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Non-Metropolitan Drinking Water Suppliers' Response to the Diagnostic Tool for Non-Technical Compliance in Limpopo, South Africa

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Abstract: Without the planning of non-technical issues, water treatment plants may face challenges in sustaining safe drinking water. Parameters such as the planning of financial resources, human resources, a lack of professional process controllers, poor working conditions, staff shortages and a lack of appropriate training of process controllers contribute to the underperformance of drinking water treatment plants. This study aimed at applying the Diagnostic Tool for Non-Technical Compliance to assess the compliance of small drinking water plants with management norms. Six water treatments (Vondo water scheme, Malamulele, Mutshedzi, Mutale regional water treatment plant, Tshedza and Tshedza package plant) were selected from the Vhembe district municipality of the Limpopo province in South Africa. From the abovementioned non-technical parameters, the results showed that during the first assessment period (August 2008 and June 2009) selected water treatment plants scored between 53% and 68% and fell under Class 2, indicating serious challenges requiring attention and improvement. During the second assessment period (November and December 2010), a slight improvement was observed as all plants scored between 72% and 80%, falling under the Class 2 category. Even after corrective actions and remeasurement, none of the plants met the compliance standards, which range from 90% to 100% to obtain the Class 1 compliance standard. The study recommended that tactical and strategic plans that clearly define the operational procedures, process controlling, financial planning, maintenance culture, emergency preparedness and regular monitoring and evaluation should be entrenched for the smooth running of the small water treatment plants. Furthermore, all water services providers and water services authorities should apply the diagnostic tools as developed, which provides guidance on a stepwise procedure on plant operations and management on a daily basis.

Keywords: non-metropolitan drinking water system; South Africa; water quality; non-technical compliance

1. Introduction

Effective auditing of the management components that play an important role in the sustainability of water treatment plants is critical for the treatment and supply of safe drinking water to communities. These components include management issues and practices, human resources, financial aspect, communication systems in place, safety, health and environmental quality (SHEQ), as well as the community involvement and awareness [1]. Proper planning for operations and maintenance, routine

operator duties, organisational alignment, capacity building and political buy-in on water issues accelerates compliance to drinking water standards [2].

The implementation of centralised systems requires highly skilled personnel for continuous maintenance and management. However, in developing countries, the lack of non-technical skills in the water sector has been highlighted as one of the major challenges to sustain quality water provision through centralised systems, especially in non-metropolitan areas [3,4]. Potential areas for capacity development include technical, managerial, marketing and public relations. This challenge underscores the need for upgrading and training of personnel in the water sector. A case-study conducted in South Africa by Momba and co-workers [4] has revealed a shortage of human resource capacity in over 70% of small water treatment systems visited in seven of the nine provinces of the South Africa (Eastern Cape, Free State, KwaZulu-Natal, Limpopo, Mpumalanga, North West and Western Cape). This study also underlined the challenges facing the country in terms of a clear framework clarifying the roles and responsibilities and communication between operating staff and management.

Non-technical issues have an adverse effect on the supply of safe drinking water by small water treatment plants, not only in developing countries, but also in the developed world. In the United States, for example, there has been an amendment of the Safe Drinking Water Act, Act No. 46 of 2003, which drew the attention of the nation to the capacity problems faced by water treatment plant operations in small communities to meet their revised standards, which were stricter [5]. Compliance with national standards promotes consumer confidence in the safety of the water they drink. Mackintosh and Colvin [6] emphasise the importance of regulatory compliance, which allows the correct interpretation of simple and readily measurable analytical determinants. Furthermore, by protecting the water resources, the contamination of the water bodies is reduced, thereby minimising the threat of contracting waterborne diseases [5].

In South Africa, the identification of non-technical problems and challenges experienced at water treatment plants has led to the development of a comprehensive diagnostic tool for non-technical compliance, which spells out the step-by-step procedures and corrective actions needed to ensure the supply of safe water to non-metropolitan communities. These diagnostic tools for non-technical compliance of water treatment plants were developed to perform an assessment of a water treatment plant and establish compliance with water quality standards and management norms [1]. Generally, the assessment focuses on management issues and practices, human resources, financial aspects, the communication systems in place, safety, health and environmental quality (SHEQ), as well as community involvement and awareness. Problem areas that are identified during the assessment are then flagged and corrective measures are proposed. A report is sent to the authorities, and compliance must be reassessed by performing a remeasurement from the first step involving the human resources assessment.

In this way, the problems resulting in non-compliance can be eliminated or addressed and preventive measures can be put in place in order to make sure that the plant managers or supervisors are able to effectively manage the challenges facing their drinking water treatment plants [1]. The main objective remains the treatment and supply of safe drinking water to communities for the protection of public health. For the purpose of this study, the diagnostic tool for non-technical compliance was applied to selected drinking water treatment plants of the Vhembe district municipality (VDM) situated in the Limpopo province. The Vhembe district municipality was selected, and it covers about 25,597 km^2 and has a population of over 1.1 million, with an estimated population increase of 0.78% living in over 335,276 households. The enormous population increase in this district has resulted in very high water consumption in households estimated at 2,011,668 kL/month in all four local municipalities, namely, Mutale, Musina, Thulamela and Makhado local municipalities [7].

2. Materials and Methods

2.1. Description of the Study Area

This study was carried out at small drinking water treatment plants situated in three of the four local municipalities of Vhembe district municipality (Figure 1), namely, Mutale, Thulamela and Makhado local municipalities (Vhembe voice: 2004). Thulamela local municipality is comprised of approximately 156,594 households (47% of Vhembe district) followed by Makhado local municipalities with 134,889 households (40%), and Mutale local municipality with 23,751 households (7%). In addition, the increase in number of households and fast population growth in local municipalities was also seen by the quantity of water consumed per municipality (Thulamela: 933,938 to 939,576 kL/month; Makhado: 804,235 to 809,334 kL/month; Mutale: 141,009 to 142,506 kL/month, and; Musina: 113,602 to 120,252 kL/month). It is anticipated that as the population grows, there will be an impact on the selected areas as well, and this will lead to water resources being depleted. Six small water treatment plants were selected from 11 water treatment plants identified based on the type of treatment processes used, and their story related to non-compliance to the required standards. Furthermore, the study also aimed to select at least two conventional treatment plants and package plant in Thulamela local municipality as it is the biggest among the three local municipalities, one conventional treatment plant from Mutale local municipality and one conventional treatment plant and one package plant from Makhado local municipality. Plants were considered to be package plants when they had a very small capacity (<2 ML/day) and no unit processes could be identified, whereas for conventional plants the following unit processes could be identified: coagulation; flocculation; clarification, and; filtration, and is typically followed by disinfection at full scale. Assessments of these drinking water treatment plants using the diagnostic tool were conducted in Thulamela local municipality (Vondo water scheme, Malamulele water treatment plant and Dzingahe package plant), Makhado local municipality (Mutshedzi water treatment plant and Tshedza package plant) and Mutale local municipality (Mutale regional water scheme). The Vondo water scheme, which is located at Phiphidi village along the road from Sibasa to Nzhelele, treats 52 ML/day of water from Vondo dam. The Malamulele water treatment plant is located at Malamulele village, approximately 20 km southeast of the town of Thohoyandou and $\pm$5 km from Nandoni dam; the plant treats 16 ML/day. The Dzingahe package plant falls under Thulamela local municipality and is found less than 5 km along the road from Sibasa to Vondwe village and within 50 m of the banks of Mutshindudi River, which is a tributary of Luvuvhu River. The plant purifies 0.4 ML/day, which is supplied to Dzingahe village with the population of about 10,000. The Mutshedzi water treatment plant purifies 13 ML/day of water and is situated at Nzhelele, along the road to Mauluma (Phadzima) village under the Makhado local municipality. The plant started treating water in 1989. Mutale regional water scheme is found next to Tshandama village under the Mutale local municipality. The plant pumps the water electrically from the Mutale River, which is then stored in the raw water dam at the plant. This plant serves $\pm$ 38 villages in Mutale area and treats 13.04 ML/day. The Tshedza package plant is located at Nzhelele (Tshedza village) under the Makhado local municipality along the road from Mandala to the town of Makhado. This plant treats 1.5 ML/day and supply water to five villages with a population of about 4000. All these plants falls under Vhembe district municipality, and this is one of the water services authorities in the Limpopo province.

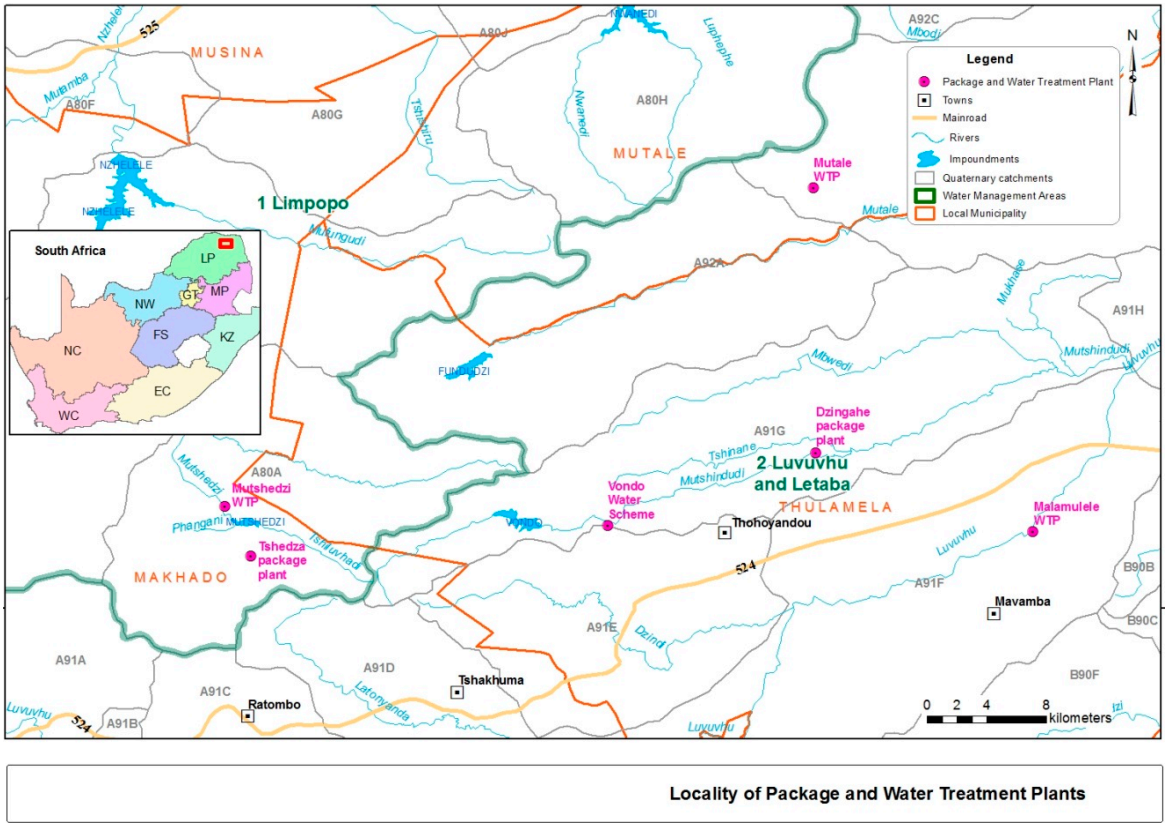

Figure 1. South African map with the location of the water treatment plants.

2.2. Application of the Diagnostic Tool for Non-Technical Compliance Assessment of the Selected Water Supply Systems

During the execution of this study, a detailed assessment of the management components of the selected drinking water treatment plants was performed between August 2008 and December 2010 using a diagnostic tool for non-technical compliance developed by Momba and Swartz [1]. The sequence of processes that were followed is reflected in Figure 2.

2.2.1. Audit of the Management Issues and Practices

The assessment mainly focused on management issues and practices, human resources, financial aspects, communication systems in place, safety, health and environmental quality (SHEQ), as well as on the community involvement and awareness. Structured interviews were conducted based on the questionnaire reflected in Table 1. The target informants included the process controllers, general workers employed as process controllers, senior plants operators, superintendents and area managers. The research team worked closely in collaboration with the water services authorities and water service providers in the Vhembe district municipality and the laboratory technicians. The assessment was conducted in a stepwise procedure as recommended by Momba and Swartz [1].

During the plant assessment, problem areas were identified for each water treatment plant and ranked in priority order. Each of these problem areas then received a scoring point from 1 to 5 according to the scoring system (Table 1) described by Momba and Swartz [1].

For each of the problem areas identified, corrective and preventative measures were recommended. Thereafter, remeasurement was done by repeating the whole non-technical compliance assessment, especially focusing on the problem areas that were identified during the first assessment and establishing whether compliance was achieved. Prior to remeasurement, a workshop was organised and all stakeholders from all the six drinking water treatment plants were invited. The main objective

of this workshop was to highlight problem areas identified during the first assessment and discuss corrective and preventive measures that should be taken in order to improve the component of the management practices that impacted the production of safe drinking water.

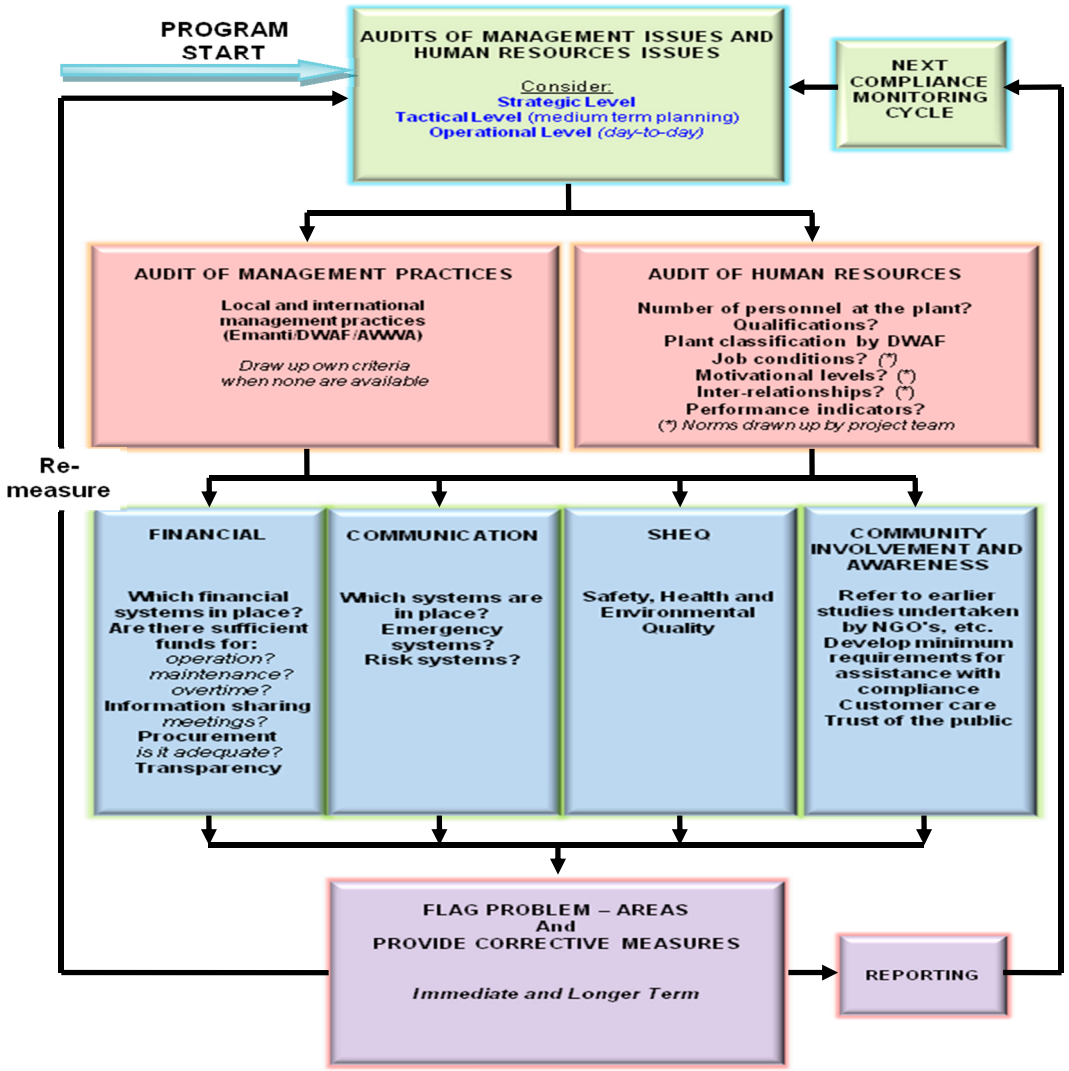

Figure 2. Frame work of the diagnostic tool for non-technical compliance of small water treatment plants developed by Momba and co-workers [1].

Table 1. Ranking of the Problem Areas in Priority Order [1].

Ranking of the Problem Areas in Priority Order	
1	Insignificant Consequence
2	Minor Consequence
3	Moderate Consequence
4	Major Consequence
5	Catastrophic Consequence

2.2.2. Scored and Weighted System for Non-Technical Compliance

Table 2 illustrates the weighting system used for the evaluation of non-technical compliance of the selected drinking water treatment plants. In order to estimate the weight, a systematic evaluation of the overall performance of potable water supplies against numerical guideline and norm values

was required to determine the level of compliance or the problems that results in non-compliance of the water treatment plants. The overall compliance rating of a water treatment plant was based on a scoring system according to the identified criteria and norms as stated in the guidelines for the assessment of the compliance of potable water supply (Table S1). Because certain compliance criteria are more important than others, a weighting system was used whereby weight is given to each of the compliance sections. These weights were determined by a panel of water treatment experts and regulation authorities, and revised on a regular basis and when necessary. The proposed weight systems for non-technical compliance are provided in the "Guidelines for the Assessment of the Compliance of South African Potable Water Supply" with "Accepted Drinking Water Quality Standards and Management Norms" (Table S2).

Table 2. Non-Technical Compliance Assessment Scoring [1].

Non-Technical Compliance Assessment Scoring	
Criterion	**Weight**
Non-Technical Assessment	
Step 1: Management Issues	0.1
Step 2: Management Practices	0.2
Step 3: Human Resources	0.2
Step 4: Financial Systems	0.1
Step 5: Communication Systems	0.2
Step 6: Safety, Health and Environmental Quality	0.15
Step 7: Community Involvement and Awareness	0.05
Total	1.0

To determine the level of compliance or the problems that resulted in the non-compliance of the selected water treatment plants, the systematic evaluation of the overall performance of potable water supplies was rated using the non-technical compliance rating reflecting in Table 3. During the design of the guideline, 80 non-technical issues were identified and, when a plant did not comply with a 50% of the non-technical issues, it was classified as Class 3 Compliance (0–50%) and between 50% and 90% (Class 2 compliance) and 90 to 100% (Class 1 compliance). It should be mentioned that this was also in relation of the seriousness of the problem as indicated by the panel.

Table 3. Non-technical compliance rating of the treatment plants [1].

Non-Technical Compliance Rating of the Treatment Plants	
Total Weighted Score	**Rating Description**
0–50	*Class 3 Compliance*: Total non-compliance; serious and immediate intervention required (TNC-Total Non-Compliance)
50–90	*Class 2 Compliance:* Serious challenges requiring attention and improvement
90–100	*Class 1 Compliance:* Acceptable compliance

2.2.3. Statistical Analysis

The data was collected from the six selected drinking water treatment plants between August 2008 and December 2010. Water samples were collected from each water treatment plant from the raw water, filtered water, and point of treatment and at the point of use. Statistical data analysis was conducted using Stata computer software (version: STATA V10, STATA Corp. LP, Texas, TX, USA, 2009). The non-parametric Wilcoxon signed-rank test was performed to compare the first assessment between August 2008 and June 2009, and the second assessment in November and December 2010 data.

3. Results

3.1. Audit of Management Issues

In order to assess the compliance of the treatment plants based on the non-technical diagnostic tools, plants were rated as shown in Figures 3 and 4. In general, all the water treatment plants during this study showed several management issues and revealed no specific strategic plans for the assessment of the drinking water supply systems, drinking water quality management, recruitment and selection processes, operational and verification of the system, training, development of water plant personnel, funding plan for the implementation of drinking water quality and community involvement. Although there were no specific strategic plans in place, process controllers were able to share and clarify their roles and responsibilities.

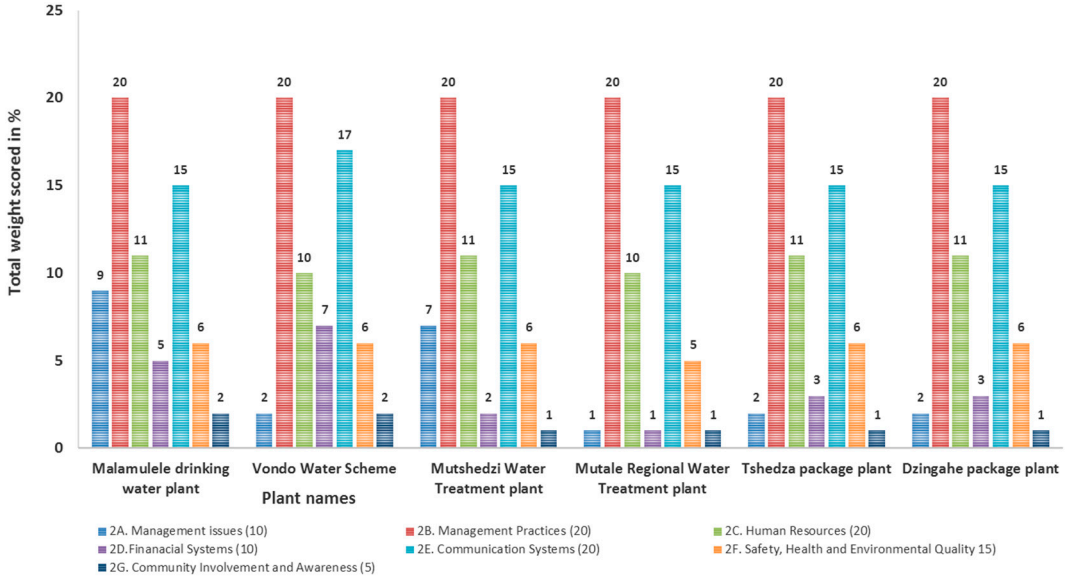

Figure 3. Scoring of water treatment plants based on the non-technical compliance assessment between August 2008 and June 2009.

Figure 4. Scoring of water treatment plants based on non-technical compliance assessment during the second assessment between November and December 2010.

Regarding the strategic plans for sharing and clarifying roles and responsibilities, if there was a vacancy for a specific position, this position was advertised and, after an interview, the best candidate was appointed using the human resources policies for recruitment and selection. Where needs arose, process controllers were sent for training and development for the proper operation of water treatment plants. In spite of this individual training, it was found that the process controllers were not fit to take up their task related to the appropriate treatment of drinking water for the distribution of safe drinking water.

With regards to the handling of emergencies, periodic overseeing of water care functions, maintenance and asset management plans, it was found that there were no specific tactical plans, however, emergency cases were handled and attended to when they occurred and they were reported to the water services authority. The communities were also informed through local radio stations and through local community sub-committees or civic associations. Furthermore, the day-to-day operational plans for all the water treatment plants were performed through an attendance register to monitor the employees because there were no clock systems in place, but the shifts were done from 6 h to 18 h and from 18 h to 6 h on a daily basis.

During the first assessment the superintendents were not found on the plant sites, but the process controllers reported that they arrived on a daily basis, although their time in the plants was limited as they had responsibilities to run not only one plant, but sometimes up to five plants in one district municipality. Process controllers believed that the appointment of substitutes in each plant is prominent in each plant as supervisors play an important role in the adequate management of the plants. All process controllers as well as supervisors were aware of their job requirements and descriptions, although there were no specific and detailed operational plans. It should be noted that the assessment of management issues was complex due to the fact that these non-technical issues were not handled directly by the water treatment plants, but at the district municipality level.

After the re-evaluation process during the application of the diagnostic tools for non-technical compliance, the Malamulele water treatment plant showed a deficit of 2% in the score, whereas the Mutshedzi water treatment plant showed a decrease in score of 1%. Contrary to the above, the Mutale regional water treatment plant showed an improvement 6% in the score followed by the Vondo water scheme 5%, and the Tshedza and Dzingahe package plants improving their score by 2%.

3.2. Audit of the Management Practices

In all the water treatment plants assessed, it was found that the water services providers (WSPs) and water services authorities (WSAs) used local management practices (Department of Water and Sanitation such as Blue Drop Systems and water safety plans), they also have an understanding of international management practices. With regard to the development of their own water safety plans, they were in a process to develop such plans during the execution of the study. This resulted in all six water treatment plants achieving compliance with a maximum score of 20%.

3.3. Audit of Human Resources

Generally, in all the targeted water treatment plants, the number of process controllers did not relate to the size of the plant, their needs also were not adequately met and there were no specific guidelines for shift workers and their deployment. In the Malamulele water treatment plant, the Vondo water scheme, the Mutshedzi water treatment plant, as well as the Mutale regional water plant and the Tshedza and Dzingahe package plants, 60% of the process controllers were general workers deployed as process controllers, and 40% were process controllers with formal qualification. All the process controllers, with and without formal education, have undergone in-house and external training coupled with vast experience of more than 10 years (>10) of water treatment.

Furthermore, during the first assessment between August 2008 and June 2009, all the water treatment plants were not classified according to the Regulation 2834, which requires that all water care works should meet certain regulatory measures such as the number of population supplied with water,

infrastructure (design capacity), control processes, operating processes and procedures. However, during the second assessment in November and December 2010, all the water treatment plants were classified in terms of the department of water and sanitation (DWS) regulations [8] for drinking water quality for water works. Based on the *Water Services Act* of 1997 set by DWS, which states the regulation relating to compulsory national standards for process controllers and water services works, 60% of the water treatment plants were falling under Class B and 40% were Class C [1,8,9]. With regard to the personnel classification, 10% of the process controllers were Class V, 70% were Class IV, 10% were Class III and 10% were not yet classified during the execution of the study. Class V and VI process controllers need some refresher training and continued training, whereas in Class I–III they require continued training until they reach a certain level. However, it was said that they submitted their particulars and were waiting for the feedback.

In terms of the scoring systems, there was a significant improvement in all the plants with regard to the audit of human resources. The results of reassessment revealed an increase in score ranging from 4% to 6% with Mutshedzi, Tshedza and Mutale showing the highest increase (by 6%), while the Vondo water scheme was the poorest-performing plant, with an increase of only 4% in its audit human resources scoring.

3.4. Audit of Financials Systems

From all the water treatment plants, the process controllers were not sure of how the budget systems or funds were allocated as they have never been involved in the budget process. Their main task has been to report matters and faults to the area offices and this is taken to the water services authorities who are responsible for budgeting, managing and allocating funds for each plant. With regards to information sharing, process controllers received feedback on what was reported, but they were not sure of the procurement systems in place, as this is carried out at the municipal level for all the water treatment plants. When activities were scored, an improvement between first and second scoring was revealed at a range of 2% to 4%. The exception to this was Malamulele, that did not show any improvement on its score, and Vondo, that showed deterioration instead as its score decreased from 7% at the first assessment to 5% at the second assessment (Figures 3 and 4).

3.5. Audit of Communication Systems

During the execution of the study, communication channels were found to be good and effective between supervisors and process controllers. There were also good interaction between maintenance team and the rest of the personnel in the whole treatment plant. However, process controllers were not sure whether there were communication channels between municipalities. Consumers were also aware of any emergency issues that could affect the supply of drinking water in their homes; this is done through the local community structures announcements and announcement on the local radio stations. When determining the scores, no improvement between the first and second assessment was noted in the Malamulele, Dzingale, and Mutale plants. On the contrary, the Vondo water scheme, Mutshedzi and Tshedza demonstrated that water treatment plants showed an increase in score ranging from 2% to 5%.

3.6. Audit of Safety, Health and Environmental Quality

Although there were no safety plans in place, the mechanisms for handling incidents and emergency situations in all the water treatment plants were assessed. The alarm or warning systems in place were used to detect if there were chlorine or ammonia gas leaks. The safety representatives attended the safety meetings at the district office with all officials. The process controllers confirmed that the working environment was satisfactory. As reflected in Figures 3 and 4, out of 15% scoring weight, all the five water treatment plants (Malamulele water treatment plant, Mutshedzi water treatment plant, Tshedza and Dzingahe package plant) obtained 6% scores; only the Mutale regional water treatment plant scored 5% during the first assessment between August 2008 and June 2009.

Three water treatment plants (Malamulele water treatment plant, Mutshedzi water treatment plant and Tshedza package plant) scored 9%, the Vondo water scheme and the Dzingahe package plant had 8%, and the remaining plant (Mutale regional water treatment plant) had a score of 10% during the second assessment between November and December 2010.

3.7. Community Involvement and Assessment

With regards to the involvement of the community in water issues, it was found that there was no direct involvement in decision-making, however, if any water quality incident occurred, communities were notified and advised immediately through the communication section of the Department of Water and Sanitation, the Water Services Authority communication section, as well as the local civic associations. These types of communications systems were applied to all the water treatment works because they were all government owned before being transferred to the WSAs. It was further noted that no formal complaint registers were available in all water treatment plants. There was no significant change when comparing the first assessment in 2009 and the second assessment in 2010 (Figures 3 and 4).

3.8. Determination and Scoring of Problem Areas

The problems areas were identified in 2009 and through a workshop that was held in the Vhembe district offices and the research team provided feedback on such problems to the municipal officials, including superintends and process controllers involved in drinking water treatment and management in the districts. Overall results revealed no significant difference between the first and the second assessment on non-technical scores as the p-value were found to be greater than 0.05 at 0.317 (Figure 5). All the plants fell under Class 2 compliance which shows that there are serious challenges that requires attention and improvement. Figures 2 and 3 shows that though there are urgent interventions that were needed in all the plants, some slight improvements were noted after reassessment in 2010.

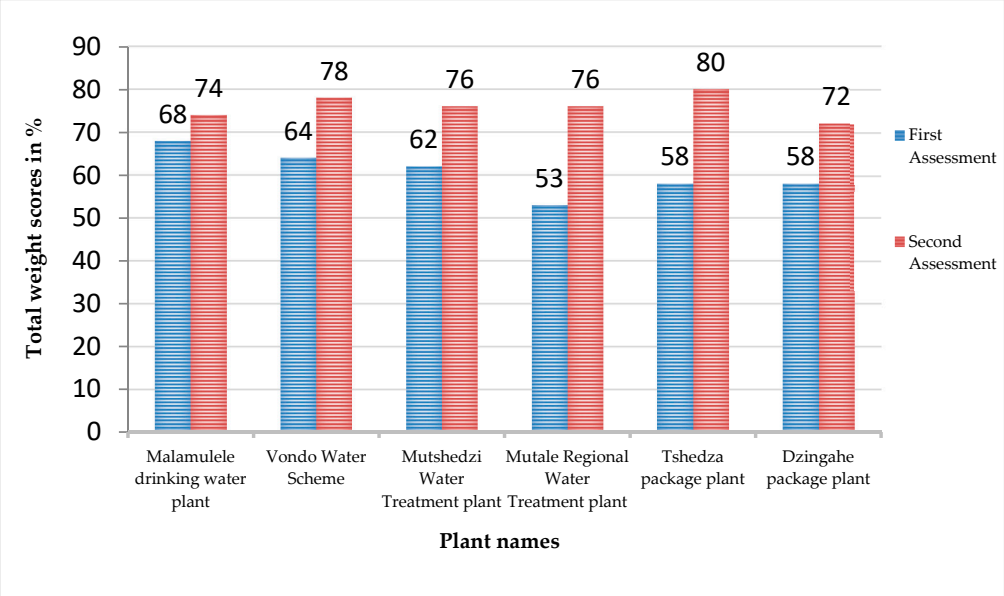

Figure 5. Overall scores for non-technical compliance assessment between August 2008 and June 2009 and the second assessment between November and December 2010.

3.9. Ranking of the Problem Areas in Priority Order

In all the water treatment plants assessed, three common problems were identified as shown in Table 4. In terms of the management issues, it was found that lack of the strategic, tactical and

operational plans in place had a high risk of affecting consumers' lives. In some water treatment plants such as the Mutshedzi water treatment plant, and the Dzingahe and Tshedza package plants, the general workers were employed as process controllers while they did not have a formal qualification. Even after in-house training of these employees there was a lack of profound knowledge and understanding of the water technologies currently used in these plants. As a result, such practices could be seen as one of the key factors that hamper the service delivery in the province. Furthermore, a lack of sufficient funding for adequate operation and maintenance of water treatment infrastructures put consumers' lives at risk. Consumers might therefore be supplied with drinking water of poor water quality due to shortage of chemical disinfectant and a lack of laboratory equipment to monitor water quality prior to delivery.

Table 4. Ranking of the Problem Areas in Priority Order.

No.	Consequence	Management Issues	Human Resources	Financial Systems
1	**Insignificant Consequence**			
2	**Minor Consequence**			
3	**Moderate Consequence**	3		
4	**Major Consequence**		4	4
5	**Catastrophic Consequence**			

The statistical evidence revealed that during the first assessment (between 2008 and 2009) and the second assessment (between November and December 2010), there was no significant difference in management issues (p = 0.3173), financial systems (p = 0.1517) or safety, health and environmental quality (p = 0.9136). However, a significant difference was noted for human resources (p = 0.0174) and community involvement and awareness (p = 0.0482). This was because the scores during the second assessment were higher than the first assessment's scores.

4. Discussion

The use of a multi-barrier approach has been reported to be crucial in ensuring that clean, safe and reliable drinking water is supplied to consumers [9,10]. This approach assists in controlling the waterborne pathogens and chemical contaminants that may find their way into the water supply systems. Although the protection of the water resources and an effective water treatment play a central role in the supply of safe drinking water, inadequate funding, a lack of qualified personnel, improper and irregular communication systems, and unattractive working conditions such as poor salaries and lack of in-service training have been pointed out as important key factors militating against efforts to ensure compliance with accepted drinking water quality guidelines and norms [11,12]. There is therefore a need for an effective monitoring system and holistic management of non-technical factors.

During the execution of the study, results revealed that a holistic management approach had not been implemented at any of the six drinking water treatment plants. Some of the core components of a holistic approach were found to be lacking, the proper strategic plan for the assessment of the drinking water supply systems, an effective drinking water quality management strategy, and appropriate recruitment and selection of plant operators. There was no system operation verification in place and no plan in place for funding the management of the plants. An operational manual was found to be the only document in place in all the plants investigated during the study period. Furthermore, there were no safety plans and no proper tactical plans for handling emergencies including communication with communities. In spite of these challenges, the supervisors and the plant operators were aware of their roles and responsibilities such as overseeing of all the water care functions. For major maintenance and repairs, professional service providers were hired. Training and development of plant operators was facilitated in the area office. The minor maintenance of equipment within the six waterworks was not prioritised. Lack of proper training and development and a lack of relevant qualifications of plant operators were found to be major barriers to the supply of safe drinking water.

While this study has not resulted in great improvement of overall non-technical issues during the reassessment of the plants during the second assessment, although the identified key challenges during the first assessment were thoroughly discussed and steps to be followed in each plants were clearly explained during the workshop. Statistically, results revealed no significant differences between the scores during the assessment period expect for human resources and community involvement and awareness that showed a significant difference ($p < 0.05$). All the plants were found to face moderate challenges in terms of management issues, while they were experiencing major consequences in terms of human resources and financial systems. Consequently, all the plants received a Class 2 certification, which indicates that these drinking water treatment plants are facing serious challenges requiring attention and improvement [1].

The findings of the present study are in agreement with those of previous authors who also identified the management of small water treatment plants as being particularly problematic in South African non-metropolitan areas [11,13–17]. These authors also found that the non-technical issues affect the supply of safe drinking water. Non-technical issues have often been viewed as responsible for the lack of sustainability in the supply of safe drinking water [11–13]. It is well known that unsafe water supply has negative impacts on public health and a ripple effect on socioeconomic development [18,19]. Waterborne diseases such as cholera and other diarrhoeal diseases account for great debility, morbidity and mortality in some parts of South Africa [11,19–22]. Communities of the Vhembe district municipality depending on drinking water supplied by the plants evaluated were therefore found to face a high risk of contracting waterborne diseases. This study suggests a need for the development of comprehensive and preventive drinking water quality measures that should be implemented in the Vhembe district municipality in accordance with the water safety plans, as indicated by Davison et al. [23]. The plan should include, among others, the risk assessment of water supplies from the catchment, the water treatment works, and the distribution networks, right up to the consumer's tap [24]. It is also important for every plant to have emergency/contingency plans that detail the emergency prevention measures, handling of natural disasters, and plant breakdowns, and there should be clear definitions of the roles and responsibilities, including emergency contact details, as suggested by previous authors when investigating the challenges facing other small water treatment plants in the Limpopo province [11].

In rural areas of South Africa, the reason for supplying water that is not safe for drinking purposes has been ascribed to the lack of understanding of basic water treatment principles by plant operators, lack of human resource capacity, and insufficient funds to carry out the maintenance of laboratory and plant equipments [16,25]. Major problems and challenges attributed to poor operations and maintenance (O and M) have always been linked lack to inadequate financial provisions [3]. To meet the required drinking water quality standards, small water treatment plants have to find solutions to the administrative issues [11]. In their studies, Obi et al. [11] also demonstrated that lack of formal education and training, lack of technical knowledge and basic principles, inadequate funding and personnel remuneration were among the key parameters that hampered service delivery in the country. water services authorities and water services providers are therefore called upon to prioritise both technical and non-technical issues faced by small water treatment plants in order to secure an adequate supply of safe drinking water in non-metropolitan areas.

5. Conclusions and Recommendations

It is concluded that all the plants were facing moderate challenges in terms of management issues, while they were experiencing major consequences in terms of human resources and financial systems. Based on the results of the first assessment between August 2008 and June 2009, the six water treatment plants (Mutale water scheme, Tshedza and Dzingahe package plants, and Mutshedzi, Vondo and Malamulele water treatment plants) received Class 2 certification in terms of compliance. During the second assessment between November and December 2010, an improvement of the score was noted on the all six (6) water treatment plants, even though they had still received Class 2

certification. While there was improvement, treatment plants are still facing challenges that require immediate attention and improvement. This study has shown that the implementation of the diagnostic tools for non-technical compliance cannot guarantee the production of safe drinking water by small water treatment plants if the management issues, the human resources and the financial systems are not addressed by the WSAs and WSPs. It is recommended that tactical and strategic plans that clearly define the operational procedures, process control mechanisms, financial planning, maintenance culture, emergency preparedness and regular monitoring and evaluation be developed and implemented for the smooth running of the small water treatment plants. It is further recommended that all WSAs and WSPs should apply the diagnostic tools as developed, as these will provide stepwise guidance for plant operations and management on a daily basis, and would also assist treatment plants in achieving Blue Drop status, which is an incentive-based regulation and a tool for effective and efficient management function of drinking water quality by water services institutions.

In light of the above, and in order to ascertain compliance of small water treatment plants with accepted drinking water quality standards and management norms in Limpopo and other provinces, future research should be conducted to remeasure the level of compliance and to determine if the diagnostic tools are still applied, as well as to continue the assessment study from the catchment by identifying all the possible pollutants before the water is treated to the point of use.

Supplementary Materials: The following are available online at www.mdpi.com/2073-4441/9/11/853/s1, Table S1: Non-technical compliance 2009 and 2011, Table S2: Ranking of the Problem Areas in Priority Order after the first assessment.

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