SUSTAINABLE WASTEWATER TREATMENT – WHAT HAS GONE WRONG AND HOW DO WE GET BACK ON TRACK?

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ABSTRACT

The delivery of sanitation services is high on the local government's agenda. Specific challenges exist for smaller and poorer communities in respect to wastewater treatment. These relate to the small scale of operation and having to establish the appropriate skills and competencies. The infrastructural, mechanical and electrical maintenance of the plants also present challenges. In order to understand the extent of challenges faced by the small and medium municipal sector, 51 wastewater treatment plants of different sizes (micro [< 500 m^3/day], small [500 to 2 000 m^3/day] and medium treatment plants [2 000 to 10 000 m^3/day]) using different technologies (ponds, trickling filters, activated sludge etc.) were evaluated. The plants were evaluated in terms of the resources deployed (capital, human resources, financial and information resources), unit process performance, maintenance, and performance. The compounding effect of all the aspects evaluated including the lack of maintenance showed that immediate intervention is required at approximately 30% of the plants in order to avoid crisis situations such as an outbreak of waterborne diseases. In the short to medium term, intervention would be required at more than 66% of the plants. The Department of Water Affairs and Forestry normally requires a 95 percentile compliance with the conditions stipulated in the Authorisation. If these criteria are strictly enforced, only 4% of the surveyed plants are adequately operated and maintained. The overall conclusion of the national survey is that the majority of micro, small and medium size wastewater treatment plants in South Africa are in trouble and do not comply with the regulatory standards. The key aspects to resolve this situation relates to the availability of trained and competent process controllers and skilled mechanical/electrical maintenance crews.

INTRODUCTION

The delivery of sanitation services is high on the local government's agenda. The majority of wastewater treatment plants in South Africa are relatively small systems. The larger metropolitan municipalities have relatively few, but large wastewater treatment plants. These plants are generally well equipped and operated. Legal compliance with discharge standards is generally good at these larger Metro plants. Specific challenges exist for smaller and poorer communities in respect of wastewater treatment. The challenges mainly relate to the small scale of operation and having to establish new skills and competencies. The infrastructural, mechanical and electrical maintenance of the plants also present challenges.

A limited national survey was done to understand the challenges faced by the small and medium municipal sector.

The national survey was based on a selected sample of wastewater treatment plants throughout South Africa and was conducted to cover the range of sizes of plants (with a focus on micro, small and medium size plants) and different treatment technologies. The data from the survey was used to define the status quo of wastewater treatment in South Africa. This paper details the findings of a national survey of 51 plants that included micro plants (< 500 m^3/day), small plants (500 – 2 000 m^3/day), medium plants (2 000 – 10 000 m^3/day) plants, located throughout the country in eight Provinces.

APPROACH

The Department of Water Affairs and Forestry Regional Offices assisted the project team in identifying at least five appropriate wastewater treatment plants in each region. They were asked to select wastewater treatment plants to include a range of different plant sizes, technologies (ponds, trickling filters, activated sludge etc.); and, plants that historically complied and plants that did not comply with the discharge standards. The technology utilized, resources deployed, operations and maintenance and overall performance was assessed at each plant. In order to obtain a true reflection of the typical day to day operation of the wastewater treatment plants, the plant personnel were not informed of the visit before the time.

It was recognised that the performance of a wastewater treatment plant depends on a number of diverse factors including:

- The plants resources available to operate and maintain the plant
- Wastewater flow and pollution load received at the plant compared to the original design flow/load
- Appropriate treatment technology installed
- Stakeholder expectations and requirements.

A generic wastewater treatment plant evaluation system was developed (Figure 1), taking the mentioned factors into account. The generic protocol for plant evaluation considered a facility within the context of the following:

- Resources available to operate and maintain the plant, including the plant treatment infrastructure, staff allocation to operate and maintain the plant, financial resources to cover all plant-related expenses and information resources to assist plant management.
- Plant performance is based on developing an understanding of the wastewater flows and associated load treated at the plant, efficiency of individual unit treatment processes, plant effluent quality and acceptable sludge handling and disposal.
- Stakeholders' needs and requirements including the plant owners and operators, the community being served and the regulatory authorities. These needs are typically evaluated in terms of compliance with licences/permits, environmental impacts and risks to neighbouring communities.

The national survey of wastewater treatment plants attempted to provide broad geographical coverage. The survey was conducted within certain logistical constraints, and was well supported by the regional staff of the Department of Water Affairs and Forestry.

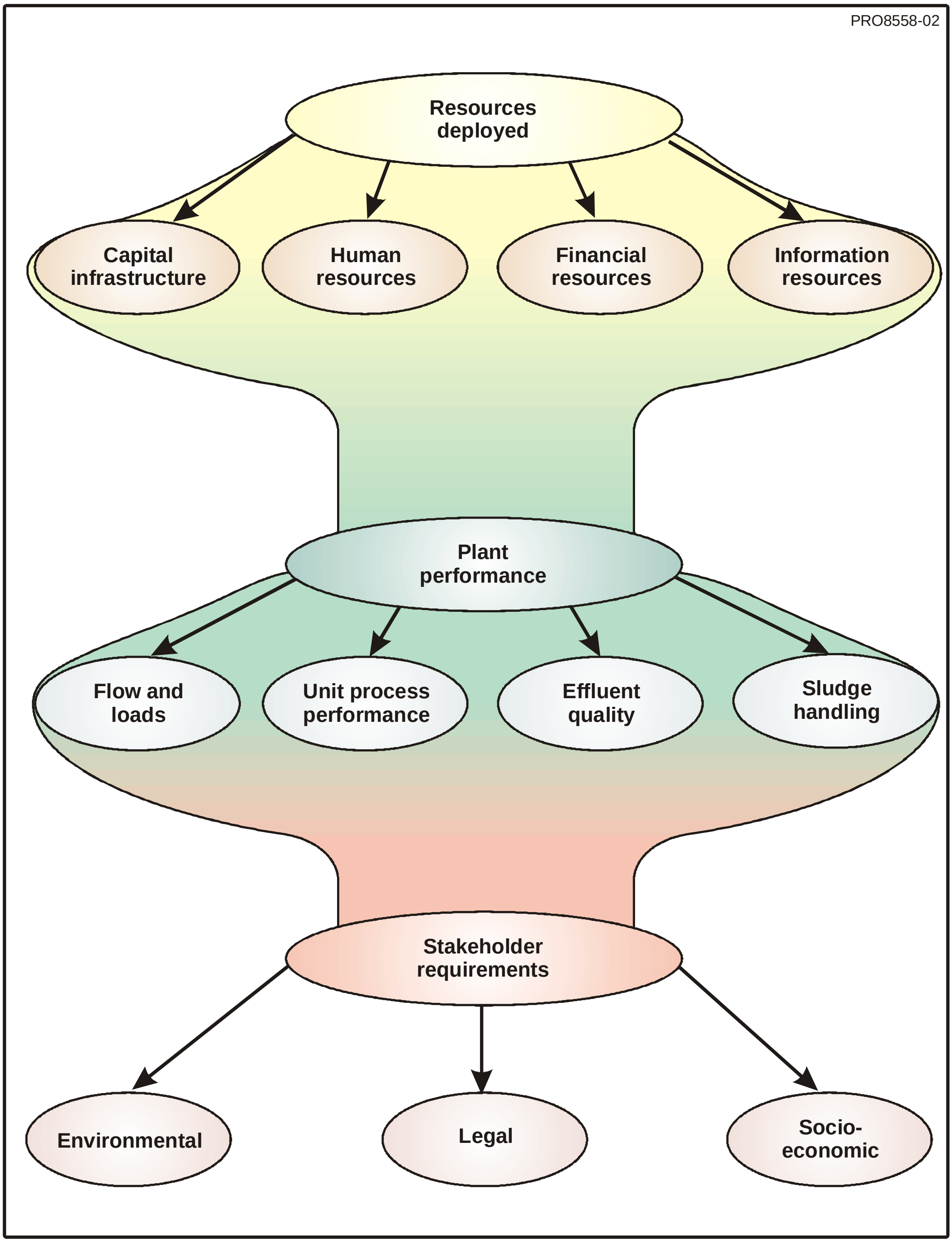

Figure 1: Generic protocol to evaluate the operations and performance of wastewater treatment plants

RESULTS AND DISCUSSION

Figure 2 shows the geographical distribution of the plants included in the survey. The section that follows gives an overview of the survey findings.

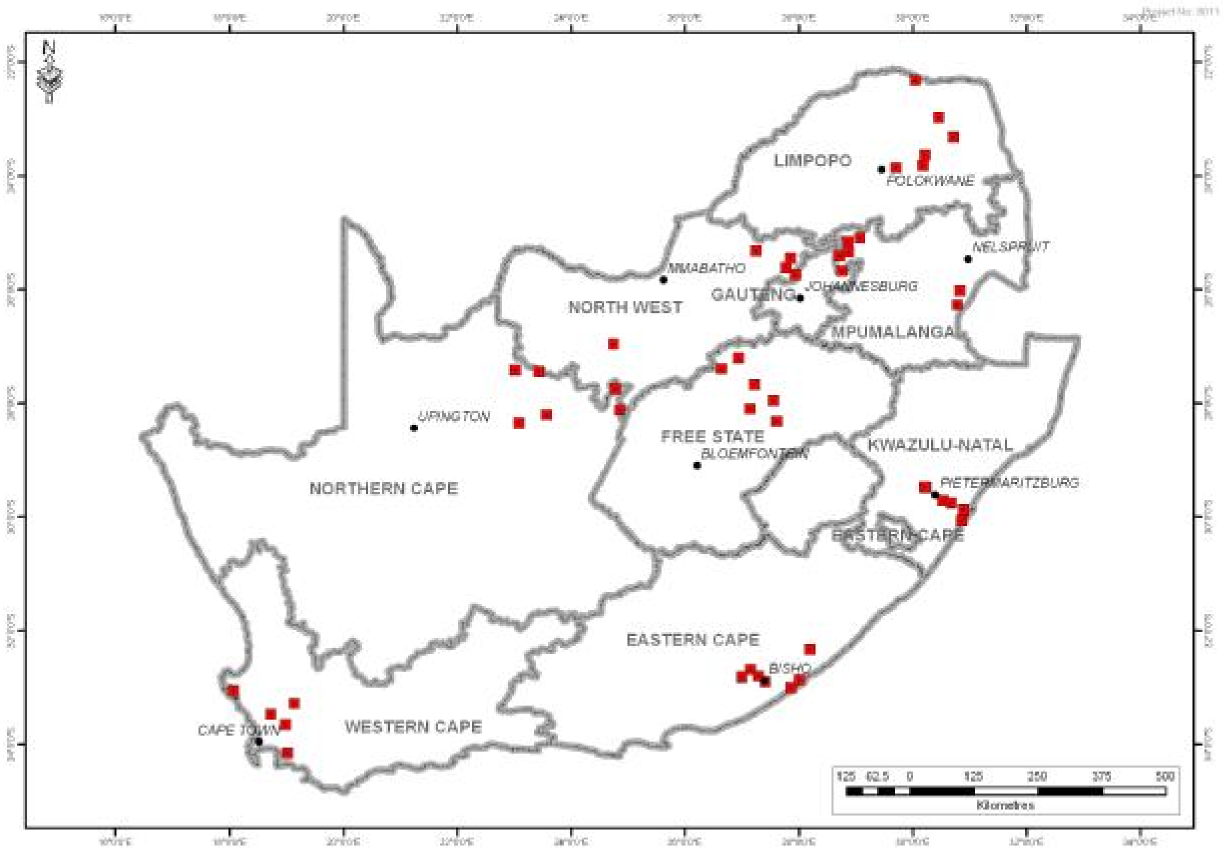

Figure 2: Location of the wastewater treatment plants included in the national survey

<u>Resources deployed on wastewater treatment plants</u>
The status of the resources deployed in the routine operation and maintenance of wastewater treatment plants is shown in Figure 3. The data show that some form of intervention is required with regards to the following:

- Capital infrastructure investment at 35% of the plants;
- Skilled operational staff required to operate the plant efficiently at 50% of the plants;
- Skilled maintenance staff required to adequately maintain the installed mechanical/electrical equipment and instrumentation at 56% of the plants;
- Financial resources to support the routine operation and maintenance at 21% of the plants; and,
- Information resources required to properly operate the plants at 63% of the plants.

The most pressing deficiency is the critical shortage of trained, skilled and experienced process controllers and mechanical/electrical maintenance staff. Most plants operate with insufficient information to guide optimised operations, but this shortcoming can be partially overcome by having trained and skilled process controllers.

The need for additional or upgraded plant infrastructure or the need for additional funding is not the root cause for the poor performance at the majority of non-compliant plants.

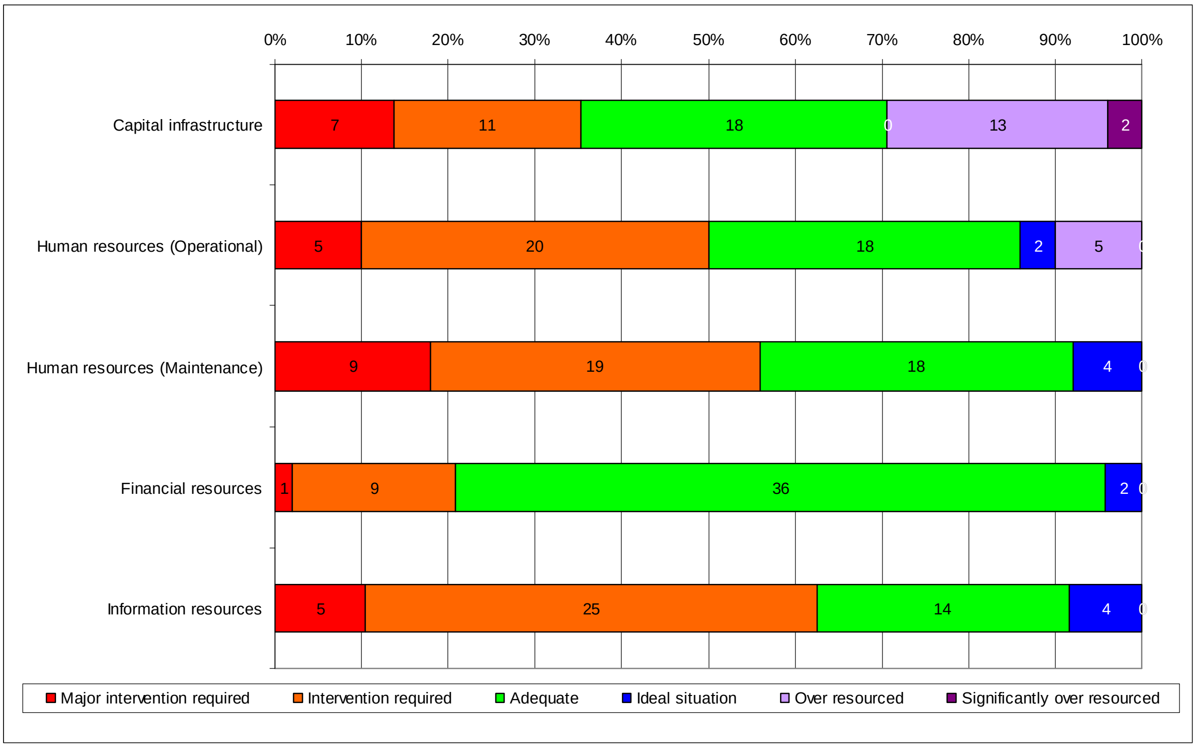

Figure 3: Status of the resources deployed in relation to the design capacity expressed as a percentage of plants where; (1) major intervention is required – (■), (2) intervention is required – (■), (3) adequately resourced – (■), (4) ideally resourced – (■), (5) over resourced – (■) and (6) significantly over resourced – (■). The figures within the bars indicate the actual number of plants in that category.

Plant wastewater flow and loads

Figure 4 shows the status of wastewater treatment plants in terms of flow and loads received and treated. Approximately 30% of the plants have spare capital infrastructure available that is either in working order or could be utilised without major capital investment.

Sixteen percent (16%) of the plants are hydraulically overloaded and 22% are overloaded in terms of the organic/nutrient load. More than 35% of the plants can accommodate higher flow and loads. This will, however, be highly dependent on the ability of the operators to operate a plant running close to or at capacity.

The bulk of the surveyed wastewater treatment plants receive wastewater flows and loads which are within the original flow and loads. The available plant infrastructure and plant equipment are therefore of adequate size to deal with the influent wastewater flows and loads. Approximately 1 in every 5 wastewater treatment plants requires additional investment in infrastructure and equipment to reliably treat the influent flow and load. The challenge is that the available plant infrastructure and equipment are not completely operated and/or sufficiently maintained.

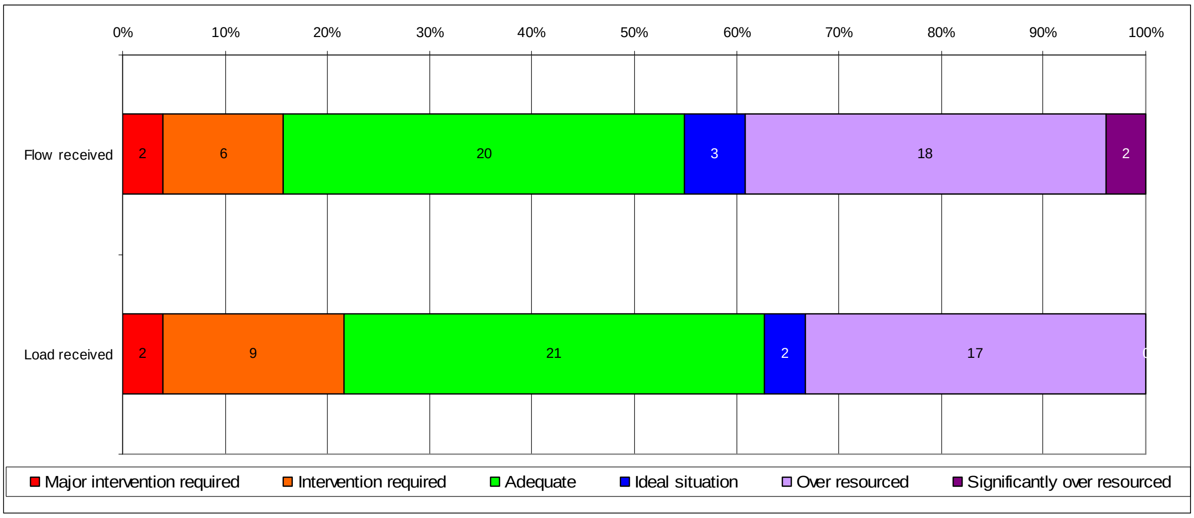

Figure 4: Status of the flow and load in relation to the design capacity expressed as a percentage of plants where; (1) major intervention is required – (■), (2) intervention is required – (■), (3) adequately resourced – (■), (4) ideally resourced – (■), (5) over resourced – (■) and (6) significantly over resourced – (■). The figures within the bars indicate the actual number of plants in that category.

<u>Treatment process technology</u>

The status of the different unit treatment processes in terms of the operation and performance is given in Figure 5. It also gives the number of wastewater treatment plants equipped with the different unit processes as well as the relative status of the unit processes. The data shows that more than half the plants experience problems with the following unit processes:

- Flow balancing;
  Flow balancing was identified as an essential part of the treatment process, but the facility is not available on the majority of surveyed plants.

- Secondary treatment;
  The main secondary treatment processes employed include pond treatment, trickling filters and activated sludge. It is important to note that the reported poor performance plants were almost equally represented in all the main secondary treatment process technologies. These main secondary treatment technologies have very different levels of complexity and mechanical/electrical component content. The complexity of the treatment technology is not a major differentiating factor in plant performance, based on the survey results.

- Activated sludge treatment;
  Activated sludge plants incorporating biological nutrient removal (BNR) experienced operational and performance challenges in 69% of the surveyed plants. This is mainly due to operational problems with the clarifiers and the management of the sludge age and mixed liquor suspended solids. This is also mainly due to operational problems and the lack of skilled operators. Eighty-eight percent (88%) of the oxidation ditch plants equipped with orbal disks or horizontal axle aerators, experience problems with the aerators (mechanical equipment problems).

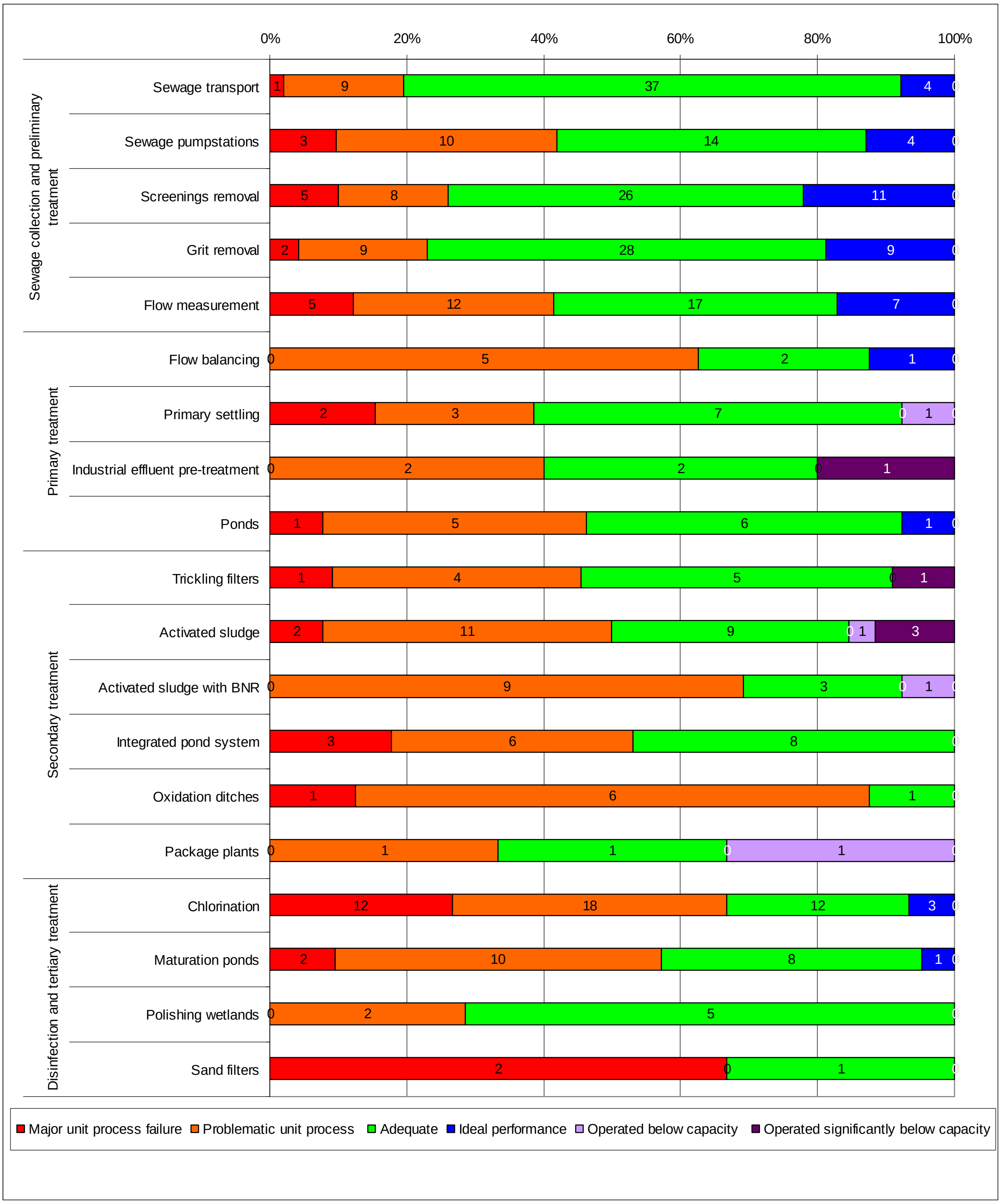

Figure 5: Status of the different unit processes deployed expressed as a percentage of plants where; (1) major unit process failure was observed – (■), (2) the unit process is problematic – (■), (3) the unit process performs adequately with occasional sub-optimal performance – (■), (4) the unit process performs ideally – (■), (5) the unit process is operated below capacity – (■) and (6) the unit process is operated significantly below capacity – (■). The figures within the bars indicate the actual number of plants in that category.

- Integrated pond systems;
  Typically, the problems are associated with the primary pond and overloading of the ponds. This is especially the case when the ponds receive septage from on site sanitation systems and buckets.

- Chlorination;
  Sixty-seven percent (67%) of the plants that disinfect the final effluent are experiencing operational problems. Problems include inadequate design of disinfection systems, inappropriate disinfection technology employed, inadequate operation and management of chlorine stock.

- Maturation ponds;
  Many of the maturation ponds are filled with sludge and overgrown with reeds. Many plants by-pass the maturation ponds and do not understand the important function of maturation ponds.

The most problematic unit process is disinfection. More than two thirds of the plants equipped with disinfection, or attempting to disinfect the treated wastewater, are experiencing problems. It is also concerning that most of these plants are not regularly measuring the effectiveness of the chlorination which relates to the lack of information resources to plant operational staff. Inadequate disinfection or failure to disinfect treated effluent discharged to a public stream can have severe impact on downstream water users, especially if the maturation ponds are bypassed.

<u>Residue and sludge management</u>
Figure 6 shows the relative number of plants that experience problems with screenings and grit disposal. Although screenings and grit disposal are fairly simple operational tasks, 24 - 25% of plants experience problems disposing of screenings and grit.

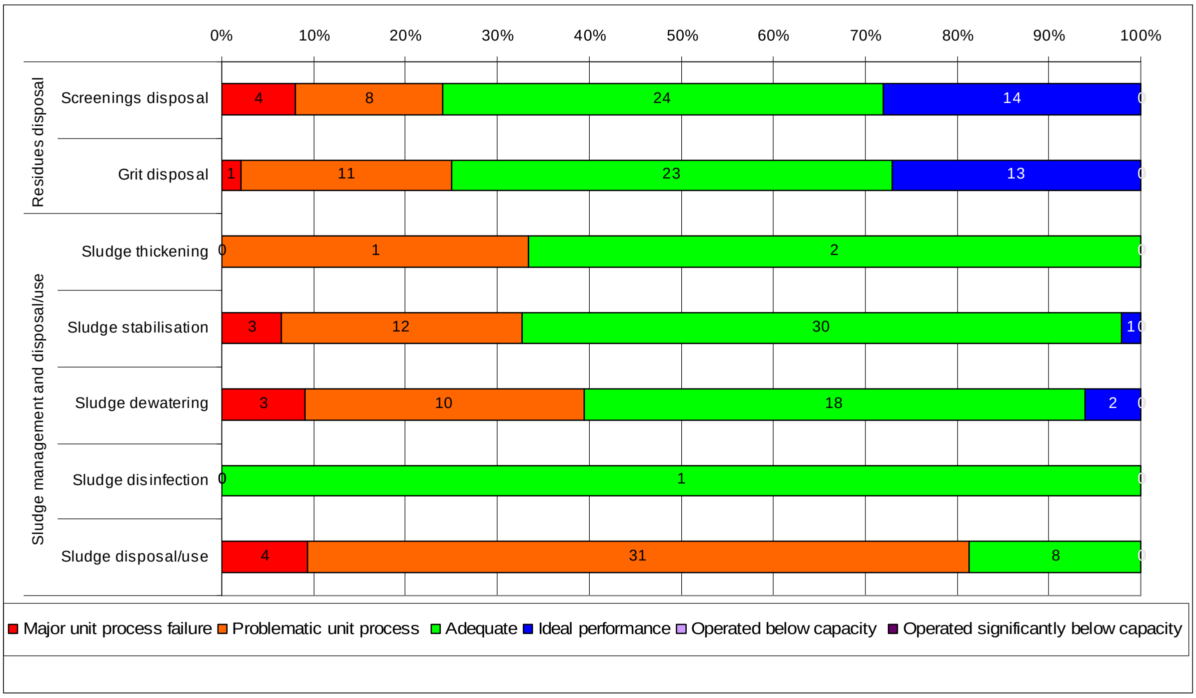

Figure 6: Status of the residues disposal and sludge management expressed as a percentage of plants where; (1) major unit process failure was observed – (■), (2) the unit process is problematic – (■), (3) the unit process performs adequately with occasional sub-optimal performance – (■), (4) the unit process performs ideally – (■), (5) the unit process is operated below capacity – (■) and (6) the unit process is operated significantly below capacity – (■). The figures within the bars indicate the actual number of plants in this category.

Operators should be trained to understand the critical importance of adequate and regular screenings and grit disposal and most of these problems can be addressed by training.

Figure 6 also shows the relative number of plants that experience problems with different sludge management processes including the thickening, stabilisation, dewatering, disinfection and disposal or use. Sludge thickening is not widely practised on the surveyed plants. Although "adequate" sludge stabilisation was reported for two thirds of the plants, most of the plants rely on either the extended aeration of the activated sludge reactors or the stabilisation effect over a long period of time in a pond system. The evaluation was not based on sludge stability data as this is typically not available. Those plants that do have sludge stabilisation processes such as anaerobic and aerobic digesters, almost all reported problems. Most of the plants rely on solar drying in drying beds or sludge ponds/lagoons. Although these are fairly simple processes, poor operational practices were observed at 39% of the plants. Disinfection processes for sludge are almost non-existing, as only one plant composts the sludge before selling it to the community. Inadequate disposal and use of sludge was found at 81% of the plants. More than half of the plants store the sludge in unlined stock-piles or pond facilities on-site. None of the plants visited would comply with the new South African Sludge Guidelines.

Maintenance aspects

The status of different maintenance aspects are depicted in Figure 7. Immediate intervention is required at approximately 30% of the plants while some kind of intervention would be required at more than 60% of the plants.

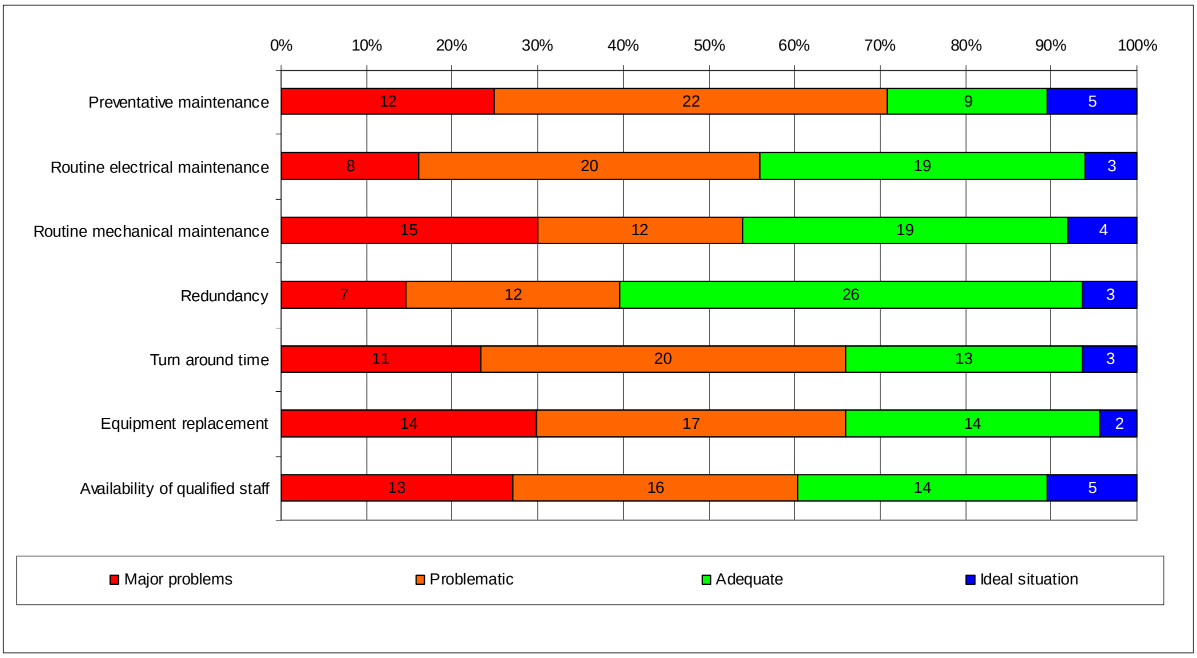

Figure 7: Status of different maintenance aspects expressed as a percentage of plants where; (1) the maintenance is completely inadequate and as a result the plant is constantly experiencing down-time and therefore not complying – (■), (2) the maintenance is inadequate and as a result, the plant experiences regular down-time that causes non-compliance at times – (■), (3) the maintenance is planned and executed to a some extent, with some lack of preventative actions – (■) and (4), the maintenance is planned and executed which is evident in cost savings and minimal down-time – (■). The figures within the bars indicate the actual number of plants in this category.

It should be noted that the plants marked "adequate" are far from the ideal situation, but were categorised as "adequately maintained' in the context of those plants that require intervention. This implies that only 10% of plants are maintained to ensure acceptable functionality. The underlying cause and reason for the overall poor track record related to plant and equipment is the lack of capable and trained maintenance staff. This is also reflected in the resources available for wastewater plant operations.

Environmental impacts and regulatory compliance

The compounding effect of all the aspects evaluated as well as the lack of maintenance is evident in Figure 8. It shows that immediate intervention is required at approximately 30% of the plants in order to avoid crisis situations such as an outbreak of waterborne diseases. In the short to medium term, intervention would be required at more than 66% of the plants. The Department of Water Affairs and Forestry require a 95 percentile compliance with the conditions stipulated in the Authorisation (Licence, permit or general authorisation). If these criteria are strictly enforced, only 4% of the surveyed plants are adequately operated and maintained.

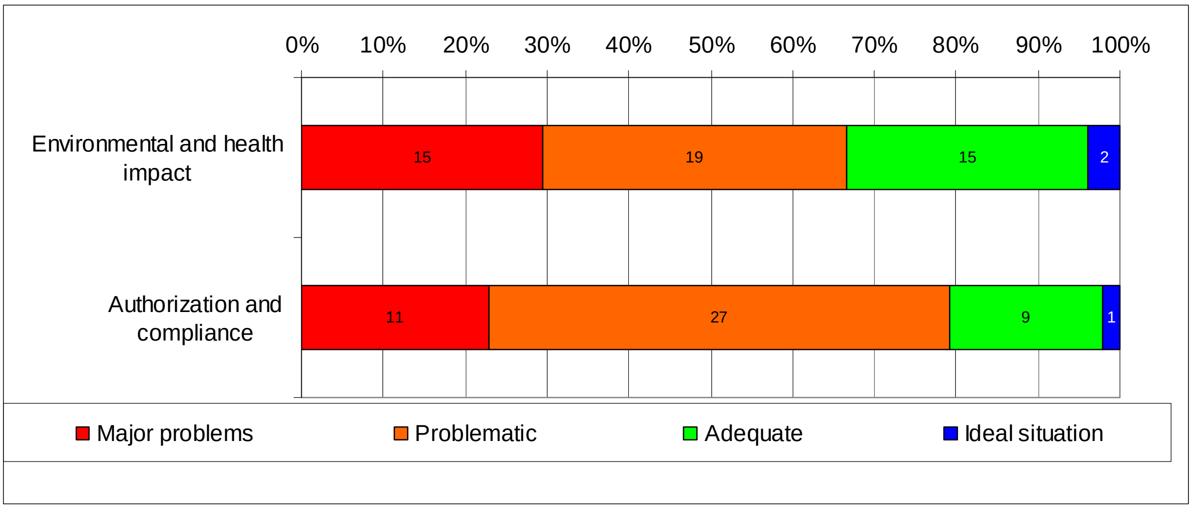

Figure 8: The relative environmental and health impact of the wastewater treatment plants expressed as a percentage of plants that; (1) is seriously impacting negatively on the receiving environment and associated community to the extent that health issues are likely and/or do not comply with the conditions in the authorization (< 50% compliance) – (■), (2) has a negative impact on the receiving environment and associated community, health issues are possible and/or often do not comply with the conditions in the authorization (50 to 75% compliance)– (■), (3) has an acceptable impact on the receiving environment and associated community and/or complies with the conditions in the authorization most of the time (> 75% compliance) – (■) and (4), has a positive impact on the receiving environment and associated community and/or complies with the conditions in the authorization (95% compliance) – (■). The figures within the bars indicate the actual number of plants in this category.

CONCLUSION

This paper summarises the findings of a national survey that included 51 wastewater treatment plants of different sizes (micro [< 500 m^3/day], small [500 to 2 000 m^3/day] and medium treatment plants [2 000 to 10 000 m^3/day]) using different technologies (ponds, trickling filters, activated sludge etc.). The plants were evaluated in terms of the resources deployed (capital, human resources, financial and information resources), unit process performance, maintenance, and performance.

The root cause for the poor performance at the majority of non-compliant plants does not seem to be the need for additional or upgraded plant infrastructure or the need for additional funding. The bulk of the surveyed wastewater treatment plants receive wastewater flows and loads which are within the original flow and loads. Approximately 1 in every 5 wastewater treatment plants requires additional investment in infrastructure and equipment to reliably treat the influent flow and load. The challenge is that the available plant infrastructure and equipment are not well operated and/or sufficiently maintained. The most pressing deficiency is the critical shortage of trained, skilled and experienced process controllers and mechanical/electrical maintenance staff. Most plants operate with insufficient information to guide optimised operations.

The most problematic unit process is disinfection. More than two thirds of the plants equipped with disinfection or attempting to disinfect the treated wastewater are experiencing problems. Inadequate disposal and use of sludge was found at 81% of the plants. None of the plants visited would comply with the new South African Sludge Guidelines.

In terms of electrical and mechanical maintenance of the pant infrastructure, immediate intervention is required at approximately 30% of the plants while some kind of intervention would be required at more than 60% of the plants. Only 10% of plants are maintained to ensure acceptable functionality. The underlying cause and reason for the overall poor track record related to plant and equipment is the lack of capable and trained maintenance staff. This was also reflected in the resources available for wastewater plant operations.

The compounding effect of all the aspects evaluated including the lack of maintenance becomes clear when the compliance is assessed. The Department of Water Affairs and Forestry require a 95 percentile compliance with the conditions stipulated in the Authorisation. If these criteria were strictly enforced, only 4% of the surveyed plants are adequately operated and maintained. Immediate intervention is required at approximately 30% of the plants in order to avoid crisis situations such as an outbreak of waterborne diseases. In the short to medium term, intervention would be required at more than 66% of the plants.

The overall conclusion of the national survey is that the majority of micro, small and medium size wastewater treatment plants in South Africa are in trouble and do not comply with the regulatory standards. The key aspects to resolve this situation relates to the availability of trained and competent process controllers and skilled mechanical/electrical maintenance crews.

ACKNOWLEDGEMENTS

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