ICIWRM – 2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19 – 21 December, 2000, New Delhi, India

# Risk management to improve raw water quality

**ADDIE WONG**
Strategi Tegas, Lyonnaise Des Eaux, 55100 Kuala Lumpur, Malaysia
**NYREE STENEKES**
Engineer, ASTRAN Water Resources, Lyonnaise des Eaux, 55100 Kuala Lumpur, Malaysia
**DRAGAN HRANISAVLEJVIC**
Manager, ASTRAN Water Resources, Lyonnaise des Eaux, 55100 Kuala Lumpur, Malaysia

## Abstract
This paper identifies methods that can be used by water supply managers to assess and manage the risks associated with raw water quality. The process begins with risk assessment, a tool used for assessing the sources of pollution risk and prioritising tasks for management. Techniques for risk assessment are discussed, including catchment surveys and developing priority rankings for the risks and various sources. Risk assessment provides the information base for the consideration of risk management options, such as improved catchment planning and better dam management. A brief case study of the activities of the Lyonnaise des Eaux group in Malaysia illustrates the use of applied RA and RM techniques for the improvement of raw water quality prior to water treatment. The importance of managing pollution upstream of the treatment plant is noted as a cost effective way of ensuring higher quality treated drinking water.

## INTRODUCTION

A risk management (RM) strategy is a tool that can be used to achieve an objective efficiently and systematically in the context of limited financial resources. In water supply, the defined objective is to achieve better potable water for the benefit of the community. Risk assessment, which forms the first part of the RM process, enables risks to be ranked in order of their magnitude and frequency of occurrence.

This paper focuses on the risk assessment and management of raw water quality as a means of achieving better quality potable water as it is often more simple and cost effective than enhancing water treatment processes. The application of risk assessment and management is illustrated in a case study on a water supply operation in Johor Baru, Malaysia, which has been successful in using these strategies to achieve cost effective improvements in raw water quality.

### Risk Assessment
**Source identification:** The RM process begins with risk assessment: identifying the sources of potential pollution and then assessing their frequency of occurrence and impact on raw water at the water supply intake. A characterisation of the risk usually includes an estimate of frequency, the number of times a pollution event is likely to occur, and magnitude, a measure of the amount or impact of pollution. Broadly speaking, there are two main areas where risks may be sourced in a water supply system: catchment and reservoir. The risks associated with reservoirs are quite different from those of the catchment although they are linked. The reservoir is often the final point in a system where storm runoff (external input) transported from the catchment is ‘held’ before being

treated. To some extent it acts as a 'buffer' zone where introduced particles and their adsorbed pollutants (e.g. ammonia) can settle out of the water column.

Elevated nutrient loadings in lakes and reservoirs provide a food source for algae and can lead to the development of algal blooms (sometimes toxic). A deterioration in raw water quality due to the presence of algae can mean more expensive water treatment and:

an increase in organic matter and pH;
less dissolved oxygen;
taste and odour problems linked to the development of $H_2S$, iron and manganese in the sediment.[1]

The pollution sources affecting raw water from the rivers and dams originate from point and diffuse sources in the catchment. Point source pollution usually derives from an identifiable location, such as sewage from the outlet of a sewage treatment works or a chemical spill from a storage tank. Whereas diffuse pollution is driven by hydrologic processes and derives from non-point sources such as agricultural runoff. A risk assessment must include a detailed survey of these potential sources followed by analysis and a scaling in order of priority.

A ranking can be attributed according to a predetermined qualitative scale of risk such as that demonstrated in the case study. The risks can also be assessed quantitatively through statistical correlations between rainfall data, raw water quality data, river levels and reservoir levels. It can get complicated when factors such as dilution, decay and conservativity of the substance are considered.

## Risk Management Techniques

Once the risks in the watershed have been identified and ranked, options may be considered for the best way to manage them. Factors eliciting a 'high' risk ranking are dealt with first. There are several different approaches for managing risks: eliminate, mitigate or accept. It is unusual for risks to be eliminated entirely, although a polluting activity could be relocated outside the catchment. Risks are usually mitigated in some way, such as providing bunding around chemical storage tanks to catch spills before they travel to water bodies and/or improving maintenance of the tank for prevention. Risks can also simply be accepted which is to rely on the design capability of the treatment plant to improve the quality of the water to the potable level.

RM strategies for the *catchment* focus on preventing, eliminating or mitigating pollution from human activities in the water supply catchment.

Risk management techniques used directly on *reservoirs* to decrease the effects of algal blooms may include:

destratification, and/or
hypolimnic aeration,
biomanipulation of the food web.

Monitoring systems can be installed to detect the parameters linked with high priority risks identified in the risk assessment. Emergency response routines provide ways of

[1] National Office of Potable Water, France, 1996, cited in Lambert, V,.

dealing with extreme situations which have already occurred thus supporting the overall risk management strategy.

## CASE STUDY

Lyonnaise des Eaux operates two water treatment plants in Johor Baru, Malaysia, the Sungei Johor and Sungei Layang (320 MLD and 160 MLD capacity respectively) with separate raw water supply catchments. The Sungei Layang WTP extracts raw water from the Upper Layang reservoir which has two additional sources of raw water: transfers direct from the Johor River and transfers from the Lower Layang reservoir

There are two main risk management strategies being employed by the company: the first is to protect the raw water through pollution prevention in the watershed, and the second is and emergency response strategy to be ready to respond to any unforeseen pollution events supported by on-line monitoring. In joint activities with the local Environment Authority, Strategi Tegas (the Lyonnaise concessionaire company) has done extensive surveys of landuse and activities in the raw water supply catchments of both the Johor River and the Upper and Lower Layang Reservoirs.

### Catchment Survey and Control

**Detailed Physical Survey and Sampling :** The Upper Layang and Johor River catchments were surveyed by boat and vehicle and landuses and activities were plotted onto a map. Water quality samples are taken from the discharge point of each activity (e.g. fish farm, vegetable farm, sand mine) for chemical analysis. Wherever possible, all chemical use was recorded such as insecticides, herbicides and fungicides for the type, brand, percentage of ingredient, manufacturer, maximum quantity and storage location.

Photos were also taken of the activities and workers interviewed to support the collection of this database. People working in and living nearby to the activities were generally very co-operative with the surveyors as they understood that they are dependent on the water source as well (for drinking and fishing).

**Risk Assessment Methodology :** The survey reports for the Upper Layang Dam and Johor River catchments were summarized in matrix tables for the risk assessment (see Tables 1 and 2). The probability category is a measure of the likelihood of a pollution event, while the effect or toxicity is the estimated impact based on the type of substance. A weighting is given for each. In the case of diesel storage, the quantity was recorded along with an assessment of the risk of spillage (based on the condition of the storage, whether the substance is locked securely away and/or if it has a safety bund). For palm oil mills, pig farms, chicken and duck farms, waste management is assessed based the existing waste treatment facilities at the site and water samples taken downstream in the river. As the vulnerability of an activity is difficult to establish, only three risk categories were used: “high”, “medium” and “low”. Priority is given to those activities, which are in the “high” and “medium” categories.

While the probability of occurrence and impact is estimated in a similar way for sources in the two catchments, the estimation of time lag is intrinsically different. Time lag, the

time taken for a pollution 'spill' to travel through the catchment, down a water course to the intake point, is estimated for emergency response purposes. Pollution lag in the Johor River catchment is based on estimations of river speed (from worst case flow and river profile) and distance to intake, neglecting tidal effects. This gives the minimum response times for the Johor River WTP.

**Table 1. Results of catchment survey, Johor River**.

| Description | Map No. & Location | Pollutant | Maximum Storage | Probability | Time Lag | Effects/ Toxicity | Mitigation Measures | Remarks |
|---|---|---|---|---|---|---|---|---|
| Palm oil mills | 16,22,23, 24,25,26 | Palm oil Effluent Diesel fuel | 30,000 L | High Medium | 3 Hour 3 Hour | Medium High | Redox Film Detector | Occurs during storms |
| Industrial rubber factory | | Ammonia Formic acid Rubber effluent | | Medium Medium Medium | 5 Hour | High Medium Medium | On-line ammonia detection | |
| Fruit factory | 17 | Diesel Effluents | 30,000 L | Medium Low | 3 Hour 3 Hour | High Medium | On-line film detector | Waste goes to palm oil mill |
| Pig farm | 18 (1000 pigs) 19 (3000 pigs) | Microbe risk Bio-organic | | High High | 2 Hour 4 Hour | High Medium | Liaise with Kesihatan & Pejebat Haiwan | Will stop Feb 1998 to relocate |
| Sand mines | 14 (river) 19 (river) 29 (River) 28 (Land) | Diesel Turbidity (clay) | 30,000 L 30,000 L 30,000 L 30,000 L | Medium High | 20 Min 1 Hour 3 Hour 3 Hour | High Low | Propose treatment Liaise with DOE & Jabatan Tanah | |
| Chicken farm | 21 | Microbe risk Bio-organic | | Low Low | 4 Hour | High Medium | Inform before washing | Chicken dung sale as fertilizer, washdowns occur once a year |
| Treatment Plant | 30 Linggu Dam 21 Sayong | Sludge Diesel fuel | 30,000 L | High Medium | 3 Hour 4 Hour | Low High | Liaise with SAJ KT Bunding and lock valve | Pollution may be removed |
| Fish farm | Kampong Sungei Telor | Turbidity Organics | 2,000 $m^3$ | High High | 20 Min | High High | Inform before discharging | |
| Sea Water Intrusion | Intake | Salinity | | Low | 5 Min | High | On-line conductivity meter | An upstream dam regulates the flow |

Time lag for the Upper Layang reservoir is the time taken for the pollution to travel from the entry point at the edge of the dam to the WTP intake located near the dam wall. Estimations of travel times within the water are based on chemical separation rates from literature and assume no flow.

***Cryptosporidium Risk Assessment :***Cryptosporidium risk for both the river and reservoir catchments has been assessed by using a method developed by Colin Nichelson, Sydney Water.[2] The method categorises the source risk into High, Medium and Low correspond-

[2] Mr. Colin Nichelson is a water engineer from Sydney Water, Australia, who was working with Northumbrian Water Ltd in the United Kingdom for 12 months on Cryptosporidium risk.

ing to a total risk score of above 7000, between 4000 and 7000 and below 4000 respectively. Both the Sungei Layang and the Johor treatment works are categorised as high risk based on the assessment method.

**Table 2. Results of catchment survey, Upper Layang Dam.**

| Description | Map No. & Location | Pollutant | Maximum Storage | Probability | Time Lag | Effects/ Toxicity | Mitigation Measures | Remarks |
|---|---|---|---|---|---|---|---|---|
| Vegetable farms X 2 | 1 Upper Layang & 2 Lower Layang | Insecticides, fungicides & fertilizer | 500 litre<br>500 litre<br>2 Ton | Medium<br>Medium<br>Medium | 1.5 Day<br>1.5 Day<br>1.5 Day | Medium<br>Medium<br>Low | Communication link<br>Communication link | Dam buffer<br>Dam buffer |
| Orchid Farm | 3,4,5,6,7,8 Upper Layang | Insecticides, fungicides, fertilizer & herbicides | 500 litre<br>500 litre<br>1 Ton<br>500 litre | Medium<br>Medium<br>Medium<br>Medium | 1.5 Day<br>1.5 Day<br>1.5 Day<br>1.5 Day | Medium<br>Medium<br>Low<br>Medium | | Dam buffer |
| Chicken distribution Transit Point | | Chicken dung, microbe risks | | Low<br>Low | 1.5 Day<br>1.5 Day | Low<br>High | | sale of chicken dung |
| Domestic Discharge (non-sewage) 1,000 population | 9 Upper Layang Ban Foo Village | Microbe risk<br>Detergent<br>Bio-organic | Small part of village | High<br>High<br>High | 1.5 Day<br>1.5 Day<br>1.5 Day | High<br>Low<br>Low | Liaise with local authority to divert drain | |
| Palm Oil Plantation | 10,11,12,13 Upper Layang | Fungicides, Fertilizers, Herbicides & Pesticides | Stored out of catchment | Medium<br>Medium<br>Medium<br>Medium | 1 Day<br>1 Day<br>1 Day<br>1 Day | Medium<br>Low<br>Medium<br>Medium | Communication link | Palm oil plantation & Rubber plantation in Upper Layang not in operation, no chemicals added |
| New Housing Area | Upper Layang | Clay & others (turbidity) | small area | High | 1 Day | Low | | |
| Duck Farm | Lower Layang | Organic waste, microbe risks | 5000 ducks | High<br>High | Removed | Medium<br>High | Removed in early 1997 with DOE and Health Ministry assistance | |

**Risk Management**

**Mitigation Measures :** Mitigation measures are planned for each activity according to the risk assessment results. Generally, high risk activities are relocated with the assistance of the Health Ministry (HM) and Department of Environment (DOE). For example, a duck farm with 5,000 ducks was relocated outside the watershed from the Lower Layang Dam catchment early in 1997. The duck farm was inspected by both HM and DOE officers along with staff from Strategi Tegas during a sanitary survey. Water samples, including BOD and suspended solids, taken from the site indicated discharge concentrations which were much higher than those permitted by DOE standards.

The vegetable farmer close to the reservoir was asked to dig drains and sumps to prevent spills and polluted runoff from entering the raw water supply dam. It was proposed to the owner that diesel fuel storage be bunded and securely locked.

Close links are encouraged between the catchment occupants and the water supply company where early warning is given before something is discharged into the reservoirs or river. For example, people are encouraged to inform the water supply company before they change the water in their fish pound. People living in the catchment are also encouraged to report accidental pollution through rewards for prompt information. These measures help prevent the treatment works from producing non-compliance water.

## Raw Water Quality Monitoring

**On-line Early Warning Station :** The mitigation measures described above will be supported by a proposed on-line monitoring system to be located at the Johor River Plant raw water intake. The monitored parameters will include a film detector, dissolved oxygen, redox, ammonia, pH, conductivity, turbidity and temperature. Should the on-line sensor detect any abnormal readings, the system will alert the Johor River plant operator so that action can be taken. These parameters would allow the detection of most of the common types of pollution in the Johor River catchment highlighted in the survey (Table 1), such as diesel fuel, palm oil effluent, sewage, animal waste discharge, fish pound discharge, sea water intrusion, ammonia and formic acid from rubber factories.

**Existing Daily Monitoring :** The measured daily river raw water parameters at the plant are pH, turbidity, dissolved oxygen, ammonia, conductivity, Total Coliforms, Faecal Coliforms, color, permanganate index, UV 254 and phenol. The repeated parameter tests will form a verification to ensure that the on-line analyzer is working properly while the remaining four (4) parameters will indicate pollutants in moderate or low concentrations which are not sensed in the on-line sensors and two hourly odour test.

**Upper Layang Dam Monitoring:** Unless a pollution spill occurs close to the Upper Layang dam intake, the dam will tend to act as a buffer for most accidental pollution. The raw water from the dam is on-line tested for pH and turbidity, while odour, color, total and faecal coliforms are tested each day. At the intake, every metre of depth is tested weekly for dissolved oxygen, temperature, turbidity and conductivity. At every two metre depth, samples are collected for analysis of pH, temperature, turbidity, conductivity, iron, manganese, ammonia, phosphate, hydrogen sulphite, permanganate index & uv 254.

**Catchment Network :** Strategi Tegas is also planning to set up a pollution network with the other three (3) waterworks so that the operators could inform each other immediately if any of the plants detect pollution and to narrow down its source. The catchments for the Johor Baru water supply (both river and dams) are surveyed quarterly by the concessionaire company to monitor the existing activities and to check for any new developments which may impact upon water quality. At least once every two years, there will be a survey conducted in conjunction with the Health Ministry and DOE under the Sanitary Survey Program instituted by the Malaysian government.

## Emergency Response Management (accidental pollution)

Under the ISO 9002 quality assurance program, emergency response procedures have been developed to manage potential pollution incidents. The procedure is put into mock periodically to ensure its efficiency in an actual situation. Generally, if there is any unacceptable pollution levels detected in the raw water, the works will close down until the quality of the raw water is confirmed to be treatable. If pollution is detected, the response procedure is as follows:

the WTP laboratory will start to monitor the raw water intensively (an external laboratory is on emergency standby for further analysis),

a safety and security department is informed and investigates the cause of the pollution,

the raw water and treated water is intensively monitored for several hours until the pollution tail has dissipated,

the client is informed if there is a stoppage affecting the water supply or if polluted water has entered the distribution system,

Government agencies (DOE) and the police may be called

In the case of the river, normally the plant will wait until all the polluted water has passed from the intake before resuming production.

For accidental pollution involving the Upper Layang reservoir, the recovery time for the raw water is estimated. Jar tests and a plant trail is conducted to ensure the water is safe for drinking or complies with the required standard before being supplied to the consumer.

## CONCLUSION

Water quality deterioration is a result of particles, nutrients and other substances being transported from areas of anthropogenic activity in the watershed (urban, industrial, agricultural, cleared land) into streams and to the supply reservoir. These factors increase the risk of supplying non-compliance water. Risk assessment and management strategies provide a means of better understanding water quality problems in raw water and can be used to guide the use of resources efficiently toward higher raw water quality targets. The case study of the Johor Baru system gives an account of how the principles of risk management can be applied (source identification, risk assessment, monitoring and crisis management) for a successful, on-going raw water quality improvement program.

## References

Clark R.M., Goodrich J.A., Lykins B.W., and Neal J.R., " Evaluating the effects of upstream dischargers on downstream water supplies: a source water protection model," Journal of Water SRT – Aqua, Vol. 47, No.5,pp. 215-222, 1998, (Water Supply and Water Resources Division; and Water Quality Management Branch, US Environmental Protection Agency)

Lambert, V., “Biomanipulation: What you must know”, Unpublished, 1999
Mitchell, D.F., Galya D., Ruffle, B., and Bleiler. J.A., “The use of risk analysis in watershed planning activities,” US Environment Protection Agency, May 1999
Meadows, M.D., “Reservoir Management”, Journal of the American Water and wastewater Association, pp. 26-31, Aug. 1987
Straskraba, M., “Ecotechnological methods for managing non-point source pollution,” Water Science & Technology, Vol. 33, No. 4-5, pp.73-80, 1996