# Term Project
# Final Documentation

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## 1.Introduction

The Occam.Dx nanoelectronic sensor makes use of a remarkably sensitive nanoelectronic component that interacts with the target chemical to produce a weak electrical signal, which allows it to be detected. This sensor is highly sensitive, selective, and responsive, and it adapts well to complex sample matrices. Low amounts of the target medication can also be detected. It searches for and recognizes minute compounds and biomolecules using cutting-edge sensing technologies. It is based on nanoelectronics and biosensing principles and has numerous applications in cosmetics testing, milk testing, water testing and sports (OccamDx).

The work listed below includes projects that Unicorn Dx's cutting-edge technology might be useful for. While other ideas have only received a limited amount of research, the more promising ones have received more. One of the most promising ideas for cosmetic testing was discovered through our research and surveys, examination of relevant information from the cosmetics sector and industry annual reports, and consultation with Unicorn Dx technology experts for advice and input to gain a more comprehensive understanding of their concepts. The group's goal was to come up with new solutions in areas where none now exist while also enhancing current efforts to boost effectiveness or performance.

The innovative technology behind Unicorn Dx and its adaptability make it appropriate for a variety of sectors. There is no doubt that it will be able to be employed in the future in a variety of complex products and their applications in all main sectors, going by the technology's quick development and the rising interest from stakeholders. We started our investigation by determining the key sectors, occupations, and uses for which our technology would be useful. Our objective was to more precisely identify the tasks that the technology could successfully carry out across various businesses. We started to focus the scope of the work to be done and categorize it from most to least important by analyzing a variety of jobs. Glanced at how these problems and executions were being handled by existing technologies. We were able to identify a prospective use for our technology—cosmetic testing through extensive research, in-depth talks, and the knowledge of Unicorn Dx specialists.

In addition, we expanded our research further and asked ourselves: what are the strengths and weaknesses of the existing technologies? How is our technology better than the existing ones? Are there cheaper and more reliable ways to test?

It became evident to us after reading the annual reports of potential fields that Unicorn Dx's technology could be able to address the issues they were having. There are a few exceptions to this rule, though. We have previously attempted to use this technology to test our crop water and drinking water, but it has proven challenging to do so because the concentration of the ingredients in the water is so low. As a result, we have only retained the markets for cosmetics, milk, and sports testing.

## 2. Cosmetics testing- Most promising idea-

### 2.1 Insights

According to the US FDA, cosmetic products with particles between 1 and 10 nanometers (nm), developed and produced using nanotechnology, are considered nanocosmetic products. Common nanocosmetic products are sunscreens, conditioners, and antibacterial agents. Sunscreens are mainly made of titanium dioxide and zinc oxide. These nanoparticles, due to their tiny size, form a transparent film and provide an effective physical barrier on the skin against ultraviolet (UV) radiation.

### 2.2 Problems

- High testing costs: Traditional cosmetic testing techniques can call for pricey lab equipment and specialist technicians, putting financial strain on producers.
- Long lead times: Because existing testing techniques demand a lot of time, firms must wait a long period to create and market their products.
- Unstable test results: Test findings are subject to some degree of uncertainty and volatility since they are affected by several variables, including the source of the sample, the testing procedure, and the environment.
- Strict regulatory requirements: The cosmetic industry has very strict regulatory requirements, involving standards for cosmetic ingredients and safety, which place higher demands on manufacturers.
- Inadequate information gathering: While it is necessary to have appropriate knowledge about a product's contents, impacts, etc. throughout the development and production of cosmetics, this knowledge is not always available or sufficiently gathered.

### 2.3 Needs

- Reduced testing expenses: To lower testing costs and relieve production pressure, a more cost-effective testing procedure is required.
- Reduce test cycles: A quicker test methodology is required to reduce test cycles and quicken the development and launch of new products.
- Enhance the stability of test results: I need a test method that is more precise and stable to guarantee the efficacy and safety of my cosmetic items.
- Compliance with regulations: To ensure that items are sold legally, a test procedure must comply with the regulations of the cosmetics sector.
- Get complete information support: To aid in the development and production of cosmetic items, more complete information assistance is required regarding the composition and efficacy of the products.

### 2.4 Current solutions

2.4.1Existing products:

Common methods of detecting nanoparticles:

1) Imaging methods (TEM, SEM, AFM): commonly used to detect shape and size, but no information on elemental composition and concentration is not easily known.

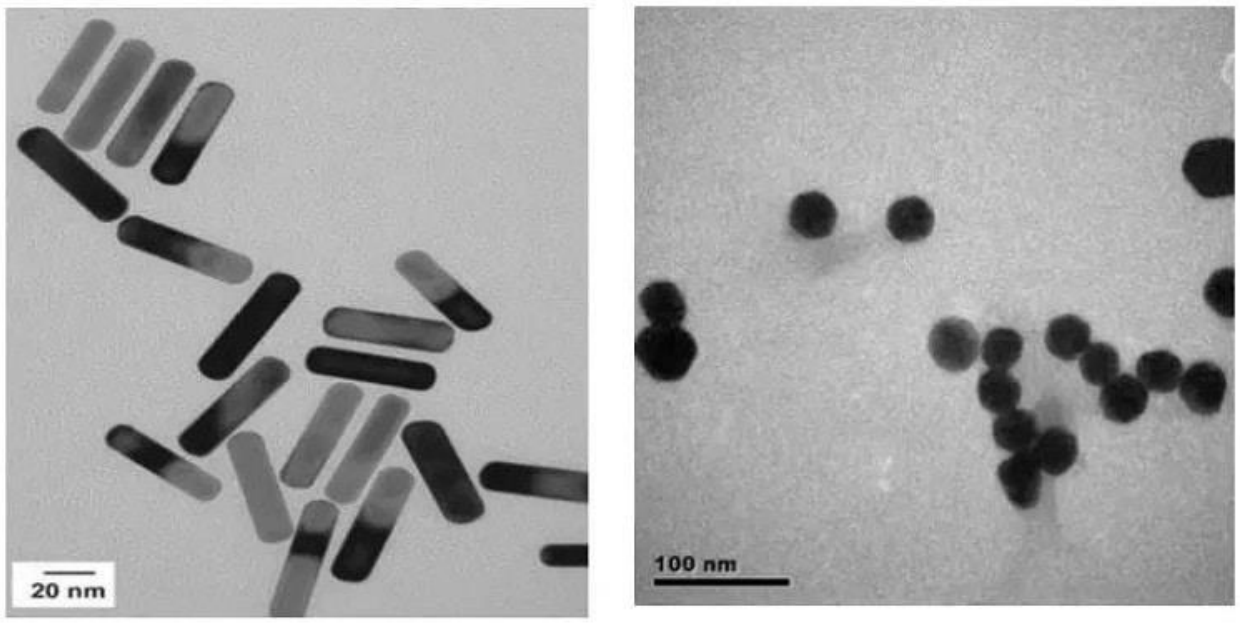



Fig. 1. Images of nanoparticles with SEM

2) Spectroscopic/optical methods (UV-Vis, Dynamic Light Scattering DLS): simpler methods, but no information on elemental composition and more susceptible to interference.

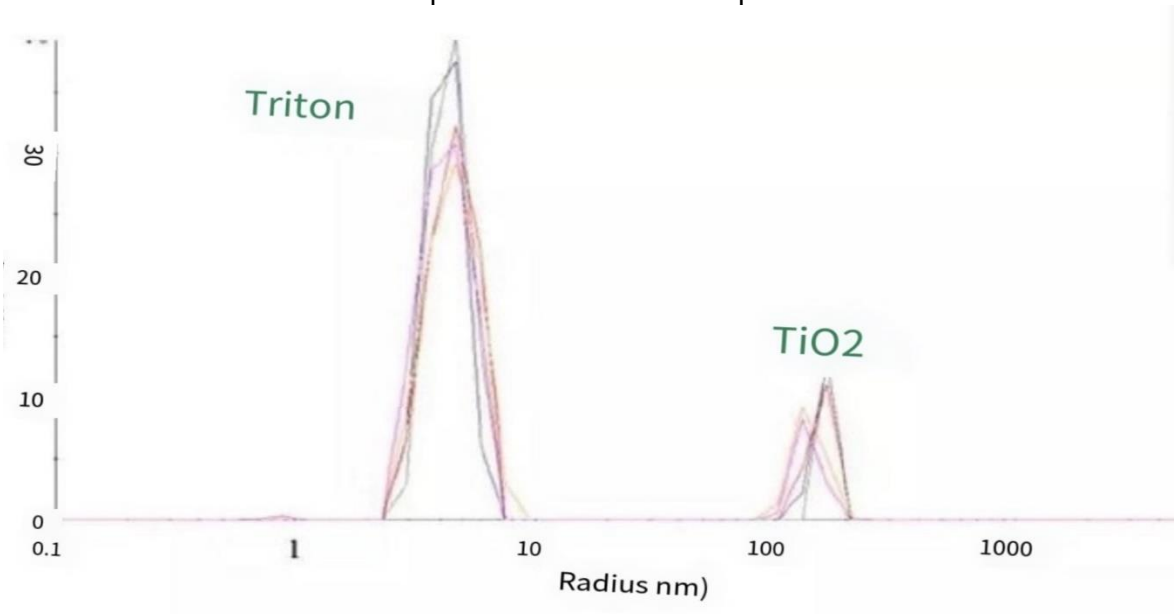
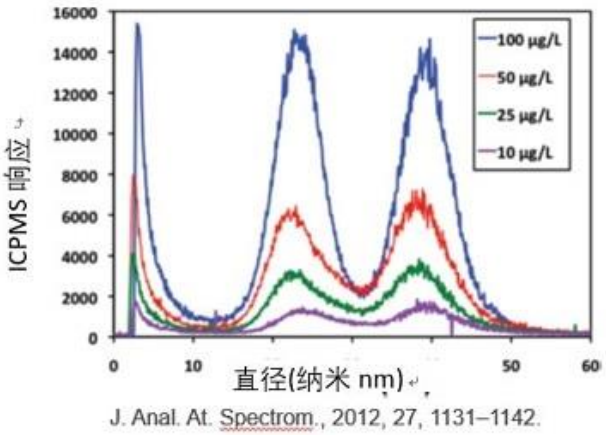



Figure 2. Signal plot of 1 ppm TiO2 using DLS analysis (from Taiwan Industrial Technology Research Institute ITRI, 2017)

3) Coupled techniques (chromatography or other inline separations combined with ICP-MS detection): allow for representative samples, provide good particle size resolution, high elemental sensitivity, but must be coupled with ICP-MS to obtain information on individual elements




4) Single Particle ICP-MS (spICP-MS): Nanoparticles are fed into the ICP-MS one by one, each ionised to produce a cloud of ions and a peak signal. The elemental species is determined from the ICP-MS, the size of the nanoparticles is determined from the intensity of the response, and the concentration of the nanoparticles is determined from the frequency of the signal. This method provides information on the size of the nano-element at once and is influenced by the signal-to-noise ratio of the instrument, the better the sensitivity of the instrument, the better the detection of small nanoparticles.

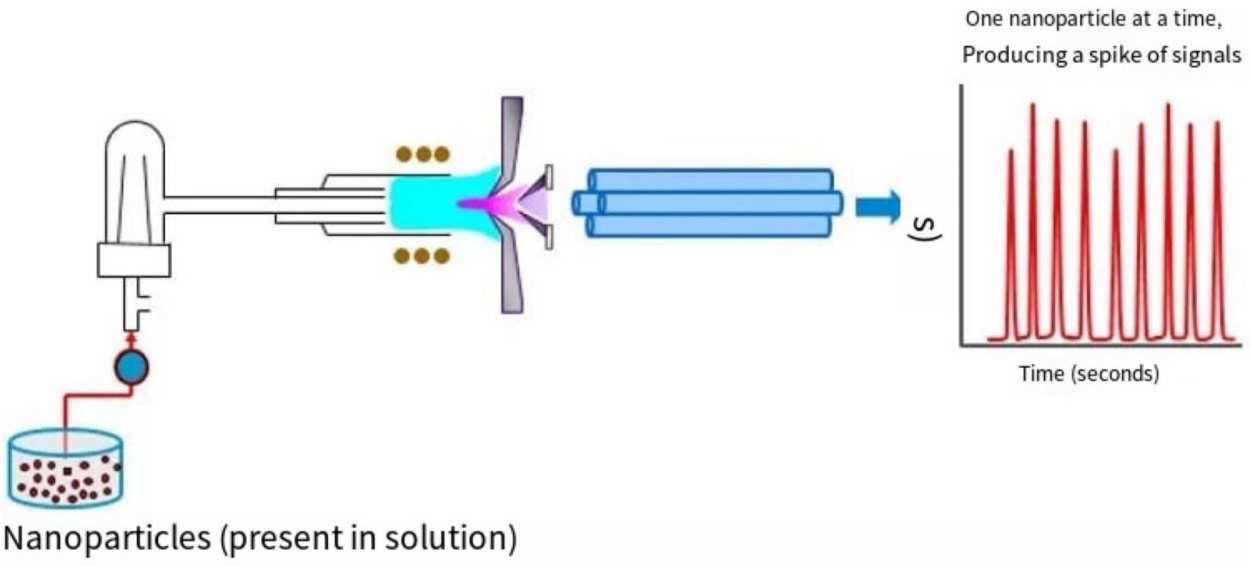



Figure 5. spICP-MS schematic

- High Performance Liquid Chromatography (HPLC): for the separation, identification and quantification of cosmetic ingredients.
- Gas Chromatography Mass Spectrometry (GC-MS): for the identification and quantification of cosmetic ingredients.
- Infrared spectroscopy (FTIR): for the identification and analysis of cosmetic ingredients.
- Liquid chromatography-mass spectrometry (LC-MS): for the identification and quantification of cosmetic ingredients and the determination of their molecular structure.
- Electrochemical analysis (ECA): for analyzing the electrochemical properties and composition of cosmetic products.
- Metallographic microscopy: for the observation of metal particles and other microscopic components in cosmetic products.
- Quality control instruments: for testing the physical properties of cosmetic products such as pH, viscosity and density.
- Human skin testing: for assessing the irritation, allergenicity and safety of cosmetic products on the skin through clinical trials or human testing.

Sources:

Materials Testing & Research | Agilent

Nanomaterials Characterization & Analysis | Agilent

Nanomaterials | Bruker

2.4.3 How has the technology of these jobs evolved?

- Nanosensors: used to find harmful chemicals, heavy metals, and other components in cosmetics.
- Nano-liquid chromatography: for the separation and detection of ingredients in cosmetics.
- Nanomass spectrometry: for the detection and qualitative/quantitative analysis of ingredients in cosmetics' products.
- Nanoparticle analysis techniques: use nanoscale particle analyzers such as Dynamic Light Scattering (DLS) or Laser Particle Sizer for the particle size and distribution of nanoparticles in cosmetics.

2.4.4 What are their strengths and weaknesses?

Their strength:

- **Nanosensors**: These sensors can generate measurable signals by interacting specifically with the target ingredient in the sunscreens' product. For example, nanoparticles can be used as markers that bind to the target ingredient in a sunscreens' product through its surface, thereby generating an optical, electrochemical, or other signal that can be detected.

- Nano-liquid chromatography: Nanofluid chromatography is highly sensitive and high resolution and can be used for the detection of trace components in sunscreens' products.
- Nanomass spectrometry: Nanomass spectrometry allows for highly sensitive analysis of complex sunscreens' samples and can detect low concentrations of ingredients.
- Nanoparticle analysis techniques: This is important for compliance testing and quality control of cosmetic products containing nanoparticles.

Their weakness

- High technical threshold: requires specialist equipment and a high level of technical skill to operate, so there may be a technical threshold and cost associated with implementation and application.
- Safety considerations: requires consideration of its safety to humans and the environment, including the biosafety of nanomaterials, environmental risks, and other aspects.
- Sample handling complexity: complex in terms of sample handling, including steps such as sample pre-treatment and sample preparation, which may require longer operating times and higher operational skills.
- Limitations: e.g., nano sensors for specific cosmetic ingredients may require specific ligands or recognition elements and therefore may have different applicability in different cosmetic samples.

### 2.5 Our solutions

2.5.1 What should we do

- Detecting trace ingredients: Unitize Occam Dx to detect minute quantities of many components, including heavy metals, harmful chemicals and more. This is particularly helpful for regulatory agencies and cosmetic firms because these compounds might be harmful to customers' health.
- Confirmation of ingredient concentration: This is essential since manufacturers must ensure that their products meet the necessary safety requirements and that the concentrations don't put consumers in danger.
- Detecting product stability: In order to determine the stability and shelf life of cosmetics, Occam Dx can detect chemical modifications and reactions in these products.

2.5.2 How the technology could work

- Sample preparation: Entails getting the cosmetic sample ready for analysis, maybe through extraction or dissolution.
- Electrochemical nanosensor loading: Combining the ready cosmetic sample with the Occam Dx nanosensor.
- Detection: After the sample comes into touch with the sensor, an electrochemical reaction takes place to reveal the sample's chemical composition.

- Data analysis: The results are transferred to a computer or other device for analysis, which can determine whether specific chemical components are present in the sample.

These sensors are highly sensitive and can detect even trace amounts of harmful chemicals, providing a level of accuracy that is unmatched by other methods. In addition, our sensors are portable, making them ideal for use in manufacturing facilities or in the field.

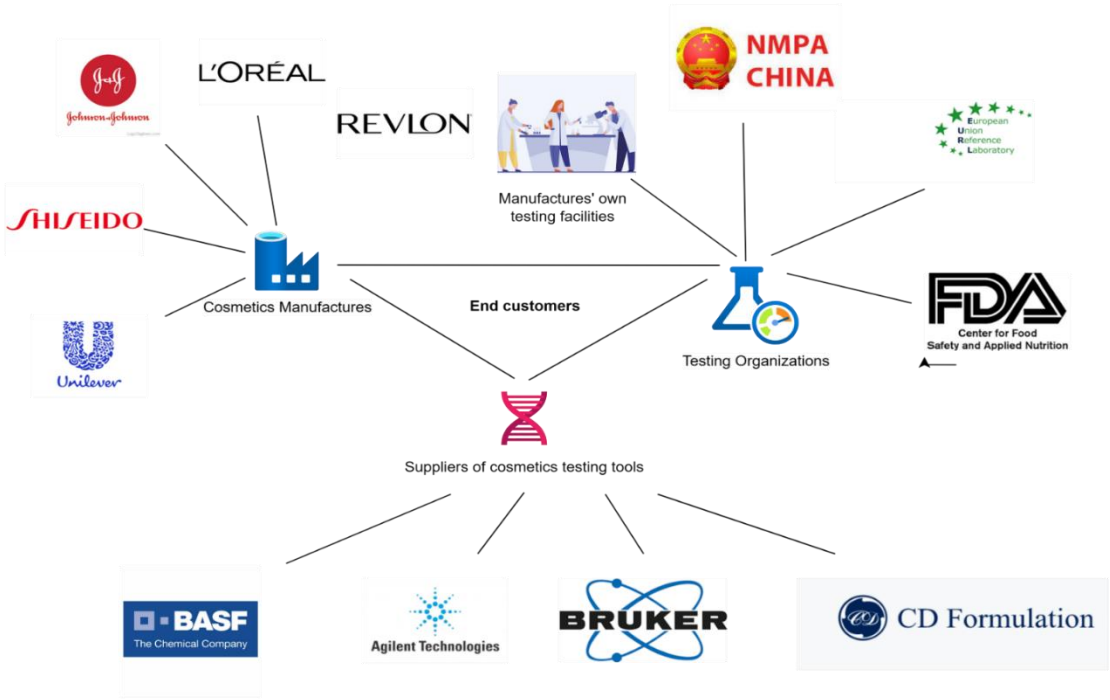
2.5.3 Main users of the testing tools?

- Manufacturers of cosmetics
- Testing companies or labs
- Environmental regulators
- Research institutions and academia
- Cosmetics retailers
- Environmentalists
- Individuals (such as people with sensitive skin or allergies)

## 2.6 Stakeholder maps

2.6.1 Identify relevant stakeholders

### 2.6.2 Stakeholder connections




- Cosmetic manufacturers: need to test their products to ensure compliance with relevant regulations and standards, to ensure product quality and safety, and to avoid losses and reputational damage caused by product problems.
- Government regulators: need to monitor cosmetics on the market to ensure that they comply with relevant regulations and standards to protect public health and safety.
- Cosmetic testing institutes: an important part of the cosmetic testing industry, providing testing services on the safety, quality and efficacy of cosmetics, providing technical support and a basis for cosmetic companies, as well as being an important partner for government regulators.
- End customers: the ultimate beneficiaries of the cosmetic testing industry and they need the results of cosmetic testing institutes to choose safe and effective cosmetic products and protect their health and rights.

Sources:


BASF – Sweden

Nanomaterials Characterization & Analysis | Agilent

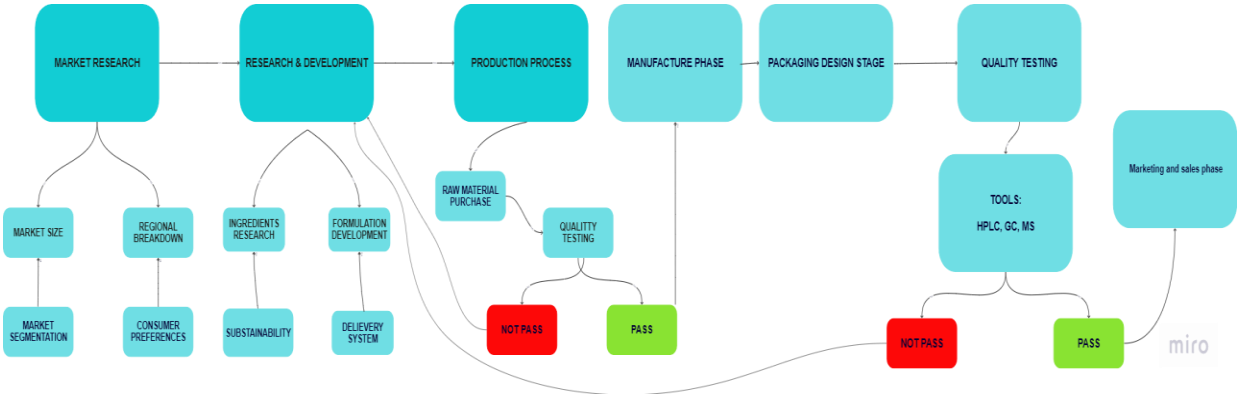
Nanomaterials | Bruker

https://www.formulationbio.com/one-stop-test-services-for-cosmetics.html?gad=1&gclid=Cj0KCQjw3a2iBhCFARIsA

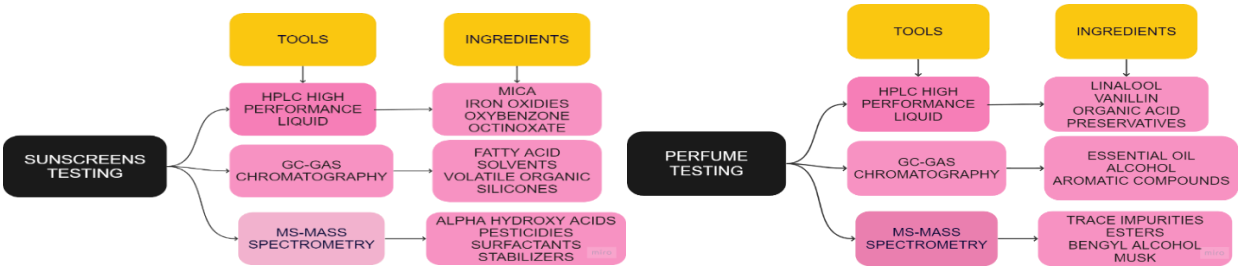
https://auriaperfumes.com/en/perfume-laboratory-cosmetics/

## 2.7 Journey maps

The whole journey map of cosmetics




Sunscreens and Perfume testing tools and ingredients




## 2.8 Persona

We spoke with a former employee of a cosmetic testing company who had worked there for fifteen years. He shared with us the difficulties and challenges he had faced at work, but he also expressed a strong desire to stay in the field because he had spent so much time there and hoped to contribute in some way to its growth. He was therefore very interested in the new technologies that had emerged in the field and hoped that they would help the industry advance. And at the same time, if the new technologies could be cheaper, so that their quality control department would have more budget to do research in other areas every year.

**Cosmetics quality control manager**

## BACKGROUND

*John has 15 years of expertise in the field of cosmetic testing and is an expert in cosmetic quality control. His years of experience and skill have given him a thorough understanding of the physical and chemical properties, microbiology, and toxicology of cosmetics. John holds diplomas and qualifications related to aesthetic testing, therefore he must treat every aspect of his work with rigor to ensure the quality and accuracy of every stage. He is a really loyal and responsible individual. John's work demands him to regularly assess and address challenges like quality concerns, technical problems, and more. Due to the quick changes in technology and the market, cosmetic quality control must also develop and evolve..John needs to keep learning new testing techniques and approaches in order to maintain his professionalism.*

## MOTTO

***"One who does not move forward is moving backward"*** -

Johann Wolfgang von Goethe

# Work in cosmetics testing company

## WORK PROBLEMS

- Work pressure: Quality control calls for a rigid attitude and a high standard of accountability. When there are immediate quality problems that need to be fixed, it could be upsetting.
- Cumbersome operational processes: sample collection, sample preparation, testing and analysis, and result recording.
- Complex tests: A wide range of tests, such as physical and chemical indicators, microbiological tests, and toxicological analyses.
- Resolving quality issues: Any time a defect in a product's quality is found, it needs to be investigated and corrected. Identify the root cause of the problem and take appropriate action, which can involve some complex work.

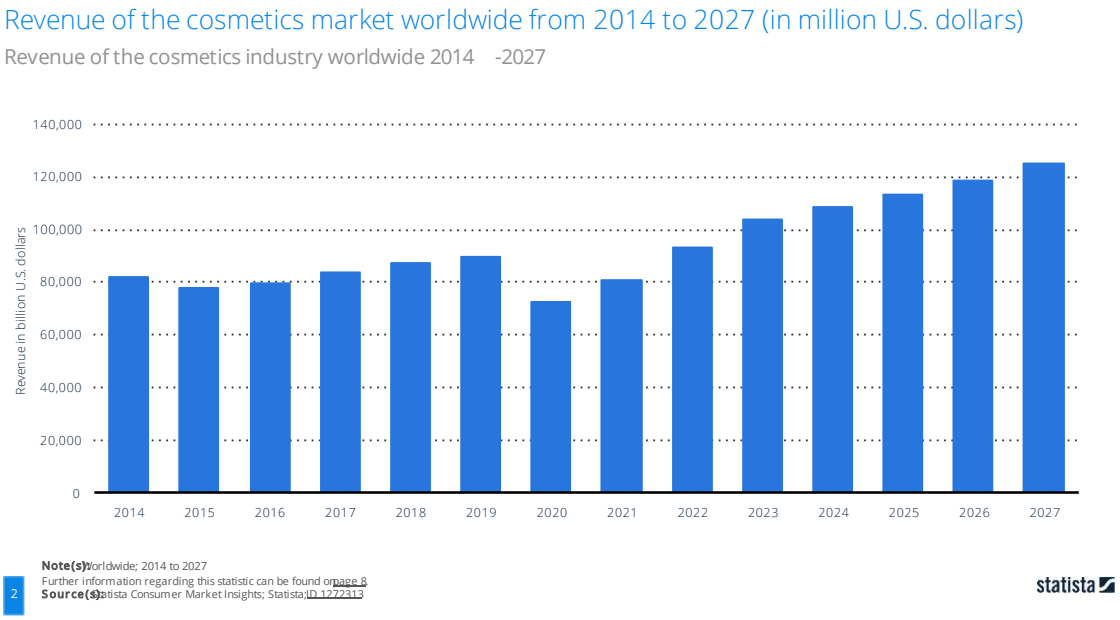
## MOTIVATIONS

- Consumer rights protection
- Work more effective
- Achieve self-worth
- Gain a sense of achievement
- Promote the development of the industry

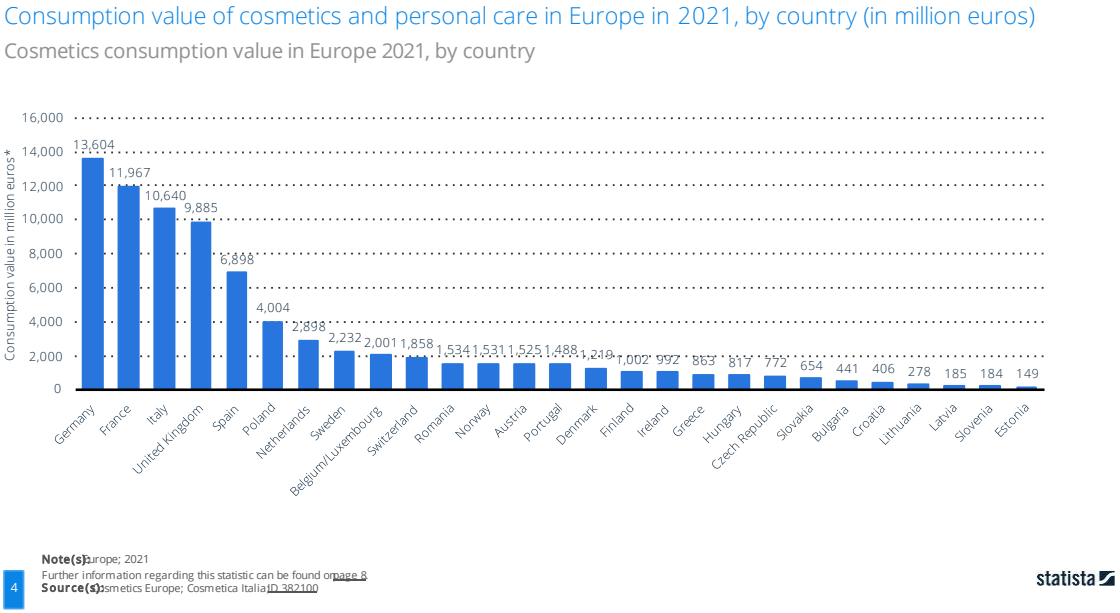
## Career Planning

- Become a divisional manager
- Become a Regional Manager
- Starting a business

## 2.9 Market size




In 2022, the global cosmetics market experienced growth of **over 16 percent** in comparison to the previous year, the worldwide revenue is **$ 93.05 bn**. The global revenue in the cosmetics was forecast to continuously increase between 2023 and 2027 by in total 21.6 billion U.S. dollars (+20.8 percent). Cosmetics industry - statistics & facts | Statista (liu.se)



Valued at **€80 billion** at retail sales price in 2021, the European cosmetics and personal care market is, alongside the USA, the largest market for cosmetic products in the world. And Germany, France and Italy are the leading three countries in consumption of cosmetics. Cosmetics Europe - The Personal Care Association :: Home

## 2.10 References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Mohamed, H.M. (2015). Green, environment-friendly, analytical tools give insights in pharmaceuticals and cosmetics analysis. TrAC Trends in Analytical Chemistry, 66, pp.176–192. doi:https://doi.org/10.1016/j.trac.2014.11.010.

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## 3. Milk testing

### 3.1 Insights

Dairy industry relies on high-quality raw materials. The authors of the article published in the journal “Food Safety” [footnote 2], note the increasing consumer demands for quality and safety of dairy products and the increased responsibility of the dairy industry in monitoring and controlling product quality. For that reason, it's important to analyze raw milk through a whole range of ways such as: microbiological, cytological, or biochemical methods. Milk producers need to be sure that it's safe for consumption and won't compromise the quality of the final products. Without paying much attention to measures, the dairy industry wouldn't be able to exist.

### 3.2 Problems

There are many problems that dairy producers may encounter. Starting from a need for checking the quality of milk just to taste good, the problem here is deeper, because badly analyzed milk can do a lot of harm to humans and failure would cost a lot of money for milk producers. R. K. Sharma, in his article "Milk testing and quality control: An overview of methods and costs" states that it is actually the cost of milk testing that is the biggest cost of production. If this cost were reduced by a large share, it would significantly affect producers. This is confirmed by the "Dairy Industry Reducing Effluent Costs" report published by Dairy Australia, which clearly indicates that testing costs are the biggest challenges to cost reduction in the dairy enterprise. Another problem, but very connected to the previous one, is contamination of the environment. In our world today, where ecosystems are more and more polluted, it is hard to provide good milk quality. What’s sometimes harder is to detect every single harmful particle. There are many publications such as “"Contamination of milk and dairy products with pesticides” [footnote 5] that show that environmental contamination can affect milk quality. Milk producers are also concerned about ethical issues. Consumers' ethical awareness is a thing nowadays. To be more competitive, they need to provide consumers with information that will build trust. This could include, for example, the results of in-depth milk studies (for example, whether cows have been fed antibiotics or not). Human health, however, should be the issue that most concerns the food industry, which includes the dairy industry. Companies cannot afford to compromise in this area. Dairy producers must be carefully investigated so that an incident such as the one in China in 2008, known as the "melamine milk scandal," does not happen again. For more on this topic, see the article "China's toxic milk scandal: why it happened and what we've learned" [footnote 6]. Last but not least milk producers'

problem is that they need to use many devices to test milk. “Handbook of Milk Composition” edited by R.G. Jensen shows that for instance. This is a real struggle for milk producers due to the fact that every machine needs to have somebody who takes care of it, knows how to use it or they just basically need their own conservation.

**In a very brief:**

- High cost of testing
- Contaminated environment
- Ethical issues
- Food safety risks
- Multiple devices for milk testing

### 3.3 Needs

They need a machine(s?) that would measure milk particles **more accurately, faster and cheaper**. Milk production companies try to balance (optimize) these three features.

### 3.4 Current solutions

Current solutions available on the market are not sufficient because they cannot measure every particle in just one sample. Companies that test for harmful substances in milk use a variety of methods and tools. Spectroscopy is used to detect electromagnetic radiation and determine the chemical composition of a sample. It is used to measure pesticides, heavy metals and dioxins. More information about it is in "Application of Spectroscopy in Dairy Industry: A Review" [footnote 9]. Next solution is Chromatography - a technique for separating complex mixtures into components. Chromatography can detect the presence of harmful substances such as antibiotics, pesticides and feed additives [footnote 10]. Immunoassays is the next technique of doing the job. It uses antibodies to detect harmful substances in milk like antibiotics and hormones. At the end PCR tests which use polymerase chain reactions to detect the presence of bacteria, viruses or GMOs in milk [footnote 11].

Here are few examples from the market of companies that produce devices with before mentioned techniques of milk testing:

- Thermo Fisher Scientific (https://www.thermofisher.com/se/en/home.html)
- PerkinElmer (https://www.perkinelmer.com/pl/)
- Agilent Technologies (https://www.agilent.com/)
- Eurofins (https://www.eurofins.com/)
- Charm Sciences (https://www.charm.com/)

### 3.5 Our solutions

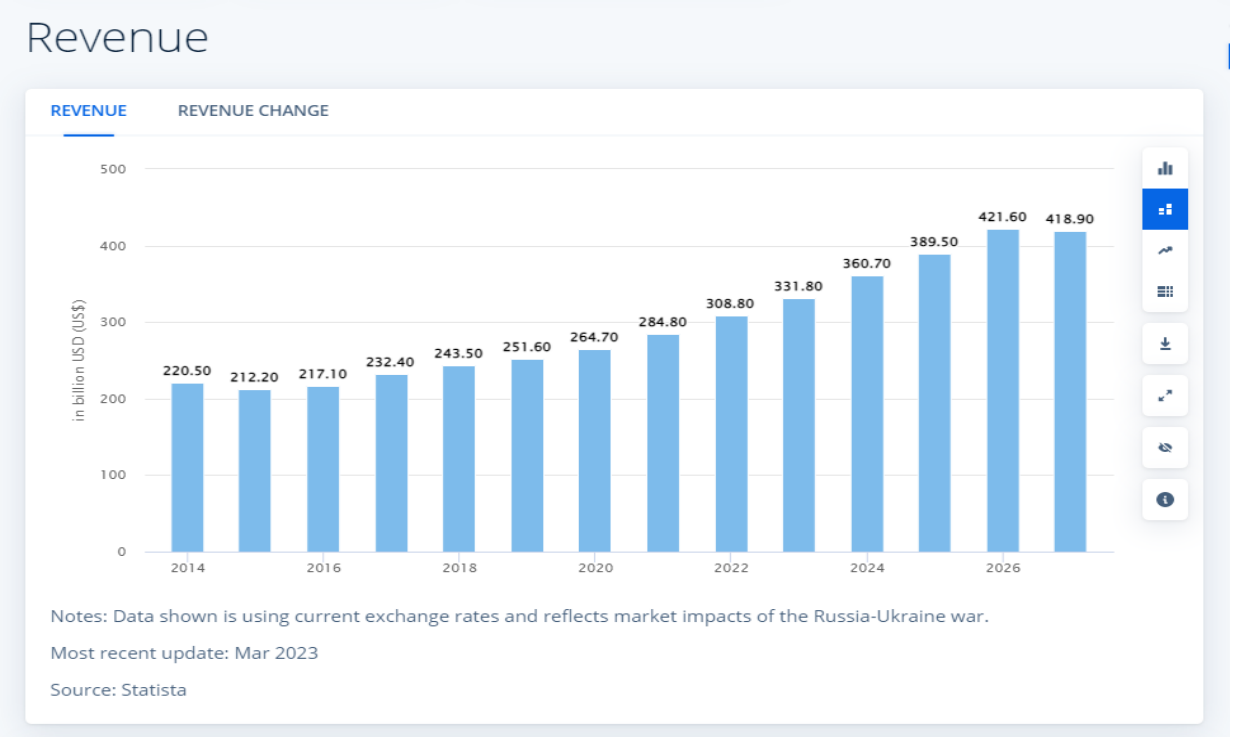
Unicorn DX makes it possible to measure **everything in one sample**. Also, time is crucial in this type of material. Our product can do the job in a noticeably short time, this will guarantee good dairy products. It can detect more cells because of ultrasensitive sensor. We can measure the health of the cows, which is crucial in terms of future milk production (if we detect diseases earlier, we can save more). What's more, it turns out that cow milk is not only what can be tested. There's a possibility of researching human milk (breast milk). I've managed to find one company who sells such a device: https://www.milkotronic.com/.

**In a brief:**

- measure every particle in only one sample
- detecting particles faster and more precisely and accurate than it has been ever done before (through nano technology)

### 3.6 Market size

According to *statista* [footnote 12] in 2022, the global milk market was $331.8 billion, and 6% growth is expected. It turns out that most revenue is generated in India because about $68 billion. What's interesting, "the average volume per person in the Milk segment is expected to amount to 30.28kg in 2023".




Source: https://www.statista.com/outlook/cmo/food/dairy-products-eggs/milk/worldwide#revenue [access: April 2023]

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## 4.Sports

### 4.1 Insights

Sports performance tests are a way of evaluating a person's physical prowess and motor skills, and they're intended to show people where they stand in terms of fitness and skill in many domains. These examinations frequently contain a variety of markers, including assessments of body composition, tests of muscle endurance and strength, sensitivity, and motor skills.

### 4.2 Problems

- Lack of resources: Government training groups may have trouble obtaining sufficient financing to purchase the essential equipment and technologies for monitoring and enhancing sports players' performance.
- Limited access to technology: Technology is not widely available: A lot of the tools and technologies used to track and enhance sports players' performance can be pricey and usage efficiently requires specialist knowledge. In developing nations or rural locations, government training institutions might not have access to these resources.
- Difficulty implementing changes: Implementing adjustments to training plans and athlete monitoring can be difficult, even with access to finance and modern technologies. Trainers and coaches could be uncooperative.
- Lack of uniformity: It may be challenging to compare players' performances or create customized training plans due to a lack of standardization across various sports or training regimens.
- Ethical issues: The use of specific tools and technologies, like blood lactate analysis or wearable technology that tracks athletes' fitness and health, can bring up issues with athlete privacy and the potential misuse of data.
- Limited time and resources: In countries where sport is not a government priority, coaches and trainers may have little time and money to spend to athlete monitoring and performance enhancement.

### 4.3 Needs

- Adequate funding: Adequate funding is required for government training organizations in order to purchase the equipment, know-how, and services needed to analyze and enhance athletes' performance.
- Technology availability: A lot of the instruments and systems used to track and enhance athletes' performance call on specific knowledge to operate properly. For government training groups to effectively promote athlete development, they need access to these resources.
- Trained coaches and trainers: Coaches and trainers with the appropriate qualifications are crucial for creating efficient training plans, keeping track of athletes' development, and pinpointing areas in which athletes need to improve.
- Standardized training and monitoring procedures: Standardized training and monitoring procedures can make it easier to compare and measure individual and team performance across sports.

- Effective communication and collaboration: To ensure that training regimens are customized to the needs of specific athletes and in line with overarching sport development objectives, it is crucial that coaches, trainers, athletes, and policymakers collaborate and communicate effectively.
- Ethical and legal frameworks: These are necessary to protect athletes' privacy and data and to ensure that they are not exposed to unnecessary risk or harm when using tools and technologies to track and improve sports players' performance.

### 4.4 Current Solution

- VO2 Max testing: This assesses an athlete's aerobic capacity by determining the maximum quantity of oxygen they can use while exercising.
- Force plates: It is possible to spot imbalances or weaknesses in the lower body by using force plates, which are used to monitor the ground response forces generated during activities like jumping or sprinting.
- Speed gates: Speed gates are electrical timing devices used to quantify sprint times over brief distances, such 10 or 20 meters.
- Video analysis software: Athletes' performances can be broken down and their technique, form, and movement patterns can be examined by coaches and trainers using a variety of video analysis software tools.
- Wearable technology: Examples include heart rate monitors to track cardiovascular response to exercise, GPS devices to track distance, speed, and acceleration during training and competition, and accelerometers to evaluate movement patterns.
- Blood lactate analysis: Analyzing blood lactate can be used to assess an athlete's anaerobic capacity and help determine the best training intensities since it monitors the quantity of lactic acid in the blood during exercise.

### 4.5 Our solutions

- Health monitoring: By delivering real-time data on biomarkers linked to fatigue, hydration, and other aspects that may affect performance, the Occam Dx electrochemical micro sensor may be utilized to monitor the health and fitness of athletes.
- Evaluation of performance: The sensor may be used to monitor biomarkers for muscular activity, metabolism, and other elements that influence sports performance. This might make it easier for coaches and trainers to assess athletes' development and pinpoint their weak points.
- Injury detection: The Occam Dx electrochemical microsensor may be utilized to detect inflammatory and tissue damage-related biomarkers, assisting in the early diagnosis of injury and enabling prompt treatment.
- Drug testing: The sensor may be used to quickly and accurately identify drugs in athlete samples, promoting fair competition and discouraging doping.

- Environmental monitoring: The Occam Dx electrochemical nano sensor may be used to identify contaminants or other environmental conditions, such as poor air quality or tainted water, that may have an effect on an athlete's health or performance.
- Data analysis: The sensor could produce a lot of information about an athlete's performance and health. This data might be analyzed using machine learning algorithms and data analysis tools to spot trends that could provide useful information.

### 4.6 Jobs to be done

- Performance tracking through analysing the sweat -
- Smart equipment: Smart equipment embedded with nano sensors can provide real-time data on an athlete's movements, such as the speed and trajectory of a ball, the forces exerted on a bat or racket, or the impact of a collision. This information can help coaches and athletes optimize their training and prevent injuries.
- Wearable nano sensors: Wearable devices that incorporate nano sensors can track an athlete's biometric data, such as heart rate, body temperature, and respiration, providing insights into their performance and health.

### 4.7 References

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