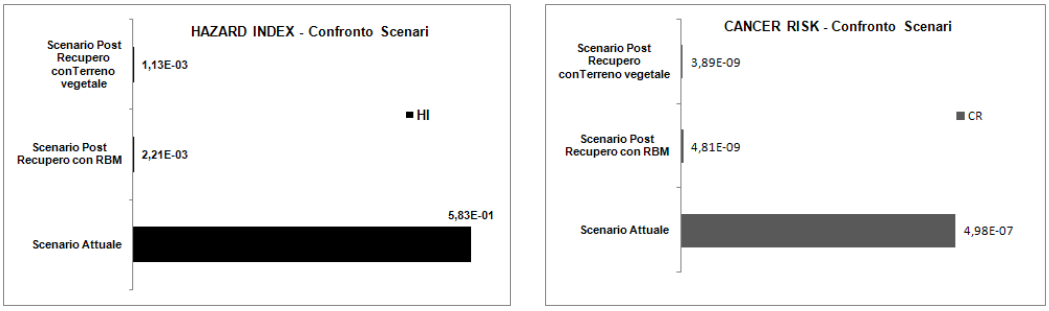

Fig.5 – *Comparison of non-carcinogenic risk (HI) and carcinogenic risk (CR) at a time in different scenarios*

2.4.2 Risk to groundwater resources

The vulnerability of the aquifer system against the possible contamination from leachate was very low, probably because of the high depth to groundwater as well as the fact that the leaching test results of RBM showed no exceedances of the limits set by existing legislation for non-hazardous waste [8]. In simulations carried out, both for the present scenario and the post-recovery environment, there has been no exceedances of either TCC or any of the background values.

From the Monte Carlo simulations carried out with the LandSim has emerged in the post-environmental recovery scenario that the risk for deep karst aquifer appears strongly attenuated compared with concentrations peak of all present pollutants which are lower and more delayed, from the peaks of showed at 40-50 years of the current scenario to 170-190 years after the recovery intervention.

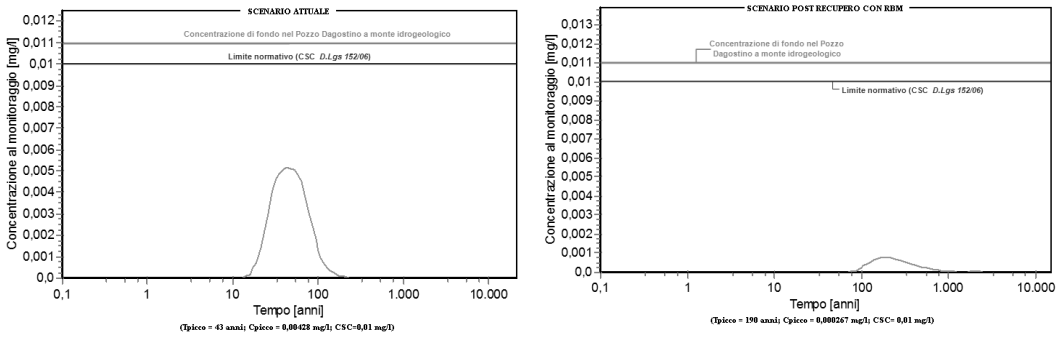

Fig.6- *Comparison of the evolution of selenium concentration at the point of compliance*

Fig. 6 shows, as an example, the comparison between the two investigated scenarios (current and post-recovery one) of the concentration of selenium (Se) at the point of compliance (hypothetical monitoring wells at hydrological downstream of the site) resulting from LandSim simulation software.

3. Conclusions

This work has set as its main objective the environmental rehabilitation of degraded area through the use of RBM. The health RA, conducted by the Code ROME, showed that after the supposed intervention for the environmental restoration of the site, the risk, both with regard to CR and HI, goes down of about two orders of magnitude. It was also found that the health risk for off-site

workers does not change substantially, even using topsoil for the filling of the quarry instead of RBM, further confirming the feasibility of the latter.

Besides, as regards risk analysis to groundwater resources, in all investigated cases there has been no exceedances of the TCC to the point of compliance, and the post environmental recovery scenario of the quarry, for all contaminants under investigation was found an attenuated risk for deep karst aquifer and pollutants concentrations peaks are lower and more delayed.

In conclusion, based on the results obtained in this experiment, we can say that the scenario of post-recovery site, by employing RBM, is more than adequate to safeguards the health of potential future off-site employees in the neighborhood of the site and for groundwater resources.

Bibliografia

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[2] **APAT**, Criteri metodologici per l'applicazione dell'analisi assoluta di rischio alle discariche, Rev.0, June 2005

[3] **APAT**, Criteri metodologici per l'applicazione dell'analisi assoluta di rischio ai siti contaminati, Rev. 2, March 2008

[4] **F. Adani**, La stabilità biologica del compost: indice di respirazione come parametro di processo, Fertilitas Agrorum 2 (1), pp. 55 – 64

[5] **UNI/TS 11184:2006**, Rifiuti e combustibili ricavati da rifiuti – Determinazione della stabilità biologica mediante l'Indice di Respirazione Dinamico (IRD), ottobre 2006

[6] **Legislative Decree 4 April 2006, n 152** "Norme in materia ambientale"

[7] **Legislative Decree 16 January 2008, n. 4**, "Secondo correttivo al D.Lgs 152/2006"

[8] **Ministerial Decree 3 August 2005**, "Definizione dei criteri di ammissibilità dei rifiuti in discarica"

SANACIJA ONEČIŠĆENIH PODRUČJA POMOĆU BIOSTABILIZIRANOG OTPADA: ANALIZA EKOLOŠKIH RIZIKA

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Sažetak

Težnja ove studije je istraživanje mogućnost korištenja biostabiliziranog otpada za potrebe sanacije onečišćenih područja. Analiziran je slučaj bivšeg kamenoloma vapnenca, koji je tijekom 1980-ih korišten kao odlagalište komunalnog otpada, koje nije do kraja ispunjeno. Proučeno je stvarno stanje odlagališta i sanacije okoliša te je napravljena usporedba kroz dvije procjene rizika. Alati korišteni u ovom radu su software-ski programi ROME release 2.1 i LandSim release 2.5.

Rezultati pokazuju da je kod provođenja sanacije korištenjem biostabiliziranog otpada došlo do smanjenja rizika oboljenja od raka i smanjenja indeksa opasnosti, dok je praćenjem rezultata LandSim simulacija uočeno smanjenje rizika glede podzemnih voda.

Ključne riječi: Biostabilizirani otpad, sanacija, procjena rizika, podzemne vode

4. Uvod

Koherentno s EU principima, talijansko zakonodavstvo o otpadu kroz dugi period vremena bilo je orijentirano na stvaranje sustava "cjelovitog gospodarenja" u svrhu postizanja rezultata ekonomske valorizacije ostatnog otpada i zaštite kvalitete okoliša.

Danas je glavni cilj sanacija okoliša napuštenih kamenoloma. Zbog činjenice da se otpad redovno odlagao u tijelo odlagališta i na taj način je zauzimao samo dio dostupnog volumena, u skladu s odredbama DC 296/02 [1], u ovom radu je procijenjena izvodljivost korištenja RBM za regulaciju geomorfologije kamenoloma.

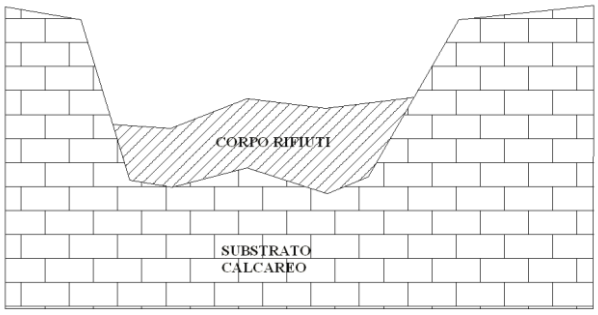
Napravljena je analiza rizika prvo za sadašnji scenarij onečišćenja lokacije, a zatim i za scenarij nakon sanacije okoliša.

5. Izvještaj

2.1 Klasifikacija područja

Područje obrađeno u radu odnosi se na bivši kamenolom smješten u gradu Giovinazzo (blizu Bari-ja) na području koje se većinom koristi za poljoprivredu. Područje je gotovo čitavo desetljeće korišteno kao skladište za komunalni otpad, koje uslijed privremenih narudžbi i/ili izuzetno hitnih narudžbi, nije održivo raspolagalo volumenom, drugim riječima nije se iskoristio cjelokupni raspoloživi volumen (slika 1). U zadnje vrijeme je područje još više opterećeno nekontroliranim i ilegalnim skladištenjem različitih vrsti otpada.

Na ovom području postoji i pritisak podzemnih voda, 110-120 m od razine tla.



slika.1 – *Shematski dijagram trenutnog scenarijapodručja*

Rezultati plana karakterizacije pokazali su da se područje treba klasificirati kao potencijalno onečišćeno obzirom je na njemu izmjereno prekoračenje graničnih koncentracija onečišćenja u podtlu i podzemnim vodama u odnosu na Tablicu 1. B talijanske uredbe 152/06.

2.2 Metodologije i software

Analiza rizika je znanstvena i sistematska metodologija za procjenu stupnja onečišćenja u okolišnim matricama sa stanovišta kvantifikacije trenutnih rizika i/ili potencijalnih rizika za ljude i okoliš.

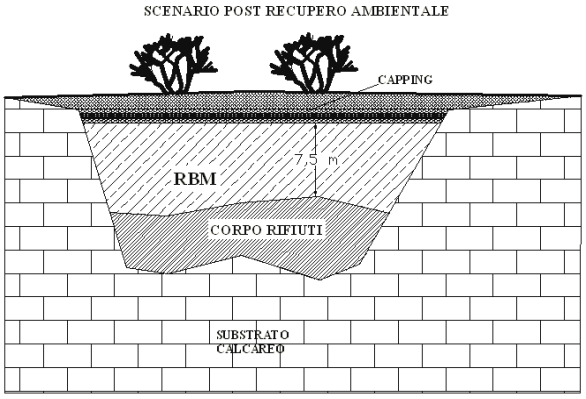
Za kancerogene tvari rizik predstavlja vjerojatnost da će određena osoba oboliti od raka kao posljedica izlaganja toj tvari, u odnosu na uobičajene životne uvjete. Za ne-kancerogene tvari, indeks opasnosti je pokazatelj koliko vremenski dugo izlaganje toj tvari uzrokuje prekoračenje tolerantnih odnosno graničnih vrijednosti.

Napravljena je specifična analiza rizika Razine 2 za sadašnji scenarij i za pretpostavljeni scenarij sanacije okoliša korištenjem RBM-a, uzimajući u obzir smjernice koje je izdao APAT [2] i [3].

Scenarij sanacije (slika 2) predviđa punjenje bivšeg kamenoloma RBM-om i zatim završno

prekrivanje koje se sastoji od dva sloja drenažnog materijala sa slojem kompaktiranog materijala i slojem zemlje na vrhu za rekultivaciju područja.

Kao operativna podrška u ovom stupnju korišteni su kodovi ROME verzija 2.1 od APAT-a za analizu rizika po zdravlje, i software LandSim verzija 2.5 od Golder Associates za analizu podzemne vode, iako je vjerojatno da je podzemna voda već onečišćena hidrološki uzvodno od ovog područja te se izravni utjecaj od strane procjednih voda praktički može isključiti.



slika.2 – *Shematski dijagram pretpostavljenog scenarija sanacije okoliša RBM-om*

Na bazi svega navedenog, izrađen je idejni model područja. Za analizu rizika na zdravlje, kao eventualno pogođene strane uzeti su samo poljoprivredni radnici.

Obzirom na sadašnji scenarij, pretpostavljeno je da receptor reagira s onečišćenim područjem detektiranim u karakterizaciji okoliša, te da je, ovisno o načinima izlaganja, kao takav aktivan u idejnom modelu: inhalacijom prašine ili para iz zemljine površine i inhalacijom para iz dubine zemlje u vanjskim uvjetima.

Za idejni model scenarija sanacije područja, prisutnost višeslojnog površinskog pokrova i temeljnog sloja RBM-a virtualno eliminira mogućnost da receptor reagira izravno s onečišćenom matricom. Aktivni načini izlaganja u usporedbi sa sadašnjim scenarijem su inhalacija para onečišćivača iz površinskog tla i iz dubine zemlje u vanjskim uvjetima. Među odabranim indeksima onečišćivača, isključen je utjecaj teških metala (osim žive) kao onečišćivača koji mogu isparavati na sobnoj temperaturi.

Kako bi se kvantificirali dodatni rizici koji mogu nastati uslijed korištenja RBM-a, napravljena je daljnja analiza rizika koja je identična prethodnom scenariju, ali uz korištenje punila od prirodnog terena umjesto RBM-a.

2.3 Karakterizacija uzorka RBM-a

Uzet je uzorak iz karakteristične biućelije postrojenja za biostabilizaciju iz bazena BA/2.

Primarni faktor u karakterizaciji RBM-a je biološka stabilnost, koja predstavlja stupanj truljenja organske tvari sadržane u biorazgradivoj organskoj matrici [4]. Zbog potrebe za indirektnim mjerenjem, u ovom eksperimentu je određivan Dinamički respiratorni indeks koristeći metodu A tehničke specifikacije UNI/TS 11184:2006 [5].

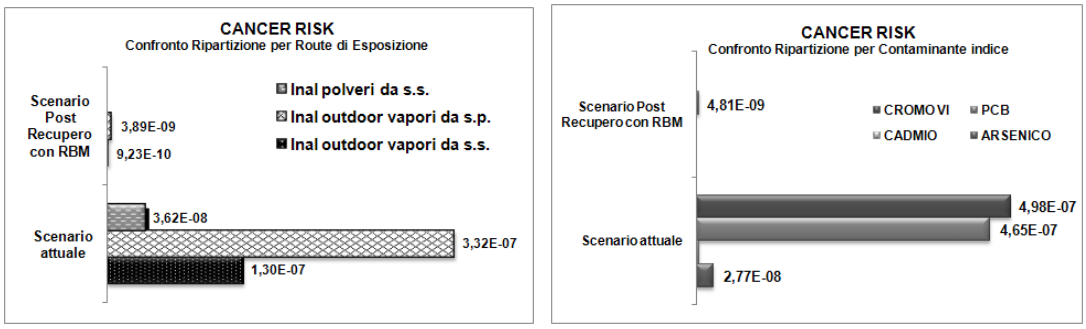
Kako bi se napravila analiza rizika u scenariju nakon sanacije, na uzorku RBM-a su određivani svi onečišćivači na uzorcima otpada i uzorcima tla.
Na uzorcima testiranim na odbacivanje biostabilizacije nije utvrđeno odstupanje od Tablice 1 iz TCC Tab.1 Col. B Zakona 152/06.

2.4 Rezultati i diskusija

Rezultati analize rizika su prikazani na grafu izrađenom na temelju izlaznih podataka dobivenih iz software-a i ROME verzija 2.1 LandSim verzija 2.5.

2.4.1 Analiza rizika po zdravlje

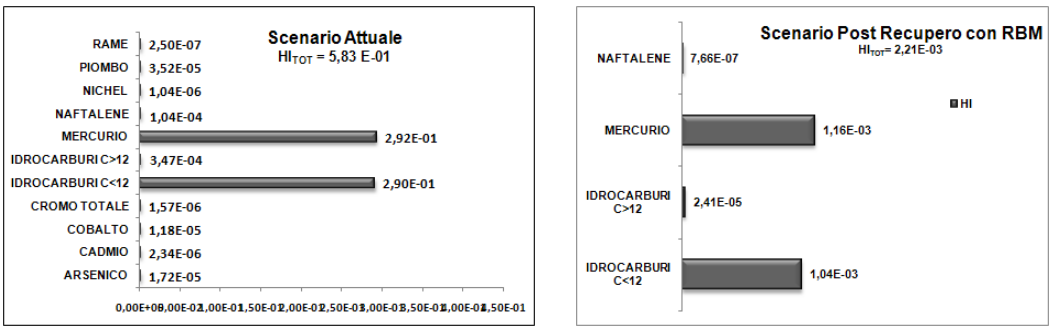
Trenutni scenarij je karakteriziran ukupnim kancerogenim rizikom (zbroj parcijalnih rizika za svaku rutu izlaganja za svaki indeks onečišćivača) od 4.98 E^{-07}, što predstavlja vrijednost manju od granične vrijednosti ([6] [7]).
Dominantan doprinos riziku od strane kancerogenih tvari predstavljaju PCB-i u iznosu od 4.67 E^{-07} (vrijednost nije puno niža od granične vrijednosti od 10^{-6} za pojedinačni rizik) do oko 93% od ukupnog rizika od kancerogenih tvari, posebno u slučaju izlaganja inhalaciji para iz dubinskog tla.
Pod istim uvjetima, Indeks opasnosti iznosio je 5.83 E^{-01}, također ne puno niže od granične vrijednosti 1, što je većinom uzrokovano ugljikohidratima i živom, i inhalacijom para iz površinskog i dubinskog tla u vanjskim uvjetima.
Prema scenariju nakon sanacije, ukupni kancerogeni rizik opao je za oko dva reda magnitude, odnosno za 4.81 E^{-09}. Značajni pad kancerogenog rizika je većinom uzrokovan izlaganjem inhalaciji para iz dubinskog tla u vanjskim uvjetima, kao što je to prikazano na slici 3. U scenariju nakon sanacije, za razliku od trenutnog scenarija, kancerogeni rizik postoji isključivo zbog koncentracije PCB-a u dubinskom tlu (otpad).



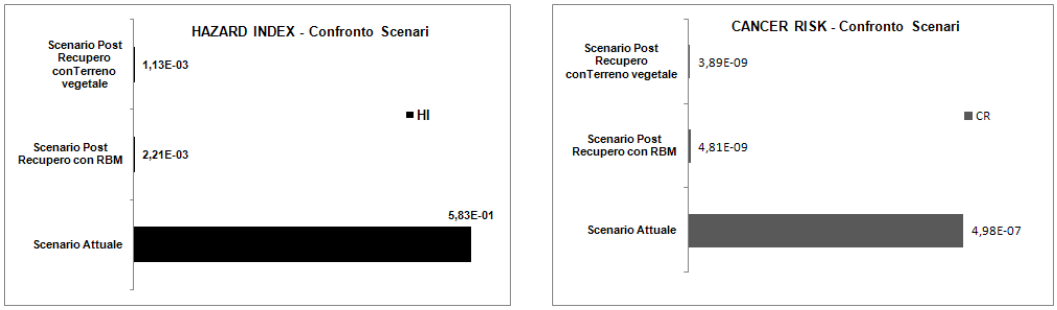
slika 3 – *Kancerogeni rizik podijeljen načinom izlaganja i indeksom onečišćenja*

Grafovi na slici 4 su povezani s ne-kancerogenim rizikom. Za ne-kancerogeni rizik u scenariju nakon sanacije kamenoloma dolazi do smanjenja za oko dva reda (5.83 E^{-01} na 2.21 E^{-03}) i isključeni su utjecaji nekih aktivnih indeksa onečišćivača u trenutnom stanju onečišćenja područja.

Kao što je već navedeno, u svrhu kvantifikacije rastućeg rizika zbog korištenja RBM-a u projektima sanacije okoliša koji su projektirani software-om ROME, napravljena je daljnja analiza scenarija sanacije slična onoj prethodnoj, no uz korištenje prirodnog tla. Kao što je to vidljivo prema zbirnim grafovima prikazanim na slici 5 ustanovljena je zanemariva promjena u odnosu na rizik koristeći prirodno tlo umjesto RBM-a.



slika 4 – *Ne-kancerogeni rizik (HI) podijeljen na indeks onečišćivača*

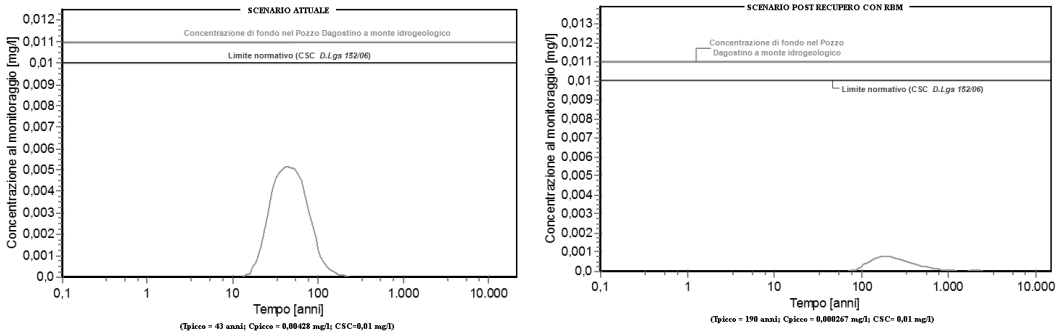


Slika 5 – *Usporedba ne-kancerogenog rizika i kancerogenog rizika u različitim scenarijima*

2.4.2 Rizik na izvore podzemne vode

Ugroženost akvifernog sustava od mogućih onečišćenja procjednim vodama je vrlo niska, vjerojatno zbog velike dubine podzemne vode te činjenice da testovi procjeđivanja RBM-a nisu pokazali prekoračenja graničnih vrijednosti prema postojećem zakonodavstvu za neopasni otpad [8]. U provedenim simulacijama za trenutni scenarij i scenarij nakon sanacije okoliša, nisu zabilježena prekoračenja graničnih vrijednosti.

Iz „Monte Carlo“ simulacije koja je izvedena uz pomoć LandSim ustanovljeno je da je rizik za onečišćenjem dubokog akvifera u scenariju nakon sanacije okoliša značajno smanjen, te da su vršne vrijednosti koncentracija za sve onečišćivače smanjene ili skroz uklonjene, u odnosu na vršne vrijednosti koncentracija u trenutnom scenariju.



Slika 6- *Usporedba evolucije koncentracija selena na točki udovoljavanja*

Slika 6 prikazuje, kao primjer, usporedbu između scenarija (trenutni i nakon sanacije) u koncentracijama selena (Se) u točki udovoljavanja odredbama (hipotetički zdenci za monitoring nizvodno od područja promatranja), kao rezultat LandSim software-a za simulacije.

6. Zaključci

Čitav postupak je izveden u cilju sanacije onečišćenog područja korištenjem RBM-a. Analiza rizika po zdravlje, izvedena pomoću koda ROME, pokazala je da je rizik nakon sanacije okoliša, kako po pitanju kancerogenih, tako i po pitanju ne-kancerogenih tvari, smanjen za dva reda magnitude. Također je ustanovljeno da se rizik po zdravlje radnika na promatranom području znatno ne mijenja, čak i kod korištenja zemlje za punjenje kamenoloma, umjesto RBM-a.

Što se tiče analize rizika po podzemne vode, u svim istraživanjima nisu zabilježena neudovoljavanja graničnim vrijednostima, a scenarij nakon sanacije kamenoloma, na sve ispitivane onečišćivače,

pokazao je smanjeni rizik po akvifer, a vršne koncentracije onečišćivača su smanjene i gotovo u potpunosti uklonjene.

Zaključno, na temelju dobivenih rezultata u ovom eksperimentu, može se zaključiti da je scenarij nakon sanacije, koristeći RBM, adekvatniji za očuvanje zdravlja potencijalnih budućih djelatnika u blizini promatranog područja te za očuvanje resursa podzemne vode.

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