CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Peiyu Ren, Yancang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546123

An Oilfield Ecological Risk Assessment System Integrating OERAM and GIS

Yingchang Xiu*[a], Wenbao Liu[a], Bing Liu[a], Haixia Li[b]

[a] College of Geomatics, Shandong University of Science and Technology, Qingdao, Shandong, China
[b] College of economics and management, Shandong University of Science and Technology. Qingdao, Shandong, China
xiuyingchang@163.com

The oilfield ecological risk assessment model (OERAM) analyzes the effects of the oil pollutants on ecological system. In this paper, according to oilfield characteristics and ecological risk assessment receptor expose effect assessment, a modified oilfield ecological risk assessment model structure is established which referencing the relationship between ecological receptor exposure ways and ecological effect. Comparing the current ecological risk assessment methods, the joint probability evaluation is selected to establish oilfield ecological risk assessment model. Finally, the oil ecological risk assessment system based on geographic information system and geo-database technology is developed integrating the modified oilfield ecological risk assessment model. This system realizes spatial information analysis, ecological risk assessment and results visualization functions. Through the application in Shengli Oilfield, the comprehensive assessment result of oilfield risk could provide decision-making basis for the oilfield environment management.

1. Introduction

Chen and Liu (2014) reported ecological risk assessment (ERA) is a major part of the environmental risk assessment which assesses the potential harmfulness of one or more risk factors to the ecological results. With the development of oil exploitation in recent ten years, oilfield ecological risk assessment has become a focus problem in the field. Oilfield risk refers to the pollution and harm of crude oil and various oil products in the stage of oil exploration, refining, storage and use. Sidortsov (2014) found it may cause damages to the local environment and even affect the development of the ecological environment. According to assess the risk level of oilfield, Posthuma et al. (2008) suggested the ERA can provide the oil risk management solutions, in order to reduce the harm of oil exploitation risk to the environment and reduce the cost of oil field development.

The oilfield risk assessment model (ORAM) experienced from environmental impact assessment to ecological environmental risk assessment which was confirmed (Tian and Gang(2014)). At first, the ORAM evaluates the possible impact on the social environment during oil development process. Later, it evaluates the hazards of oilfield development to the whole social environment and ecological system. Especially in recent years, the oilfield risk assessment has aroused widespread concern with the rapid development of risk assessment on natural disasters and man-made disasters. Chengzao et al.(2014) found in China, the oil industry has become one important basic industries which support the sustained and rapid development of the national economy. However, Li et al. (2014) reported the study on risk assessment of oil mining area is still weak. What's worse, the ecological environment of the regions where mining area distributed is fragile and the oil exploitation may damage the local biodiversity. These brought great difficulties to the traditional ecological risk study which was confirmed by Xu et al. (2004).

In this study, according to previous studies of Carignan and Villard (2002), Liao et al.(2013), La and Martinico (2013), Wang et al.(2012) etc., the oilfield ecological risk assessment system for oilfield ecological environment protection is designed integrating the modified oilfield environmental risk assessment model (OERAM) and geographic information system (GIS) technology to analyse and simulate the oilfield ecological risk.

Please cite this article as: Xiu Y.C., Liu W.B., Liu B., Li H.X., 2015, An oilfield ecological risk assessment system integrating oeram and gis, Chemical Engineering Transactions, 46, 733-738 DOI:10.3303/CET1546123

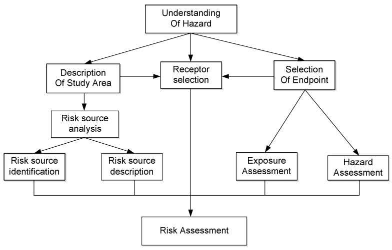

Figure 1: Modified oilfield ecological risk assessment model

2. Modified oilfield ecological risk assessment model

General studies suggest that ecological risk assessment include hazard assessment, exposure assessment, receptor analysis and risk characterization. The oilfield ecological risk assessment was similar to it. According to the ecological risk assessment framework proposed by Hunsaker et al.(1990), Suter II et al.(2003) and Hayes and Landis(2004),we established a framework to assess the regional ecological risk. The key components include: (1) selection of endpoints; (2) description of reference environment; (3) development of source terms; (4) exposure or habitat modification assessment; (5) effects assessment (Figure 1). In this study, pollution receptor selection was introduced to the framework.

In this framework, before the risk assessment of oil, a detailed survey of oil mining area, containing the economic, social and environmental, is necessary. Then identify the pollution factors that may produce harmful effects on the ecological environment, this contains oilfield risk identification and oilfield risk description. Next, the receptor which will became the bearer of the harmful effects from pollution factors need to be identified, and it must follow the two principles: (1) it may reflect the overall oil pollution in the region; (2) it's simple calculation and facilitate understanding. Exposure assessment function analysis the transfer and change process when oilfield pollution seeps into soil and water. The environmental pollutants concentration (PEC) was used as a monitoring index. It can be obtained by detecting or through forecasting model. Considering the space distribution difference between risk source and receptor, the effects of pollutants can't be superimposed. So it makes the exposure analysis complicate and difficult which was confirmed by Oughton et al.(2013). The relationship between risk source and risk receptor can be expressed as the following Eq(1).

$$F = \int_{t_2}^{t_1} C(t)dt \tag{1}$$

in which, F represents the amount of total exposure from t_1 to t_2, C(t) represents the concentration of toxic substances at a certain moment, $t_1$and t_2 represent the start and end time. In addition, the hazard analysis is closely linked with exposure analysis. Through it, the probability damage of risk sources to risk receptor could be calculated. Before analysing the hazard, the mechanism of pollution source on risk receptor needs to be clear. Combining related assessment technologies, the hazard could be assessed and predicted. At last, summarizing the previous content, we could assess the risk and the probability of occurrence. In the risk assessment, the influence of toxicity is not independent, but a comprehensive result of several compounds. The comprehensive impact assessment of pollutants is necessary. In order to realize the comprehensive evaluation, each kind of pollutants was given a weight. The weight formula is Eq (2).

$$w_{ij} = \frac{x_i / p_{ij}}{\sum_{i-1}^{k} (x_i / p_{ij})} \tag{2}$$

in which, x_i represents the average exposure concentration of pollutants i; p_{ij} represent hazard concentration of pollutants i to biological receptors j; k represent the number of pollutants. According to the weight, we could obtain the comprehensive risk assessment result P of oilfield pollutants in the whole region. See Eq (3).

$$P = \sum_{n=1}^{k} (w_{ij} F_{ij}) \tag{3}$$

Finally, we ranked the risk level based on the study of Moraes and Molander(2004) (Table 1).

Table 1: The level of oil pollution risk

Level	P	Warning type	Description
1	P<0.1	No alert	Pollutants had no effect on receptor
2	0.1<P<0.2	Blue alert	Pollutants had a litter effect on receptor, the receptor can grow normally
3	0.2<p<0 .3	Yellow alert	Environment was destroyed, the receptor growth was affected
4	0.3<P<0.5	Orange alert	Environment was greatly destroyed, the receptor can’t grow
5	0 .5<P<1	Red alert	Environment was seriously destroyed, the receptor dying

3. System design

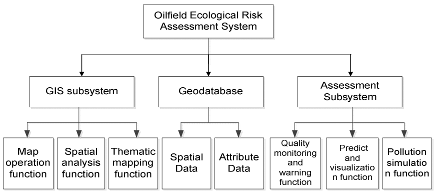

Figure 2: System function structure

As a decision support system, oil ecological risk assessment system (OERAS) covers data transmission, data management, data analysis, pollution accident motoring, pollution accident simulation analysis, pollution incident handling, decision support functions and other aspects (Figure 2). The remote sensing (RS) and GIS were used to realize the qualitative, quantitative and visual expression of the result. The C/S structure was used to construct the OERAS Framework. As ArcGIS Engine is a major component GIS, this paper uses ArcGIS Engine as GIS integration environment. C # development language was selected and the database uses oracle 10g.

3.1 GIS subsystem

Map operation function provides the operation on electronic map commonly used. It includes zoom in, zoom out, map roaming, map display, distance measurement, area measurement, print, eagle eye, legend, point selection, polygon selection and so on. The function was built based on unified data standard and unified interface specification.

Spatial analysis function contains overlay analysis, buffer analysis and data conversion, such as mutual conversion between raster and vector data. What’s more, the graphical query and attribute query also can be achieved.

Thematic mapping function contains thematic map production, thematic map classification, thematic map editor and thematic map storage. In addition, the function can manage varieties of info graphic, such as pollution source monitoring map, basic ecological information and ecological environment quality.

3.2 Geodatabase

Spatial database is the key of system construction. It stores all the spatial data and attribute data of the oil area. The spatial data objects include Basic topographic maps, oil field distribution maps, remote sensing maps and thematic maps. Specifically, basic topographic maps include elevation map, administrative map, river map, land cover map, soil type map. Oil field distribution maps include point distribution and polygon distribution of oil field. The polygon distribution map was obtained by scanning and victimization of remote sensing data. The point distribution map was obtained by sampling point. Remote sensing maps include different formats of image data. Thematic map is drawn according to the actual needs. In this study, the attribute data of sampling points were organized in table forms and these data include sampling point code. In this system, the link between spatial data and attribute data was established through the sampling point code. The association of spatial data and attribution data was shown in Figure 3.

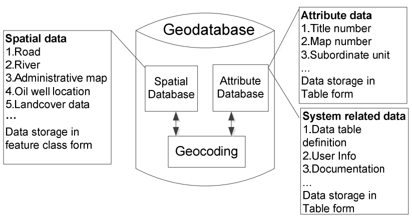

Figure 3: Geodatabase structure

3.3 Assessment subsystem

The assessment subsystem encapsulates the modified OERAM and invokes it in the system. These functions include quality monitoring and warning function, predict and visualization function and pollution simulation function. The details are as follows.

(1) Quality monitoring and warning function

According to the dynamic monitoring data of ecological receptor in oilfield exploitation area, the change of monitoring data and ecological assessment data will be intuitive displayed using the curve and histogram. Once an indicator exceeds the threshold of risk, the system will automatically alarm.

(2) Predict and visualization function

After the pollution accidents, the temporal and spatial variation of pollutants will be predicted by the pollutant diffusion model and ecological risk assessment model. Through the visualization of GIS, the scope and extent of pollution can be intuitively reflected. The economic losses and the direct impact on the structure and function of ecological system also can be reflected semi quantitatively.

(3) Pollution simulation function

The diffusion process of oilfield pollutants could be simulated dynamically when petroleum pollutants are discharged into the environment. This could provide pollution-control plan for the manager.

4. Application

4.1 Study area and data source

Shengli Oilfield is selected as the study area. It is the second largest oilfield in China, located in the Yellow River Delta area, close to the Bohai Sea. We sample in Shengli Oilfield Zhuangxi Oil Production Station and Gudong Oil Production Station. Choose 6 heavy oil wells, and wells as the centre of the 3 directions of radiation distribution. Considering the oil field distribution law, get sampling according to three kinds of design sample survey such as the point, line and plane. Sample at the distance of 5m, 10m, 20m, 50m, 100m from the bottom of the well. Sampling depth is for the topsoil of 0 ~ 15cm, each sampling point locates quadrat of 2m*1m. Within each quadrat choose 3 sampling point, evenly mixed into 500ml mixed sample back to the laboratory. There were 129 soil samples.

Through getting sampling data, using oilfield ecological risk assessment model, we obtained the risk impaction of Suaeda glauca, reed and Lythrumy from naphthalene (Nap, for short) and phenanthrene (Phe, for short) in Shengli Oilfield. Pollutants in the Dongying area risk coefficient diagram is obtained by interpolation function of the system, as shown in Figure 4.

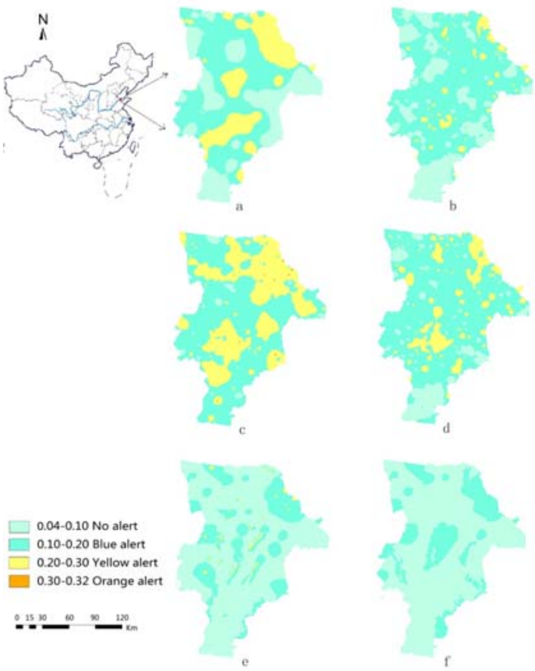

Figure 4: Risk assessment result. a shows the risk of Nap to Suaeda salsa; b shows the risk of Phe to Suaeda salsa; c shows the risk of Nap to reed; d shows the risk of Phe to reed; e shows the risk of Nap to Lythrumy; d shows the risk of Phe to Lythrumy.

4.2 Results Analysis

Through calculation of the system it can be seen that the risk coefficient scope of Nap for land plants Suaeda salsa and reed is generally in 0.01--0.33 in the whole area of Shengli Oilfield, which Phe on two receptor of the risk coefficient range roughly in 0.011-0.270. And Nap on aquatic plant Lythrumy of the risk coefficient is in 0.04-0.23. Phe to Lythrumy of the risk coefficient is in 0.04-0.17. Thus it can be seen that the Nap risk probability for the whole oilfield is the highest, in other words, the regional dynamic effects on plant from Nap is maximum. Nap is the largest effect of the region on plants and animals. From the results, we can also see that the risk coefficient of the Nap and Phe to the terrestrial plants is higher than that of the aquatic plants, which is related to the water's characteristic. The oil pollutant diffusion in the water body is quick, so the high risk factor won't appear in a certain region.

The results of the assessment shown that in the vicinity of wells the two compounds of receptor risk coefficient was the highest, and far away from the well region, risk coefficient can down to a quarter or 1/5 of the highest point. This is because of the pollutants in the contaminated soil or water retention, accumulation, through runoff, percolation into surface water bodies and through volatilization and diffusion into the atmosphere, and soil and water self-purification capacity and pollutants self-attenuation, resulting with distance from the well of the farther, the lower the toxicity of the compounds.

5. Conclusion

The GIS-based oilfield ecological risk assessment system built in this paper encapsulates the modified ecological risk assessment models, and invokes it on the platform of GIS. This system provides collection and storage of oil area spatial and attributes data and provides data support for oilfield risk assessment model. What's more, it integrates risk assessment models, GIS spatial analysis functions and information management system to realize the association analysis of spatial data and attribute data. The assessment result is visually shown by tables, thematic maps and other ways. Finally, the comprehensive risk assessment of Shengli Oilfield by the OERAS provided decision-making basis for the oil risk management.

Acknowledgments

This work was supported by the Scientific Research Foundation of Graduate School of Shandong University of Science and Technology (YC150315).

Reference

Carignan, V., Villard, M. A. (2002). Selecting indicator species to monitor ecological integrity: a review. Environmental monitoring and assessment, 78(1), 45-61, DOI: 10.1023/A:1016136723584

Chen, Q., Liu, J. (2014). Development process and perspective on ecological risk assessment. Acta Ecologica Sinica, 34(5), 239-245, DOI: 10.1016/j.chnaes.2014.05.005

Hayes, E. H., Landis, W. G. (2004). Regional ecological risk assessment of a near shore marine environment: Cherry Point, WA. Human and Ecological Risk Assessment, 10(2), 299-325, DOI: 10.1080/10807030490438256

Hunsaker, C. T., Graham, R. L., Suter II, G. W., O'Neill, R. V., Barnthouse, L. W., Gardner, R. H. (1990). Assessing ecological risk on a regional scale. Environmental management, 14(3), 325-332, DOI: 10.1007/BF02394200

Jia, C.Z., Zhang, Y.F., Zhao, X. (2014). Prospects of and challenges to natural gas industry development in China. Natural Gas Industry B, 1(1), 1-13, DOI: 10.1016/j.ngib.2014.10.001

La Rosa, D., Martinico, F. (2013). Assessment of hazards and risks for landscape protection planning in Sicily. Journal of environmental management, 127, S155-S167, DOI: 10.1016/j.jenvman.2012.05.030

Li, Z., Ma, Z., Van der Kuijp, T. J., Yuan, Z., Huang, L. (2014). A review of soil heavy metal pollution from mines in China: pollution and health risk assessment. Science of the total environment, 468, 843-853, DOI: 10.1016/j.scitotenv.2013.08.090

Liao, X., Li, W., Hou, J. (2013). Application of GIS based ecological vulnerability evaluation in environmental impact assessment of master plan of coal mining area. Procedia Environmental Sciences, 18, 271-276, DOI: 10.1016/j.proenv.2013.04.035

Moraes, R., Molander, S. (2004). A procedure for ecological tiered assessment of risks (PETAR). Human and Ecological Risk Assessment, 10(2), 349-371, DOI: 10.1080/10807030490438427

Oughton, D. H., Stromman, G., Salbu, B. (2013). Ecological risk assessment of Central Asian mining sites: application of the ERICA assessment tool. Journal of environmental radioactivity, 123, 90-98, DOI: 10.1016/j.jenvrad.2012.11.010

Posthuma, L., Eijsackers, H. J., Koelmans, A. A., Vijver, M. G. (2008). Ecological effects of diffuse mixed pollution are site-specific and require higher-tier risk assessment to improve site management decisions: A discussion paper. Science of the Total Environment, 406(3), 503-517, DOI: 10.1016/j.scitotenv.2008.06.065

Sidortsov, R. (2014). Reinventing rules for environmental risk governance in the energy sector. Energy Research & Social Science, 1, 171–182. DOI: 10.1016/j.erss.2014.03.013

Suter II, G. W., Vermeire, T., Munns, W. R., Sekizawa, J. (2003). Framework for the integration of health and ecological risk assessment. Human and Ecological Risk Assessment, 9(1), 281-301, DOI: 10.1080/713609865

Tian, J., Gang, G. (2012). Research on regional ecological security assessment. Energy Procedia, 16, 1180-1186, DOI: 10.1016/j.egypro.2012.01.188

Wang, M., Bai, Y., Chen, W., Markert, B., Peng, C., Ouyang, Z. (2012). A GIS technology based potential eco-risk assessment of metals in urban soils in Beijing, China. Environmental Pollution, 161, 235-242, DOI: 10.1016/j.envpol.2011.09.030

Xu, X., Lin, H., Fu, Z. (2004). Probe into the method of regional ecological risk assessment—a case study of wetland in the Yellow River Delta in China. Journal of Environmental Management, 70(3), 253-262, DOI: 10.1016/j.jenvman.2003.12.001