Selection of an appropriate risk assessment tool for waste water risk abatement planning: an eThekwini case study

A. Singh

eThekwini Municipality, 3 Prior Road, Durban 4000, South Africa. E-mail: akash.singh@durban.gov.za

Abstract

A Wastewater Risk Abatement Plan (WWRAP) has become an integral part in the operation of wastewater treatment plants across South Africa with the introduction of the Green Drop initiative. With each successive Green Drop season the WWRAP has become more of a focal point of the assessments and is intended to engender a more risk aware and risk averse philosophy into the operation of wastewater plants. The WWRAP, itself, is intended to be used as a tool to prioritize the deployment of limited resources and funds to achieve better compliance and management of wastewater treatment plants across the country. This is only effective if the method used for rating risk successfully identifies risks inherent on the plants. In essence the WWRAP will not achieve its objectives unless risks are properly identified. This paper explores the two successive WWRAPs produced by the eThekwini Municipality and the evolution of the risk rating systems employed. In 2011 the eThekwini Municipality’s WWRAP was based on a modified risk matrix as proposed in the Draft Guidelines for the development of WWRAPs by DWA and the WRC. While the results of this assessment generally correlated with the Department of Water Affairs’ Cumulative Risk Rating assessments, the rating system was based primarily on health targets and as a result was ineffectual as a tool for prioritization of resources. In 2012 with the next revision of the WWRAP there was a need to further ‘tweak’ the risk matrix used in order to more accurately reflect and identify risks on the various plants. This entailed increasing the complexity of the risk rating methodology and care was taken to ensure usability while still enhancing the efficacy of the risk assessment process. It was decided that ‘Administrative’ or ‘Reputational’ risk be taken into account when evaluating risk at the various plants and the risk assessment matrix was adjusted accordingly. It was decided that both administrative and reputational risk could be adequately represented by the influence that a particular risk had on the Affairs’ potential Green Drop score. Multiple permutations and approaches were evaluated to determine which method would best reflect the ‘on the ground situation’. Using the new rating system, a total of 1,235 low risks were identified over the previous year’s 913, medium risks numbered 223 over the 17 from 2011 and 105 high risks were identified for 2012 as compared to 2011 where no high risks were identified at all. The new rating system was thus deemed a more appropriate tool for the prioritization of resources for the municipality.

Key words: eThekwini, green drop, risk assessment, WWRAP

INTRODUCTION AND RATIONALE

To mitigate potential risks arising from the treatment of wastewater, a Wastewater Risk Abatement Plan (WWRAP) becomes a valuable primary risk management tool to enhance municipal wastewater service delivery. The WWRAP should encompass all steps in the wastewater value chain, from production to discharge or reuse in a particular catchment.

The WWRAP is a risk assessment process and as such allows for the quantification and ranking of the risks associated with potential hazards. This in turn allows for resources to be allocated to mitigate risks based on the hierarchy resulting from the assessment. Effectively this means that an organization
such as a Municipality can allocate limited funding or scarce skilled staff objectively to where these resources are actually most required and where they would make the most impact.

Most risk assessment methodologies quantify risk in terms of probability of a hazard resulting in an undesirable event and the consequences of said event. Key to this approach is the risk assessment tool, which is typically a matrix, defining what the levels of probability and consequence are so that risks can be objectively quantified. Risk assessment tools will be covered in more detail in subsequent sections.

When performing a risk assessment it is important to note the purpose of the assessment. For example, the purpose to ensure compliance with discharge standards, protect human health, ensure health and safety compliance during operation, protect the lifespan of assets or a combination of two or more of these factors. The purpose or objective of the risk assessment greatly influences how the risk assessment is carried out and what risk assessment tool is used.

Selection of the risk assessment tool becomes vital as, if not selected properly, the outputs of the risk assessment could be useless. Often it is found as a result of a misaligned risk assessment tool, that risks identified are all low or worse yet all high. An ideal risk assessment allows for risks to be distributed evenly thus allowing those risks that need immediate action to be easily identifiable. It is often said in risk assessment circles: “If everything is important, then nothing is”.

The eThekwini Municipality, which owns and operates 27 wastewater treatment facilities of varying size and complexity, engaged in the development of a WWRAP document during the fourth quarter of 2010. The documents resulting from this process were used as a case study during the development of the WRC guideline for WWRAP Development [Manus & Botha (2011)]. eThekwini is acknowledged in the final document and is used as an example of an alternate approach. The focus of this document was purely related to the various plants operated by the Municipality.

This notwithstanding, it was identified that solely evaluating risk on health based consequences did not enable the WWRAP to be the effective management tool it could be for the municipality. This was as a result of a misalignment of the risk assessment tool to the needs of the organization. The decision was therefore taken to refocus the risk assessment tool as well as expand the approach to factor in ‘Administrative’ or ‘Reputational’ risk in the next WWRAP revision. This paper seeks to chronicle this process and its outputs as well as advise as to how it can be generically applied to other municipalities in South Africa and elsewhere.

**WHAT IS A RISK ASSESSMENT?**

A risk assessment is the process whereby risks associated to hazards are identified, quantified and ranked. This is done with the view to mitigate against said risks and ultimately meet the objectives of the organization and improve its outputs. The risk assessment forms part of a greater risk management strategy as illustrated in Figure 1 below.
A risk assessment tool, as defined in this paper, is the method used to enumerate and quantify risks associated with identified hazards. As stated previously such a tool is typically in matrix form tabulating the quotient of probability of an event and the consequences of said event yielding a risk score. A simple risk matrix is shown below in Figure 2.

<table>
<thead>
<tr>
<th>Risk Matrix</th>
<th>Probability Score</th>
<th>Severity Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rare (1 in 5 years)</td>
<td>Insignificant (No Impact)</td>
</tr>
<tr>
<td>2</td>
<td>Unlikely (once per annum)</td>
<td>Minor (Minor Impact to a large population)</td>
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<td>3</td>
<td>Moderately Likely (once per month)</td>
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<td>4</td>
<td>Likely (once per week)</td>
<td>Major (Population exposed to significant illness)</td>
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<td>5</td>
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For each hazard identified, the probability and severity of consequence would be evaluated in accordance with the scoring definitions listed. The product of these scores would yield the risk score. For example a rare event (Probability = 1) with catastrophic consequences (Severity = 5) will have a risk score of 5. Similarly a likely event with moderate consequences would have a risk score of 12. The output of the risk assessment thus allows for ranking of risks according to this scoring. Application of resources to mitigate risks would be in order of priority where the risk of 12 is dealt with before the risk of 5.

**METHOD FOR RISK TOOL SELECTION AND CALIBRATION**

The method described below for risk tool selection and calibration was used in the development of the eThekwini WWRAP [Singh & Chellan (2012)]. It must be noted that this method was developed as a direct result of the lessons learnt during the development of eThekwini’s WWRAP as described in the next section. This paper seeks to serve as a guideline for selection and modification of the risk assessment tool used while developing a WWRAP it is not a guide on how to perform risk assessments or develop a WWRAP. It is best to read this paper in conjunction with the WRC guideline for WWRAP development [Manus & Botha (2011)].

Risk assessment is an iterative process with the aim to achieve progressively better outputs with each successive generation. The method described below takes cognizance of this fact and is divided into three distinct phases, viz. Selection, Calibration and Implementation, that can relate iteratively to each other. While technically developed for WWRAP development, the following method can be applied to most risk assessment scenarios. The process is summarized in Figure 3 below.

Phase one is a preparatory and deals with the ‘Selection’ initial approach. The first step in the process would be to define the objective or purpose of the risk assessment. Ultimately a risk assessment is carried out to prioritize scarce resources in order to meet an organization’s goals or objectives. This defines the terms in which the consequences of a hazard should be measured. It is therefore pointless to perform a safety risk assessment when the goal of the organization is to improve productivity. Selecting the wrong objective or objectives can be extremely counter-productive. Definition of the objectives should be work-shopped to determine what is expected as an outcome of the process,
this is usually done at a strategic or senior management level. A team should be setup before or concurrently with this process to guide further development. A single objective should be chosen initially and parallel or sub-objectives can be added over time as the risk approach of the organization matures.

Once the objectives are defined, a generic tool should be selected as a kick-off point. There are many different risk assessment methodologies available. Typically the number of objectives selected would inform the structure of the tool. In practice the more objectives the more complex the risk rating tool will become. At the first iteration of the WWRAP it is best to start with a simple tool. The Guidelines for WWRAP Development by the WRC [Manus & Botha (2011)] provides an excellent kick-off point for this selection.

While it is possible to use the generic tool selected as is, it is best to look at the limits/ranges in the tool to ensure that they are aligned with the objectives. It is not necessary to spend an inordinate amount of time adjusting the limits at this stage, further tweaking can be done during the Calibration Phase.

For example, if the objective is to allocate a short term budget to improve end of pipe compliance then the tool needs to look at the effect that a hazard would have on said compliance. As an example a critical impact may be deemed as an event which results in an excess 50% dip in compliance whereas an insignificant impact may only have a <1% impact. Adjusting the definitions of these impacts can have a huge effect on the output of the risk assessment tool. If the majority of impacts in the organization have a greater than 50% impact then the output of the assessment will show a large number of high risks. While this may ostensibly be true, it does not help in the effort of prioritization of resources.

The frequencies for the probabilities also need to be examined depending on the scope of the assessment. It may be that daily and weekly risks effectively ranking the same for a particular organization.
It therefore makes no sense to split them. The risk assessment matrix may cater for monthly risks but how does one fit seasonal risks in? The key is to ensure that the bands for probability and consequence make sense for the organization. They must be clearly defined in such a way that the scoring can be attributed easily rather than attempting to fit data to a particular band.

The next phase is the ‘Calibration’ of the risk approach. This process is analogous to the calibration of an analytical instrument against known standards. Experienced staff often have a good gauge of what constitute high and low risks in their areas. The goal of most risk assessment processes is to harness this experience and objectively apply it across all hazard. Effectively reverse engineering the experience and incorporating it into the risk assessment tool used. To achieve this a selection of known risks must be used to test the outputs of the risk assessment tool. At this phase it is best to have a mix of experience and youth in a team to define those risks that will be used as a benchmark. A good indicator to use for a known low risk would be that of a plane crashing on to the plant.

A desktop exercise using the risk assessment tool must be carried out to see if the outcome expected is achieved. For example, a risk related to micro compliance risk and disinfection is known to be high. This is further supported by compliance data for this plant. If this risk is assessed using the risk assessment tool and it comes out as a low risk then the ranges/parameters of the risk assessment need to be adjusted and the risk reassessed. In addition should the risk ranking not be correct then further iteration would be required. That is to say, if the risk assessment output states that one should mitigate against a plane crash before attending to the disinfection plant, it is a fairly good indication that more calibration is required. The process should be carried out for low, medium and high benchmark risks, the more risks used to test the better. When this is done for several known benchmark risks the process should yield a finely tuned risk assessment tool. In some cases there may be a need to actually choose a different type of risk assessment tool altogether or to add additional factors in as with the case of the Green Drop factor in eThekwini’s case.

The last phase is ‘Implementation’. Though the risk assessment tool may have been benchmarked against a few known risks there is no guarantee that it will perform as desired in all cases. It is a good idea to look at the outputs of the risk assessment and gauge user feedback as well as correlation with known data. At this point it would be prohibitive to modify the tool and redo the risk assessment. As previously stated, risk assessment is an iterative process and does not have to be perfect on the first go. It is more important that one evaluates the outputs and learns from them and adapts the process accordingly. To this end, any deviations should be noted for the next revision of the WWRAP to ensure continuous improvement in the risk assessment process.

BACKGROUND TO ETHEKWINI’S WWRAP DEVELOPMENT

As stated previously, in November 2010 the Works Branch embarked on a WWRAP development process in order to minimize risk and prioritize work allocation and funding. This entailed carrying out risk assessments on the process and unit operations for all 27 wastewater treatment works operated by the municipality. A workshop with the Area Engineers and their respective plant Superintendents was held to sensitize these Area Management Teams to the WWRAP process and at this meeting a list of generic hazards to be evaluated was generated. Examples of risk scoring methodology were also presented. Thereafter the area management teams were charged with carrying out the individual plant risk assessments.

The original approach to the risk assessments was based on a modified risk matrix from the then draft guidelines for WWRAP development by the WRC and DWA [Manus & Botha (2011)]. This approach was in turn based on the World Health Organization’s guidelines for the development of Water Safety plans [Water Safety Plan Manual (2006)].
This matrix evaluated risk in terms of frequency and health consequences. The matrix was altered to preferentially deal with high frequency/low consequence risks over low frequency/high consequence risks. Table 1 below shows the risk matrix used for the 2011 WWRAP Process.

### Table 1 | EWS works branch risk matrix

<table>
<thead>
<tr>
<th>Probability Score</th>
<th>Severity Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rare (1 in 5 years)</td>
<td>Insignificant (No Impact)</td>
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<td>Unlikely (once per annum)</td>
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</tr>
</tbody>
</table>

Hazards were evaluated and scored on the probability of occurrence as well as the severity of the resulting consequences as raw or uncontrolled risks. The percentage efficacy of any existing control measures were also factored in yielding the final or residual risk rating. It was decided that any ‘High Risks’ identified would require a formal action plan to deal with mitigation of these said risks. Table 2 displays an example of the risk tables used in the aforementioned exercise.

### Table 2 | Risk assessment table 2011

<table>
<thead>
<tr>
<th>Area</th>
<th>Location</th>
<th>System</th>
<th>Hazard/Risk Description</th>
<th>Could this issue result in a risk?</th>
<th>Inherent Risk Score (before consideration of any controls)</th>
<th>Inherent Risk Characterisation</th>
<th>Existent controls</th>
<th>Control Reference</th>
<th>Residual Risk Score</th>
<th>Residual Risk Characterisation</th>
<th>Comment</th>
<th>Recommended mitigation/improvement plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Coastal</td>
<td>Umbilical</td>
<td>Actuated</td>
<td>Industrial Bollard leaks</td>
<td>Y</td>
<td>5</td>
<td>20</td>
<td>Medium</td>
<td>Incident reporting protocol</td>
<td>20</td>
<td>Medium</td>
<td>WAVAP329 WAF02</td>
<td>Pollution prevention and source control/regulated</td>
</tr>
<tr>
<td>Hard areas</td>
<td>Hammar</td>
<td>Inlet</td>
<td>Removal and delivery replacing &amp; repairing non functional flume/conveying equipment</td>
<td>Y</td>
<td>4</td>
<td>16</td>
<td>Medium</td>
<td>Reservoir maintain</td>
<td>0</td>
<td>Medium</td>
<td>WAVAP329 MA-01</td>
<td>MI2 receive additional staff</td>
</tr>
</tbody>
</table>
Despite skewing the risk matrix this process did not identify any high residual risks. Only 17 medium residual risks were highlighted and these risks were largely repetitive and were dealt with collectively via two action plans. While this low risk rating generally correlates well with the municipalities Green Drop and CRR ratings, solely evaluating risk on health based consequences did not enable the WWRAP to be the effective management tool it could be for the municipality. This is due to the fact that the vast majority of plants in the municipality have very small, if any all, populations of downstream users or abstracters. It therefore stands to reason that health risks associated with these works would be minimal.

eThekwini’s approach at this stage was still in its infancy. Evaluating the approach used against the tool selection methodology it is noted that at the Selection phase the purpose of the risk assessment was not selected correctly. In addition, although the risk matrix was skewed, additional benchmarking or Calibration was not done.

Clearly the risk assessment tool used was not aligned to the needs of eThekwini. The decision was therefore taken to expand the approach to factor in ‘Administrative’ or ‘Reputational’ risk in the next WWRAP revision as well as ‘Level of Service’ risk.

ETHEKWINI’S APPROACH TO SELECTION AND MODIFICATION OF A RISK ASSESSMENT TOOL

As discussed above, there was a need to further ‘tweak’ the Risk Matrix used in order to more accurately reflect and identify risks on the various plants. This entailed increasing the complexity of the risk rating methodology and care was taken to ensure usability while still enhancing the efficacy of the risk assessment process.

The original two dimensional (2D) probability/consequence matrix was used as a basis for the new rating system. The probability scoring method did not change significantly for the this iteration however the consequence severity was adjusted to reflect ‘Process’ or ‘Level of Service’ thus aligning the tool to the needs of eThekwini as can be seen from Table 3 below.

As previously stated, it was decided that ‘Administrative’ or ‘Reputational’ risk be taken into account when evaluating risk at the various plants. Modification of the 2D matrix was a relatively simple process, adding in the addition aforementioned factors however proved to be a more complex task.

It was decided that both administrative and reputational risk could be adequately represented by the influence that a particular risk had on the plant’s potential Green Drop score as calculated based on the 2010 Green Drop Requirements [Manus & Botha (2010)]. Multiple permutations and approaches were evaluated to determine what method would best reflect the ‘on the ground situation’. To this end a multiplier was incorporated into the risk rating resulting from the 2D matrix as can be seen in Table 4. The ‘Green Drop Factor’ effectively increases the base 2D risk depending on its particular effect on the Green Drop Score. The effect was quantified in terms of the total percentage impact said risk would have on the plant GD rating.

As can be seen from the table an insignificant GD factor did not change the base risk at all whereas a Critical GD factor would effectively treble the risk associated with a particular hazard.

The risk categorization from the 2D matrix was maintained. Therefore risks in excess of 25 were still categorized as high. This effectively skewed the risk scoring distribution yielding a broad range for high risks (25–90). While this may seem excessive at first glance, analysis of risk rating permutations revealed a balanced risk distribution from low to high risk.

The selection of the GD factors was initially arbitrary and then fine-tuned through iteratively testing against a selection of experientially known risks. For example it was known that on a certain plant Microbiological-Compliance is an issue and the reliability of disinfection was a critical risk while on the same plant the head of works screens’ failures were seen to be a low risk as there were manual backups in place. These two risks were analyzed using the risk assessment tool and the factors
were adjusted until the tool resulted in a risk scoring that correlated with experience. It must be noted that the danger inherent in such testing of a process lies in the reliability the experiential risk used. It is best to use a risk where there are data available to verify the experience given by operational teams, etc. rather than just relying on ‘word of mouth experience’.

The effect that the Green Drop Factor had on control effectiveness evaluation, however, is more noticeable. For example a risk score of 25 with a GD factor of 1 and a control effectiveness of 60% would yield a residual risk of 10 and thus it would be categorized as a low risk. Taking the same scenario but changing the GD factor to 3 results in the residual risk becoming 30 and still remaining categorized as a high risk. This inherently requires tighter control measures for higher GD risks and theoretically makes the new three-dimensional (3D) risk matrix a more robust tool for prioritizing GD related risks as well as evaluating control efficacy.

Once satisfied that the risk matrix provided reasonable risk ratings the tool was rolled out in the same way as was done for the 2011 WWRAP for the 2012 revision of the document. The new rating system generally highlighted more risks overall as well as identifying those risk areas known experientially to be problematic. The new rating system was generally viewed as an improvement over the previous system by the users. Risk ratings correlated well with what was expected and new high risks that previously had been overlooked came to the fore.

Overall 1563 individual hazard/risk areas were rated across 27 plants during the 2012 process. This was an improvement over the 930 over 24 plants from the previous year. Glenwood Road, Magabeni and Cato Ridge were not assessed in the 2011 risk assessments. A total of 1,235 low risks were identified over the previous year’s 913, medium risks numbered 223 over the 17 from 2011 and 105 high risks were identified for 2012 as compared to 2011 where no high risks were identified at all. Figure 4 below shows the risk profile for 2012 versus 2011.
To gain the most out of a risk assessment and produce meaningful WWRAPs, the selection of an appropriate risk assessment tool is key. Failure to do so can result in poor risk quantification and
prioritization. This ultimately leads to poor risk management in general. Following the approach described in this document of ‘Selection’, ‘Calibration’ and ‘Implementation’ allows for the alignment of the risk assessment outputs to the organization’s needs and results in a more representative ranking of its priorities.

As can be seen from the case study, application of this methodology has yielded an improved risk ranking for eThekwini. The risk profile that resulted from the WWRAP 2012 better enabled the Municipality to identify priority problem areas and allocate its resources accordingly. This in turn will improve its wastewater treatment performance and service delivery.

REFERENCES