Biological wastewater treatment and odour control by use of effective micro organisms, Ujams ponds, Windhoek, Namibia

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Abstract

The City of Windhoek and the Polytechnic of Namibia conducted research on biological wastewater treatment and odour control. This was a result of the bad smell emanating from the Ujams wastewater ponds, after nearby residents signed a petition asking for action to be taken to control the smell. In addition, wastewater stored in Ujams ponds had the potential of contaminating groundwater and the surrounding environment. These two problems could lead to the properties in the vicinities of these ponds losing value and the need for borehole water treatment. With Windhoek relying partly on groundwater supplies from artificial recharge, the water stored in aquifers risked contamination from wastewater ponds The aim of the project was to investigate whether micro organisms could viably and economically treat wastewater by improving its quality and reduce odour.

One part of this project was done by conducting a survey of residents in the vicinity of the ponds about their perceptions of the smell, including influence of season, time of day and weather conditions. The other part involved treatment of the pond wastewater with different treatments of effective micro organisms (EM) and 8 Alive (liquid bacteria) and analysing the physical and chemical aspects of the wastewater. This was done by simulating the ponds' conditions in buckets and adding small quantities of multiplied SCD EM Plus, SCD EM Plus fermented Moringa and 8 Alive (liquid bacteria) together with new wastewater daily.

The parameters monitored were Conductivity, pH, Hydrogen sulphide, Manganese, Copper and Chromium using the Hach system.

The results showed that effective microorganisms (SCD EM Plus) and 8 Alive (liquid bacteria) have the potential to treat and reduce odour in wastewater. Hydrogen sulphide and heavy metals were reduced drastically over the period, and other parameters showed an improvement in the quality of the wastewater. The cost of the use of effective microorganisms and 8 Alive was found to be economical as the technique does not need specialised people and sophisticated machinery.

Key words

Effective Micro organisms, EM-fermented Moringa, Hach system, Heavy metals, SCD EM Plus

1 Introduction

The research on odour control and wastewater was done by simulating the ponds' conditions in buckets and by use of an anaerobic digester, which were kept at the Polytechnic, and adding small quantities of multiplied SCD EM Plus, SCD EM Plus fermented Moringa and 8 Alive (liquid bacteria) together with new wastewater daily. Samples of this treated wastewater were analyzed and compared to the control at the Civil engineering laboratory. The parameters that were measured were the wastewater's conductivity, pH, hydrogen sulphide, manganese, copper and chromium.

With Windhoek relying partly on groundwater supplies from artificial recharge, the water stored in aquifers risks contamination from wastewater ponds, hence the necessity to treat the wastewater. Biological wastewater treatment is also environmentally friendly and cheap compared to the traditional wastewater treatment. Besides groundwater, surface water quality in areas near the ponds can be considerably degraded, and hence the need to treat the wastewater before discharge. All along there was a belief that a series of pond systems would treat wastewater. However, reports on the performance of these pond systems in practice highlighted that effluent quality was very variable and often poor. Further, there has been increasing concern about the impact of other pollutants in wastewater such as ammonia, phosphorus, pathogens etc., and the efficacy of the pond systems in reducing the amounts of these pollutants in the effluent. Most wastewater treatment works in the country have focused on basic and mechanical system designs with a general reliance on microorganisms naturally present.

This research was initiated to evaluate whether EM technology and 8 Alive (liquid bacteria) can offer viable solutions to Namibia's effluent quality in treatment ponds. This research showed the potential of EM in wastewater treatment, which could particularly benefit residents who reside close to the Ujams wastewater ponds. With the Environmental Act threatening to impose high penalties for environmental pollution, this research may provide a solution to many industries that produce effluent, as they would need to construct the mechanical wastewater treatment plants, which are expensive to install and need high energy to operate.

The main objective of this research was to find out whether effective micro-organisms technology could viably reduce odour in wastewater and treat the wastewater by improving its physical and chemical quality.

The specific objectives were:

- To assess the perception of the residents staying in the vicinity of the ponds on odour generated by the ponds
- To evaluate the wastewater treatment capabilities of EM and 8 Alive
- To estimate the cost of applying SCD Plus EM and liquid bacteria (8-Alive) in the case of Ujams.

2 Literature Review

2.1 Effective Microorganisms

The technology of Effective Microorganisms (commonly termed EM Technology) was developed in the 1970's at the University of the Ryukyus, Okinawa, Japan. The inception of the technology was based on blending a multitude of microbes, and was subsequently refined to include principal types of organisms commonly found in all ecosystems. These were blended in a molasses or sugar medium and maintained at a low pH under ambient conditions (Sangakkara, 2001)

Effective Microorganisms are a mixture of groups of organisms that have a reviving action on humans, animals, and the natural environment (Higa 1995) and has also been described as a multi-culture of coexisting anaerobic and aerobic beneficial microorganisms. The main species involved in EM include:

- Lactic acid bacteria – Lactobacillus plantarum, L. casei, Streptoccus lactis
- Photosynthetic bacteria – Rhodopseudomonas palustrus, Rhodobacter spaeroides
- Yeasts – Saccharomyces cerevisiae, Candida utilis
- Actinomycetes – Streptomyces albus, S. griseus
- Fermenting fungi – Aspergillus oryzae, Mucor hiemalis (Szymanski and Patterson, 2003).

Organic materials within wastewater originate from plants, animals or synthetic organic compounds, and enter wastewater via a number of routes including human wastes, detergents, and industrial sources (Taylor et al. 1997). In the current wastewater treatment process (either municipal or domestic on-site) microorganisms play a significant role in the treatment of domestic sewage. Many different organisms live within the wastewater itself, assisting in the breakdown of certain organic pollutants (Taylor et al. 1997).

The key to the success of EM is not the microbes working in isolation from each other…but the combination and synergistic effect when they are used together. This is what makes EM so effective. The diverse combination of microbes in EM also gives it adaptability. And this is why it works in such a broad range of conditions. The leading roles of each family of microbes will change as the environmental conditions change.. EM causes a fermentation process when applied to organic matter rather than a putrefying process. EM will compete with and displace, through competitive exclusion, other microbes such as pathogenic microbes, some of which cause disease.

2.1.1 Wastewater Treatment by use of EM

Effective microorganisms have a unique ability to stabilize complex proteins through a shift from anaerobic putrefaction cycles to a fermentative cycle. Hair and plastics can play havoc with the balancing of an anaerobic digester by creating over-thickening of the scum layer. Hair is primarily composed of complex proteins, which have been historically difficult to stabilize to a point at which the biological breakdown will occur in a timely manner. Effective microorganisms will assist by accelerating protein stabilization. (EM•1® Waste Treatment for Wastewater, undated)

On site, effective microorganisms are applied at various stages in the treatment process for optimum results. The application site and dosage amounts are dependent on the type of treatment system, the age of the system, and the goals of the parties involved. Application rates can vary from 1: 1000 to 1: 40,000. The average rate into a treatment system is around 1: 10,000 (based on daily flow). (EM•1® Waste Treatment for Wastewater, undated)

The microbes secrete beneficial substances such as organic acids, enzymes and antioxidants (chelated minerals and vitamins) when in contact with organic matter. In wastewater applications, EM assists in shifting conditions from putrefactive to non-putrefactive. This unique ability enables EM to transition the wastewater collection system into a pretreatment system, thereby lowering the loading demand on wastewater treatment plants or to the environment. Essentially, consistent applications of Effective Microorganisms Technology into the collection system will increase the capacity of the treatment plant, decrease the operation costs, and improve the efficiency of the entire system.(EM•1® Waste Treatment for Wastewater, undated)

When free Ammonia is bound to carbon and H_2S is removed from influent during generation, “sweet” methane can be produced, thereby increasing amounts of clean methane gas by 30% or more. Other benefits with the removal/lowering of free Ammonia and H_2S are reduction in odor control expenses by elimination or reduction of chemicals, less wear and tear on equipment, elimination of corrosion, and greater efficiency of wastewater treatment due to a dramatically increased digestion of sludge. A significant drop in the quantity and density of sludge will also result in as much as of 50% reduction of polymer use.

The goal of the wastewater treatment is to get as many solids out of the wastewater in as short a time as possible. Polymers are often used to thicken wastewater to pull solids out of suspension and bring them to the bottom so they can be removed. EM works like a natural polymer, pulling items out of suspension. A wastewater system can expect an average of 50% reduction in polymer use when they use EM. Total Suspended Solids will drop by as much as 80% as well, causing better flocculation, improving water clarity in the clarifiers. These are some of the ways that EM use increases the capacity and efficiency of the system.

2.2 Liquid Bacteria (8 Alive)

8-Alive is a combination of five strains of live bacteria (2 facultative and 3 aerobic) with 7 different enzymes that work together to rapidly penetrate, liquefy, and digest fat, oil grease, hydrocarbons, ureic salts, cellulose, protein and starch into simple, environmentally – friendly by-products like carbon dioxide and water. The bacteria are non-pathogenic (i.e. they cannot cause disease), and the product itself, is non-acid and non-alkali, making it environmentally safe in any and all systems.

2.2.1 How 8-Alive Works

The bacteria consume harmful chemicals like phosphates, ammonia, and nitrates while improving water quality. When the right bacteria are present in the right quantities and in the right conditions, they can digest organic wastes very efficiently. The right conditions vary from bacteria to bacteria. Since 8-Alive contains five different bacteria, each one performs well in its suited condition. Each of these five bacteria also performs differently at various pH levels, dissolved oxygen levels and temperature. Each of the five bacteria produces different enzymes at different rates in order to digest different types of waste.

The enzymes that are mentioned above are actually listed as follows:

- Protease – breaks down proteins and other enzymes
- Amylase – breaks down starch & carbohydrates
- Lipase – Breaks down fat, grease and other lipids
- Esterase – breaks down fatty esters
- Cellulase – breaks down cellulose into simpler sugars
- Xylanase – breaks down plant material like pulp and paper goods
- Urease – Breaks down ammonia, ureic salts and some other nitrogen compounds

The work of the enzymes is to speed up digestive processes and reactions, aiding bacteria's metabolism rather to reproduce or consume waste. Due to the make up of the enzyme group within the 8-Alive mixture, the break down of complex wastes are done, but simple compounds are not digested which will cause problems in down stream water treatment, because for the enzymes to function properly the assistance of the five bacteria groups must be included (Gary, Undated)

2.2.2 Uses of 8-Alive

Regular use of 8-Alive will establish thriving colonies of waste-digesting bacteria to provide continuous cleaning action in drains, plumbing, septic systems and all other waste disposal systems currently used by the municipalities to treat blocked sewage pipes. Although the bacteria in 8-Alive reduce odours by digesting greases and fats, the product is also perfumed for more pleasant application. This makes it suitable for spraying onto refuse dumps, and applying to other areas where waste disposal and odour problems occur. In septic tanks, 8-Alive provides the necessary digestion to eliminate carry-over, reduces the need for pump-outs, and introduces micro-organisms into the soil to open soil pores and keep French drains operating smoothly with improved drainage. It is also ideal for use in portable and pit toilets. 8-Alive is being successfully and widely used not only in large commercial buildings, hospitals, hotels, supermarkets, food processing plants and municipalities, but also aboard ships and floating oil rigs. (*Momar 8-Alive and the environment, undated)*

2.2.3 How 8-Alive reacts on Organic Matter

As 8-Alive bacteria enter a drain system, the bacteria seek out and feed on "easy to digest" organic waste materials such as sugar and starch. As they eat these organics, they multiply and produce enzymes to digest the "tougher to digest" organic materials such as grease, fats, protein and oil. If the organic waste materials were simply allowed to break down without the assistance of 8-Alive, a substantial amount of oxygen would be required. The measure of this oxygen amount is B.O.D. Because 8-Alive reduces the amount of organic waste, the amount of oxygen required to break down the remaining organic matter is reduced which means 8-Alive reduces the B.O.D. level.

In addition to organic compounds, waste water contains inorganic compounds such as soda ash, phosphates and detergent builders. Although 8-Alive is not effective in breaking down inorganic compounds, the C.O.D. test itself measures the attack on both organic and inorganic soils. Since there is a reduction in the organic portion of the waste, there is a corresponding reduction in the total C.O.D.

Because 8-ALIVE enables waste to arrive at the waste treatment plant with reduced levels of organic and inorganic compounds (lower B.O.D. and C.O.D. levels), less oxygen is required to "break down" the remaining waste. Because less oxygen is required, less treatment is required. Less time and money are required because less treatment is required at the waste treatment plant; waste can be processed more efficiently and more economically**.** (*Momar 8-Alive and the environment, undated)*

2.3 Moringa oleifera

Moringa oleifera is a fast growing, aesthetically pleasing small tree adapted to arid, sandy conditions. The species is characterized by its long, drumstick shaped pods that contain its seeds. Within the first year of growth, moringa has been shown to grow up to 4 meters and can bear fruit within the same first year (Folkard and Sutherland, 1996). Virtually every part of the tree is beneficial in some way, which is of great importance in areas where people have a direct dependence on trees, crops and animals for their livelihood. The studies that have been performed on moringa have taken place primarily in India and Africa, but it seems that there may be a growing interest in the cultivation possibilities in the more humid tropics, including Central and South America. Depending on the purpose and quantity desired, moringa can be grown in a nursery as a community project or on a smaller scale at the family level. It can function as windbreaks for erosion control, live fences, as an ornamental or intercropped to provide semi-shade to species requiring less direct sunlight.

2.3.1 Moringa oleifera and Water Purification

Within the pods is possibly the best part of the tree...the seeds! Not only can they be pressed for a high grade oil, comparable to olive oil, but the press cake remaining after oil extraction has been shown to retain the active ingredients for coagulation, making it a marketable commodity (Folkard and Sutherland, 1996). According to Meitzner and Price, 1996, Moringa oleifera has been compared to alum in its effectiveness at removing suspended solids from turbid water, but with a major advantage. Because it can be produced locally, "using moringa rather than alum would save foreign exchange and generate farm and employment income.

At the Thyolo Water Treatment Works in Malawi, Africa, two researchers, Drs. Geoff Folkard and John Sutherland from the University of Leicester, England, have worked on substituting moringa seeds for alum to remove solids in water for drinking. Not only were the tests successful in removing as much solid material as alum, but the seeds used were "purchased from enthusiastic villagers in Nsanje Region in Malawi" (Folkard and Sutherland, 1996).

2.4 Statistical Analysis of the data

2.4.1 Kruskal Wallis Test (KW)

The KW procedure tests the null hypothesis that k samples from possibly different populations actually originate from similar populations, at least as far as their central tendencies, or medians, are concerned. The test assumes that the variables under consideration have underlying continuous distributions. In what follows, assume we have k samples, and the sample size of the i-th sample is ni, i = 1, 2, . . ., k.

In the computation of the KW statistic, each observation is replaced by its rank in an ordered combination of all the k samples. By this we mean that the data from the k samples combined are ranked in a single series. The minimum observation is replaced by a rank of 1, the next-to-the-smallest by a rank of 2, and the largest or maximum observation is replaced by the rank of N, where N is the total number of observations in all the samples (N is the sum of the ni).

The next step is to compute the sum of the ranks for each of the original samples. The KW test determines whether these sums of ranks are so different by sample that they are not likely to have all come from the same population. It can be shown that if the k samples come from the same population, that is, if the null hypothesis is true, then the test statistic, H, used in the KW procedure is distributed approximately as a chi-square statistic with df = k - 1, provided that the sample sizes of the k samples are not too small (say, ni>4, for all i).

H is defined as follows:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$

Where
k = number of samples (groups)
n_i = number of observations for the i-th sample or group
N = total number of observations (sum of all the ni)
R_i = sum of ranks for group i

2.5 Description of the study area

Ujams ponds, situated north of the city of Windhoek, serves as the wastewater collection point for northern industries. The wastewater from these industries is high in suspended and dissolved solids. These solids sediment and float at the ponds and as they decompose, produce a very strong odour. The Ujams ponds are made up of four anaerobic, four oxidation and five maturation ponds. The anaerobic ponds are used alternatively, that is only two ponds are used at a time while the other two are drying. The effluent from the maturation ponds is used for irrigation of fodder crops.

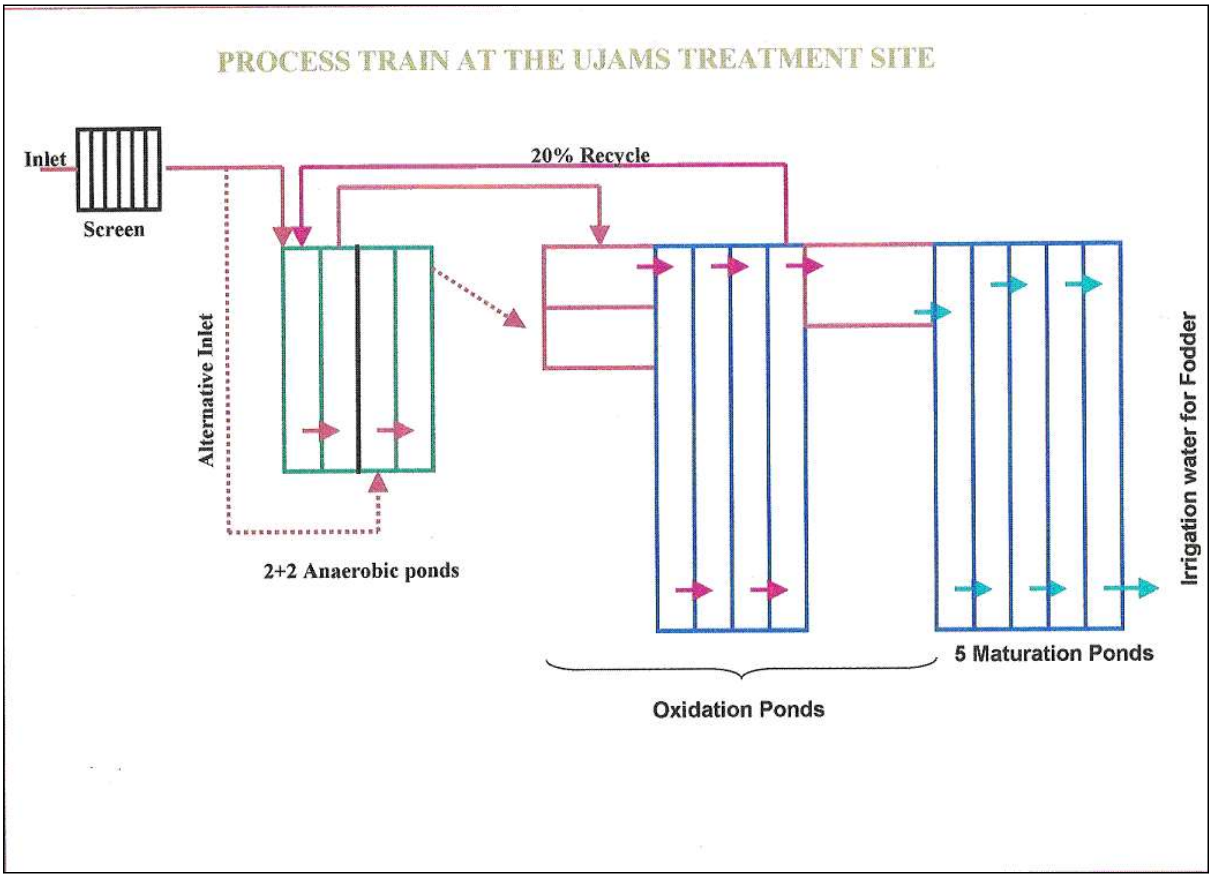


Figure 1: Schematic diagram of Ujams ponds

3 Methodology

3.1 Survey

A questionnaire was designed for interviews with residents who signed the petition or live in the vicinity of the Ujams ponds. Thirty residents from Brakwater and Nubuamis were targeted for the survey. Although 30 residents had signed the petition, only 14 of them were reachable by phone and nine of them were eventually interviewed. Three claimed that they did not live nearby Ujams, one indicated that he does not have a problem with the smell, while the other even expressed surprise at hearing that his name had been on a petition. Therefore 21 other residents, not on the petition list, were added to the survey after meeting them at their homes. Twenty-five of the residents chose to be interviewed face to face, while the remaining five were interviewed over the phone. Their responses to the questionnaire were fed into a Microsoft Excel spread sheet and analyzed.

3.2 Bucket System

Three treatments of wastewater and a control, each replicated five times in buckets of 20-litre capacity were used. The contents of the buckets were adjusted daily to simulate the anaerobic Ujams ponds, with the removal of about 25% of the volume followed by topping up the buckets with fresh waste water collected daily from Ujams. Five litres (5 *l*) (25% of volume) of the twenty litres (20 *l*), were removed from the top level of the buckets. New wastewater collected from the pond's inflow, (directly from the inflow inlet pipe from the industrial wastewater), was used to top up the buckets. The collected wastewater was then distributed into the buckets, which simulated the ponds for the experiment. The amount of water, which was thrown out as an outflow from the buckets, was replaced with the same amount of new wastewater as an inflow into the buckets.

Before the buckets were refilled, the fresh five litre wastewater as an inflow was treated with either the EM, 8 Alive or the Moringa solution and then used to top up the buckets.

The samples of wastewater from the buckets, were tested weekly for different parameters.

The process of taking out of five litres (outflow) and refilling (inflow), treatment of the inflow wastewater and the collection of the data were done everyday throughout the project period.

The treatments involved micro organisms, with one treatment using liquid bacteria (8 Alive) and the other treatments using SCD EM Plus and SCD EM Plus with Moringa. The treatments were applied daily to the fresh wastewater before pouring into the respective buckets.

The three treatments were:

1. 8-Alive applied at a high rate of 20 ml/m^3 of waste water (50 000 x dilution).
2. SCD EM Plus, using the ratio of 1 part stock EM to 1 part molasses to 18 parts water, applied at a rate (about 5 000 x dilution).
3. SCD EM Plus, using the ratio of 1 part stock EM to 5 parts molasses to 94 parts water, fermented with leaves and seeds of *Moringa oleifera*, and applied at a rate (about 5 000 x dilution)

Treatments 1 and 2 were selected to be of equivalent cost. Treatment 3 would cost much less, at 25% of the costs for Treatments 1 and 2 plus the cost of Moringa, which is currently unkown as it is unavailable on the local market.

Samples of water were taken weekly from each bucket from September until December. Measurements of Conductivity, pH, Hydrogen sulfide, Manganese, Copper and Chromimium using the Hach system were taken.

4 Results

4.1 Survey

Of the thirty residents interviewed, only 16 notice the smell at their homes (Figure 1). All notice the smell when driving past, either to or from town.

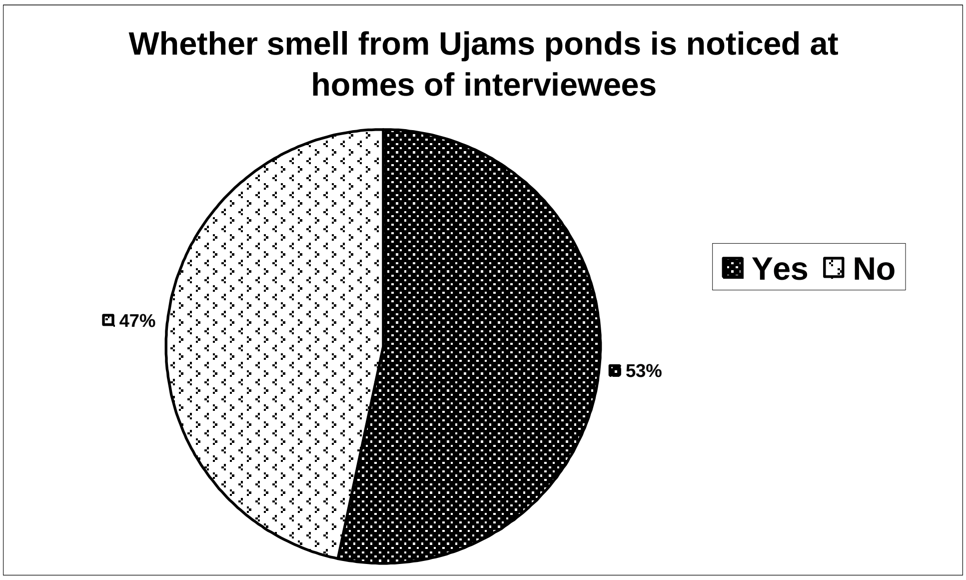


Figure 1 Responses of interviewees to question on whether they notice the smell from the Ujams ponds at home**.**

All interviewees lived either north, north west, or west of the ponds, since there are no residential areas nearby the ponds in the other directions. There was no significant difference in the proportion of residents living in a particular direction who noticed the smell from their homes.

Of more importance to noticing the smell than direction from the ponds is the distance that homes are from the ponds, with residents who do not notice the smell living an average of more than 6km from the ponds compared with an average of 3km for those who noticed the smell from their homes.

A majority of interviewees (16) indicated that the smell is worse during summer, while six thought it worse in winter and 8 noticed no difference between seasons (Figure 2).

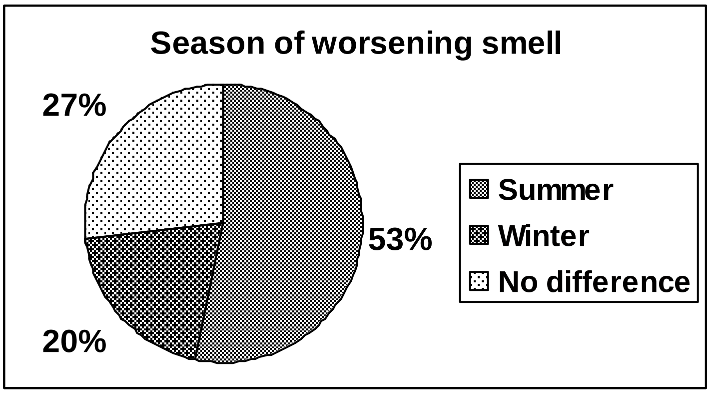


Figure 2 Season when the smell from the Ujams ponds is perceived to be worse.

More interviewees felt that the smell is worse during evenings (16), followed by morning time (7) and afternoon (5). One interviewee felt that the smell is worse during both the morning and after sunset, while the remaining interviewee considered there to be no difference (Figure 3).

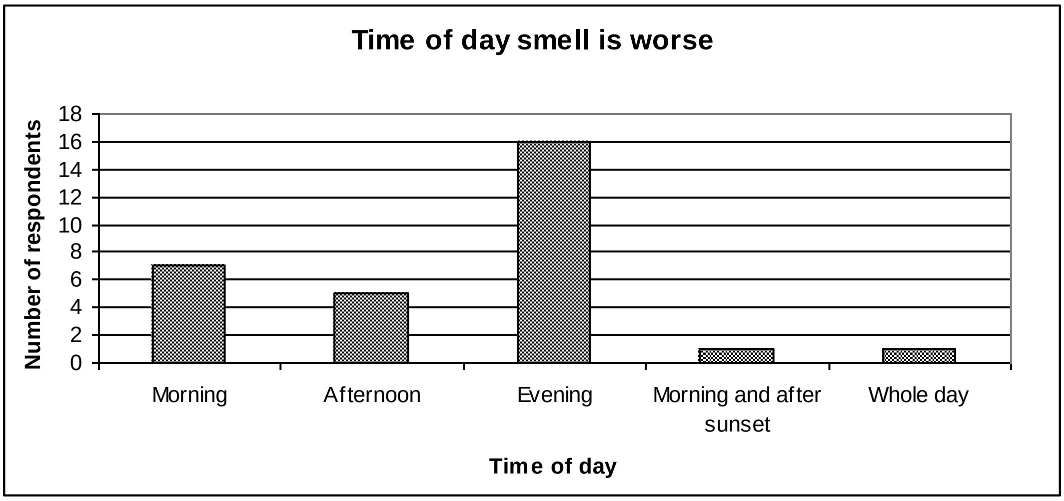


Figure 3 The time of day when smell from the Ujams ponds is perceived to be worse.

Although the smell is noticed more during the evenings than at other times of the day, it might be because more of the survey interviewees are at home during this time than any other time, as during the day many are at work in town. They felt that wind is the most important weather factor influencing the strength of smell from the Ujams ponds (16), followed by the combination of high temperature and wind (8), low temperature and humidity (3), and low temperature and wind (3) (Figure 4). The furthest the smell is experienced from homes is 8 km.

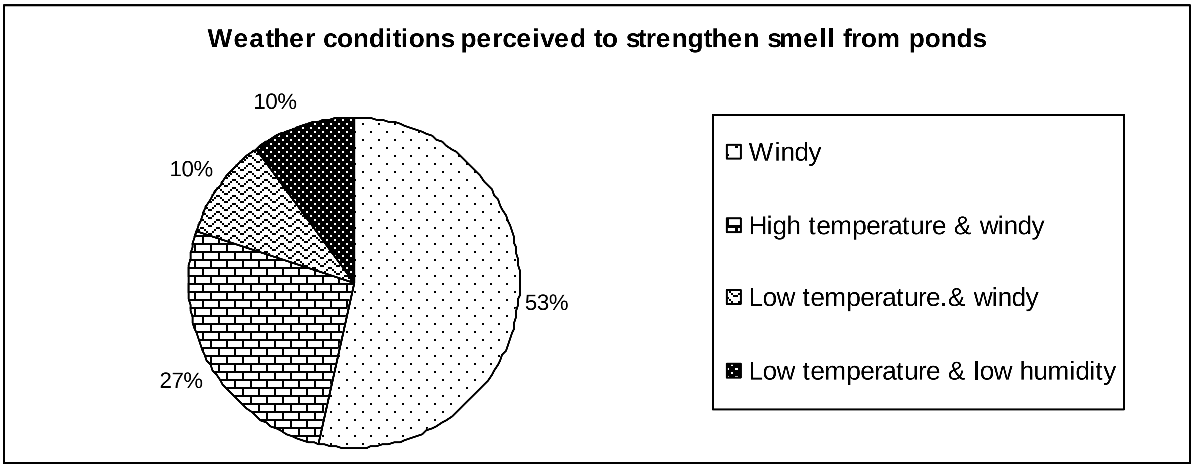


Figure 4 Weather conditions that are perceived to influence the strength of the smell from the Ujams ponds**.**

None of the interviewees ever contracted a disease from gasses or pathogens accompanying the smell from the Ujams ponds. The majority responded that the smell makes it uncomfortable for them to breathe (13), six indicated only that it is an unpleasant smell, five responded that they usually wake up feeling sick because of the smell, two indicated having experienced nausea and the other two indicated having experienced sneezing and coughing. The rest indicated that they usually experience a loss of appetite and lack of fresh air to breathe (Figure 5).

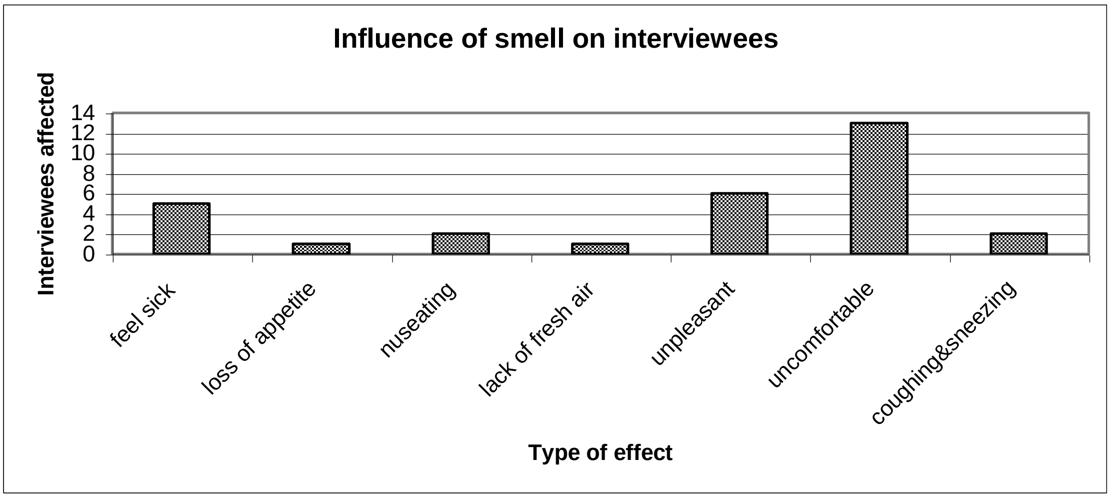


Figure 5 Effects that smell from the Ujams ponds has on interviewees

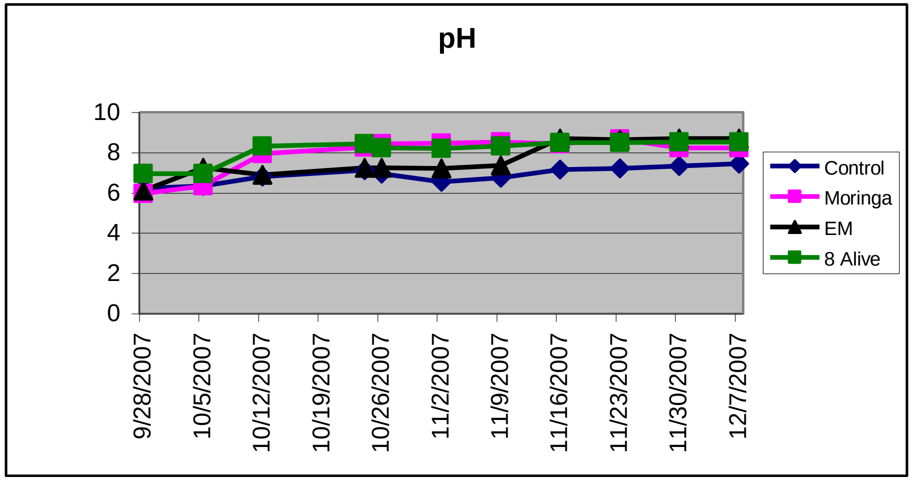
Finally, residents were asked what they consider to be the most appropriate action the Municipality should take to control the smell. Nine interviewees suggested that that the ponds should be relocated far away from residential areas; five responded that they do not know how the smell could be controlled; four suggested that the ponds should be constructed under ground so that the smell cannot escape; three suggested that the City's engineers should go to learn from other cities how they manage their waste; two suggested that the waste should be treated at their sources before dumping; another two suggested that stronger chemicals be applied to the waste; two suggested that research should be conducted to understand the problem; one suggested that the ponds be closed on top, another suggested that waste-adapted plants should be planted to use up the nutrients from the waste; one suggested that the ponds should be expanded to accommodate more waste.

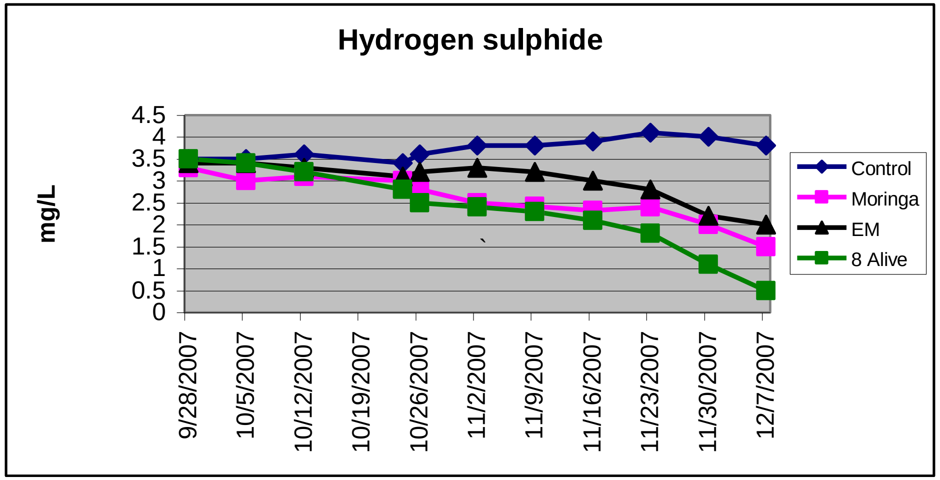
On the question of whether interviewees had other important information not asked about on the questionnaire, seven responded that it is a health risk; five responded that the problem needs urgent action; another five responded that the smell harms their businesses; thirteen responded that they had nothing else to add regarding the smell.

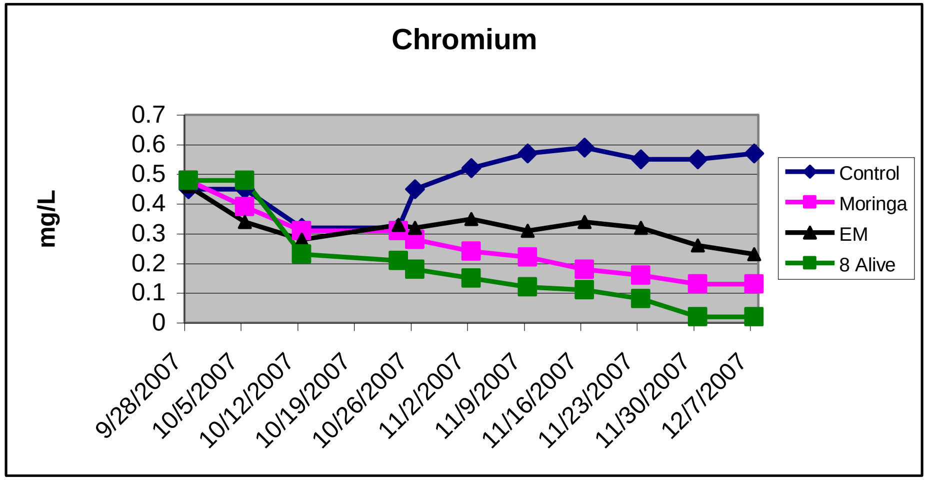
In addition, many interviewees expressed their worries of the ponds being a mosquito breeding ground that will cause malaria and that they might contract serious diseases from the wastewater. Some also indicated that it is an environmental hazard as a while ago when the ponds could not handle the volume they overflowed into a nearby river bed, creating a pool that attracted large numbers of birdlife that could be harmed. They further stressed possible contamination of underground water and loss of property values. A business couple also expressed their grievances that the municipality charges them for property rates while providing no service. They were of the opinion that they should stop being charged until the smell problem has been solved. However, agricultural business operators, such as grain and animal hides' processors and a dairy farmer, were not open to take part in the survey, claiming they do not experience any smell from the ponds even when they drive by.

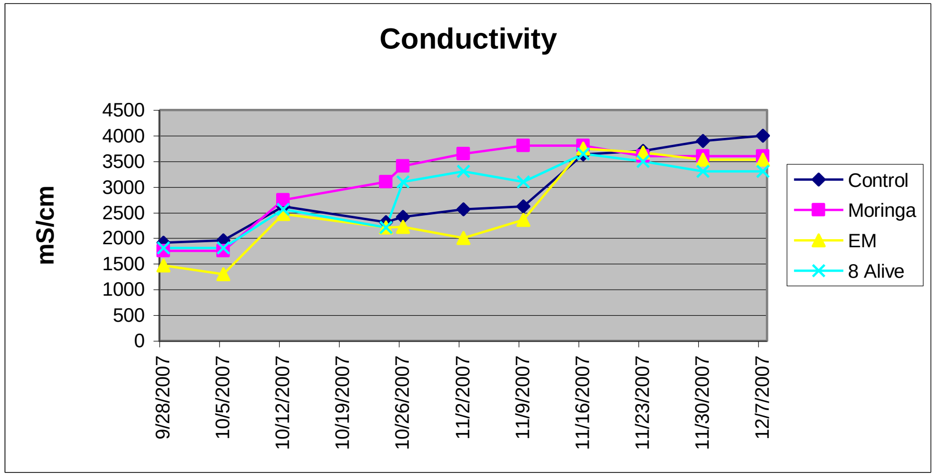
4.2 The bucket system

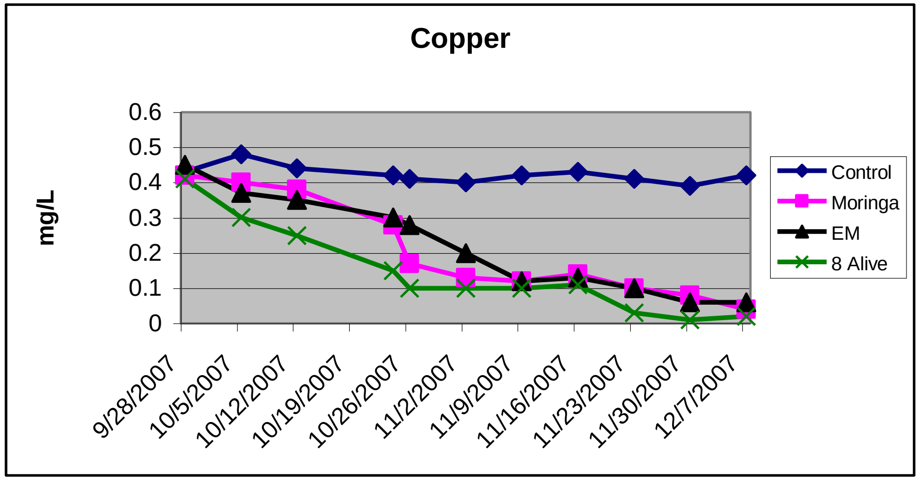
All measurements are based on the Hach system unless otherwise stated










Copper
mg/L
0.6
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0
9/28/2007
10/5/2007
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Control
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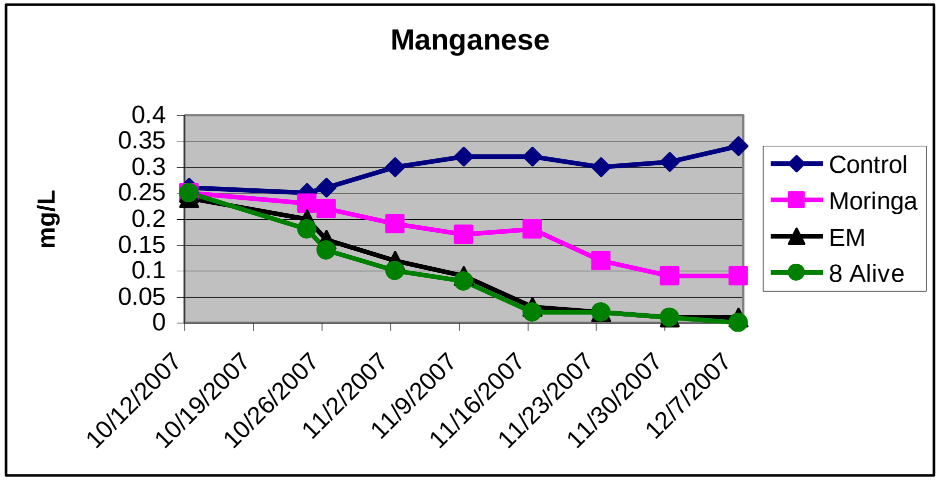
Manganese
mg/L
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11/2/2007
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Control
Moringa
EM
8 Alive

5 Discussion

The buckets treated with Moringa showed a purple colour after three weeks. This may be due to the toxic effects of mainly sulphide on the algae and the consequent predominance of purple and green anaerobic photosynthetic bacteria. These bacteria use light energy to fix carbon dioxide with the concomitant oxidation of hydrogen sulphide to sulphur and sulphate. There are many photosynthetic bacteria, but two main groups are important in ponds: the purple sulphur bacteria belonging to the family of Chromatiaceae and the green sulphur bacteria belonging to the family Chlorobiaceae. It would seem that Moringa facilitated the build up of these bacteria.

The pH of the treatments increased compared to the control. This increase was checked by use of the Kruskal Wallis test at $\alpha = 0.05$. The hypothesis H was that the pH figures are the same. The H value found was 11.8 compared to 7.8 from the chi square table, hence the hypothesis was rejected meaning that the pH values are significantly different. Therefore, on this research SCD EM Plus and liquid bacteria (8 Alive) increased the pH of the wastewater. This statistical analysis was done to all other tests and it showed that the difference in values obtained over the entire period were statistically different.

The possible reason for the increase in pH can be attributed to photosynthesis. All other buckets except Moringa treated buckets showed a green colour after three weeks signaling the growth of algae, which intensified during the period of observation. Readings of pH were done around 1400hrs, the time photosynthesis dominates over respiration. The process of photosynthesis consumes carbon dioxide and converts the bicarbonate ion to hydroxyl ion. This then leads to pH rise. Therefore, as the algae population grew with time, there is a possibility that this caused the pH rise, which stabilized with time. SCD EM Plus and liquid bacteria showed the ability to raise pH hence could eliminate the need to apply lime to ponds. As the pH rose to a maximum of 8.6, hydrogen sulphide, which causes bad odours could have been converted to the odourless bisulphide ion hence the decrease in the concentration of hydrogen sulphide as shown on the graph. (Sperling, 2007). The wastewater from Ujams ponds had a very strong odor the first day the experiment was set up. After three weeks, there was a noticeable decrease in all the treated samples but there was no significant difference in the control sample. From the third week, the Moringa treated sample started turning purple and the smell was rather a sweet composting smell.

The rise in pH also could have lead to the precipitation of heavy metals as hydroxides and carbonates. Precipitating the residual heavy metals in solution could be achieved by using organic sulfides and inorganic sulfides.

The simulation of the ponds by use of buckets, though not the best method, produced quite interesting results on odour control during the experiment period. It can be noted that EM, 8 Alive and Moringa have the potential to control odour. This experiment would be followed up in a laboratory. This will include the use of anaerobic and aerobic digesters, which have dosing pumps that can be used to simulate the ponds' influent and effluent. This equipment is available at the Polytechnic of Namibia.

As EM has no known harmful environmental impact, the experiment could be carried out on site where the EM/Moringa is dosed into the influent and tests and observations done on the pond over time.

The fact that Moringa showed some effect in odour control is very encouraging. Since Moringa seeds and leaves are not yet a saleable commodity in Namibia, it remains to be seen whether their addition to the treatment would be more cost effective than applying higher concentrations of EM without Moringa. Since Moringa trees are being promoted by the FAO urban agriculture project, it is likely that many people will soon be able to supply Moringa seeds and leaves. Alternatively, Moringa trees could be grown on Municipal land in the vicinity of Ujams, although there is a risk that baboons might raid them once they discover how edible they are.
At the Vryburg Abattoir in South Africa EM was used successfully to treat wastewater for aquaculture and irrigation of fodder starting at 1000 times dilution for the first few months followed by 10000 times dilution for follow-up maintenance. Perhaps their wastewater is not as polluted initially as the Ujams wastewater that receives lots of industrial waste apart from that of the Meatco Abattoir. It may also be possible that real pond applications require lower EM applications than the artificial buckets, but this can only be discovered by actual pond application. It is unlikely that alternative cheaper methods can be found, but EM application is likely to be cheaper and of greater benefit if applied on site at the industries, rather than further down the line at Ujams.

Based on the Ujams ponds, with an inflow of 4 000 m^3/day, the cost of using EM Plus, fermented with leaves and seeds of *Moringa oleifera,* would be the lowest (in the region of N$400 000 per annum plus the unknown price of Moringa leaves and seeds). The annual cost of the EM Plus treatment would be in the region of N$1 500 000 and the cost of 8 Alive about N$1 900 000. Application of 8-Alive would be easier than the EM treatments because EM needs to be fermented for 1-2 weeks before use. From other research carried out, 8 ALIVE should be dosed at intermittent periods throughout the day, rather than as a single daily dose, preferably through the use of a dosing pump with a 24-hour timer

6 Recommendations and Conclusions

From the results above, 8 Alive seemed to perform better than the other treatments, followed by the cheaper Moringa treatment. SCD EM Plus comes third. The costs of SCD EM Plus and 8 Alive were not significantly different at the rates applied, while the Moringa treatment is more cost effective although less convenient. This research will be followed up with the simulation of the ponds by use of an anaerobic digester. This equipment simulates anaerobic ponds. The wastewater will be fed into the equipment by use of a pump at a constant rate. Though the buckets were used to simulate the anaerobic ponds, the conditions could be more like the facultative ponds, which could have affected the treatment rates of the different treatments.

As chromium and zinc inhibit the growth of microorganisms, it is possible that the effective microorganisms' effectiveness was reduced by the presence of these metals. It is recommended that when wastewater has chromium and zinc present, precipitation of these metals should preceed the introduction of effective microorganisms.

The main conclusion from the survey is that no one is happy with the smell generated by the Ujams ponds. Although not all interviewees do experience the smell at their homes, the majority indicated that the smell is stronger during the summer season, particularly in the evenings, and is worse when windy; smelling like sewerage. The smell is more noticed at north west of the ponds, as that is where most of the nearby homes are situated. Residents indicated that the smell from the Ujams ponds has long existed since some have been living there as early as the 1980s. No one has a lasting solution against the smell either at home or when driving by. Although it might be expensive, the majority of residents think the most appropriate action the City of Windhoek could take to control the smell is relocating the ponds faraway. The hardest hit are business people such as guest house operators and property developers, who said the smell drives their customers away. They complained that they lose considerable income as the smell leaves a bad experience for the visitors and they are unlikely to return. A few individuals stressed that the municipality should learn from bigger cities and towns who manage their wastewater well. The fact that agricultural business operators were not willing to take part in the survey suggests that they are afraid that they might be seen as contributors to the problem, which may lead to the closure of their businesses.

These survey results can form the baseline with which to compare residents' perceptions after action has been taken to control the smell emanating from Ujams.

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