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Risk Analysis of Wastewater Reuse in Agriculture Using Baysian Network

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ABSTRACT

The advantages of treated wastewater such as decrease of water resource limitation and environmental pollution reduction caused to be considered as a valuable source in irrigation. However, the probable pollutants in the treated wastewater cause some restriction on its reuse. Risk assessment is an important tools in understanding the potential risks of a project and its potential consequences. In this study, the risk assessment of wastewater reuse is done using the technique of Bayesian networks. In this method, a network of cause and effect is created and two indexes of hazards and impacts are defined. Hazards are due to treated wastewater pollutants and impacts referred to the effects of hazards on human and plant as the main receptors in this analysis. The present survey is applied for the risk analysis of wastewater reuse of Alborz industrial park treatment plant located in suburb of Ghazvin city for irrigation of adjacent farmland. Results showed a 46% risk for human and 38% for the plant which the cadmium, detergent and nitrate have the highest share in the total assessed risk. Mitigations measures for risk reduction includes construction of pretreatment, precise supervision and improve the operation and continuous monitoring.

KEYWORDS:

Treated Wastewater, Hazards Index, Impact Index, Risk Assessment, Bayesian Network.

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1- INTRODUCTION

Risk assessment is an appropriate method for identification and control of the potential hazards due to the pollutants in the reclaimed water. In the risk assessment of wastewater reuse in agriculture.

One of the newest and effective methods in risk assessment is Bayesian network (BN). BN is a probabilistic graphical model that represents a set of random variables and their conditional dependencies. Pollini et al. (2007) evaluated the use of BN in ecological risk assessment and described how the use of data and expert opinion were combined as the input to the network. Lee & Jai Lee (2006) applied the BN in the risk assessment of radioactive pollution in a site of nuclear waste disposal.

In this study an algorithm based on BN method is used in the risk assessment of wastewater reuse of an industrial complex. The reclaimed water is used in irrigation of agricultural lands adjacent to Alborz industrial complex located in Gazvin province, Iran. The pollutants and receptors are considered as the hazards and impacts in the concept of risk. Finally using the Bayesian conditional probability relationships total risk is calculated.

2- METHODOLOGY

BNs are one of newest statistical tools that are applied in description of relationships among the parameters of a set and managing the uncertainty in expert systems. These networks are specific type of graphic models that represents the dependency structure among effective variables and are useful in cases that the condition of a system is dependent on the prior situation. Therefore, BNs are effective tools for decision making under uncertainty.

Each decision variable in a BN is modeled as a node. Each node has different states or a set of probabilities for each variable. Arrows called edges show the connection between nodes, representing the causal relationships. How one node affects the other nodes is determined through the conditional probability tables (CBT) which is defined for each group of nodes.

The hazard index is determined through the study of WWTP effluent data and assessment of the parameters exceeding the standard limits. The impact index is also defined for human and plant as the receptors, according to the type of each hazard. The hazard pathways for each receptor are shown schematically in Fig. 1. According to Fig. 1, the major impacts for human health are due to the entrance of pollutants to the body from drinking water or eating polluted food product. For the plant, the impacts are in the form of crop yield loss.

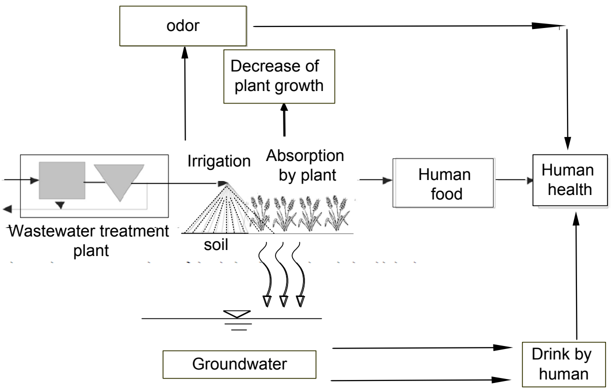

Figure 1. Pathways of pollutants transport to the receptors.

In Fig. 2 and 3 by developing the relations between the receptors and hazards factors, a diagram of the relationships between variables, hazard index and impact index are presented. In this study, a BN of the defined hazard and impact index is established using HUGIN software according to the diagrams in Fig. (2) and (3).

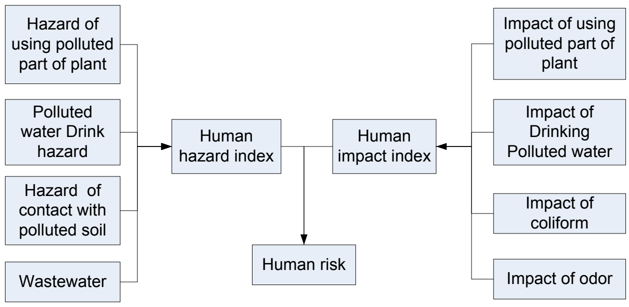

Figure 2. Connections among indices of hazards and impacts for Human as the receptor

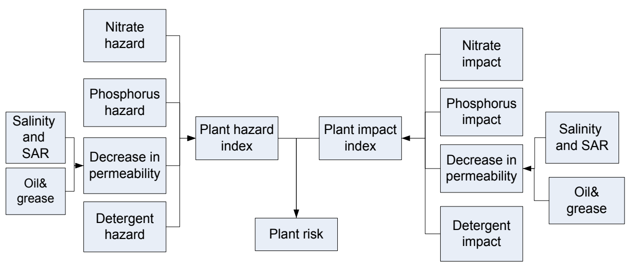

Figure 3. Connections among indices of hazards and impacts for plant as the receptor

2- 1- DETERMINATION OF THE PROBABILITIES OF BN FOR HAZARDS INDEX

To determine the conditional probability of effect node given the cause node, first the probability occurrence of all hazards related to a receptor, as the effect node, is generally obtained using the expert's opinions. Then considering a defined weight ratio, the conditional probabilities of each node is calculated by multiplying the conditional probability of total hazards by the weight ratio according to Eq. (1).

$$PH_{pj}=PT_H\times WH_J \quad (1)$$

Where PH_{pj} is the fraction of j[th] hazard in the total probability and PT_H is the probability of total hazards related to the effect node which is obtained by averaging the opinions of three experts. WH_J is the weight ratio of the probability of each hazard node to the probability of total dependent hazards in the BN.

2- 2- DETERMINATION OF THE PROBABILITIES OF BN FOR IMPACT INDEX

To determine the conditional probability of the impact on receptor (the effect) relative to each pollutant (cause), first the total conditional probability for the impact on a receptor due to all pollutants is determined based on the averaging all expert opinions. Then the fraction of each pollutant in total conditional probability is calculated as in Eq. (2):

$$PI_{pj}=PT_I\times WI_J \quad (2)$$

where is the fraction of jth impact in total probability, total impact probability (based on expert opinion) and is the weight ratio of conditional probability of the impact of each pollutant to the total pollutants for a receptor in the BN.

After determination of the probability of each node and the conditional probability of the node on the network of hazard index and impact index, CPTs are completed. Then, the probability of the hazard and impact indices is calculated. To determine the final risk, the extent of hazard probability and impact intensity is divided to the five grades of very low, low, medium, high and very high. Then the final risk will be calculated based on the allotted probability for each grade obtained by the experts' opinions.

3- RESULTS

The probability of initial nodes in the Baysian network are entered in HUGIN software based on the percent exceedance from standard limit in CPT network according to Eq. (2)

By the completion of BN in HUGIN software, the final risk of wastewater reuse for human health and plants are calculated 46% and 38% respectively.

Cadmium from eating contaminated plant and groundwater has the most contribution in the hazards occurrence. In the subsequent order, there are detergent, nitrate, copper, cobalt, phosphorus and coliform from the most to least contribution in hazards. Also as in Table V, the impact of cadmium has the greatest probabilities. Therefore, the most important factor in the final risk is cadmium.

The calculated risk can be reduced by execution of measures such as: establishing pretreatment facilities for the units which their effluent contains cadmium, detergent and nitrate, precise inspection in the pretreatment facilities of metal plating factories which have the most contribution in the cadmium production and continuous monitoring of the WWTP effluent quality.

4- CONCLUSION

In this study using BN method, human and plant were considered as two main receptors of hazards due to wastewater reuse. Hazards are mainly as the pollutants that adversely affect the human health and crop yield through the groundwater penetration and absorption by plant. Results showed that cadmium has the highest contribution in hazard creation through eating the plant and drinking contaminated groundwater. Detergent and nitrate are in the subsequent tier and copper, cobalt and coliform have the least share in the hazards index. Thus controlling the cadmium in the effluent has the most priority in the mitigation measure for risk reduction. The total risk was calculated through the built up BN for hazard and impacts and the values were 46% for human and 38% for the plant. The acceptable risk in different systems is comparative and is dependent on the critical conditions in achieving the goal and relative conditions of the components.

5- REFERENCES

[1] Tabatbaiee A., Dashtizadeh P., "Introduction of Bayesian network and their application in bridges maintenance", 14th nationwide students conference of civil engineering, 2008

[2] Pollini C.A., Woodberry O., Nicholson A., Korb K., T.Hart B., "Parameterization and evaluation of a Bayesian network for use in an Ecological Risk Assessment", Environmental Modeling & Software, Vol. 22, pp.1140- 1152, 2007

[3] Lee Chang-Ju, Jai Lee Kull, “Application of Bayesian network to probabilistic risk assessment of nuclear waste disposal”, Reliability engineering and system safety, Vol. 91, pp. 515-532., 2006

[4] Ghazvin Water Regional company, “Technical report on Wastewater Reuse in the city of Alborz”, pp.25- 38, 2009

[5] HUGIN tutorials, Available on: http://www.hugin.com/technology/tutorials/biuld-bn, 2012