CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

FOOD WASTE LIQUEFIER ORCA GREEN

A thesis submitted in partial fulfillment of the requirements

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by

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DEDICATION

This thesis is dedicated to:

The memory of my father Mohammad Ali DeHaghin, who thought me live with compassion.

To my lovely mother Mina for all her sacrifices, support, encouragement, and unconditional love during my long educational journey.

To my siblings: Mojgan, Ali, and Leila for being always supportive.

To myself for believing in me and never give up on my goals and accomplishments.

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ABSTRACT

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Daily Food Waste is a recurrent issue across many industries, in specific Universities, Colleges, Schools, restaurants and food service organizations. These establishments have continuously explored the ability to recycle their DFW as a sustainable means to transform eatable-organic food into a reusable effluent, preventing it from entering into the landfills. Thus, decreasing the carbon footprint and reducing the costs of its disposal.

Loyola Marymount University in affiliation with Sodexo purchased the ORCA Unit, the ORCA machine is a food liquefier. It transforms food waste into water effluent; it is then released into the sewer system. *The forward-looking statements* from the "ORCA Totally Green Company" are that "the end result is a nutrient-rich water effluent that can be reused for irrigation, or it can be disposed of into the sewerage".

The main purpose of the study was to examine the chemical and biological components in this effluent derived from the "ORCA Totally Green" food reduction system; investigated whether this effluent would be presumed safe for humans and plants. Secondary intention of the study was to identify if the effluent benefits LMU garden campus as a fertilizer, as the company has claimed. The design of study was experimental; a variety of tests such as BOD, Oil and Grease, Total Solids, Nitrate, Total Phosphates, Total coliform, and E.coli were performed on the chemical, physical and biological water quality of ORCA effluent samples, the results were then

compared to the values of a typical domestic raw sewage. The Microbiological tests focused on determining concentrations of *the fecal indicator bacteria* including total *Coliforms, E. Coli, Enterococci,* followed by species' identification of the *cultured-isolates* determined that potential *pathogenic strains* were present. The discoveries included high levels of fecal indicator bacteria, mainly total *Coliforms and Enterococci.* The preliminary data indicated that there was a potential for the opportunistic human pathogen(s), one as such was *Klebsiella Pneumonia*.

The study concludes that although ORCA effluent contains a high nutrient value, bacterial data indicated potential human health concerns. Therefore, ORCA effluent belongs in the sewer and should not be used around Loyola Marymount University Campus on plants. This project will be applicable to all colleges and universities. The final results from the study will be of interest to Dining Services professionals, recycling coordinators, compost coordinators, sustainability coordinators, and environmental scientists.

CHAPTER I

INTRODUCTION

The world today is faced with many challenges. One of these challenges lies in finding the best way in which the refuse that we produce is disposed off carefully to ensure that it does not affect the environment negatively. Waste management, as it may be thought of is an aspect that many companies have been forced to content with. This has mainly been informed by the increased attention that has been paid to the debate on climate change. The issue though of solid waste management has been around for a long while now. Its existence superseded the discussions that were being had on the effect of air and water pollution.

The discussions on how best to manage solid waste discharged from various sources have largely been informed by the increase in population that the world is experiencing at the moment (Chandrappa & Das, 2012). The increase in population has meant that more and more waste is being produced every day. The management of this waste is necessary for financial and environmental, and for protecting the future livelihoods of the earth's inhabitants. Due to the increased concerns that have been raised by the management of solid waste, the responsibility has become one that is shared in many different jurisdictions. This is where the role has moved from solely being that of the different municipalities to that of the municipalities in conjunction with the different institutions within these municipalities.

Over the recent years there have been changes in the ecosystem that have been experienced in different parts of the world. These changes in the ecosystem have mainly been driven by what scientists have come to call climate change (Casper, 2010). The debate on climate change has elicited different points of view from different quarters. The main discussion is on what is termed as global warming. This is in reference to the increase in ambient temperatures of

the atmosphere. The discussion on the use of the Organic Refuse Conversion Alternative (ORCA) will not be complete without an introductory and extensive discussion on the issue of climate change which will conclude by looking at the strides that have been made in the way that companies handle refuse.

The study of climate change has been in existence for more than 2 centuries now. In the earlier days of the discussion there was little attention that was paid to the effect of the changing environmental factors to the future of the earth (Fleming, 1998). Most attention on the subject was paid to understanding and knowledge of what was going on at that time. It is important to note that most of the progress in terms of the current knowledge that is available on the subject is largely from the improvements in technology.

Solid waste has the effect of increasing greenhouse gases in two main regards. The first is that the disposal of solid waste in landfills usually leads to the emission of greenhouse gases such as methane. On the other hand, the transportation of this waste will mainly be done by road. This method of transportation has been known to increase the amount of emissions into the atmosphere from the trucks and vehicles used.

One of the effects of the improvements in technology lies with the increase in the accuracy to which certain environmental factors can be measured (Joshi & Singh, 2011). This includes the changes that are brought about by the different factors that are released in the atmosphere in the course of our daily lives. One of these has been with the study of the levels of carbon dioxide in the atmosphere and the difference in the temperature that this has created. These studies have enabled better modeling of future trends in the changes of the atmosphere. Enabling the study of how solid waste and the constituent management systems affect the environment in the current time. This data is then used in the modeling of future trends if given different situations. This allows the making of more informed solid waste management practices.

Some of these changes include the use of satellites, which have been commissioned by

different governments that have improved the tracking of changes in the weather. These satellites have also been able to improve the study of other planets in the solar system. There is also the improvement in computing power that improves the analysis of the data collected by these machines.

The current debate on climate change is basically centered on the increased amounts and levels of Carbon Dioxide (CO_2) that are present in the atmosphere. Understanding the mechanics of this allows a connection to be made on how solid waste affects the environment in as far as leading to climate change. CO_2 and other gases are thought to have considerable effects on environmental temperatures and have been termed as greenhouse gases. These are mainly gases that are responsible for trapping heat in the atmosphere which raises the overall temperature of the earth. These gases have been identified as CO_2, Methane (CH_4), Nitrous Oxide (N_2O), Chlorofluorocarbons (CFCs), and atmospheric water (H_2O). The effect of CO^2 and H^2O had been studied in the earlier years while the others only became a concern in the 1970s.

These gases work to reduce the reflectivity of the earth's atmosphere. The earth is therefore forced to retain more heat from the radiation of the sun than it reflects back into space. The additional heat that is then retained affects the overall weather patterns that are being experienced in various places of the earth. The persistent change in the weather pattern is what then leads to the change in the climate. Some of the most notable effect lies in the melting of the ice glaciers that are found in the North Pole.

There are two effects that are created by the melting of the ice caps. The first one is that there is an increase in the amount of the water that is in our oceans. This level then threatens some of the low lying islands and coastal towns (Chiras, 2004). The other effect is that the increase in the amount of water in these oceans leads to an increase in the temperatures. This is due to the consideration that there is no more cooling effect of the atmosphere that is provided by

the polar ice caps. The science behind this lies in the study of the warm and cold fronts that blow over the oceans seasonally and that also have an effect on the ambient temperature of land masses.

There are different human activities that may be associated with the increase in the amount of the so called greenhouse gases in the atmosphere. In the past, the issue of rising levels of CO_2 was mainly attributed to the gaseous waste of factories and the burning of oil and coal for energy. This was in amounts that were considered greater than the current plant cover was able to utilize in food production. Biology dictates that plants utilize CO_2 for photosynthesis, a process that leads to production of Oxygen (O_2). Over the years, increased studies have shown that other greenhouse gases are produced in a similar manner as well. The other factor lies in the increase of the population that has meant more and more land cover has been converted for commercial use and is not under plant cover. This reduces the ability of the earth's ecosystem in terms of reducing these levels of CO_2. On the other hand, the increase in population has meant a need for more energy. At present, most sources of energy are not green.

Solid waste, on the other hand, is managed by mainly being sent to landfills. Its decomposition leads to the production of greenhouse gases such as methane and carbon dioxide. Depending on the type of waste and the management process (especially if the waste is burned), may lead to the production of oxides of nitrogen that are also considered greenhouse gases. The increase in population has also increased the amount of solid waste that is produced and thereby increased the levels of these gases in the atmosphere.

Our main concern in the undertaking of the research lies in two areas of study. The first is in the reduction of solid waste to landfills. Increased collection of solid waste in landfills has been credited with the production of CH_4 gas. There have been different suggestions as to how this gas can be utilized and thereby reduce its effect on the environment. One among these suggestions has

been in the production of energy from these landfills (Gore, 2008). This has its own challenges and the viability may be limited in certain cases. Another has been in the reduction of the solid waste that is taken to these landfills all together; this is more as a preventive measure.

The breakdown of solid waste into the various gaseous compounds occurs in four phases. The first phase involves aerobic breakdown of the constituents of the solid waste. This is where bacteria in the landfills use oxygen to breakdown the longer chains in compounds such as proteins, carbohydrates, and other matter. This leads to the production of mainly CO_2. The depletion of Oxygen leads to anaerobic decomposition of the waste in phase II. The decomposition by these anaerobic bacteria usually leads to the formation of a number of alcohols and acids that dissolve the nutrients in the waste. These acids include acetic and formic while the alcohols are mainly methanol and ethanol, the main by product being CO_2 and hydrogen. The dissolution of the nutrients increases the availability of these nutrients to the bacteria in the waste.

In the third phase, anaerobic decomposition continues but in this case the bacteria consumes the acid produced in phase to form an organic acid known as acetate. This neutralizes the PH of the landfill leading to a conducive environment under which bacteria that produce methane may thrive. Phase four is usually characterized by the continued constant production of green house gases. Gas production in these landfills may last long depending on the organic nature of the waste. Usually it consists of 45-60% methane by volume, 40-60% CO_2, and 2-9% of other gases such as sulfides (Cheremisinoff, 2003).

This is where food disposal machines such as the ORCA machine come in. The second point of the study lies in looking at the liquid waste that is produced by the machine. This is so as to make a determination as to the ability of the water to be recycled for use in other areas. This determination will be mainly conducted from a health perspective. These two factors maybe better understood by considering the issues that surround management of solid waste.

Waste management has come to play an increasing role in the way in which companies'

operations are judged. The reason for this is that with increased climate change debate so too have the discussions on managing the waste that humans produce gained prominence. One of the ways in which this has been done is through implementation of recycling measures. Usually, recycling has involved the separation of waste into different components. This can neither be recovered to make the initial product nor reused in the making of new products. This is in the process of recycling.

The concept of this has been captured in the waste hierarchy. The birth of which was in the earth summit held in Rio de Janeiro in 1992. It commonly advocates for the first step to be the reduction in the amount of waste that is produced. To the waste that may not be reduced then its ways of reusing this is then sort. Finally, the concept advocates for the recycling of waste if either of these options may not be viable (Dhir et al. 2001).

One of the areas where this has gained prominence is in the use of aluminum where it requires less energy to recycle than to produce. On the other front, grater calls for companies and municipalities to reduce the amount of refuse that they send to landfills have seen an increase in the uptake of new technologies to solve the problem. These technologies are usually meant to improve the capabilities of companies to handle their waste. One area that had, in the past, gained increased attention is in the management of air and water discharges from companies. This is with the increased cases of pollution and the increased negative effects that could be linked to these modes of refuse disposal.

The increased attention that has been paid to the management of solid waste may be attributed to a number of factors. One of these factors has been population growth. Over the past few years, there has been a rapid increase in population that has meant an increase in the amount of solid waste that is produced. There has also been an increase in the amount of competition in terms of scarce resources. One among this is land. This limits the space that can be found by which to dump the ever increasing amounts of solid waste that is being produced. This, therefore,

required the development of solutions that would work both in the long term and in the short term and among these was the development of waste composting machines.

In dealing with solid waste, there are various technologies that have been developed that are intended to deal with the issue of solid waste. These technologies such as wind row composting, which is used in the production of fertilizer from organic waste, are based on the type of waste that is being dealt with. This is both in terms of its physical characteristics as well as with its chemical characteristics. These two features of solid waste are important in that they affect the limits of the processes that may be used in dealing with the waste. Chemical characteristics are considered in the disposal of hazardous waste material, in the case of waste that contains elements such as asbestos may not be burned or disposed in a way that it may leach into underground water sources. On the other hand, while the physical attributes of waste such as plastics, glass, and wood may allow for them to be crashed, this may not be available in the case of metal solid waste as it is uneconomical.

The handling of food waste requires special consideration. The fat and grease content of food waste limits the ability of its disposal in the sewer systems. Hence, special consideration needs to be given to this. On the other hand, the decomposition rate of these wastes may also the ability of this waste to be disposed in landfills. This is due to the effluent that may be emitted. This increases the need for innovative solutions to solve the problem.

One of the solutions that have been proposed for this purpose has been the ORCA machine. The ORCA machine works to reduce the solid waste that is sent to landfills by kitchens. This is by decomposing some of this waste allowing its disposal into the sewer system. It also allows this waste to be recycled and used as fertilizer. This limits the effect to the environment that may have been created by the transportation of this waste to landfills. It also minimizes the release of greenhouse gases that may have been produced had these wastes made their way into landfills.

Handling food waste is usually complicated by the organic content of this type of waste. This organic material may be difficult to process and may provide a good environment for the growth of a variety of harmful microbiological organisms. The other factor is that it may provide pests as well as other insects with an ideal environment where they will thrive. This may later become a public nuisance or an environmental hazard. One final issue is in the water content of food waste. It has been found that food waste is composed of roughly 70% water. This water content affects disposal in that it may contaminate water sources that are used for other purposes if not effectively managed at the time of disposal (Ranken et al.1997).

Other issues that are of importance in the case of recycling solid waste lie in the legislation that is involved in the area where the company is operating. There are different rules and regulations that are in place in different jurisdictions. These rules and regulations may be used as a guide for the formation of frameworks that may be used in the development of the right form of waste recycling mechanism. In this case, the consideration lies mainly in what may be permitted by the law and what may be in contravention to the law. The basis of the law is usually meant to ensure that the waste that is disposed by the different companies is not harmful in any way; both to the environment and to those who may get to handle or get in to contact with the waste (Arvanitoyannis, 2008).

An example of such legislations that are meant to guide the standards in as far as handling waste is concerned is that which guides the European Union member countries. These are outlined in the Environmental Act 1995 as a series of guidelines:

- Waste is to be handled in a way that does not endanger humans or the environment.
- Technology used in waste disposal is to be current with a consideration of the cost.
- Waste management procedure is to be self-sufficient.
- Clean and green waste management practices are to be adopted.

- Waste reclamation, reuse, and in use in energy production should be done.

  (Arvanitoyannis, 2008).

An important aspect that is the basis of this analysis lies in the consideration that the waste that the ORCA machine is meant to handle is food waste. In this case, there is a need for greater care in two regards. The first is that the machine is a meant to be a small scale unit that will be handled by kitchen staff of the Loyola Marymount University (LMU) dinning services. This means that the machine should be used safely and its use should follow the already prescribed health codes. This is to avoid any contamination of the food served in the kitchen from the wrong handling of the waste. The other consideration lies in looking at how the treatment of this waste will affect the environment. This is from the microbiological and chemical composition of the effluent resulting from the recycling of the waste (Knechtges, 2012).

The company that manufactures the ORCA machine has stated that the machine works by breaking down the solid waste into ever small pieces. In this case, the physical structure of the waste is affected by the rotating rotor blades in the machine. The second aspect of the machine lies in the microbiological break down of the waste produced by the machine. Thus, microorganisms associated with carrying “biochips” are added to the machine to break down the mixture. There is also the addition of water to the process that is being undertaken. The water is mainly used to aid in the breaking down of the waste that passes through the machine. Secondly, this allows the effluent waste to be easily discharged to the sewers.

The first consideration of this research will be on how well the machine is able to breakdown materials physically. This process largely determines how best other processes such as the biological breakdown of the organic matter will work. This is due to the fact that it increases the surface area of the waste that may be acted upon by the bacteria, which works to improve the efficiency of the machine.

The second consideration lies in the biological breakdown of the organic matter. This aspect deserves our attention due to the nature in which the waste water is being utilized after the process. The reason for this consideration is that the chemistry and organic nature of this water will affect the environment. The use of water is as to make it easier to dispose the waste through the current sewer system if need be. The analysis of this water in this regard is required as some elements may make their way into the sewer systems causing problems further away in the system.

Other forms of solid waste may also cause problems if they accumulate in the sewer systems. This may be exemplified by the recent blockage of the sewers of London by what came to be known as the 'Fatberg'. This was a 15 ton mass of rotting fat and other waste (Webb, 2013). One other such story was also reported in the fact that Scotland spends 7 million pounds a year to clean up the blockage that is caused by household waste. Among these were wastes such as fat, oils, and grease that are predominant waste products from a kitchen. This creates the need to know the ability of the machine to prevent the discharge of these forms of waste in ways that may cause the said blockages (Evening Times, 2013).

In the undertaking of the research and the making of the conclusions as to the effectiveness of the machine, a relative comparison will be done. This is on two fronts. This comparison will be done in consideration of other types of machines that are available in the industry that may be thought to be in the same group as the ORCA machine. This will be with regard to the technology and with regard to the physical aspects of the machine. The technology will be a consideration of the way in which the waste is processed as compared to the way in which other machines do this. This will help determine the options available to the university in terms of the best food waste processing machine.

The consideration of the materials is mainly meant to be used to determine the life span of the

machine. The material composition may also affect the type of food waste that is processed by the machine. In certain cases, the acidity and alkalinity of the food waste may corrode the material of such machines overtime. In other cases, they may increase the concentration of certain harmful chemicals in the waste that is released.

These considerations though will play a less critical role as compared to the chemical and organic composition of the waste. Their consideration, to the minimal extent, will be undertaken to improve on the thoroughness of the study. This is to ensure that all aspects that play a role in affecting the elements that affect the adoption of the machine are presented. Their inclusion will also improve the decision-making process that will go into the consideration of whether the choice to use the ORCA machine was the best.

CHAPTER II

REVIEW OF LITERATURE

The first paper that is considered is that which was written on the study of the ORCA food waste machine. The paper presented information on the way in which the ORCA machine works as well as most of the pertinent issues that are in need of consideration. In this case the presentation begins by looking at the way in which the machine breaks down the solid waste physically. This is through the use of paddles that are attached to a shaft that is made of stainless steel. There are various other additional enzymes and microorganisms that are then added to the mixture in the machine. These are aimed at ensuring that there is complete breakdown of the waste that is fed into the system. The paper has proposed that the system can be fed continuously with the only limitation of the system being the inherent capacity of the machine. In this case the consideration is as to whether the machine is able to accommodate the amount of waste that it has been fed.

This is important as a starting point as it provides the needed background knowledge that is required in the study of the machine. The best point to begin with is by looking at the way in which the machine processes solid waste. This provides the beginning point of the analysis in the effectiveness of the machine as a food waste processor. This is with the consideration of how effective it is in terms of the physical decomposition of the solid waste that the machine gets to handle. The paper also provides a way in which the preliminary study of this physical analysis. This is by looking at issues such as the amount of waste that it can process in a given time, the life time of the machine, the replacement rate of the machines components among other such

factors. In this case the consideration may then be used to provide a comparison of this machine as to others that are available in the market. This comparison may be used in making either a preliminary decision on the matter or may be used in the improving the efficacy of the arguments for or against the machine.

One other factor that this brings into play lies with the consideration of how the physical aspects of the machine play a role in the decision making process. This is a factor that has been discussed in a paper written by Rasmussen and Bergstrom. The introduction of the paper presents arguments that show the consideration that goes into the decision making process as to the adoption of ORCA food waste machine. One of the factors that have been identified in this paper is the space consideration. In this case there is limited space that is available in the institutions of higher learning to accommodate the establishment of large facilities. In this case the ORCA machine provides a good replacement that enables these institutions in their endeavors to recycle the organic waste that they produce. These same arguments can be made for the ORCA machine. The second consideration in this case lies with the cost savings that are gained with the implementation of on sight recycling. These costs are saved mainly due to the cost of transportation that is involved in the moving of the solid waste from the institution to the landfills.

One element of the paper written by Dorsey and Rasmussen, which is considered to be of importance in this particular research, is the attention that the authors have paid to the biological element of the study. In this case the paper looks at the biological composition of the effluent that is the byproduct of the ORCA machine. The reason as to why the writers looked into this was from the consideration of the companies claim that the effluent discharged by this means can be recycled and used in irrigation. The study was able to take into consideration a wide range of bacteria that are thought to have differing effects in the ecosystem. This paper was able provide

insight into how our research would be conducted as well as providing some of the results that were used in this particular research. These results will be used later in the comparison of how they compare to those thought to be within the safe range for the uses that the company has claimed.

The issue of safety in terms of the use of the discharge is deal t in by a number of other papers. There are different studies that have been conducted on the effects that different microorganisms play in the ecosystem. These different studies have informed the various legislations that have been passed in a bid to regulate the discharge of the effluents that is disposed from different institutions. Therefore an important element in the study lied with the comparison of the figures that have been obtained in the study with the limits of the current discharge of the system. One paper that provides this direction is an extract from the purple book that seeks to inform on the levels to which water is considered to be safe. The paper does not present the entire regulatory environment to which the waste water will be treated though. It was used in the research study as a guide in terms of the direction that is taken by the regulating bodies in terms of their treatment of waste water. In this case the paper has provided direction in term of the consideration that the local government gives in terms of the treatment of waste water products. This regulation is in terms of both the infrastructure as well as the fees that are needed for the required permits.

The consideration of the influence of the regulatory environment in the issue of the use of the ORCA food waste liquefier was informed by a clean water report that was written by the bureau of sanitation. This report had important points and consideration that were used in the development of the research parameters, considerations among other elements. In this case the paper outlined some of the functions that the local government has been tasked with. One among this was with the treatment and disposal of this waste water. The major part of the paper was on the discussion of the financial position of this institution and how this affects its operation. This shows the

importance of the consideration of the financial aspect of the machine in the study. This is with the effect of the permit costs and how this influences the overall costs that the institution will be faced with. These regulations provide guidelines that companies should follow in the determination of the nature of the effluent that they produce.

The use of food waste disposers may be traced as far back as the early 1930s. The consideration of the historical aspect will play a significant role in the analysis of the ORCA machine. This is due the fact that this analysis will provide a background to the developments that have been made in food waste disposers and the trend in terms of technology used and the improvements made thus far (Spencer, 2008).

One of the food waste disposer that is presented in the paper by Spencer is known as the pulper. The working system of this is different from the one that is under study but it provides a fair kind of analysis as to the steps that have been taken towards the making of the current versions of the food waste disposers. In their inception, the main consideration for their adoption was with the reduction in the amount of waste that was being sent to landfills and the cost that this attracted.

The paper shows that during these early days, the uptake of these machines was supported by the local authorities due to the fact that it reduced the amount of Biological Oxygen Demand that the municipal treatment facilities were loaded with.

At the time, the machines simply worked to remove the liquid waste from the solid waste by the use of different methods. The liquid waste could then be disposed off through the local sewerage facilities. The solid waste could then be sent off to different sites. Over the years, it was realized that this could be used by composting facilities to make fertilizers and that was the application with which it was to later given. Over the years, these improvements in this process were mainly driven by the fact that the associated costs still included that of transporting the solid

waste to composting facilities. These costs were still thought to be a hindrance to the whole process. This informed the need to create improvements in the process with time.

One other notable historical point that is brought to light in this paper is with regard to the developments in terms of the adoption of these machines in the recent past. This is where a considerable amount of attention was paid to the use of these machines. The paper has pointed out that this has mainly been informed by the increased attention and concentration that has been given to the issue of climate change. The machines have been noted to reduce the carbon footprint of the institutions that use them in terms of waste disposal. On the other hand, improvements in technology have also worked to improve the overall design and efficiency of the machines. These improvements have meant that new machines such as the ORCA, which is under consideration in this study, are able to have a greater amount of output. There have also been great improvements in areas such as the energy consumption of these machines among other factors.

The undertaking of the research will require knowledge in two regards. These two areas will provide us with the needed background information that is required in the undertaking of the study. The first area of analysis is with the understanding of the various elements that are found in the waste water and their effect on the environment, human beings as well as other animals. The second aspect lies in the understanding of the methods in which waste disposal in this regard may be considered. The second aspect will tend to look at the advantages and the disadvantages of these methods. The developments in terms of refuse disposal have already been touched on lightly in the previous discussions.

An important aspect in waste water treatment lies in the determination of the amount of dissolved and particulate organic matter. In this regard, one can infer two important parameters. The first of these is the effect of the treatment method in the reduction of the organic matter

present in the water. The second is the effect of the waste water discharge on receiving waters. The basic theory behind this is outlined in a text written by Pepper. The argument is that water contains dissolved oxygen. This oxygen is important in that it determines the survival of water in flora and fauna. It is used to sustain of water ecosystems. The reason for this consideration is that waste water contains organic matter. The organic matter utilizes oxygen for organic and in organic processes. Therefore, their concentration will affect the levels of oxygen in the water (Pepper, Brendecke & Gerba, 2005). For this reason, the amount of oxygen that is available in the water may be used as an indirect way to measure the amount of organic matter that is present in the water. This will ensure that if the waste water is to be released into other sources of water it may not deprive these sources of dissolved oxygen thereby affecting other life such as fish and water plants.

This method described above of using the oxygen demand of the water to determine organic activity in the water is highly favored despite the fact that there are limitations to these methods as discussed by Sperling et al. in his book (2005). There are various advantages that are provided by the use of this method, among them is that it provides a good approximation of oxygen consumption by the organic matter in the waste water. The process of undertaking this experiment has also been outlined in the text, which has provided information that proved invaluable in the undertaking of the study (Sperling et al., 2005). They note that the experiment is best done during a period of five days and at a temperature of 20^{o}C. They also argue that these results present the most ideal condition for the undertaking of the experiment.

Another important aspect in the consideration of the effectiveness of the study of waste water treatment lies in the determination of bacteria in the water. An important aspect of this consideration is in the determination of the harmful bacteria that is available in water sources. The determination of bacterial matter in waste water is usually meant to consider the pathogens

that are carried by the water. Vesilind (2003) states that, due to the difficulty that is associated in measuring these bacterial matters, the use of other microorganisms is required. He states that the most commonly used microbes are known as *coliforms* (Vesilind, 2003). He is able to give the reasons as to why the use of these microbes is done. The text is also to guide in terms of the background information that is used in the development of the experiment to be conducted in the undertaking of the research. Fecal bacteria are usually bacteria present in human waste. They are not harmful but may be indicative of disease carrying pathogens. It is for this reason that their presence in water is determined.

To understand how this, one needs to know what *coliforms* are and how they affect pathogenic behavior. An understanding of this is provided by Mara and Horan in their text. They have provided some knowledge as to the development in the definition of *coliforms* as well as the current meaning that is applied to the word. Stating that *coliforms* are"…members of the Enterobacteriaceae possessing the gene coding for the production of β-galactosidase" (Mara & Horan, 2003).This is a definition that was proposed by the Department of Environment in 1994. Among this category of bacteria includes the *E.coli* bacteria. These two texts also indicate the

The research study will be conducted with an evaluation of the historical aspects. The analysis will look at the evolution of the food waste disposers. A paper written by Spencer provides some of the needed information on the subject. The presentation in the paper provides some background knowledge as to the start point of the historical aspects. The paper has presented an introduction that states that the beginning of the use of these disposers was in the 1930s. The paper has also presented some preliminary information on some of the disposers that have been in use over the years. In this case the information works out to be the starting point to which further analysis of the historical study will be conducted.

One of the food waste disposer that is presented in the paper by Spencer is known as the

pulper. The working system of this is different from the one that is under study but it provides a fair kind of analysis as to the steps that have been taken towards the making of the current versions of the food waste disposers. In their inception the main consideration for their adoption was with the reduction in the amount of waste that was being sent to landfills and the cost that this attracted. The paper shows that during these early days the uptake of these machines was supported by the local authorities due to the fact that it reduced the amount of Biological Oxygen Demand that the municipal treatment facilities were loaded with.

At the time the machines simply worked to remove the liquid waste from the solid waste by the use of different methods. The liquid waste could then be disposed off through the local sewerage facilities. The solid waste could then be sent off to different sites. Over the years it was realized that this could be used by composting facilities to make fertilizers and that was the application with which it was to later be given. Improvements in this process were mainly driven over the years by the fact that the associated costs still included that of transporting the solid waste to composting facilities. These costs were still thought to be a hindrance to the whole process. This informed the need to create improvements in the process with time.

One other notable historical point that is brought to light in this paper is in regards to the developments in terms of the adoption of these machines in the recent past. This is where a considerable amount of attention was paid to the use of these machines. The paper has pointed out that this has mainly been informed by the increased attention and concentration that has been given to the issue of climate change. The machines have been noted to reduce the carbon footprint of the institutions that use them in terms of waste disposal. On the other hand improvements in technology have also worked to improve the overall design and efficiency of the machines. These improvements have meant that new machines such as the ORCA, which is under consideration in this study, are able to have a greater amount of throughput. There have

also been great improvements in areas such as the energy consumption of these machines among other factors.

The undertaking of the research will require knowledge in two regards. These two areas will provide us with the needed background information that is required in the undertaking of the study. The first area of analysis is with the understanding of the various elements that are found in the waste water and their effect on the environment, human beings as well as other animals. The second aspect lies in the understanding of the methods in which waste disposal in this regard may be considered. The second aspect will tend to look at the advantages and the disadvantages of these methods. The developments in terms of refuse disposal, which has already been touched on lightly in the previous discussions.

An important aspect in wastewater treatment lies in the determination of the amount of dissolved organic matter. In this regard one can infer two important parameters. The first of these is the effect of the treatment method in the reduction of the organic matter present in the water. The second is the effect of the wastewater discharge on other water sources. The basic theory behind this is outlined in a text written by Pepper. The argument is that water contains dissolved oxygen. This oxygen is important in that it determines the survival of water flora and fauna. It is used in the sustaining of water ecosystems.

On the other hand wastewater contains organic matter. The organic matter utilizes oxygen for organic and inorganic processes. Therefore their concentration will affect the levels of oxygen in the water (Pepper, Brendecke & Gerba, 2005). For this reasons the amount of oxygen that is available in the water may be used as an indirect way to measure the amount of organic matter that is present in the water. This will ensure that if the waste water is to be released into other sources of water it may not deprive these sources of dissolved oxygen thereby

affecting other life such as fish and water plants.

This method is highly favored despite the fact that there are limitations to these methods as discussed by Sperling and others in his book. There are various advantages that are provided by the use of this method among them is that it provides a good approximation of oxygen consumption by the organic matter in the wastewater. The process of undertaking this experiment has also been outlined in the text, which has provided information that proved invaluable in the undertaking of the study (Sperling et al., 2005). He notes that the experiment is best done during a period of five days and at a temperature of 20 ^{o}C. He argues that these results present the most ideal condition for the undertaking of the experiment.

Another important aspect in the consideration of the effectiveness of the study of wastewater treatment lies in the determination of bacterial matter in the water. An important aspect of this consideration is in the determination of the bacteria that is available in water sources. The determination of bacterial matter in wastewater is usually meant to consider the pathogens that are carried by the water. Vesilind states that due to the difficulty that is associated in the measuring of these bacterial matters, the use of other microorganisms is required. He states that the most commonly used microbes are known as *coliforms* (Vesilind, 2003). He is able to give the reasons as to why the use of these microbes is done. The text is also to guide in terms of the background information that is used in the development of the experiment to be conducted in the undertaking of the research.

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Horan, 2003).This is a definition that was proposed by the Department of Environment in 1994. Among this category of bacteria includes the *E.coli* bacteria. These two texts also indicate the effects of the presence of these microbes in waste water.

The use of *coliforms* in the undertaking of the study on the pathogenic levels of waste water was also studied in a different research by George and his team. They were able to conclude that the use of bacteria in determining microorganism activity in water provides a fair estimation. They were also able to conclude that the method was effective in the determination of the effectiveness of the waste water treatment methods that is being applied in the treating of the waste water produced (George, Crop & Servais, 2001).

The study of these bacterial matters' effect on soil was studied by Gantzer and his colleagues. His study broadly looked at a number of different microbes, one among these was the fecal coliforms. The study was able to show that there are certain factors that determine the extent and effect of the semicroorganisms in soils samples. Their main concern was looking at the survival and adsorption of the semicrobes in soil where waste water has been used in irrigating (Gantzer et al., 2001). This is an important aspect of the study in regards to the effect of the use of the wastewater in irrigation.

There was also a study that had been conducted that look at the effect of soil on the penetration of pathogens (Gerba, Melnick & Wallis, 1975). The study was able to establish that there were a variety of factors that affect the survival of bacteria in the soil. They concluded that among these factors were issues such as the temperature of the soil, moisture content of the soil, the organic matter, and also the relationship that exists between the soil micro flora and the bacteria. Soil impedes pathogenic penetration through factor such as sedimentation, adsorption, and the straining of the fluid at the surface of the liquid. The determination of this is able to assist in the development of conclusions as to the ability of the soil to carry disease causing pathogens once

the water from the ORCA machine is used in the irrigation of the soil.

The paper also provides discussion on issues that relate to how the soil pH levels may affect the penetration of the pathogens through the soil. They observed that if the conditions are not favorable, these pathogens may not be able to survive in the soil. Other factors included the electrical charge between the virus and the soil, salt concentration in the soil as well as the organic content of the soil. These changes may also affect the way in which these pathogens travel on the surface and subsurface of the soil. This make the determination of these soil factors an important factor in the consideration of the pollution effect of the waste water discharged by the ORCA machine.

The variability of waste water and the treatment methods that are applied play an important role in the undertaking of the research. This is due to the fact that it forms the basis of this study. This knowledge will be applied in the comparison between how the effluent discharged by this mode can be compared to that discharged by other modes of waste disposal. The information that is required for this kind of study is provided by the text written by Henze (Henze, 2012). He is able to provide guidance on the characteristics of various types of waste. In the process, he shows how the nature and characteristics of these wastes affect the way in which they are treated.

The presence of fats, oils, and grease in waste water has been shown to lead to loss of hydraulic pressure in the sewerage system that may interfere with the proper functioning of sewerage systems. Other effects that have been linked to FOG in waste water include the clogging of screens that are used in the separation of solid waste from the liquid waste. On the other hand, it leads to problems in terms of settling in these dimension tanks that are used in the waste treatment facilities. The other issue that is raised by high content of FOG in waste water is the poor separation of grit (National Research Council (U.S.), 1993).

CHAPTER III

METHODOLOGY

The results in the study were based on research that had been conducted in collaboration with a group of undergraduate students from LMU and me. The assistance gained was in terms of the testing of the samples and the basic analysis of the results. The research was meant to establish the physical, chemical and biological properties of the wastewater that is produced by the ORCA machine. This was as previously discussed in this paper. The approximate volumes of effluent samples collected seven times, three aliquots from each sample for testing.

Biological Oxygen Demand (BOD in mg/L)

This initial discussion on the methodology will focus on the procedure to determine the Biological Oxygen Demand (BOD). The undertaking of the experiment simply involves the filling of a sample of fluid into an airtight bottle. This bottle is then to be placed at a specified temperature for a predetermined period of time. This is usually five days. The value of the BOD as earlier stated is then calculated as the difference between the initial and the final value of dissolved oxygen (DO) (Rastogi, 2005).

The experiment will commence with the use of four 300 mL bottles, two will be used for the sample while two for the blank. A sample of 10mL is added to the two BOD bottles and then filled up with water. The other two bottles are filled up with the diluted water. After this done, one is to immediately seal the bottle with the use of stoppers to avoid interactions of the content of the bottles with atmospheric air. The bottles should also be labeled for identification. Preliminary analysis will be done to one of the BOD bottles and one of the blank bottles immediately. The remaining two bottles should then be stored in an incubator at a temperature of

20^{o}C. The analysis will need to be conducted carefully to ensure that there is no bubbling of the contents being tested.

Using the pipette and placing it just below the liquid surface, 2mL of manganese sulfate is added and is followed by 2mL of alkali-iodide-azidere agent. The reason for holding the pipette just underneath the surface of the liquid is to ensure that there is no addition of oxygen into the mixture which might otherwise taint the results of the experiment. Let the mixture settle by allowing these to settle at the bottom of the bottle. This is to ensure that there is sufficient time for these elements to react with the oxygen. After this has settled, the bottle can be shaken by turning it upside down. This process is then repeated for 2mL of sulfuric acid.

After this is done, one then immediately transfers the content into an Erlenmeyer flask. The burette is then rinsed with sodium thiosulphate and filled with the same solution. 203 mL of the sodium thiosulphate is then transferred to the Erlenmeyer flask. The solution is then titrated until the yellow color fades out. 1 mL of starch solution is then added and the titration is continued until a point where the solution loses its blue color to become clear. The amount of sodium thiosulphate used is then noted as this will provide the amount of DOinmg/L. This procedure may be repeated to ensure consistency of the results obtained.

This procedure will then be repeated at the end of five days to the remaining two samples that were incubated. The presence of oxygen in the two samples will be indicated by the observation of a brownish-orange precipitate that will form in the fluids once the manganese sulfate and alkali-iodide-azide has been added. The lack of oxygen in the two final samples may call for the repeat of the experiment. This is due to the fact that the lack of oxygen will lead to an inability to make a determination as to the rate of oxygen use. This is from the fact that currently there is no way in which a determination can be made as to the day in which the amount of oxygen in the sample was depleted. The results obtained by the above method are then used to calculate the needed values of

the BOD in the samples

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Nutrient analysis

nutrients were tested for concentrations (mg/L) of nitrates and orthophosphates were determined in each aliquote. Nitrates were tested using the cadmium reduction method (Hach Method 8192) and orthophosphate using the ascorbic acid method (Hach Method 8048)(Hach, 2002. Water Analysis Handbook. 4th Ed. Hach Company, Loveland, CO.).

Bacterial Analysis

bacterial analyses were based on methods used by Dorsey et al. 2013. Then paraphrase the following: Effluent samples were tested for total coliforms, *E. coli* and enterococci based on the enzyme substrate test (Idexx materials, Colilert®-18 and Enterolert™ media, Quanti-Tray® 2000 97-well trays) as described in Standard Methods (APHA *et al.* 1998: Standard Methods Section 9223 B). Tests for these fecal indicator bacteria were performed on three aliquots from each sample of ORCA effluent. Dorsey et al. 2013 demonstrated that other bacteria grow in the Quanti-Tray cells, and can be isolated on agar then identified using the Vitek® 2 Compact microbial analysis system. This approach was done here to determine other bacteria occurring in the effluent samples. From each set of three replicate Quanti-Trays®, 10 wells testing positive for coliforms and 10 for enterococci were randomly selected, 10 µL extracted and mixed into 10 mL of sterile DI water to yield a 0.001 % suspension, streaked onto tryptic soy agar

(TSA). TSA plates from the total coliform trays were incubated at 35 °C, and those from the enterococci trays at 41 °C. After 24–48 h of incubation, a colony was selected from each TSA plate, suspended in 3 mL of sterile DI water, streaked onto nutrient blood agar (5 % sheep blood in TSA) to obtain pure isolates, and then incubated as done for the initial TSA plates. One isolate from each blood agar plate then was identified using the Vitek® 2 Compact according to manufacturer's specifications.

Total Solids

In the determination of the total solid waste, the experiment was done using standard methods. In this case a petri dish is cleaned and dried and its weight recorded. A known sample of the fluid is then added to the dish, this was 100mL. The dish is then placed in an oven and heated for about 24hrs at about103 ^{o}C to evaporate the water. The dish is then cooled and weighed to make a determination of the weight of solid waste. This can then be used to calculate the g/L of total waste in the waste water. This presents the total solid waste which is composed of two main types of solid waste. These are suspended solid waste and dissolved waste.

Another important aspect of waste water that needs careful examination lies in the amount of phosphorous in the water. An understanding of the factors that influence this component is important before the discussion on the testing methods is outlined. Phosphorous is one of the most important nutrients needed for plant growth. Phosphorous is mainly found in the ecosystem as part of the already formed rock formation among other various forms. In the case of water sources, the dissolved phosphorous is utilized by plants for the manufacture of the molecules that they need for their food (Enger & Eldon, 2007).

This basic concept is the reason why there is a need to study Phosphorous deposition in waste water. The issue is that the nutrient is not found in high concentrations in most water sources. The introduction of this element therefore into other water sources will lead to the changing of the ecosystem largely due to the increased amount of plants. In the case of water sources, this may lead to the competition of resources with other water animals and plants. This factor is called eutrophication.

The release of large amounts of phosphorous in waste water may lead to the unhealthy growth of algae in the water that may make treatment of the waste water from this source a little bit more challenging. The next reason for the testing of phosphorous is that it may give an

indication as to the nutritional value of the waste water as this is required for the growth of plants. This is in the case where this is used as recycled water in the watering of plants. This nutritional nature of the water from the ORCA machine will help in the determination of the effectiveness of the water use with regard to irrigation purposes.

The presence of phosphates in waste water may be attributed to three factors. The first is the presence of organic phosphorous from the organic matter. This is usually contained in the protoplasm of living organisms. The second is in organic phosphates compound that is contained in compounds such as detergents. The final form is an insoluble form called orthophosphate. This is the compound that is tested for in the case of the ORCA machine (Vesilind, 2003). The occurrence of these may be in three main forms. The first one being the already mentioned in organic orthophosphate, there is also the condensed phosphates that a real so known as polyphosphates and in organic phosphates (Sincero & Sincero, 2003).

The testing of the levels of phosphorous in water by the use of orthophosphates largely steams from the fact that most biological treatment methods lead to the conversion of other forms of phosphorous in to orthophosphates (Bratby, 2006). That is in that most other forms of phosphates that may be dissolved in the water are converted to this form. This is usually the effect of most forms of treatment. The other lies in the fact that orthophosphates is the most common form in which phosphorous occurs as.

This testing is done in accordance to the guidelines outlined by Hach method 8048, which is provided in the appendix. The following is a discussion of the main elements of that testing method. There are two basic methods that have been outlined in the Hach guides. The discussion will look at the powder pillow procedure. The testing of orthophosphates begins with the preparation of the sample by filling a sample cell with 10mL of the sample. The contents of PhosVer3Phosphatere agent are then added to this cell. After this, the cell is immediately closed

and shaken for about half a minute. This is done to allow for complete mixing of the contents in the cell with the agent.

Depending on the treatment of the sample, the timing of the reaction may range from 2 minutes to 10 minutes immediately after the shaking. The wait period of 10minutes is if the sample was digested by AcidPersulfate. Another cell is then filled with the sample which will act as the blank for the test. After the allotted time has ended, the blank is then cleaned and then inserted into a cell holder. This is then zeroed. The sample that was prepared is then also cleaned and placed into the cell holder. The results of which will be read after pushing the red button.

The other factor that was tested for was the presence of nitrates in the water. Nitrates will act as the main source of nitrogen for aquatic plants. Nitrogen is an integral part in plant life as it is used in the production of protein that is utilized by most animals and plants. It is also used as the building blocks of most of the sources of plant food. Nitrogen and, in this case, presence of Nitrates in the water are tested as it may lead to eutrophication in a similar way as phosphorous does. This may even affect large water masses such as was experienced in Lake Kastoriain Greece (Ansari, 2011).

The testing of nitrates was conducted using the Hach method 8192 which is also known as the powder pillow procedure and should not be confused with the test for phosphorous that goes by a similar name. The appendix has provided a more detailed layout of the experiment in addition to the list of needed equipments and chemicals. The experiment begins by filling 15 mL of the sample into the cylinder of the instrument. The contents of one of the pillows containing NitraVer6 Reagent are added to the cylinder after which the timer is started and the contents of the cylinder are given 3 minutes for the reaction to occur. During this time, to improve the reaction of the contents, the cylinder is shaken for the entire period. After which the timer is then set for 2 minutes.

After this, carefully transfer 10 mL of the prepared sample into the sample cell. In which one is to ensure that cadmium particles are not transferred together with this. The contents of a Pillow of NitriVer3 Reagent are then transferred into the sample cell. The timer is then set for 30 seconds during the time the sample cell is closed and shaken. If there are nitrates in the test sample, the solution will change color to pink. After which time a 15 minute timer is started after which a second sample cell is filled with 10mL of the initial sample.

The blank is then cleaned and inserted into the cell holder. The machine is then zeroed. The prepared sample is then cleaned and inserted into the cell holder where the readings of the machine are taken. It should be noted that the formation of Cadmium during the undertaking of this experiment necessitates the need for caution when disposing off of the waste from the experiment. There are different regulations in various localities that guide in the disposal of this compound.

Fats, Oil and Grease (FOG) were tested by a contract lab using EPAMethod1664A (http://water.epa.gov/scitech/methods/cwa/oil/).

RESULT

CHAPTER IV

Chemical-Physical Measurements

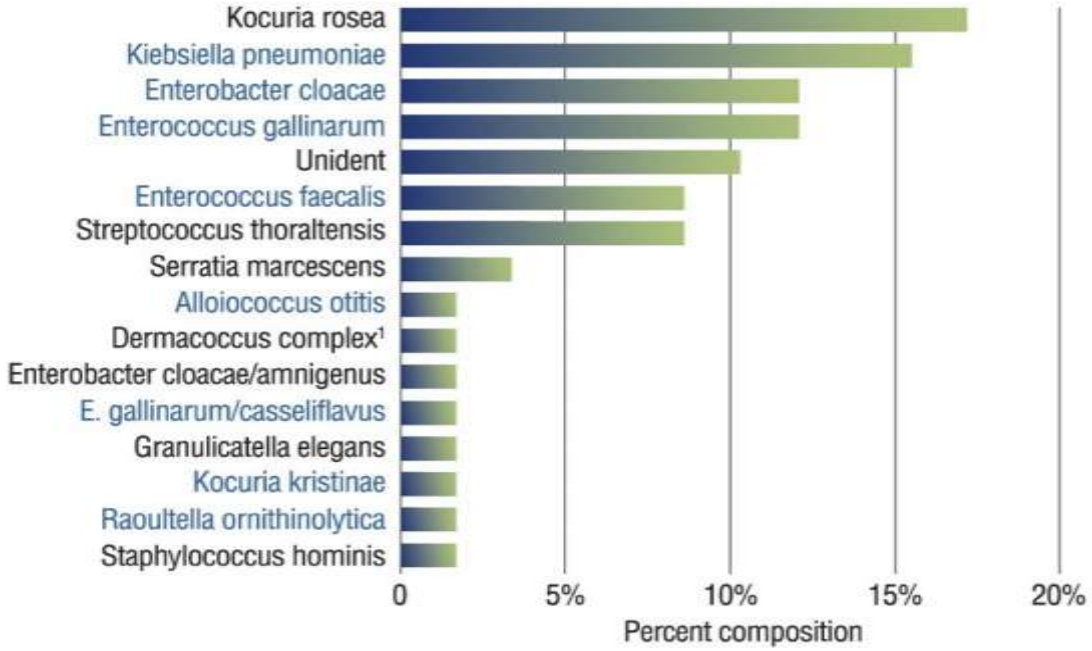
The values of BOD, FOG, total solid waste, nitrates and orthophosphates were found to be greater than that which was found in raw sewage. On the other hand, these values were found also to be greater than that for domestic waste in terms of the BOD only. Domestic waste, which is a common household waste, was found to contain more solid waste, Nitrate and orthophosphates as shown. The data for domestic waste was attained from different sources. These are provided in the appendix. These were after several measurements were taken as indicated in table 1.

Table _. Results of water quality testing on ORCA effluent from the period February through April 2012.

Constituent	**Method**	**n**	**Mean**	**SD**	**Range**	**Raw Sewage***
BOD (mg/L)	Hach Method 8043	4	5291.0	2221.2	3156-9030	350
Fats, Oil & Grease (FOG) (mg/L)	EPA 1664A	1	211.7	--	--	100
Total solids (g/L)	Standard Methods	21	9.0	7.0	1.5-29.5	1.2
Nitrate (mg/L)	Hach Method 8192	27	13.2	10.2	1.0-35.0	0
Orthophosphate (mg/L)	Hach Method 8048	15	17.5	11.6	2.3-38.1	10

* Values from Metcalf & Eddy (2003, Table 3-15) for high strength domestic wastewater.

Figure 1. Percent distribution of bacterial species among the 59 isolates identified



Species in blue have been associated with human illness.

[1]The Dermacoccus complex indicated low discrimination between Dermacoccus nishinomiyaensis, Kytococcus sedentarius, and Kocuria rosea.

Table 2- Results of analyses for fecal indicator Bacteria (FIB).

FIB Grp	Range	Raw Sewage*
Total coliforms	10^5-10^7	10^6-10^8
E. coli	10^1-10^2	10^3-10^5
Enterococci	10^5	10^5-10^6

* Total and fecal coliform values from Metcalf &Eddy (2003: Table 3-15) for low strength domestic wastewater; enterococci from Ahmed *et al.* 2008; Srinivasan *et al.* 2011.

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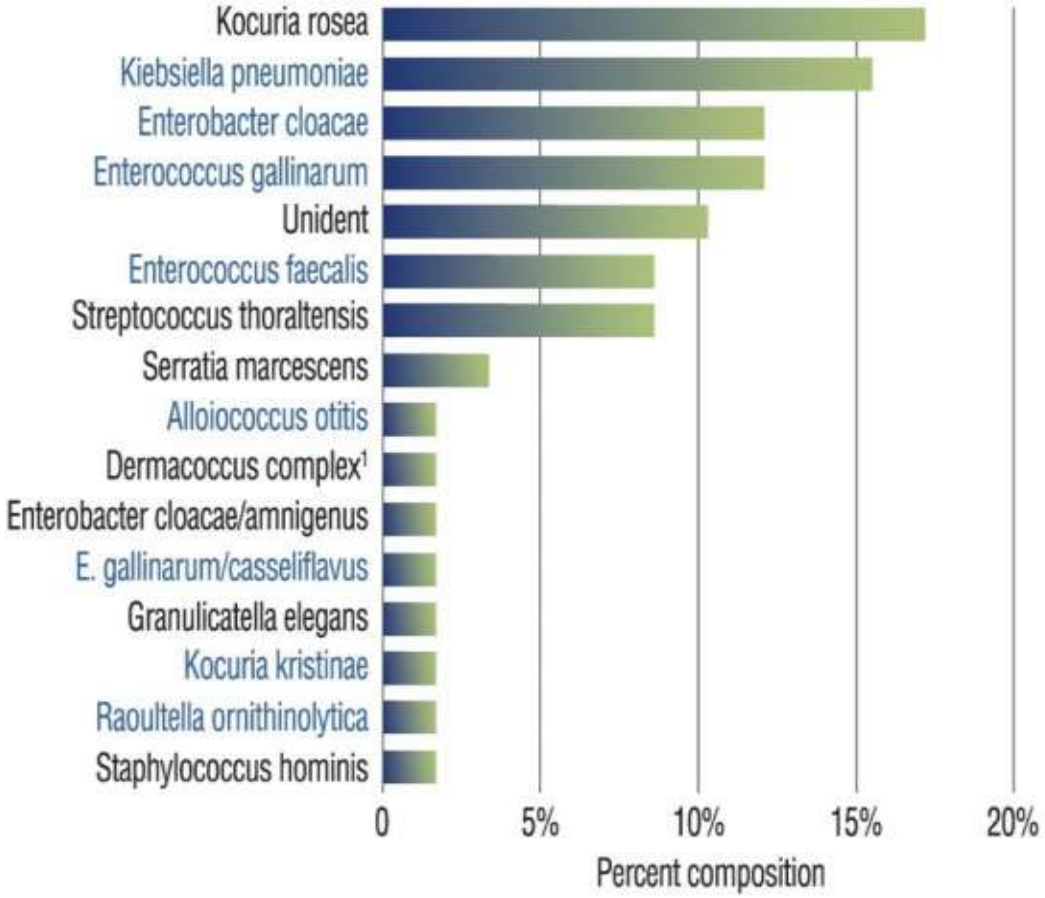

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CHAPTER V

DISCUSSION

The main aim of the study was intended to look at two major factors: 1) whether the effluents of the ORCA machine are safe for humans and plants, and 2) determine the nutritional content of the effluent for use as a fertilizer.

Safety of ORCA Effluent

The effluent that was discharged from the ORCA machine was found to be of greater concentration in most of the elements that were tested in comparison to raw sewage. The results of the experiment indicated that the amount of BOD in the wastewater that was attained was a mean of 5291.0 with a range of between 3156-9030. This level is indicative of high organic content in the water (Potter&Hotchkiss,1998).

The other consideration was with the amount of fats, oils and grease in the wastewater. The mean of the samples was found to be 211.7. This was at a level which was higher than the 100. This is higher than that which was found for sewage discharge. This may be higher than sewerage wastewater from the fact that the waste is largely from a kitchen and does not include other forms of domestic waste. The measurement of this type of waste which is usually referred to as FOG in short is meant to limit problems that are caused by its disposal in sewerage systems (NationalResearchCouncil U.S., 1993).

The other experiment that was conducted was with the total solid waste in the water. The issue that is raised from the amount of solid waste lies in the generation of volatile gas. These gases may cause issues when it comes to the flow of these gases. The other is in the foul smells that are produced from this waste (InternationalConferenceonWater and Environment,Singh, &WE-2003, 2003). In the consideration of the ORCA machine, it may cause unwarranted discomfort for those around the campus. This hinders the use of this water for the purpose of

irrigation.

Use of ORCA Effluent for Fertilization and Irrigation

The other tests that were conducted were on the nitrate and phosphate content of the waste water. The mean amount of nitrates that were found in the wastewater was determined to be 27mg/L and that of phosphates was determined to be 15mg/L. These were observed within the ranges of 1-35 for the nitrates and 2.3-38.1. This high content of nitrates as well as orthophosphates is indicative of the nutritional content of the water and of its ability to be used in irrigation. This is because it will aid in the growth of the plants that are being watered by this method.

The wastewater that is produced by the ORCA machine may therefore be used to a limited extent as far as irrigation is concerned to avoid its integration into other water sources. This is due to eutrophication that may occur once this happens. The understanding of this fact therefore calls for better irrigation management technologies (Ali, 2003). This is aimed at avoiding over-enrichment of water sources. If widely adopted and for prolonged periods of time, this may lead to unwarranted changes in the ecosystem.

The other tests that were performed to the wastewater were in the determination of the microbiological composition of the wastewater. The testing of these pathogens is done using what are known as indicator microorganisms. These microorganisms are used to infer the presence or absence of certain pathogens or bacteria. On the other hand, one should understand that due to the limitations of the testing of wastewater by most methods, the absence of these microorganisms may not be indicative of the lack of disease causing pathogens (Gerardi & Zimmerman, 2004). It is also difficult to test for all the wide variety of known pathogens. Tests for these pathogens were able to culture 59 isolates. Out of these the main concern lays in the identification of that were thought to contain pathogenic properties. This restricted the use of the water in terms of irrigation purposes.

These results may be compared more effectively with those of other types of domestic waste. The consideration here is that this comes close to a fair representation of the waste that is produced in most of the households. In this case, the average amount of BOD of domestic waste is given by 300mg/L, the total solid waste is given on average by 1.1g/L, while the amount of nitrate 45mg/L, while that of phosphates is thought to be 7g/L (Sperling, 2007). These figures are all lower compared to that of the ORCA machine with the exception of the amount of nitrates. This indicates that the discharge of this type of waste on the environment will have a greater amount of influence than that of domestic waste.

One factor of research is that the researcher(s) are faced with multiple challenges in the undertaking of their study. In this case, these limitations have to be taken under consideration in the final discussions of the study as they play an influential role in the research. A limitation that was experienced in the undertaking of the study was with the lack of funding. This limited the scope of the study in different regards.

The consideration of the study was to look at how the wastewater produced by the machine will be effective in the watering of plants. In this case, the consideration should have taken into account the fact that there are different types of soil. Each has its own characteristics that may affect the efficacy of the constituent nutrients in the wastewater. In this case, the examination may have included looking at the wastewater and how it would have influenced the irrigation of landscapes in a variety of other areas. The inclusion of these other sources was limited in that there were no funds available to include the extra cost of studying these other areas.

The second point of limitation in terms of the extent of the study was that only one ORCA machine was studied. This, therefore, means that the results that were obtained in this case can only be applied to that particular ORCA machine that was studied. Despite the fact that the machines may be assumed the same, different working conditions may influence the operation ability of the machines. This therefore necessitates the taking of an average performance and range for the data collected from a variety of these machines.

One other limitation that existed in the undertaking of the research lays in the fact that the results that were obtained in the undertaking of the research were not compared with any other results. In this only set, data were collected and analyzed for the undertaking of the research. In this case then, there may have existed a number of errors in the results that were obtained that may have been difficult to identify. Though the presence of these errors may be minimized by the careful nature in which the study was undertaken there is still a need to take this factor into consideration. As earlier stated, the limitations in terms of finances limited the conduction of multiple tests. It also limited the use of outside labs to confirm and countercheck the results that were obtained.

The aim of the study was to establish whether the wastewater that was discharged by the ORCA machine would be effectively used as recycled water in the watering of plants. The study established two factors that may influence its use for this purpose. The first was that the contents of the wastewater were that the nutritional value of the water was greater than that which would be achieved by other means. This was with the presence of high levels of phosphorous and

Nitrates in the wastewater produced by this method. This may be used by different plants in the production of their food.

There is one other implication of this though that limits its use for this purpose. This lies in the fact that large concentrations of these nutrients will affect any preexisting aquatic ecosystems. That is the concentration of the elements in the wastewater will have to be controlled such that they do not make their way into other water sources. This is from the consideration of the fact that if this happens, there would be increased concentration of these elements in water sources.

This increase in concentration will lead to the increased growth of aquatic plants that may greatly influence other aquatic plants and animals. This is by increasing the competition of the limited resources in terms of dissolved gases and nutrients with these animals. This may lead to the death of aquatic animals. In other cases, it may lead to the increased growth of algae that may limit sunshine penetration in water that would lead to the death of aquatic plants. It is therefore for this reason that its use for irrigation purposes should not be encouraged.

On the other end, there is the existence of different types of bacteria. These bacteria point to the existence of disease carrying pathogens if these pathogens are to interact with humans as well as with other animals. There are a variety of pathogens that are of concern when it comes to wastewater treatment facilities. These have been known to have various effects on the staff that use these machines as well as on the other animals. In the case of the ORCA machine, the Greatest concern is raised with the presence of pathogens that are known to cause ailments in humans.

There are basically two types of disease causing pathogens that may be found in wastewater. These are known as true pathogens which are transmitted from one person to the next through contact. This includes the likes of *Shigella*. The other types are the opportunistic bacteria that are termed as opportunistic bacteria. These are pathogens such as *EscherichiaColi* which only affect humans when their immune system is compromised. Usually, these are found in low concentrations in the human body (Geradi, 2006). The presence of this bacteria in the Wastewater that is discharged by this method may lead to diseases in cases where it is handled by the kitchen staff or when they infect one who has low immunity.

The research was able to provide more evidence against the use of the wastewater for irrigation of plants as opposed to its discharge into water sources. This led to the conclusion that even though this is regarded as the ideal use of the machine by the company, the wastewater that is obtained from the ORCA machine needs to undergo further treatment. This, therefore, creates the need to release the discharge from the machine into the current sewerage system. The research has presented some of the basic knowledge that may need studying when it comes to looking at food waste disposal mechanisms and machines. This research is inconclusive and may require additional input when it comes to the study of the machine. Despite this fact, it provides the basic aspects of the machine which may prove helpful in future study.

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Phosphorus, Reactive

(Orthophosphate)

USEPA[1] PhosVer 3® (Ascorbic Acid) Method[2] Method 8048

®0.02 to 2.50 mg/L PO_4^{3-} Powder Pillows or AccuVac Ampuls

Scope and application: For water, wastewater and seawater.

[1] USEPA Accepted for reporting for wastewater analyses. Procedure is equivalent to USEPA and Standard Method 4500-P-E for wastewater.

[2] Adapted from Standard Methods for the Examination of Water and Wastewater.

Test preparation

Instrument-specific information

The tables in this section show all of the instruments that have the program for this test. Table 1 shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests. Table 2 shows sample cell and adapter requirements for AccuVac Ampul tests.

To use either table, select an instrument, then read across to find the corresponding information for this test.

Table 1 Instrument-specific information for powder pillows

Instrument	Sample cell orientation	Sample cell
DR 6000 DR 3800 DR 2800 DR 2700	The fill line is to the right.	2495402 
DR 5000 DR 3900	The fill line is toward the user.	
DR 900	The orientation mark is toward the user.	2401906 

Table 2 Instrument-specific information for AccuVac Ampuls

Instrument	Adapter	Sample cell
DR 6000 DR 5000 DR 900	—	2427606 
DR 3900	LZV846 (A)	

DR 3800 DR 2800 DR 2700	LZV584 (C)	 2122800

1

Before starting

Install the instrument cap on the DR 900 cell holder before ZERO or READ is pushed.
For best results, measure the reagent blank value for each new lot of reagent. Replace the sample with deionized water in the test procedure to get the reagent blank value. Subtract the reagent blank value from the sample results automatically with the reagent blank adjust option.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used and use any recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Use the Safety Data Sheets for disposal information for unused reagents. Consult the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

Items to collect

Powder pillows

Description	Quantity
PhosVer® 3 Phosphate Reagent powder pillow, 10-mL	1
Sample cells. (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.)	2

Refer to Consumables and replacement items on page 6 for reorder information.

AccuVac Ampuls

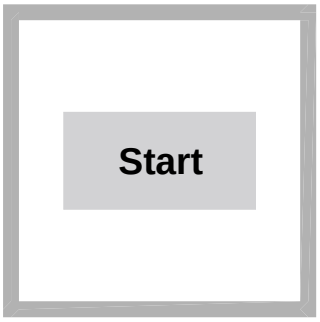
Description	Quantity
PhosVer® 3 Phosphate Reagent AccuVac® Ampul	1
Beaker, 50-mL	1
Sample cells (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.)	1
Stopper for 18-mm tubes and AccuVac Ampuls	1

Refer to Consumables and replacement items on page 6 for reorder information.

Sample collection and storage

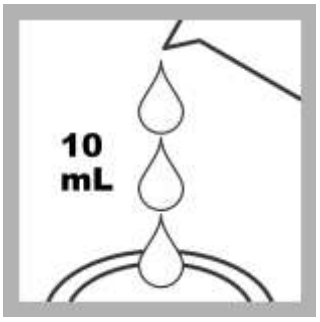
- Collect samples in clean glass or plastic bottles that have been cleaned with 1:1 hydrochloric acid and rinsed with deionized water.
- Do not use a detergent that contains phosphate to clean the sample bottles. The phosphate in the detergent will contaminate the sample.
- Analyze the samples as soon as possible for best results.
- If prompt analysis is not possible, immediately filter and keep the samples at or below 6 °C (43 °F) for a maximum of 48 hours.
- Let the sample temperature increase to room temperature before analysis.

Powder pillow procedure



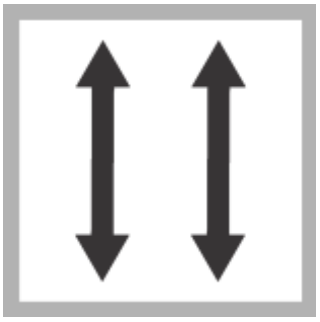
1. Start program **490 P React. PP**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

Note: *Although the program name may vary between instruments, the program number does not change.*



2. Prepare the sample: Fill a sample cell with 10 mL of sample.

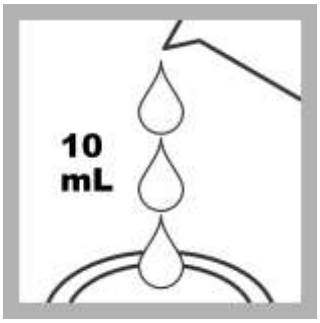
3. Add the contents of one PhosVer 3 Phosphate Reagent Powder Pillow to the cell.



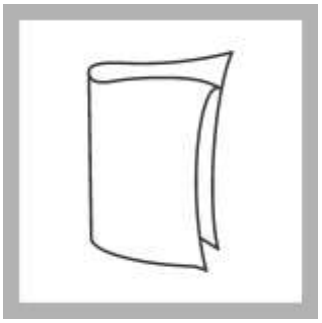
4. Immediately close the sample cell. Shake vigorously for 30 seconds.

5. Start the instrument timer. A 2-minute reaction time starts.

If the sample was digested using the Acid Persulfate digestion, a 10-minute reaction period is necessary.

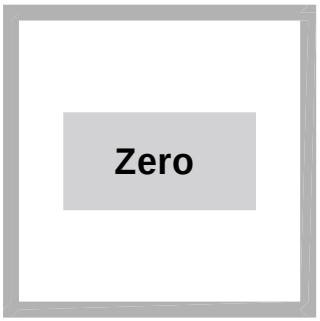


6. Prepare the blank: Fill a second sample cell with 10 mL of sample.

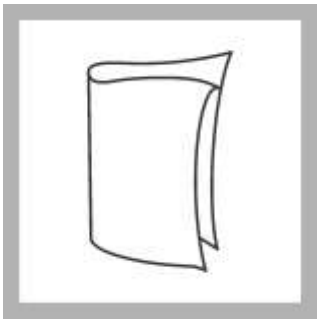


7. When the timer expires, clean the blank.

8. Insert the blank into the cell holder.



9. Push **ZERO**. The display shows 0.00 mg/L PO_4^{3-}.

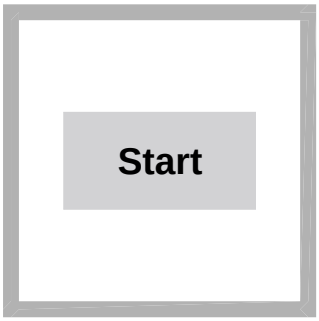


10. Clean the prepared sample.

11. Insert the prepared sample into the cell holder.

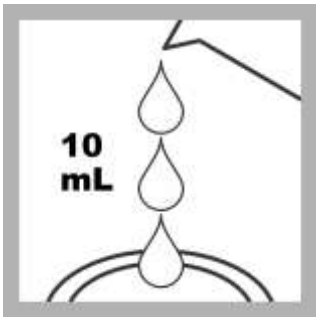
12. Push **READ**. Results show in mg/L PO_4^{3-}.

AccuVac Ampul procedure



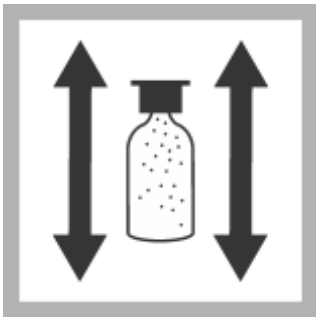
1. Start program **492 P React. PV AV**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

Note: *Although the program name may vary between instruments, the program number does not change.*



2. Prepare the blank: Fill the sample cell with 10 mL of sample.

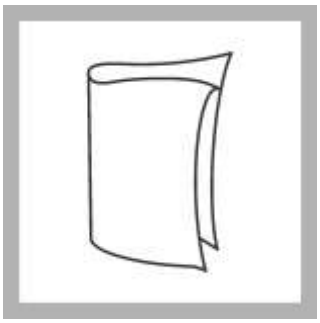
3. Prepare the sample: Collect at least 40 mL of sample in a 50-mL beaker. Fill the AccuVac Ampul with sample. Keep the tip immersed while the Ampul fills completely.



4. Close the AccuVac Ampul. Shake for approximately 30 seconds. Accuracy is not affected by undissolved powder.

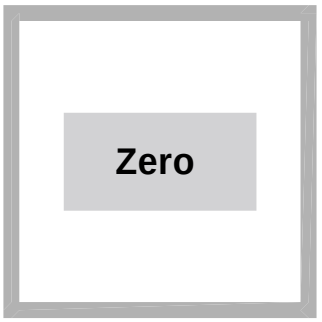
5. Start the instrument timer. A 2-minute reaction time starts.

If the sample was digested using the Acid Persulfate digestion, a 10-minute reaction period is necessary.

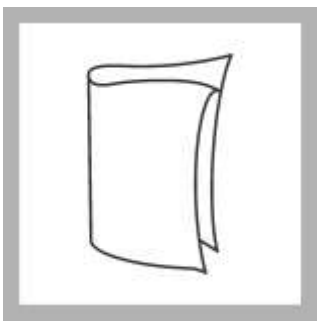


6. When the timer expires, clean the blank.

7. Insert the blank into the cell holder.

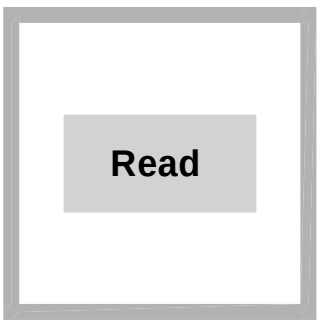


8. Push **ZERO**. The display shows 0.00 mg/L PO_4^{3-}.



9. Clean the AccuVac Ampul.

10. Insert the prepared sample AccuVac Ampul into the cell holder.



11. Push **READ**. Results show in mg/L PO_4^{3-}.

Interferences

Interfering substance	Interference level
Aluminum	More than 200 mg/L
Arsenate	Interferes at any level.
Chromium	More than 100 mg/L
Copper	More than 10 mg/L
Hydrogen Sulfide	Interferes at any level.
Iron	More than 100 mg/L
Nickel	More than 300 mg/L
Highly buffered samples or extreme sample pH	Can prevent the correct pH adjustment of the sample by the reagents. Sample pretreatment may be necessary. A pH range of 2–10 is recommended.
Silica	More than 50 mg/L
Silicate	More than 10 mg/L
Turbidity or color	May cause inconsistent results. The acid in the powder pillow can dissolve some of the suspended particles and the desorption of orthophosphate from the particles can vary. For highly turbid or colored samples, add the contents of one Phosphate Pretreatment Powder Pillow to 25 mL of sample. Mix well. Use this solution to zero the instrument.
Zinc	More than 80 mg/L

Accuracy check

Standard additions method (sample spike)

Use the standard additions method (for applicable instruments) to validate the test procedure, reagents and instrument and to find if there is an interference in the sample.

Items to collect:

- Phosphate standard solution, 50 mg/L PO_4^{3-} ampule
- Ampule breaker
- Pipet, TenSette®, 0.1–1.0 mL and tips
- Mixing cylinders, 25-mL (3)

1. Use the test procedure to measure the concentration of the sample, then keep the (unspiked) sample in the instrument.
2. Go to the Standard Additions option in the instrument menu.
3. Select the values for standard concentration, sample volume and spike volumes.
4. Open the standard solution.
5. Prepare three spiked samples: use the TenSette pipet to add 0.1 mL, 0.2 mL and 0.3 mL of the standard solution, respectively, to three 10-mL portions of fresh sample. Mix well.

   Note: *For AccuVac® Ampuls, add 0.2 mL, 0.4 mL and 0.6 mL of the standard solution to three 50-mL portions of fresh sample.*
6. Use the test procedure to measure the concentration of each of the spiked samples. Start with the smallest sample spike. Measure each of the spiked samples in the instrument.
7. Select **Graph** to compare the expected results to the actual results.

   Note: *If the actual results are significantly different from the expected results, make sure that the sample volumes and sample spikes are measured accurately. The sample volumes and sample spikes that are used should agree with the selections in the standard additions menu. If the results are not within acceptable limits, the sample may contain an interference.*

Standard solution method

Use the standard solution method to validate the test procedure, reagents and instrument.

Items to collect:

- 50 mg/L phosphate standard solution
- 100-mL volumetric flask, Class A
- 4-mL volumetric pipet, Class A and pipet filler
- Deionized water

1. Prepare a 2.00 mg/L phosphate standard solution as follows:
   a. Use a pipet to add 4.00 mL of 50 mg/L phosphate standard solution into the volumetric flask. *(Alternately, use one of the available mixed parameter standards. These standards contain 2.0 mg/L phosphate.)*
   b. Dilute to the mark with deionized water. Mix well. Prepare this solution daily.
2. Use the test procedure to measure the concentration of the prepared standard solution.
3. Compare the expected result to the actual result.

   Note: *The factory calibration can be adjusted slightly with the standard adjust option so that the instrument shows the expected value of the standard solution. The adjusted calibration is then used for all test results. This adjustment can increase the test accuracy when there are slight variations in the reagents or instruments.*

Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users may get different results under different test conditions.

Program	Standard	Precision (95% Confidence Interval)	Sensitivity Concentration change per 0.010 Abs change
490	2.00 mg/L PO_4^{3-}	1.98–2.02 mg/L PO_4^{3-}	0.02 mg/L PO_4^{3-}
492	2.00 mg/L PO_4^{3-}	1.98–2.02 mg/L PO_4^{3-}	0.02 mg/L PO_4^{3-}

Summary of method

Orthophosphate reacts with molybdate in an acid medium to produce a mixed phosphate/molybdate complex. Ascorbic acid then reduces the complex, giving an intense molybdenum blue color. The measurement wavelength is 880 nm for spectrophotometers or 610 nm for colorimeters.

Consumables and replacement items

Required reagents

Description	Quantity/Test	Unit	Item no.
PhosVer® 3 Phosphate Reagent Powder Pillow, 10-mL	1	100/pkg	2106069
OR			
PhosVer® 3 Phosphate Reagent AccuVac® Ampul	1	25/pkg	2508025

Required apparatus

Description	Quantity/Test	Unit	Item no.
Beaker, 50-mL	1	each	50041H
Stoppers for 18-mm tubes and AccuVac Ampuls	2	6/pkg	173106

Recommended standards

Description	Unit	Item no.
Phosphate Standard Solution, 10-mL Voluette® Ampul, 50-mg/L as PO_4	16/pkg	17110
Phosphate Standard Solution, 50-mg/L as PO_4	500 mL	17149
Phosphate Standard Solution, 1-mg/L as PO_4	500 mL	256949
Drinking Water Standard, Mixed Parameter, Inorganic for F^-, NO_3, PO_4, SO_4	500 mL	2833049
Wastewater, Effluent Inorganics, for NH_3-N, NO_3-N, PO_4, COD, SO_4, TOC	500 mL	2833249
Water, deionized	4 L	27256

Optional reagents and apparatus

Description	Unit	Item no.
AccuVac® Drainer	each	4103600
AccuVac® Snapper	each	2405200
AccuVac® vials for sample blanks	25/pkg	2677925
Ampule Breaker, Voluette® ampules	each	2196800
Bottle, sampling, with cap, low density polyethylene, 250-mL	12/pkg	2087076
Cylinder, mixing, 50-mL	each	189641
Flask, volumetric, Class A, 100-mL	each	1457442
Hydrochloric Acid, 6.0 N 1:1, 50%	500 mL	88449
Paper, pH, 0–14 pH range	100/pkg	2601300
Phosphate Treatment Powder Pillow	100/pkg	1450199
Phosphate Standard Solution, 10-mg/L as PO_4	946 mL	1420416
Phosphate Standard Solution, 15-mg/L as PO_4	100 mL	1424342
Phosphate Standard Solution, 100-mg/L as PO_4	100 mL	1436832
Phosphate Standard Solution, 10-mL Ampule, 500 mg/L as PO_4	16/pkg	1424210
Phosphate Standard Solution, 500-mg/L as PO_4	100 mL	1424232
Pipet, TenSette®, 0.1–1.0 mL	each	1970001
Pipet, TenSette®, 1.0 to 10.0 mL	each	1970010
Pipet tips for TenSette Pipet 1970001	50/pkg	2185696
Pipet tips for TenSette Pipet 1970001	1000/pkg	2185628
Pipet tips for TenSette Pipet 1970010	50/pkg	2199796
Pipet tips for TenSette Pipet 1970010	250/pkg	2199725
Pipet, volumetric, Class A, 4.00-mL	each	1451504

Cadmium Reduction Method

Method 8192

0.01 to 0.50 mg/L NO_3^-–N (LR)

Powder Pillows

Scope and application: For water, wastewater and seawater.

Test preparation

Instrument specific information

The table in this section shows all of the instruments that have the program for this test. Table 1 shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests.

To use the table, select an instrument, then read across to find the corresponding information for this test.

Table 1 Instrument-specific information for powder pillows

Instrument	Sample cell orientation	Sample cell
DR 6000 DR 3800 DR 2800 DR 2700	The fill line is to the right.	2495402 
DR 5000 DR 3900	The fill line is toward the user.	
DR 900	The orientation mark is toward the user.	2401906 

Before starting

Install the instrument cap on the DR 900 cell holder before ZERO or READ is pushed.
For best results, measure the reagent blank value for each new lot of reagent. Replace the sample with deionized water in the test procedure to get the reagent blank value. Subtract the reagent blank value from the sample results automatically with the reagent blank adjust option.
This method is technique-sensitive. Shaking time and technique influence the color development. For most accurate results, use a standard solution that is within the test range and run the test several times. Increase or decrease the shaking time to get the expected result. Use the adjusted shaking time for sample measurements.
The reagents that are used in this test contain cadmium. Rinse the sample cell immediately after use to remove all cadmium particles. Collect the reacted samples for proper disposal.
A deposit of unoxidized metal will remain at the bottom of the sample cell after the reagent dissolves. The deposit will not affect results.
Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used and use any recommended personal protective equipment.
Dispose of reacted solutions according to local, state and federal regulations. Use the Safety Data Sheets for disposal information for unused reagents. Consult the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information.

1

Items to collect

Description	Quantity
NitraVer® 6 Nitrate Reagent Powder Pillow, 10-mL	1
NitriVer® 3 Nitrite Reagent Powder Pillow, 10-mL	1
Cylinder, graduated mixing, 25-mL	1
Sample cells (For information about sample cells, adapters or light shields, refer to Instrument specific information on page 1.)	2

Refer to Consumables and replacement items on page 6 for reorder information.

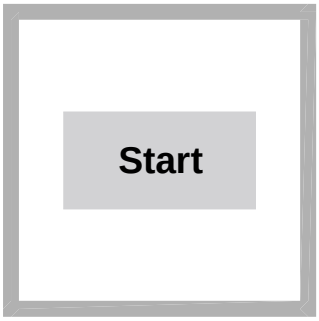
Sample collection and storage

- Collect samples in clean glass or plastic bottles.
- Analyze the samples as soon as possible for best results.
- If prompt analysis is not possible, immediately filter and keep the samples at or below 6 °C (43 °F) for a maximum of 48 hours.
- To preserve samples for up to 28 days, adjust the sample pH to 2 or less with concentrated sulfuric acid (about 2 mL per liter) and keep at or below 6 °C (43 °F). The test results then include nitrate and nitrite.
- Let the sample temperature increase to room temperature before analysis.
- Before analysis, adjust the pH to 7 with 5.0 N sodium hydroxide standard solution.
- Correct the test result for the dilution from the volume additions.

Powder pillow procedure

CAUTION

Hazardous waste exposure. Prepared samples contain cadmium. Refer to the SDS for safe handling and disposal instructions. Obey all local and regional disposal regulations.



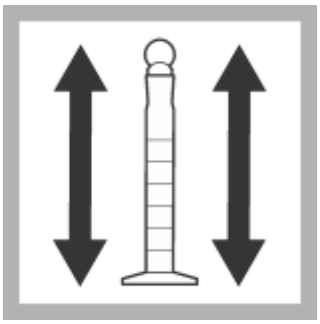
1. Start program **351 N, Nitrate LR**. For information about sample cells, adapters or light shields, refer to Instrument specific information on page 1.

Note: *Although the program name may vary between instruments, the program number does not change.*

2. Fill the mixing cylinder with 15 mL of sample.

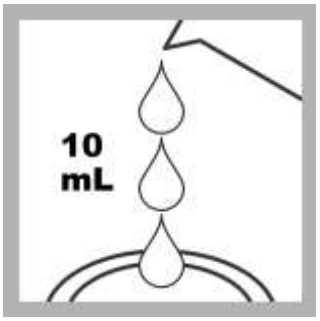
3. Add the contents of one NitraVer 6 Reagent Powder Pillow to the cylinder. Close the cylinder.

4. Start the instrument timer. A 3-minute reaction time starts.



5. Shake the cylinder vigorously during the reaction period. Some powder may not dissolve.

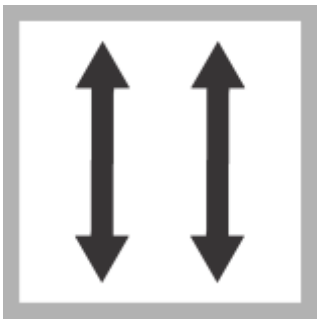
6. When the timer expires, start the timer again. A 2-minute reaction time starts.



7. Prepare the sample: When the timer expires, carefully pour 10 mL of sample into a sample cell. Do not transfer cadmium particles to the sample cell.

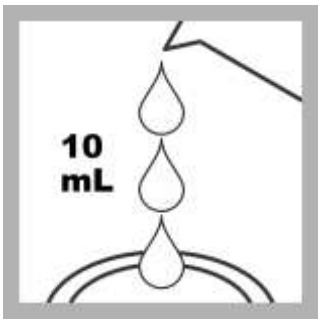
8. Add the contents of one NitriVer 3 Reagent Powder Pillow to the prepared sample cell.

9. Start the instrument timer. A 30-second reaction time starts.

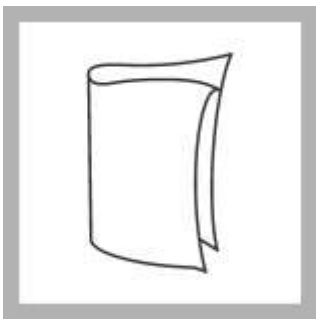


10. Close the sample cell. Shake the sample cell gently during the 30-second timer. A pink color shows if nitrate is present in the sample.

11. Start the instrument timer. A 15-minute reaction time starts.

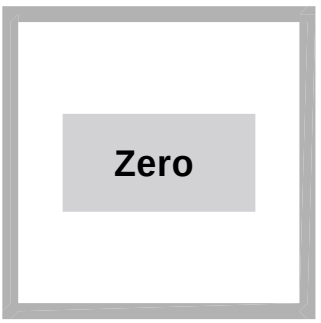


12. Prepare the blank: When the timer expires, fill a second sample cell with 10 mL of the original sample.

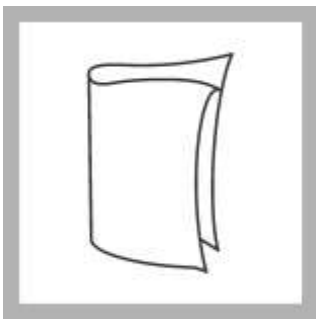


13. Clean the blank.

14. Insert the blank into the cell holder.

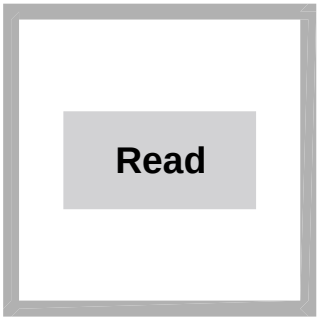


15. Push **ZERO**. The display shows 0.00 mg/L NO_3^-–N.



16. Clean the prepared sample.

17. Insert the prepared sample into the cell holder.



18. Push **READ**. Results show in mg/L NO_3^-–N.

Interferences

Interfering substance	Interference level
Calcium	100 mg/L
Chloride	Chloride concentrations above 100 mg/L cause low results. The test can be used at high chloride concentrations (seawater) if a calibration is made with standards that have the same chloride concentration as the samples (refer to Seawater calibration on page 4).
Ferric iron	Interferes at all levels
Nitrite	Interferes at all levels Compensate for nitrite interference as follows: **1.** Add 30-g/L Bromine Water by drops to the sample until a yellow color remains. **2.** Add one drop of 30-g/L Phenol Solution to remove the color. **3.** Use the test procedure to measure the concentration of the treated sample. Report the results as total nitrate and nitrite.
Highly buffered samples or extreme sample pH	Can prevent the correct pH adjustment of the sample by the reagents. Sample pretreatment may be necessary.
Strong oxidizing and reducing substances	Interfere at all levels

Seawater calibration

Chloride concentrations above 100 mg/L cause low results. To use this method for samples with high chloride concentrations, calibrate the instrument with nitrate standard solutions that contain the same amount of chloride as the samples.
Prepare calibration standards that contain chloride and 1.0, 3.0, 5.0 and 10.0 mg/L nitrate (as NO_3^-–N) as follows:

1. Prepare 1 liter of chloride water that has the same chloride concentration as the samples.
   a. Weigh the applicable amount of ACS-grade sodium chloride: (chloride concentration of samples in g/L) x (1.6485) = g of NaCl per liter.
      Note: *18.8 g/L is the typical chloride concentration of seawater.*
   b. Add the sodium chloride to a 1-liter volumetric flask.
   c. Dilute to the mark with deionized water. Mix thoroughly. Use this water as the dilution water to prepare the nitrate standard solutions.
2. Use a pipet to add 1.0, 3.0, 5.0 and 10.0 mL of a 100 mg/L nitrate-nitrogen (NO_3^-–N) standard solution into four different 100-mL Class A volumetric flasks.
3. Dilute to the mark with the prepared chloride water. Mix thoroughly.
4. Complete the test procedure for each of the standard solutions and for the prepared chloride water (for a 0-mg/L standard solution).

5. Measure the absorbance of the standard solutions and enter a user calibration into the instrument.
6. Use the user program to measure samples that contain high concentrations of chloride.

Accuracy check

Standard additions method (sample spike)

Use the standard additions method (for applicable instruments) to validate the test procedure, reagents and instrument and to find if there is an interference in the sample.

Items to collect:

- Nitrate Nitrogen Standard Solution, 100-mg/L NO_3^-–N
- 50-mL volumetric flask, Class A
- 6-mL volumetric pipet, Class A and pipet filler
- Deionized water
- Pipet, TenSette®, 0.1–1.0 mL and tips
- Mixing cylinders, 25 mL (3)

1. Prepare a 12 mg/L nitrate nitrogen standard solution as follows:
   a. Use a pipet to add 6.0 mL of a 100 mg/L NO_3^-–N standard solution into a 50-mL volumetric flask.
   b. Dilute to the mark with deionized water. Mix well. Prepare this solution daily.
2. Use the test procedure to measure the concentration of the sample, then keep the (unspiked) sample in the instrument.
3. Go to the Standard Additions option in the instrument menu.
4. Select the values for standard concentration, sample volume and spike volumes.
5. Prepare three spiked samples: use the TenSette pipet to add 0.1 mL, 0.2 mL and 0.3 mL of the prepared standard solution, respectively, to three 15-mL portions of fresh sample. Mix well.
6. Use the test procedure to measure the concentration of each of the spiked samples. Start with the smallest sample spike. Measure each of the spiked samples in the instrument.
7. Select **Graph** to compare the expected results to the actual results.

   Note: *If the actual results are significantly different from the expected results, make sure that the sample volumes and sample spikes are measured accurately. The sample volumes and sample spikes that are used should agree with the selections in the standard additions menu. If the results are not within acceptable limits, the sample may contain an interference.*

Standard solution method

Use the standard solution method to validate the test procedure, reagents and instrument.

Items to collect:

- Nitrate Nitrogen Standard Solution, 10-mg/L NO_3^-–N
- 100-mL volumetric flask, Class A
- 4-mL volumetric pipet, Class A and pipet filler
- Deionized water

1. Prepare a 0.40 mg/L nitrate nitrogen standard solution as follows:
   a. Use a pipet to add 4.00 mL of 10 mg/L nitrate nitrogen standard solution into the volumetric flask.

b. Dilute to the mark with deionized water. Mix well. Prepare this solution daily.

2. Use the test procedure to measure the concentration of the prepared standard solution.
3. Compare the expected result to the actual result.

Note: *The factory calibration can be adjusted slightly with the standard adjust option so that the instrument shows the expected value of the standard solution. The adjusted calibration is then used for all test results. This adjustment can increase the test accuracy when there are slight variations in the reagents or instruments.*

Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users may get different results under different test conditions.

Program	Standard	Precision (95% Confidence Interval)	Sensitivity Concentration change per 0.010 Abs change
351	0.40 mg/L NO_3^-–N	0.35–0.45 mg/L NO_3^-–N	0.003 mg/L NO_3^-–N

Summary of method

Cadmium metal reduces nitrate in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with chromotropic acid to form a pink-colored product. The measurement wavelength is 507 nm for spectrophotometers or 520 nm for colorimeters.

Pollution prevention and waste management

Reacted samples contain cadmium and must be disposed of as a hazardous waste. Dispose of reacted solutions according to local, state and federal regulations.

Consumables and replacement items

Required reagents

Description	Quantity/test	Unit	Item no.
Nitrate Reagent Set, low range, 10-mL	1	100/pkg	2429800
Includes:			
NitraVer® 6 Nitrate Reagent Powder Pillow, 10-mL	1	100/pkg	2107249
NitriVer® 3 Nitrite Reagent Powder Pillow, 10-mL	1	100/pkg	2107169

Required apparatus

Description	Quantity/test	Unit	Item no.
Cylinder, graduated mixing, 25 mL with stopper	1	each	2088640
Stoppers for 18-mm tubes and AccuVac Ampuls	2	6/pkg	173106

Recommended standards and apparatus

Description	Unit	Item no.
Flask, volumetric, Class A, 100-mL	each	1457442
Nitrate Nitrogen Standard Solution, 10.0-mg/L NO_3--N	500 mL	30749
Nitrate Nitrogen Standard Solution, 100 mg/L NO_3--N	500 mL	194749
Water, deionized	4 L	27256

Optional reagents and apparatus

Description	Unit	Item no.
Bromine Water, 30 g/L	29 mL	221120
Pipet, TenSette®, 0.1–1.0 mL	each	1970001
Pipet tips for TenSette Pipet 1970001	50/pkg	2185696
Pipet tips for TenSette Pipet 1970001	1000/pkg	2185628
Pipet, volumetric, Class A, 4.00-mL	each	1451504
Flask, volumetric, 50-mL	each	1457441
Pipet filler, safety bulb	each	1465100
Phenol Solution, 30-g/L	29 mL	211220
Sodium Hydroxide Standard Solution, 5.0 N	1 L	245053
Sulfuric Acid, concentrated, ACS	500 mL	97949
Sodium Chloride, ACS	454 g	18201H
Pipet, TenSette®, 1.0 to 10.0 mL	each	1970010
Pipet tips for TenSette Pipet 1970010	50/pkg	2199796

Oxygen Demand, Biochemical

DOC316.53.01200

Dilution Method[1]

Method 8043

Scope and Application: For water and wastewater.

[1] Adapted from *Standard Methods for the Examination of Water and Wastewater* and from Klein, R.L.; Gibbs, C. *Journal of Water Pollution Control Federation*, 1979, 51(9), 2257.

Test preparation

Before starting the test:

The BOD test is a 5-day test. Follow all steps carefully to make sure that the test does not have to be repeated.
The dilution water for this test must not have an oxygen demand or any toxins. When incubated for 5 days at 20 °C, the dissolved oxygen concentration in the dilution water must not change by more than 0.2 mg/L.
Carbonaceous BOD (CBOD) can be determined by the addition of nitrification inhibitor. A test for CBOD is recommended for biologically treated effluents, samples seeded with biologically treated effluents and river water.
The *Troubleshooting—Graphical calculation method* provides an alternate system for calculating results and is a convenient tool for troubleshooting problems in BOD measurements. The graphical calculation method is not approved for regulatory reporting.

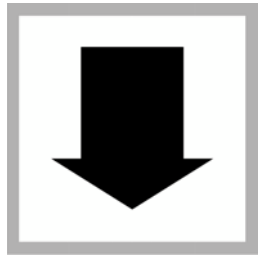
Collect the following items:

Description	Quantity
BOD bottles, 300-mL, glass, with glass stoppers and plastic caps	6
Dilution water containing nutrient buffer and seed (see *Dilution water preparation*)	varies
Nitrification inhibitor (for CBOD only)	1 bottle
Pipet, serological	1
Incubator	1

See *Consumables and replacement items* for reorder information.

Dilution method

1. Prepare the dilution water using a BOD Nutrient Buffer Pillow. See *Dilution water preparation*.



2. Select the sample volumes. See *Sample size selection*.

Note: *If the minimum sample volume is 3 mL or more, determine the dissolved oxygen in the undiluted sample; this determination can be omitted when analysing sewage and settled effluents known to have a dissolved oxygen content near 0 mg/L.*

When analyzing disinfected samples or industrial effluents, refer to *Interferences*.

3. Stir the sample gently with the pipet. Use the pipet to add the minimum sample volume to the first BOD bottle.

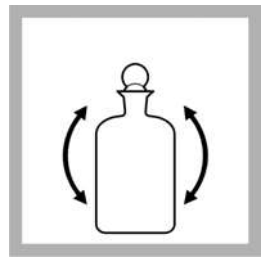
Add the remaining four sample volumes to four more BOD bottles. Mark the bottles and record the contents of each bottle.

4. Fill an additional BOD bottle with dilution water only. This will be the dilution water blank.

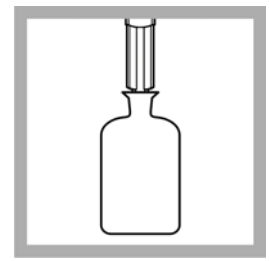
5. If the test is for CBOD, add two portions of Nitrification Inhibitor (approximately 0.16 g) to each bottle.

The oxidation of nitrogen compounds will be prevented. Report results as CBOD.

6. Fill each bottle to just below the lip with dilution water. Allow the dilution water to flow down the sides of the bottle to prevent air bubbles from becoming trapped in the bottle.



7. Stopper the bottles carefully to prevent air bubbles from becoming trapped. Tightly twist the stopper into place. Press down on the stopper and invert the bottles several times to mix.



8. Measure the initial dissolved oxygen concentration in each bottle. Use a probe and meter or titration. If a titration is used, two sets of BOD bottles must be prepared.

Be sure to measure the DO of the dilution water blank.

Oxygen Demand, Biochemical

Dilution method

9. Stopper the bottles carefully to prevent air bubbles from becoming trapped. Add dilution water to the lip of each BOD bottle to make a water seal.

10. Place a plastic cap over the lip of each bottle. Put the bottles in an incubator at 20 (±1) °C. Incubate for five days.

11. After five days, measure the remaining dissolved oxygen concentration in each bottle.

At least 1.0 mg/L DO should be left in each BOD bottle.

12. Calculate the BOD value (see *Calculation Methods—Standard Methods*).

Dilution water preparation

The dilution water must be prepared very carefully to make sure that no source of oxygen demand or toxins are added. The water that is used to prepare the dilution water must be of very high quality. The water must not have any organic compounds or any toxic compounds such as chlorine, copper and mercury.

Use the following guidelines to make sure the dilution water is of high quality.

Guidelines

- Use distilled water from an alkaline permanganate distillation for the best results.
- Do not use deionized water from ion exchange columns. The resins in the cartridges (especially new cartridges) will occasionally release organic materials that have an oxygen demand. In addition, bacteria can grow on the columns and contaminate the dilution water.
- Store the distilled water in clean jugs in an incubator at 20 °C. Fill containers till about ¾ full and shake the jugs to saturate the water with air, or cap the jugs loosely and store for 24 hours or more, to allow dissolution of oxygen.
- A small aquarium pump or air compressor can be used to saturate the water with air. Make sure that the air is filtered and that the filter does not grow bacteria. Clean the apparatus before and after use.
- Add the nutrients and seed (if necessary) to the distilled water immediately before the test.
- The dissolved oxygen concentration in the dilution water must not change by more than 0.2 mg/L when incubated for 5 days at 20 °C.

Procedure

1. Prepare and store the distilled water at 20 °C (see *Guidelines*).
2. Select a BOD nutrient buffer pillow from the *BOD nutrient buffer pillows* table.
3. Tap the pillow on a hard surface then shake the pillow to mix the contents.

4. Add the contents of the pillow to the distilled water in a jug with ample headspace above the water. Cap the jug and shake vigorously for one minute to dissolve the nutrients and to saturate the water with air.

5. If the sample is known to be low in bacteria, for example industrial waste or sewage that has been disinfected, add 3 mL of bacterial seed to each liter of the dilution water. Use raw sewage for the bacterial seed. Allow the sewage to stand undisturbed at 20 °C for 24 to 36 hours before use. Pipet from the upper portion of the sewage. Make sure to measure the BOD of the seed so that it can be subtracted from the BOD of the sample. A seed that has a BOD of 200 mg/L (a typical range for domestic sewage) will typically deplete at least 0.6 mg/L DO, when added at a rate of 3 mL/L of dilution water. If insufficient oxygen depletion occurs, increase the quantity of the seed.

Table 302 BOD nutrient buffer pillows

Volume of dilution water to prepare	BOD nutrient buffer pillow catalog no.
300 mL (add pillow to each BOD bottle)	1416066
3 liters	1486166
4 liters	2436466
6 liters	1486266
19 liters	1486398

Note: *To prepare dilution water by the conventional method, pipet 1 mL of each of the following solutions per liter of distilled water at 20 °C: Calcium Chloride Solution, Ferric Chloride Solution, Magnesium Sulfate Solution, and Phosphate Buffer Solution. Cap the bottle and shake vigorously for one minute. The Phosphate Buffer Solution should be refrigerated to decrease the rate of biological growth. Use care with all solutions to avoid contamination.*

Sample size selection

Make an estimation of the sample volumes that are necessary for the test. At least 2.0 mg/L of dissolved oxygen (DO) should be consumed during the test and at least 1.0 mg/L DO should be left in the BOD bottle.

Samples such as raw sewage will have a high BOD. Small sample volumes must be used because large samples will consume all of the oxygen. Samples with a low BOD must use larger sample volumes to make sure that enough oxygen is consumed to give accurate results.

The elevation of the laboratory changes the amount of oxygen that can dissolve in water (see *Oxygen saturation values at various altitudes (20 °C)*). At higher elevations, the amount of oxygen that can dissolve in water decreases, so less oxygen is available to microorganisms.

Procedure

1. Refer to the *Minimum sample volume* table to select the minimum sample volume. For example, if a sewage sample is estimated to contain 300 mg/L BOD, the minimum sample volume is 2 mL. For sewage effluent with an estimated BOD of 40 mg/L, the minimum sample volume is 15 mL.

2. Refer to the *Maximum sample volume* table to select the maximum sample volume. At 1000 feet, with an estimated BOD of 300 mg/L, the largest sample volume is 8 mL. For a BOD of 40 mg/L the maximum volume is 60 mL (also at 1000 feet).

3. Select two or more other sample volumes between the minimum and maximum volumes so that there are four or five sample volumes total.

Table 303 Minimum sample volume

Sample type	Estimated BOD (mg/L)	Minimum sample volume (mL)
Strong trade waste	600	1
Raw and settled sewage	300	2
	200	3
	150	4
	120	5
	100	6
	75	8
	60	10
Oxidized effluents	50	12
	40	15
	30	20
	20	30
	10	60
Polluted river waters	6	100
	4	200
	2	300

Table 304 Maximum sample volume[1]

BOD at sea level	BOD at 1000 ft	BOD at 5000 ft	Maximum sample volume (mL)
615	595	508	4
492	476	406	5
410	397	339	6
304	294	251	8
246	238	203	10
205	198	169	12
164	158	135	15
123	119	101	20
82	79	68	30
41	40	34	60
25	24	21	100
12	12	10	200
8	8	7	300

[1] Samples with higher concentrations should be pre-diluted, per Standard Methods.

Table 305 Oxygen saturation values at various altitudes (20 °C)

Altitude (ft)	Average Pressure in mBar at this altitude	Oxygen value (mg/L) in water saturated with air
Sea level (0)	1013	9.09
1000	977	8.76
2000	942	8.44
3000	908	8.13
4000	875	7.82
5000	843	7.53
6000	812	7.24

Calculation Methods—Standard Methods

Use the Standard Methods calculation when the results must be reported to a regulatory agency.

When dilution water is not seeded:

$$BOD_5,\ mg/L = \frac{D_1 - D_2}{P}$$

When dilution water is seeded:

$$BOD_5,\ mg/L = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

where:

BOD_5 = BOD value from the 5-day test

D^1 = DO of diluted sample immediately after preparation, in mg/L

D^2 = DO of diluted sample after 5 day incubation at 20 °C, in mg/L

P = Decimal volumetric fraction of sample used

B^1 = DO of seed control before incubation, in mg/L

B^2 = DO of seed control after incubation, in mg/L

f = ratio of seed in diluted sample to seed in seed control =

(% seed in diluted sample)/(% seed in seed control) OR

If seed material is added directly to sample or to seed control bottles:

f = (volume of seed in diluted sample)/(volume of seed in seed control)

Report results as $CBOD_5$ if nitrification inhibitor was added.

Averaged results are acceptable if more than one sample dilution meets all of the following criteria:

- The remaining DO is at least 1 mg/L
- The final DO value is at least 2 mg/L lower than the initial DO value
- There is no evidence of toxicity at higher sample concentrations
- There are no obvious anomalies

Interferences

Many chlorinated and industrial effluents require special handling to ensure reliable BOD results. Usually, careful experimentation with the particular sample will indicate what modifications should be made to the test procedure.

Toxins in the sample will adversely affect any microorganisms present and result in lower BODs.

To eliminate small amounts of residual chlorine, allow the sample to stand for one to two hours at room temperature. For larger quantities, determine the amount of sodium thiosulfate to add to the sample as follows:

c. Measure 100 mL of sample into a 250-mL Erlenmeyer flask. Using a 10-mL serological pipet and a pipet filler, add 10 mL of 0.020 N Sulfuric Acid Standard Solution and 10 mL of Potassium Iodide Solution, 100-g/L, to the flask.

d. Add three full droppers of Starch Indicator Solution and swirl to mix.

e. Fill a 25-mL buret with 0.025 N Sodium Thiosulfate Standard Solution and titrate the sample from dark blue to colorless.

f. Calculate the amount of 0.025 N Sodium Thiosulfate Standard Solution to add to the sample:

$$\text{mL 0.025 N sodium thiosulfate required} = \frac{\text{mL titrant used x volume of remaining sample}}{100}$$

g. Add the required amount of 0.025 N Sodium Thiosulfate Standard Solution to the sample. Mix thoroughly. Wait 10 to 20 minutes before running the BOD test.

To eliminate the effect of phenols, heavy metals or cyanide, dilute the sample with high quality distilled water. Alternately, the seed used in the dilution water may be acclimatized to tolerate such materials. Acclimatize seed as follows:

a. Fill a one-gallon stainless steel or plastic container with domestic sewage and aerate for 24 hours. Allow the heavier material to settle.

b. After settling for one hour, siphon off three quarts of material and discard.

c. Fill the container with a mixture of 90% sewage and 10% wastes containing the toxic material.

d. Aerate for 24 hours. Repeat steps b and c with increasing amounts of waste until the container holds 100% toxic waste material.

Optimum pH for the BOD test is between 6.5 and 7.5. Adjust samples to pH 7.2 with Phosphate Buffer Solution or 1 N Sulfuric Acid or Sodium Hydroxide Standard Solution if the pH is not in this range.

Cold samples may be supersaturated with oxygen and will have low BOD results. Fill a one-quart bottle about halfway with cold sample and shake vigorously for two minutes. Allow sample to reach 20 °C. Then shake the bottle vigorously for two minutes.

Accuracy check

ezGGA Method

Required for accuracy check:

- BOD Standard Solution, Voluette® Ampule, 300-mg/L, 10-mL (300-mg/L of glucose and 300-mg/L of glutamic acid)
- Seeded dilution water
- 4 BOD bottles
- 1.0–4.0 mL Class A volumetric pipets and pipet filler or 1–10 mL TenSette Pipet and Pipet tips
- Dissolved oxygen measurement apparatus

DO measurement with the LBOD probe:

1. Add the necessary seed to a 300-mL BOD bottle.
2. Fill the BOD bottle with dilution water until the water level is approximately ¼ inch up the ground glass portion of the neck. (See dimension "x" in illustration).
3. Put the 2-mL BOD standard ampule into the ampule breaker and rinse the assembly with deionized water.
4. Hold the ampule and breaker over the rim of the BOD bottle.
5. Use the ampule breaker to open the ampule and allow it to fall into the BOD bottle. Leave ampule in the BOD bottle during incubation period.
6. Follow the general procedure for the BOD test.
7. Calculate the BOD concentration of the standard solution. The 2 mL in the vial is equivalent to 6 mL as prepared by Standard Methods. Calculate the BOD concentration as though there were 6 mL added to the bottle instead of 2 mL. The dilution factor for this standard is 50x.

DO measurement with the Clark Cell electrode:

1. Add the necessary seed to a 300-mL BOD bottle.
2. Use the ampule breaker to open the ampule.
3. Pour the contents of the ampule into the BOD bottle. Tap the ampule on the rim of the bottle to dislodge the contents. Do not drop ampule into the bottle when using a Clark Cell.
4. Fill the ampule with buffered dilution water and add the water to the BOD bottle.
5. Repeat step 4.
6. Fill the BOD bottle with dilution water until the water level is approximately ½ inch up the ground glass portion of the neck.
7. Follow the general procedure for the BOD test.
8. Calculate the BOD concentration of the standard solution. The 2 mL in the vial is equivalent to 6 mL as prepared by Standard Methods. Calculate the BOD concentration as though there were 6 mL added to the bottle instead of 2 mL. The dilution factor for this standard is 50x.

Note: *The ampules include precisely 2 mL of 450 mg/L GGA. Pouring the entire solution into the bottle is the same as adding 6 mL of 150 mg/L solution as per the Standard Methods.*

Troubleshooting—Graphical calculation method

The Graphical Method helps troubleshoot problems in BOD measurements. This method cannot be used when the results must be reported to a regulatory agency.

1. Plot the mg/L dissolved oxygen (DO) remaining in each diluted sample versus the mL sample taken. Draw the best straight line through the plotted points. See *Dissolved Oxygen per mL of Sample*.

Note: *An erroneous point is visually evident at this time and can be disregarded. However, at least three points should be on the line or very close to it. For unseeded dilution water, the line should cross the mg/L DO Remaining scale near or below the oxygen saturation value for the altitude of the laboratory as discussed in Dilution water preparation.*

2. To calculate the BOD, use the following equation which is mathematically equivalent to the BOD equation in Standard Methods.

   mg/L BOD = (A x 300) – B + C

   where:

   A = the slope

   The slope of the line is equal to the mg/L DO consumed per mL of sample taken. Take any point on the line and subtract the mg/L DO Remaining at that point from the mg/L DO where the line crosses the DO scale (Y intercept, mg/L DO Remaining). Divide the difference by the mL of sample at the point chosen.

   300 = the volume of the BOD bottle

   B = the Y intercept

   This is the DO value where the line crosses the “DO Remaining” scale. (This should be very close to the actual dilution water blank value.)

   C = the sample DO

   This is the DO of the undiluted sample.

   Another way to write this equation is:

   mg/L BOD = (Slope x 300) – Y intercept + Sample DO

   Note: *If the best straight line is obtained by linear regression through use of a calculator, the sign (-) of the slope must be changed (+) before multiplying by 300.*

Example:
The mg/L DO remaining was determined for a series of four dilutions of domestic sewage after five days of incubation. Results were as follows:

mL of sample taken	mg/L DO remaining
2.0	7.50
3.0	6.75
6.0	4.50
9.0	2.25

The DO values were plotted versus the mL of sample taken and a straight line drawn as in *Dissolved Oxygen per mL of Sample*. If a set of BOD dilutions is run correctly with a homogeneous sample, a graph of the mg/L DO remaining versus the sample volume would result in a straight

line. The value where the line intersects the y-axis is equal to the DO content of the dilution water

after incubation, although this is not actually measured. In this case, it was equal to 9.0 mg/L and the DO of the domestic sewage sample was assumed to be zero. If another type of sample is used, the DO of an undiluted sample should be measured either by the Winkler titration or with a luminescent or electrochemical probe.

The *Calculation Methods—Standard Methods* formula for calculating BOD also can be written as follows (not approved for reporting purposes):

$$\frac{\text{mg/L DO remaining w/smaller sample volume} - \text{mg/L DO remaining w/larger sample volume}}{\text{mL of larger sample volume} - \text{mL of smaller sample volume}} \times 300 - DO_D \pm S = \text{mg/L BOD}$$

Using this information in the example:

mg/L DO remaining with smaller sample volume = 7.50

mg/L DO remaining with larger sample volume = 2.25

mL of larger sample volume = 9.0

mL of smaller sample volume = 2.0

300 = volume (mL) of BOD bottle

DO_D = mg/L DO of dilution water = 9.0

S = mg/L DO of sample = assumed in this case to be zero

Therefore:

$$\frac{7.50 - 2.25}{9.0 - 2.0} \times 300 - 9 + 0 = \text{mg/L BOD} = 216 \text{ mg/L BOD}$$

Using the equation below:

(slope x 300) – Y-Intercept + sample DO = mg/L BOD

To determine slope, arbitrarily select point A in Figure 1. At this point the mg/L DO remaining is equal to 3.0 mg/L. The mL of sample at this point is 8 mL.The difference between the y-intercept of 9.0 mg/L and 3.0 mg/L equals 6 mg/L; 6 mg/L divided by 8 mL = 0.75 mg/L per mL.

slope = 0.75 mg/L per mL

Y intercept = 9.0 mg/L

sample DO = 0 (Because the sample is domestic sewage, this is assumed to be zero.)

Therefore:

(0.75 x 300) – 9.0 + 0 = mg/L BOD = 216 mg/L BOD

Summary of method

Biochemical Oxygen Demand (BOD) is a measurement of the oxygen requirements of municipal and industrial wastewaters and sewage. The test results are used to calculate the effect of waste discharges on the oxygen resources of the receiving waters. The BOD test is of limited value in measuring the actual oxygen demand because temperature change, biological population, water movement, sunlight, oxygen concentration, and other environmental factors cannot be reproduced accurately in the laboratory. The BOD test is of greatest value after patterns of oxygen uptake for a specific effluent and receiving water have been established.

The BOD test is performed by incubating a sealed wastewater sample (or a prepared dilution) for the standard five-day period and then determining the change in dissolved oxygen content. The BOD value is then calculated from the results of the dissolved oxygen tests.

Consumables and replacement items

Required reagents

Description	Quantity/Test	Unit	Catalog number
BOD Nutrient Buffer Pillows, for 3 liters of dilution water	1 pillow	50/pkg	1486166

Required apparatus

Description	Quantity/Test	Unit	Catalog number
BOD Bottle, glass-stoppered, 300-mL, unlabelled	6	6/pkg	62106
BOD Bottle Cap	6	6/pkg	241906
Bottle, wash, 500-mL	1	each	62011
Clippers, large	1	each	96800
Pipet, serological:			
Pipet, serological, 1-mL	1	each	919002
Pipet, serological, 5-mL	1	each	53237
Pipet, serological, 10-mL	1	each	53238
Pipet Filler	1	each	1218900
Dissolved Oxygen measurement apparatus	—	—	—

Recommended standards

Description	Unit		Catalog number
BOD Standard Solution, Voluette® Ampule, 300-mg/L, 10-mL		16/pkg	1486510
ezGGA BOD Standard Ampules, 450 mg/L, 2 mL		20/pkg	—

Optional reagents and apparatus

Description	Unit	Catalog number
BOD Nutrient Buffer Pillows		
for 300 mL of dilution water	50/pkg	1486166
for 4 liters of dilution water	50/pkg	2436466
for 6 liters of dilution water	50/pkg	1486266
for 19 liters of dilution water	25/pkg	1486398
Buffer Solution, APHA, for BOD, pH 7.2, phosphate type	500 mL	43149
Calcium Chloride Solution, APHA, for BOD	500 mL	42849
Ferric Chloride Solution, APHA, for BOD	1 L	42953
Magnesium Sulfate Solution, APHA, for BOD	500 L	43049
Nitrification Inhibitor	35 g	253335
Dispenser Cap, for Nitrification Inhibitor	each	45901
Potassium Iodide Solution, 100-g/L	500 mL	1228949
Sodium Hydroxide, pellets, ACS	500 g	18734
Sodium Hydroxide Standard Solution, 1.000 N	100 mL MDB	104532
Sodium Thiosulfate Standard Solution, 0.025 N	1 L	35253
Starch Indicator Solution	100 mL MDB	34932
Sulfuric Acid Standard Solution, 0.020 N	1 L	20353
Sulfuric Acid Standard Solution, 1.000 N	1 L	127053
Potassium Permanganate	454g	16801H
Bottle, BOD, Serialized: 1-24[1]	24/pkg	1486610
Bottle, BOD, Disposable	117/case	2943100
Stopper for Disposable BOD Bottle	25/pkg	2943900
Bottle Rack, BOD, 12 bottle	each	2094200
Brush, cylinder, 2-in. diameter	each	68700
Incubator, BOD, Compact Model 205, 110 Vac	each	2616200
Incubator, BOD, Compact Model 205, 220/240 Vac	each	2616202
Leash, rubber, for stopper & bottle	6/pkg	2091606
ATU (1-1-allyl-2-thiourea)	50 g	2845425
Nitrification Inhibitor	500 g	253334
BOD Seed Inoculum, Polyseed	50 capsules	2918700

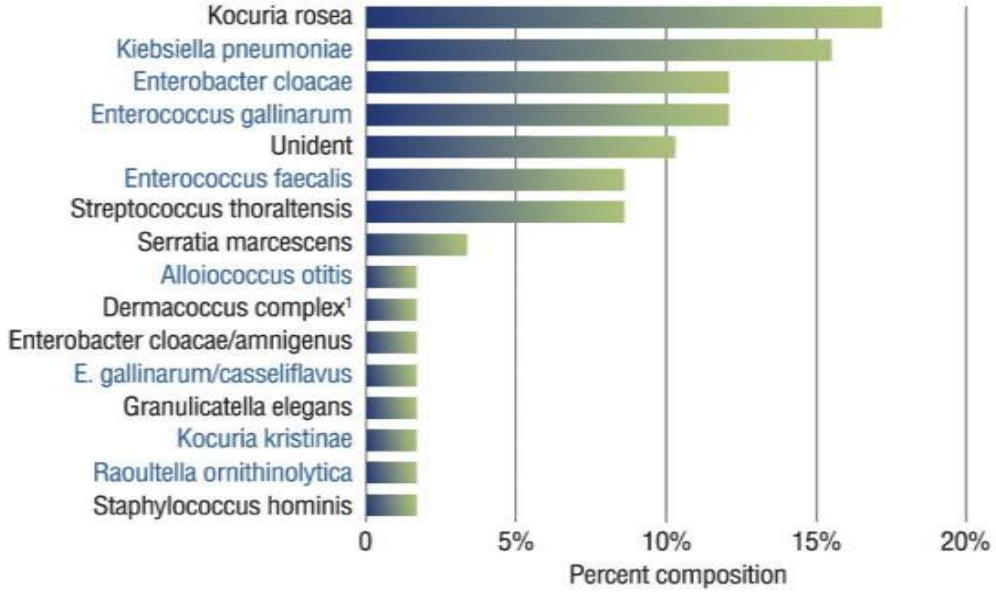
[1] Other numerical series are available

Table 2.24. Physical-chemical characteristics of raw domestic sewage in developing countries

Parameter	Per capita load (g/inhab.d)		Concentration (mg/L, except pH)	
	Range	Typical	Range	Typical
TOTAL SOLIDS	120–220	180	700–1350	1100
Suspended	35–70	60	200–450	350
• *Fixed*	7–14	10	40–100	80
• *Volatile*	25–60	50	165–350	320
Dissolved	85–150	120	500–900	700
• *Fixed*	50–90	70	300–550	400
• *Volatile*	35–60	50	200–350	300
Settleable	–	–	10–20	15
ORGANIC MATTER				
BOD_5	40–60	50	250–400	300
COD	80–120	100	450–800	600
BOD ultimate	60–90	75	350–600	450
TOTAL NITROGEN	6.0–10.0	8.0	35–60	45
Organic nitrogen	2.5–4.0	3.5	15–25	20
Ammonia	3.5–6.0	4.5	20–35	25
Nitrite	≈ 0	≈ 0	≈ 0	≈ 0
Nitrate	0.0–0.3	≈ 0	0–2	≈ 0
PHOSPHORUS	0.7–2.5	1.0	4–15	7
Organic phosphorus	0.7–1.0	0.3	1–6	2
Inorganic phosphorus	0.5–1.5	0.7	3–9	5
pH	-	-	6.7–8.0	7.0
ALKALINITY	20–40	30	100–250	200
HEAVY METALS	≈ 0	≈ 0	≈ 0	≈ 0
TOXIC ORGANICS	≈ 0	≈ 0	≈ 0	≈ 0

Sources: Arceivala (1981), Jordão & Pessoa (1995), Qasim (1985), Metcalf & Eddy (1991), Cavalcanti et al (2001) and the author's experience.

Figure 1. Percent distribution of bacterial species among the 59 isolates identified



Species in blue have been associated with human illness.

[1]The Dermacoccus complex indicated low discrimination between Dermacoccus nishinomiyaensis, Kytococcus sedentarius, and Kocuria rosea.