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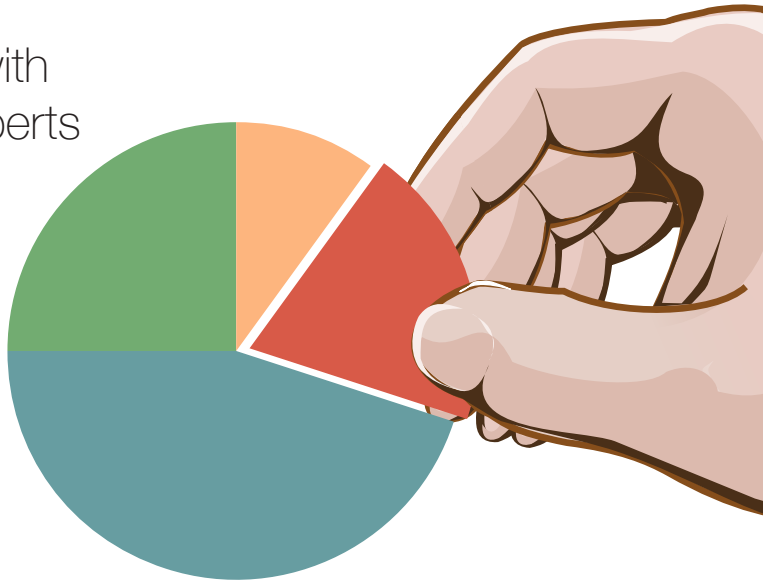
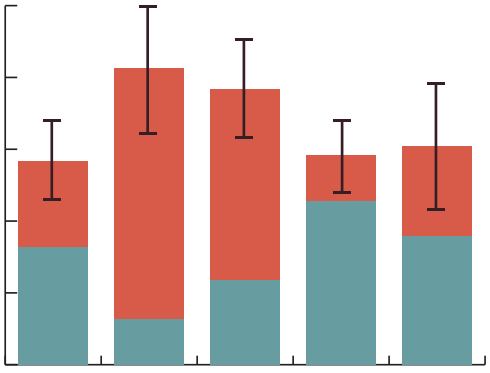
JUnQ

Statistics in Science - Is your Data Fitting?

(Mis)use of Statistics: Interviews with Statistic Experts



Commentary: Open Access Sharing



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Preface

Editorial Note

Dear Reader,

Even though I was a member of this editorial board for almost five years, I never wrote the editorial of an issue. Since I finished my university education and will soon start my industrial career, forcing me to leave JUnQ, it is my pleasure to write it for the current issue.

The feature topic this time deals with a problem, which has been in the press a lot lately: Misuse of Statistics. The highly fitting cover for this subject was once again designed by former editorial board member Robert Lindner.

Especially in the life sciences, many published results are not reproducible. But these publications are the foundation for further studies. Without being too negative, but this situation is highly critical, especially in the medical context, and corrections are of utmost importance. To allow a good overview of the scientific misconduct in statistics we contacted several experts of the field for interviews. Dr. Gerta Rücker, a biostatistician at the Medical Center of the University of Freiburg and associate of Cochrane Germany, was interviewed about the errors regularly observed in life science studies. She presents the reasons for misbehavior as well as some solutions on page XXXII.

But not only the life science are fields of erroneous statistics. Also physics and mathematics itself have to deal with this problem. Due to the similarity of both fields, two representatives of the respective fields were asked the same interview questions. Dr. Nicolai Bissantz is a mathematician and head of the work group "Inverse Problems" at the chair of stochastics at the University of Bochum. His answers from the mathematical point of view are presented on page XXXI. Our other interviewee is Dr. Rainer Wanke of the Institute of Physics of the University of Mainz. He is an experimental physicist, who works in particle detector development. His interview about the importance of statistics in physics can be found on page XXIX.

Starting this month, July 2016, we begin a cooperation with the Wiley-VCH journal "Chemie in unserer Zeit" (ChiuZ).[1] This German, bimonthly journal presents current topics of chemical research, which are presented in a way to allow laymen to understand the articles. We will present tidbits of JUnQ content to spread the message of the importance of negative results. Thank you, Dr. Fischer-Henningsen, editor in chief of ChiuZ, for the assistance in our challenge.

Furthermore, I am very happy to present three scientific contributions in this issue. A study about pretreatment of steel and zinc surfaces with phytic acid of M. Dornbusch *et al.* can be found in the Articles section at pages 1–7. We were also allowed to reprint an outstanding study of K. Roth *et al.* about chemical free household products on pages 8–9. This manuscript was originally published in ChiuZ and poses an interesting question to society about what an average person defines as chemical free or what he/she is afraid of in chemical containing products. Lastly, a study about waste water treatment in Pernambuco, Brazil *vs.* Hof, Germany by *C. Pahl et al.* is part of our Views on Life section on page 1.

I hope you will enjoy the second issue of JUnQ in 2016. It was a very educational, entertaining, and creative time for me in this team. Thank you very much!

—Andreas Neidlinger

[1] http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1521-3781

A Quick Word on Open Access Sharing

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Open access sharing contributes nowadays a major part to the publication process in many different scientific disciplines. One could think it is an invention of modern time, however, the idea to make data and literature widely available is quite old: Libraries. In 1836, Anthony Panizzi, the future principal librarian of the British Museum said:
"I want a poor student to have the same means of indulging his learned curiosity, of following his rational pursuits, of consulting the same authorities, of fathoming the most intricate inquiry as the richest man in the kingdom, as far as books go, and I contend that the government is bound to give him the most liberal and unlimited assistance in this respect."[1]
Sounds pretty much like the idea of open access sharing of modern times, just two key aspects were missing: Low cost reproduction of texts and fast, cheap and reliable transfer of the data. In modern times, this can be achieved by electronic documents and the internet – providing the biggest commonly available library that ever existed on earth. So, what is stopping us from extending this network? Why don't we have one huge library for all scientific disciplines? While following this question, we will discover that open access sharing in general might be currently at a critical point in its development.[2]
The hurdles open access in science has to face are the impact factor and money; or to be more precise, copyright. For many years, publishers were only intermediaries within the publication process. However, nowadays research-based journals do not pay for papers and pre-prints they receive and which appear in their journals (actually, they expect that authors pay fees for getting published), although they earn money by selling the finished issue. Researchers additionally assign their copyright to the publishers who can afterwards act as if they created the article.[2] The whole peer review process is also completely gratuitous.
While one could argue that researchers still get a lot out of this publishing culture, we can now close the loop to Mr. Panizzi: Academic literature that was funded by companies or society via taxes becomes exclusive again and is only available by paying significant license fees to the (monopolistic) journals. Their profit margins here are correspondingly large, while at the same time some universities cannot afford the access licenses anymore.[3,4]
In times of the internet there is, however, an alternative: Open access websites like arxiv.org, which was one of the first established platforms.[5] Arxiv went online in 1991 as an initiative of physics professor Paul Ginsparg. More than 20 years[6] after its launch, it has become one of the biggest open access websites with thousands of submissions per month.[2] Eventually, the journals had to adapt to the new system and introduced a hybrid system. In this context, 'hybrid' refers to journals that "carry both open-access and traditional-access articles: an extra fee (...) has to be paid in order to make an article in it freely available to all."[2] This was meant to be a transition to purely open access based publications, however, the publication fee (including the additional open access fee) eventually rose to twice the required payment for a "born-digital full open access journal".[7] Therefore, the hybrid journals still charged significant fees while the open access trend was meant to reduce the overall costs. Several alternative systems followed, but never really reduced the overall costs, maintaining the huge profit margins of the journals. All the old difficulties between traditional paid access licensing and open access remained in place.[2]
Currently, established journals show increasing interest in buying open access platforms. Richard Poynder, an independent journalist who observed the open access world for more than a decade sees the development now at a critical point:
"In the end, the key question is whether the research community has the commitment, the stamina, the organizational chops and/or the resources to reclaim scholarly communication. While I would love to end on a positive note, I am personally doubtful that it has. The fact is that, OA [open access, note by JUnQ] advocates aside, there does not appear to be much appetite in the research community for giving up publishing in prestigious journals, and abandoning the notorious Impact Factor. More importantly, university managers and funders do not want to see anything that radical occur. We live in an age of bureaucratic scrutiny, and scrutineers crave simple and standard ways of practicing their dark arts. That is exactly what the IF [impact factor, note by JUnQ] and legacy journals provide. If I am right, OA will surely remain a half-revolution, for now at least."[8]
Of course, not everyone sees the open access development negatively. Many scientists expect the original open access idea to win eventually. Currently, there are a few attempts

to force an open access data base for paid publications. The illegal website Sci-Hub is one example or the tragic story of Aaron Swartz.[2,9] Open access for everyone cannot and should not be an illegal enterprise and we can only hope to, in the end, find a compromise between traditional publishing and open access sharing that keeps the quality of scientific articles on a high level and is, on the other hand, acceptable for the publishing houses. So that in the end we meet Anthony Panizzi's idea of widely accessible knowledge for everyone.

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Extensive Material for Further Reading Provided by the UNESCO:
www.unesco.org/new/en/communication-and-information/resources/news-and-in-focus-articles/all-news/news/unescos_open_access_oa_curriculum_is_now_online

The Use of the Term "People" in Research –

a Commentary on "Most People are not WEIRD" by Joseph Henrich *et al.*, Nature (2010)

Prof. Joseph Henrich[1] is an anthropologist at the Department of Human Evolutionary Biology at Harvard University, Cambridge, USA. His focus is on evolutionary approaches to psychology, decision-making and culture. Together with his colleagues Stephen J. Heine and Ara Norenzayan at the University of British Columbia, Vancouver, CA, he was the first to point out that, in economics, psychology and cognitive science, conclusions are generally drawn from study participants with the same background: Western, Educated, Industrialized, Rich and Democratic (WEIRD). In addition, primarily students form the majority of test subjects. Still, researchers – often unintentionally – claim that their findings apply to everybody.

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Let's do a thought experiment. You are a researcher and you are particularly interested in human social behavior. You design an experiment, in which your human participants are solving a task, let's say 50 trials of the shell game. In addition, you introduce a reward component and they win money upon correct answers. After the third correct hit, you tell half your participants, that you only have a budget of 100 € per day to spend on your subjects. Therefore, the more money each person wins, the less you have left for the subsequent experiment. The other half of your experimental group is not told that you have budget restrictions, because you would like to see how the general performance in that task is. And, frankly, you have more money to give away and your initial enquiry is to find out whether persons in the first experimental group behave any differently once they are told that the game they play might leave other persons at a disadvantage.

After testing 100 persons, you find that both experimental groups show equal performance. You write a paper about your findings and title it "Humans do not renounce reward in a gambling task for the good of other players". Your statistics are flawless, your group size adequate, and your experimental design state of the art. Nevertheless, there is one flaw about it that cannot be canceled out by simple math. Ok, the group size was age- and gender-matched; but who exactly are your test subjects? You managed to recruit mostly people from the moderate radius of the city you conduct your research in. It is hard to convince persons who live in distinct cities to come to your site for a test that lasts approximately 30 mins and that remunerates subjects with at most 100 €. Furthermore, there were a lot of students who participated, because they were actively seeking for these kinds of tests to earn a few euros on the side. What they for sure all have in common, is that they are humans (yes, it's a thought experiment but we're not in Metropolis or in San Fernando Valley, so neither Superman nor Alf participated).

So, you assume that your findings apply to humans, because that seems like the best and shortest description of your entire subject pool. However, those people are only a minute fraction of more than 7 billion humans living on Earth; humans living on different continents, several time zones, having different cultures and a different history. Of course, you might as well name your paper "People living in Gotham city do not renounce reward in a gambling task for the good of other players", however this could falsely indicate that your results hold true only for this specific city. You are pretty sure that you could potentially reproduce the same findings in most of the other cities of your country. Therefore, the exact spatial or temporal location of your subject pool might not be the key criterion for obtaining specifically these results. It is the culture and history they share that makes them behave the way they do.

The generalization of the term "humans" in research was bothering the team of Joseph Henrich, Stephen J. Heine and Ara Norenzayan at the University of British Columbia already in 2010. In their Nature opinion article, they point out that "Most people are not WEIRD".[1] This slightly ambiguous abbreviation comprises Western, Educated, Industrialized, Rich, and Democratic and basically describes Western Societies. The term was chosen because it "creates a mirror in which we see ourselves in reflection", says Henrich. The team firstly created awareness of the fact, that scientists use the words "humans" or "people" to describe only a small percentage of persons that share the same cultural and historical background, namely the North American and European one.[2] However, the use of these words suggests that their findings apply to anybody, which rarely holds true when studying human behavior. If we tried to reproduce our thought experiment in a non-WEIRD environment, it is likely that the subjects would react differently. To put it in a more neuroscientific context: behavior is complex and individual, that's why we distinguish it from reflexes, which are simple and common within one species.[3] Moreover, the team around Henrich noted that a big portion of data was acquired by studying behavior of students, just like the data

of our thought experiment. As mentioned above, students often actively seek to participate at experimental studies and are more likely to hear about such studies because they spend most of their time at the university, where most of these studies are conducted.
Since the publication on this issue, six years have passed. Joseph Henrich, who is now at the Department of Human Evolutionary Biology in Harvard, reports that it had an impact on the use of the terms "people" and "humans" in research: "There have been changes, but only slowly. Economics has responded most efficiently. Parts of psychology have responded, but other parts remain unmoved. Many psychologists don't really know how to respond.". JUnQ furthermore asked Henrich by which means researchers could include "non-WEIRD" study participants into their experiments nowadays. Henrich points out that they have already performed several large-scale comparative projects using teams of researchers to collect ethnographic and experimental data in diverse societies. These studies provide a model that other scientists could build upon.
To sum up, the findings that we conclude from our data do not only depend on good experimental design and the use of proper statistics, but also on the perspective out of which we look at them. Sometimes, we need to take a step backwards and reconsider if not only the numbers are normally distributed but also the sample pool, out of which we caught the fish.

—Theresa Weidner

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[2] J. Henrich, S. J. Heine, A. Norenzayan, *Behav. Brain Sci.* **2010**, *33*, 61–83.
[3] I. P. Pavlov, Lecture on conditioned reflexes **1941**, *2*, 199 pp.

(Mis)Use of Statistics in Science – Interview with Dr. Rainer Wanke

Dr. Rainer Wanke[1] is a physicist working in the field of experimental particle physics at the University of Mainz, Germany. He is working on the NA62 experiment at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland, which measures ultra-rare K-meson decays. This involves both, particle detector development and the analysis of data taken with those particle detectors. He furthermore teaches statistics for undergraduate students in Mainz.

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JUnQ: In your view, how important is statistics in your discipline, also compared to other disciplines, e.g., physics, chemistry, biology, psychology?

Dr. Wanke: A very good knowledge of statistics is indispensable for data analysis in particle physics. As all processes are quantum mechanical, i.e. intrinsically random, statistics is the only way to describe them. It is used for determining probabilities, efficiencies, and limit setting for very rare processes, and last but not least in Monte Carlo simulations of physics processes as decays and detector interactions of particles. The statistical methods used in particle physics are very often highly sophisticated and discussed within the community, with still many papers being published on specific topics as, e.g. limit setting. Since I'm a physicist and not working in another discipline, it is a bit difficult for me to compare the statistics used in particle physics to those in other disciplines. At a glance, it seems to me that other disciplines – in particular medicine and social sciences – do not use nor need as highly specialized methods. However, they also do have other needs like, e.g. determination of regressions, which is of not much use in particle physics.

JUnQ: In your opinion, is it important that only mathematicians teach statistics?

Dr. Wanke: In particle physics, all more recent relevant text books and publications have been written by particle or nuclear physicists. In my opinion, mathematicians would not have the overview nor the experience of the special topics of statistics needed in particle physics. In fact, I do not know any institute, where (higher) statistics for physics data analysis is taught by mathematicians.

JUnQ: Should students from different fields have the same statistics training or should this be individually adjusted for different fields (e.g. physics vs. biology)?

Dr. Wanke: Since the requirements are very different between the different disciplines, there should also be different statistics courses, at least for the more advanced methods. Basic knowledge as means and variances, error propagation, least-squares method, etc., which is already relevant for beginners lab courses, of course can easily be taught together.

JUnQ: Do you teach statistics in your own discipline / in other disciplines? If yes, in which phase of the students' education?

Dr. Wanke: I am teaching statistics and data analysis for the Master of Science in Physics.

JUnQ: To your mind, is statistics in general taught in an appropriate way in your discipline so that, e.g., PhD students are capable of applying statistics to the interpretation of their data in a correct way?

Dr. Wanke: When I was studying (in the 80's), statistics courses for physicists were very rare or non-existent and I had to learn it myself during my PhD from the only existing textbook. Today it looks much better and I believe that any serious Physics Master of Science program involves a course in advanced statistics. For PhD students in particle physics, there even exist schools of one or two weeks, which teach advanced topics of statistics used in particle physics. Still, the situation for basic statistics as, e.g. needed in lab courses, does not always seem to be sufficient: very often basic statistical methods are just taught in an introductory lesson of the lab courses, only aiming on the direct application but not at any deeper understanding of the underlying principles.

JUnQ: What is the usual sample size you are dealing with?

Dr. Wanke: Very different: from 0 events to several billions.

JUnQ: Do you think that it's common practice to exclude "outliers"?

Dr. Wanke: No. However, in particle physics we are in a bit of a privileged situation: Usually we take millions and billions of data events under the very same conditions, therefore we usually do not have good arguments to exclude single "outliers".

JUnQ: Have you ever experienced misuse of statistics to make data appear better than it actually is?

Dr. Wanke: I do not remember any case in my personal environment in my whole career, that statistics were intentionally misused. However, unintentional misuse happens quite frequently in my opinion. The reason is practically always that selection criteria are chosen by looking at the data. This is in most cases (and all cases I know) not bad intention, but a mixture of laziness and unawareness. Performing a "blind analysis" usually requires a lot of effort and, in addition, the need of a blind analysis is very often not realized.

JUnQ: What do you think can be done on the educational level to improve good scientific practice regarding statistics?

Dr. Wanke: Statistics courses should probably be more applied and less theoretical. In particular, the problem mentioned in the previous answer needs to be addressed and emphasized.

JUnQ: Thank you very much for this interview!

—Kai Litzius

(Mis)Use of Statistics in Science– Interview with PD Dr. Nicolai Bissantz

PD Dr. Nicolai Bissantz[1] is a mathematician at the Ruhr University Bochum, Germany. His research fields are applied and mathematical statistics, in particular with applications in science and engineering. Amongst these fields are applications of statistical inverse problems in astronomy and in image reconstruction. Such problems arise e.g., in the recovery of images from fluorescence microscopy imaging and in medical imaging devices such as PET (positron emission tomography).

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JUnQ: In your opinion, is it important that only mathematicians teach statistics?

PD Dr. Bissantz: Understanding the results from a statistical analysis requires both experience with the basics and advanced ideas behind the methods which are applied and some understanding of the field of application to understand the implications of the result. Hence, statistics for science should in my opinion be taught by mathematicians (or very closely related fields like, theoretical physics) who should have a good knowledge of the field of application.

JUnQ: Should students from different fields have the same statistics training or should this be individually adjusted for different fields (e.g. physics vs. biology)?

PD Dr. Bissantz: Statistics is statistics, i.e. the basic methods are globally the same. However, there are particular specialities and often rather different methods used in the different disciplines. Moreover, understanding statistics appears to be much more straightforward if the lecture is based on examples well known to the students. Hence, it is preferable to have specific lectures for the different fields. Nevertheless, e.g. students from science should all have some advantage from taking a lecture such as statistics for biology if it is of substantial quality (e.g. includes examples, focuses on the main ideas, etc.).

JUnQ: Do you teach statistics in your own discipline / in other disciplines? If yes, in which phase of the students' education?

PD Dr. Bissantz: Both for math and for students from geography and biology in the bachelor / master phase and as courses and as statistical consulting for students from all subjects with a focus on the MINT (math, informatics, science, engineering) subjects and psychology for bachelor, master, PhD thesis projects and advanced projects from postdocs etc.

JUnQ: To your mind, is statistics in general taught in an appropriate way in your discipline so that, e.g., PhD students are capable of applying statistics to the interpretation of their data in a correct way?

PD Dr. Bissantz: I hope (and think) that this is the case for our statistics lectures, in particular for students from other fields (of course also for mathematicians). At some universities, there may be, to my experience, lectures for non-mathematicians somewhat too much biased to a main subject math lecture.

JUnQ: Have you ever experienced misuse of statistics to make data appear better than it actually is?

PD Dr. Bissantz: Not in science and academics. However, obviously in the public discussion (in newspapers, TV news etc.) this is ubiquitous – some well-known popular books are full of examples collected from a variety of sources.

JUnQ: What do you think can be done on the educational level to improve good scientific practice regarding statistics?

PD Dr. Bissantz: Close collaboration with applied statisticians in research projects should start at an early phase, if possible in the phase of experimental design. In general, interdisciplinary teaching and research should be ranked high to attract, both from math and applied fields, high ranking teachers and researchers.

JUnQ: Thank you very much for this interview!

—Jennifer Heidrich

(Mis)Use of Statistics in Science – Interview with Dr. Gerta Rücker

Dr. Gerta Rücker,[1] a mathematician by training, works as a biostatistician at the Medical Center – University of Freiburg, Germany. Her special area is meta-analysis, and she is associated with Cochrane Germany. She has written a large number of research papers on statistical methods, and co-authored a number of Cochrane reviews. Additionally, she is engaged in teaching meta-analysis methods and is one of the authors of a book 'Use R for meta-analysis'.

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JUnQ: Dear Dr. Rücker, you are familiar with misconduct and errors in scientific publications and studies as well as with the publication bias. Furthermore, you are an expert in the statistical sector. Can you please explain the importance of good statistics? Or more importantly, how easy or difficult is it to look at statistics objectively?

Dr. Rücker: Two different questions. Good statistics is important because all empirical science results in data, sometimes "Big data", that is, numbers, lots of numbers. Whether big data or very small data sets (as often found in the medical science) – it is impossible to make inference without certain skills in how to analyze them. This is what statisticians are qualified for. To the second question: First, admittedly, statisticians, particularly in Germany, sometimes have failed to explain their methods sufficiently clearly to the public (it is a little different in Britain, with its much older and better developed statistical culture). Secondly, there is a broad range of statistical methods, and often more than one approach is appropriate for a research question. But finally, undoubtedly, statistics is a science with rigorous methods, and statistical education should play a greater role in the curricula of all sciences, especially the life sciences, and even the humanities.

JUnQ: What is, in your opinion, the biggest problem with interpretation from statistics in the life sciences?

Dr. Rücker: The dominance of the p-value! This recently has been spoken out clearly in a statement of the American Statistical Association (ASA), published in the American Statistician and accompanied by twenty invited commentaries very much worth reading.[1] There, leading statisticians from all over the world plea for abandoning the unfortunate big role of hypothesis testing, p-values and the arbitrary 5% threshold. Instead, statistical modeling, estimation with uncertainty and Bayesian methods should be preferred. Unfortunately, statisticians over decades have failed to convey this message when teaching statistics.

JUnQ: In the last few years several studies showed that up to 80% of preclinical studies are not reproducible, i.e., in spite of scientific publications stating positive results, the data is erroneous. How is such a big percentage possible?

Dr. Rücker: For a long time, clinical researchers have been told that they should produce as many "significant" results as possible. Consequently, they do lots of experiments, look at lots of hypotheses, look at lots of outcomes or models, until they find a significant p-value, which they finally decide to publish. If someone else repeats just this experiment, he must fail. There are many names for this kind of conduct – p-hacking, data dredging, publication bias.

JUnQ: Glenn Begley, a former employee of Amgen, recently cited a conversation he had with a scientist about a cancer study published in Cancer Cell.[2] He and his team tried to reproduce the published results, but failed a hundred times. The author of the study said: "Oh yes, we performed this experiment about a dozen times and achieved the published result only once. But in the end, we decided to publish exactly this." How can it be that experienced scientists deal with experimental data in that way? It is obviously incorrect and can even be very dangerous in the case of medical studies.

Dr. Rücker: Just as I said, this example is by no means an exception. It also demonstrates that the problem goes far beyond statistics. I cite Stephen Senn, who in his commentary to the ASA statement noted psychological reasons for these kinds of misconduct: "An impatience with the necessary nuances of expression that good statistical reporting requires; the (usual) prejudice of scientific journals in favor of 'positive' results; the common habit of transforming

[1]R. L. Wasserstein, N. A. Lazar, *Am. Stat.* **2016**, *70*, 129–133.

[2]http://www.deutschlandfunk.de/wissenschaftsmuell-wenn-forschung-nicht-haelt-was-sie.740.de.html?dram:article_id=330956 (last access on 24.05.2016).

shades of gray into either black or white; and the desire of individual scientists for recognition and reward."

JUnQ: During our research about the subject, we found two different extremes. First, there are huge studies with a great amount of data albeit with an unclear formulation of the question. And second, very small studies with too few participants. To deal with the first mentioned extreme of immense amount of data: It is obvious that one can find proof for nearly every hypothesis if the amount of data is large enough. In case of studies in which the initial problems are not clearly identified, this allows the researcher to find some positive results. Can you please explain why this is not a good scientific practice? Is it not often the case that you find the greatest results in science serendipitously?

Dr. Rücker: We distinguish two approaches: the exploratory or hypothesis-generating approach, and the confirmatory or hypothesis-proving approach. If you have a huge data set and no particular idea (this is often the case in genome-wide association studies) it is completely legitimate to look at millions of p-values first. But you have to be very clear that this is only the very first step, it is completely exploratory. Statisticians working in the area of high-dimensional data are currently working on refined methods of model selection for this huge challenge. Only after further steps of model selection in a statistically principled way, we can expect reproducible results.
I definitely agree that serendipity plays a great role in science. However, both before and after the great moment of a discovery, science is very hard unspectacular work, first in order to come up with the idea and to recognize its meaning, and afterwards to prove its usefulness.[3]

JUnQ: And for the other extreme of studies with too small a data set: Why is it so that a researcher is almost guaranteed to find the desired results if there are too few participants in the study? What is meant by "regression towards the mean"?

Dr. Rücker: It is by no means guaranteed that a researcher finds the desired result in a small study. On the contrary, in most cases the researcher does not find the desired result and therefore switches to another outcome, a different analysis, deletes some observations, or doesn't publish the study at all. At the end of the day, we mainly see "desired results".
"Regression to the mean" is a different issue. If you have a strong headache and see the doctor (or not so), you will feel better the next day, the most probable reason being that you felt so very bad the day before. Likewise, if a study investigator selects only patients in the worst health, these patients are likely to benefit more from the treatment than patients with mild disease, whose health would improve anyway, with or without treatment.

JUnQ: "Statistical power" is a term for the necessary number of cases in a study to achieve significant results. Can you please explain how it is defined and why many studies lack statistical power even though most medical scientists should be aware of the problem?

Dr. Rücker: Statistical power is not the number of cases. Rather, it is a probability. The power of a statistical hypothesis test, designed to compare the outcome between two treatments, is the probability that a pre-specified difference between the two treatments can be demonstrated by the test. It depends, among other things, on the number of cases: the larger the sample size, the greater the power.
Why do many studies lack statistical power? There is a simple explanation, at least for the medical science: clinical trials, particularly if conducted thoroughly, are extremely expensive. Most doctors want to do their MD degree, they cannot invest much time or money, and simply collect some existing data for a simple analysis.

JUnQ: Even though this terminology – exploratory and confirmatory study – should be clear to researchers with statistical background, why are many exploratory studies published in a way so that they seem confirmatory? What is the biggest danger behind such an approach?

Dr. Rücker: Many clinical researchers are trained physicians. Physicians are used to making decisions. If there is a patient in want of a diagnosis or in need of a treatment just before you, you must make a decision. Even to do nothing and to send the patient home to bed is a decision. My experience is that physicians are not used to accepting uncertainty. They even don't accept continuous variables, they always want to classify and to dichotomize. It is all black and white. This is one reason why the p-value is so attractive to them, and why they only reluctantly accept that a result might be exploratory. They always want certainty.

JUnQ: Apart from these clear errors in basic statistical procedure, many studies are executed without proper systematic literature studies. The British journal Lancet published an article series "Research: increasing value, reducing waste" in 2014 about the problematic situation of results in medical studies, i.e., poor study design, inaccessible research, and selective reporting.[4] Accordingly, a lot of studies only repeat previous work leading to waste of time and money. Or they are predestined to fail. Are the scientists just too lazy to design their study properly or is there a different problem in dealing with published results?

Dr. Rücker: I already mentioned some of the reasons: lack of time, money, patience, education. Also, often there are soft factors with very negative impact like career needs, reputation of institutions or other dependencies in the academic world.

[3] J. Kimmelman, J. S. Mogil, U. Dirnagl, *PLoS Biol.* **2014**, *12*, e1001863.
[4] http://www.thelancet.com/series/research (last access on 24.05.2016).

JUnQ: Due to the publication bias, i.e., the predisposition to publish mostly positive results, many medical studies remain unpublished. Can you give us an estimate of the percentage of unpublished studies?

Dr. Rücker: 50%. It is a very stable figure that has been reproduced in many studies around the world.[5]

JUnQ: Why does this count towards being a huge problem?

Dr. Rücker: The answer to a research question provided by a study often helps only future patients. The patients who volunteered to participate in a clinical trial may not benefit from their participation. Their motivation for participating is the desire to help others. Having this in mind, we have a strong ethical obligation to make all research results available to the public by publishing it. Secondly, being published or not is strongly dependent on the results of a study. So-called "negative" results are much more likely to remain unpublished, resulting in a strongly biased evidence base for all following steps in the knowledge process. The result is strong over-optimism in the assessment of diagnostic tests and therapies.

JUnQ: What leads to such gross misbehavior? Is the education of junior scientists flawed or might there be a place for incorrect motivation set by the current publication system?

Dr. Rücker: Both. I don't think that "the publication system" is the biggest problem. A well conducted study with sufficient power for answering a relevant question will almost surely be published. But, undoubtedly, there are some deficiencies in the education of young scientists, at least in Germany.

JUnQ: Since this is no new problem, most scientists should be aware of the issue. However, the present procedure changes only very slowly. Can you think of an easy to implement viable solution?

Dr. Rücker: Some instruments already have been implemented, at least in clinical medicine, such as trial registration and reporting guidelines. The role of statistics is more acknowledged and better positioned in teaching and clinic than twenty or thirty years ago, think of the well developed methodology of systematic reviews and Cochrane. However, in basic research, animal experiments, and medical devices, we are far from the standards that would be desirable. There is not much hope that a viable solution will quickly lead to substantial improvements. It is rather an ongoing struggle to keep and improve quality, and a major and probably effective step would be to include these issues in the education of students and later in the training of scientists.

JUnQ: Thank you very much for the interview!

—Andreas Neidlinger and Soham Roy

[5] A. Blümle, J. J. Meerpohl, M. Schumacher, E. von Elm, *PLoS One* **2014**, *9*, e87184.

Questions of the Week

The Journal of Unsolved Questions presents a "Question of the Week" on its homepage every week. Set up and formulated by the members of the editorial board, or guest writers, the main purpose of the "Question of the Week" consists in intriguing the reader by presenting topics of ongoing research. "Questions of the Week" published so far cover a wide variety of scientific fields, but share the feature to be of certain interest to several disciplines.
In the following, we present selected "Questions of the Week" from the last six months.

The Origin of the Moon

by Nicola Reusch

In the history of mankind, the sky above us has always fascinated and inspired. Many investigations with different scientific questions have led to great progress towards better understanding of the universe and our solar system. But many questions are still waiting to be answered – not only in the distant universe, but also in our direct neighborhood. One such question is about the origin of the moon.

Astronomers have presented several hypothesis how the satellite of the earth could have been formed. Most likely, the moon has not been captured and is also not the result of a fission process.[1] Nowadays, most scientists agree on the giant impact hypothesis: Another celestial object named Theia collided with the proto-earth about 4.5 billion years ago.[2] After the impact, matter in the orbit around our planet could have accumulated to form the moon. Compared to other planet and satellite pairs, the moon is peculiarly large. To explain the corresponding angular momentum, Theia must have been as large as Mars.[3] But this hypothesis does not explain all characteristics of the moon. Whereas the density differs between the earth and the moon, the chemical composition, mainly investigated in terms of abundances of some element isotope ratios (e.g. oxygen, titanium, or tungsten), is rather similar. This is odd, because most other objects in our solar system show significant differences that represent their different origin in the solar system. Therefore, the moon's chemical composition should resemble the one of Theia – at least for the assumed impact angle and velocity and mass ratios.[3]

One possible solution: coincidence! The composition of proto-earth and Theia as collision partners must have been similar. Earlier this was thought to be too unlikely, but new investigations and simulations show that there is a certain probability of about 20% for this incident to happen.[1] Subtle differences in isotope ratios may be the result of a late accretion following the impact.[4,5] But why this accretion led to the isotope ratios astronomers observe nowadays, still remains a riddle.

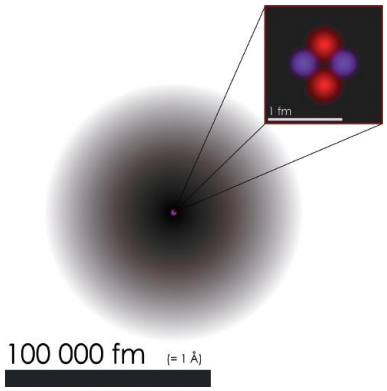
Read more:

[1] A. Mastrobuono-Battisti, H. B. Perets, S. N. Raymond, *Nature* **2015**, *520*, 212–215.
[2] R. M. Canup, E. Asphaug, *Nature* **2001**, *412*, 708–712.
[3] R. M. Canup, *Icarus* **2004**, *168*, 433–456.
[4] M. Touboul, I. S. Puchtel, R. J. Walker, *Nature* **2015**, *520*, 530–533.
[5] T. S. Kruijer, T. Kleine, M. Fischer-Goedde, P. Sprung, *Nature* **2015**, *520*, 534–537.

What is the Size of an Atom?

by Kristina Klinker

This might seem to be a very odd question at first, because we practically know everything about particles, atoms, molecules, and their sizes, right? When we are in school, we learn that an atom is composed of a nucleus, which is very small in comparison to the atom itself and is surrounded by a "cloud of electrons". This description implies already that we cannot be sure, where the electrons actually are; we describe this fact as electron densities, thus entailing that an atom does not have clearly defined edges. In theory, an electron can be found in any distance from the nucleus, but the probability decreases substantially when you go farther away. This is the case because of what we call wave–particle dualism.



Visualization of a Helium atom.[1]

[1] "The helium atom" by user:Yzmo. Licensed under CC BY-SA 3.0 via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:Helium_atom_QM.svg.

An electron behaves like a particle as we know from classical physics, but due to its very small size, an electron can also be described as a wave following the laws of quantum mechanics. Among other methods, people have used a type of scanning probe microscopy called atomic force microscopy (AFM) to determine actual radii of atoms. AFM relies on the detection of the interaction of a sample and a very sharp tip. It is a little bit as if a finger would profile an atomic surface. In contrast to optical microscopy methods, the resolution of AFM is not constrained by the optical diffraction limit, which makes the visualization of single atoms possible. But since this interaction between the tip and the sample atom depends on the respective electron clouds described by a certain wave function, it would not be fair to say that we know the definitive size of an atom.

Read more:

[1] F. J. Giessibl, *Mater. Today* **2005**, *8*, 32–41.
[2] http://blog.thingswedontknow.com/2015/02/how-big-are-atoms.html (last access 10.01.2016)

What Moves the Rocks of Death Valley National Park?

by Tatjana Dänzer

As we all learned in our childhood, solid rocks belong to the abiotic environment and cannot move by their own selves. They have no will of their own and besides, no locomotor system.

The rocks in Racetrack Playa, located in the Death Valley National Park in south-west USA – a hostile place of annual heat records (the hottest temperature on earth since recording was measured in the Death Valley in July 1913 and came to 56.7 °C)[1] – however seem to overrule this fundamental law of biology.

The name Racetrack Playa is no accident: over decades, tens to hundreds of rocks have been found with tracks behind them as if they were slowly sliding leaving grooves in the dusty soil (Figure 1). The tracks are often parallel and run in the same direction looking as if the rocks were participating in a slow-motion race (Figure 2).

Figure 1. Rock with a distinct track.[2]

This phenomenon was first discovered in 1948 and started versatile speculations about its origin. Some of the rocks weigh more than a hundred kilos, so help by humans is only possible with heavy equipment but no such traces can be found around them. Mud and even slime-producing algae as well as the weather were considered.[2]

Wind in conjunction with ice floes, as the most possible critical factors for rock movement, were supposed for years but no direct observation was made since studying in person is not recommended due to the temperatures and the restricted access in the Death Valley. But during the winter of 2013/2014, the group of Richard D. Norris and James M. Norris was able to monitor the motion using GPS in combination with information from weather stations.[3] Several rocks were provided with GPS transmitters and the area was observed by time lapse photography. Between November and February most of the Playa was covered by a shallow rainwater pool which froze at night-time. During sunny and windy days the ice melted partly and the rocks were driven on their ice sheets by the wind and running water. On this occasion, they pushed the mud beneath them aside forming long flat furrows. Some rocks only glided a few meters, some travelled up to 66 m and some shared an ice sheet which produced parallel lines. Under some rocks, the ice was already crushed so they showed no movement at all. At the end of February, the temperatures rose, the water evaporated and the spurs were exposed. Norris' results prove that freezing temperatures for the formation of ice sheets and wind forces of 3–5 m/s are necessary for a rock movement of 2–5 m/min whereas the velocity is also dependent on the individual texture of the stone's surface and weight.[3]

Figure 2. Aerial image of rocks moving in the same direction.[3]

This is an excellent example of a long unexplained phenomenon that finally found elucidation by rigorous re-

[2] "The Racetrack in Death Valley, Ca" by user:Tahoenathan. Licensed under CC BY-SA 3.0 via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:Runningrock2.jpg.

[3] "Sailing Stones at Racetrack Playa, Death Valley National Park, California, USA. The image shows the tracks of rocks that were moved by floating ice on a thin water layer." by users:Richard D. Norris, James M. Norris, Ralph D. Lorenz, Jib Ray, Brian Jackson. Licensed under CC BY 1.0 via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:Racetrack_playa_2013-12-20.jpg.

search. Do such allegedly mysterious occurrences lose their charm by an objective, scientific clarification like this? No! On the contrary, they show how complex and versatile the interactions of nature's mechanisms are even by such a peculiar phenomenon as the wind-driven "wandering" rocks in the desert.

Read more:

[1] http://wmo.asu.edu/world-highest-temperature (last access 17.01.2016)

[2] R. P. Sharp, D. L. Carey, J. B. Reid, P. J. Polissar, M. L. Williams, *Geol. Soc. Am.* **1996**, 765–767.

[3] R. D. Norris, J. M. Norris, R. D. Lorenz, J. Ray, B. Jackson, *PLoS One* **2014**, *9*, 1–11.

The Hum – Imagination or Unsolved Question?

by Andreas Neidlinger

Tinnitus – the non-stopping auditive experience – is a well-known malady. Patients with tinnitus hear sounds even though no source of this acoustic impression is present; at least not outside of the brain.[1] The source of the sound is in fact inside the brain, which is proven by several observations. Firstly, patients whose acoustic nerves have been severed still "hear" the sound. And secondly, the acoustic sensation is independent of the position of the ears. Both facts do not comply with regular sounds. Furthermore, EEG analysis showed that neuronal activity is altered in tinnitus patients.[2]

In the current Question of the Week, however, I do not want to focus on tinnitus, but on another similar phenomenon: The Hum. First mentioned in the 60s of the previous century, the hum has been detected around the world.[3] But what is this hum? People who complain about it "hear" a low-frequency humming sound similar to a diesel engine or a turbine without any physical source.[4] But what is the difference compared to regular tinnitus? It displays some dissimilar properties like varying volumes depending on the location of the patient and modulation, e.g. it is not perceived as a single tone but more as a vibrato like sound.[5]

So if it is not tinnitus, what is the reason for the hum? There are a variety of speculations. Most of them assign the hum to electromagnetic fields emitted by modern technology like mobile telephones or sending masts as well as Wi-Fi networks. But this cannot be the (only) case, since the hum was already described before these technologies existed. Until now, no unambiguous explanation for the hum exists, but it is mainly described in high-technology societies like Europe or Northern America.[6] This however might just be accounted to limited data from other countries of the world. In fact, the hum is still an unsolved question and it remains unclear if it indeed has an origin which waits for its detection or if it is just the imagination of the patients.

Read more:

[1] http://www.entnet.org/content/tinnitus (last access 20.06.2016)

[2] I. Adamchic, B. Langguth, C. Hauptmann, P. A. Tass, *Front. Neurosci.* **2014**, *8*, 284.

[3] http://www.sueddeutsche.de/gesundheit/akustisches-phaenomen-das-brummen-im-schwarzwald-1.2286219 (last access 20.06.2016)

[4] http://www.dailymail.co.uk/sciencetech/article-1184592/Have-heard-The-Hum-The-throbbing-noise-just-wont-away.html (last access 20.06.2016)

[5] http://acousticalsociety.org/sites/default/files/docs/echoes/v5n3.pdf (last access 20.06.2016)

[6] http://www.thehum.info/ (last access 20.06.2016)

Are We Getting Smarter? (The Flynn Effect)

by Jennifer Heidrich

Have you ever wondered if you are smarter than your parents or grandparents? Actually, that might not be completely unlikely! At least according to the so called Flynn effect, which was first described in 1984 by the political scientist James Robert Flynn.[1] It refers to the observation that a generation scores in average slightly higher on an IQ test[4] than the generation before. This effect has been investigated for more than 20 industrial countries and for different types of intelligence tests that were specified on problem-solving (fluid intelligence) and knowledge and experience-based questions (crystallized intelligence), respectively.

Many people do not believe in the IQ test as a benchmark for intelligence and therefore seek a different explanation than increasing intelligence for Flynn's observation. They argue that the measured IQ might just be related to something else, for example a training effect.

Anyways, according to Flynn, statistics seemed convenient. But if we really are getting smarter, the central question that arises is, of course: Why? The discovery heated up the old genes vs. socialization influence debate. Dealing with the latter, different theories were developed in the last decades:[2]

- **Social environment:** As the world is getting more and more complex due to modernization and new technologies, people are more often confronted with abstract concepts.

[4] The informative value of an IQ test is widely discussed and will be a topic for a Question of the Week in the future.

- **Education:** Probably there is a connection between intelligence and learning. The education in general has been improved in the last century – schools are getting better equipped and school attendance is compulsory.
- **Dedicated parents:** In general, parents are more dedicated to seek for a more inspiring environment for their children, than they had for themselves.
- **Nutrition:** Nowadays, people are better nourished compared to earlier generations.

What people obviously have learned from Flynn's discovery is that there needs to be a regular updating for IQ tests and other tests in order to reset the normal distribution to the average value of 100.
Is the Flynn effect ongoing or is it just describing IQ test results from the first three-quarters of the 20th century? More recent studies indicate that the test results in Norway are more or less stable since the nineties.[3] Another publication even claimed a recent reversal of the Flynn effect.[4] In 2012, on the other hand, Flynn himself pointed out that there are new statistics leading to an increasing IQ.[5]
At least we can agree, that the Flynn effect is a controversial field in psychology and will keep scientists busy for many more years.

Read more:

[1] J. R. Flynn, *Psychol. Bull.* **1984**, *95*, 29–51.
[2] A. Furnham, *50 Psychology Ideas You Really Need to Know*, Hachette UK, **2009**.
[3] J. M. Sundet, D. G. Barlaug, T. M. Torjussen, *Intelligence* **2004**, *32*, 349–362.
[4] T. W. Teasdale, D. R. Owen, *Intelligence* **2008**, *36*, 121–126.
[5] J. R. Flynn. *Are We Getting Smarter? Rising IQ in the Twenty-First Century*, Cambridge University Press, New York, **2012**.

Why Do Some People Faint When They See Blood?

by Jennifer Heidrich

> Many will swoon when they do look on blood.
> (Shakespeare, *As You Like It*, Act IV, Scene III)

Some people know this phenomenon only from movies, TV shows or books. Others from relatives, friends or even themselves: The terrible weak feeling of fainting that is triggered by the sight of a large amount (or sometimes even just single drops) of blood. Such people are, in most cases, not suitable for donating blood, not to mention, work in emergency rooms in hospitals.

But where does this strong reaction come from? Is it even good for anything?

First of all, we are talking of the so called blood phobia, also known as hemophobia. It is part of a whole group of blood-injection-injury phobias (BII), as categorized by the Diagnostic and Statistical Manual of Mental Disorders (DSM).[1]

The general consensus behind the cause of exaggerated blood phobia, which results in vasovagal responses, is that they originate from the psychological traits of an individual rather than from their genetic heritage. It seems, for example, sometimes to be caused by childhood traumata.[2] On the other hand, twin studies suggest that there might also be certain genetic predispositions which are common for phobias in general.[3]

Anyways, are there any explanations? Indeed, there are three more or less fascinating ideas that could hold the key:

- **The danger theory:** Seeing blood is an alarm signal. So when we start feeling weak, we automatically seek for a safe place to rest and/or hide. This would of course only make sense, if the process of fainting takes some time, allowing us to act.
- **The "play dead" theory:** During stone-age, some predators were not interested in paralyzed preys. They would actually wait for a person to flee, only to follow them. Good for the people with hemophobia during those ancient hunts!
- **The self-healing theory:** The blood pressure decreases during fainting. An injured person could thereby slow down the blood loss and instead support the blood coagulation.

Whatever the true origin might be, nowadays the fear of blood is nothing more than annoying. But luckily, as with any phobia, blood phobia can be cured.[4]

Read more:

[1] J. D. Lipsitz, D. H. Barlow. S. Mannuzza, S. G. Hofmann, A. J. Fyer, *J. Nerv. Ment. Dis.* **2002**, *190*, 471–478.
[2] B. A. Thyer, J. Himle, G. C. Curtis, *J. Clin. Psychol.* **1985**, *41*, 451–459.
[3] K. S. Kendler, M. C. Neale, R. C. Kessler, A. C. Heath, L. J. Eaves, *Arch. Gen. Psychiatry* **1992**, *49*, 273–281.
[4] http://sm.stanford.edu/archive/stanmed/2013spring/article6.html (last access on 30.06.2016).

What is the Shape of the Universe?

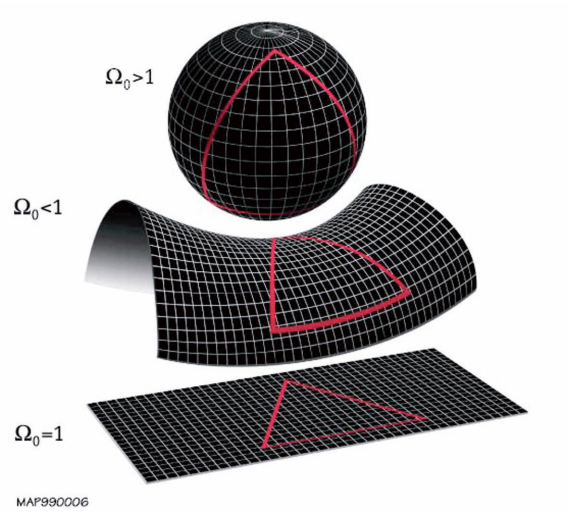
by Tatjana Dänzer

Since way back, humankind is looking up into the night sky, observing orbs and wondering about the origin and the look of the cosmos. Is the universe really expanding as we all learn in school? How does the border of the universe (if it exists) look like? Admittedly, a modern scientific approach to this problem is very abstract and not easily explained in layman's terms.The following explanation therefore spares any detailed mathematical considerations for simplification. Derived from Einstein's theory of relativity, there are found different possibilities. In simplified terms, mass warps the space and thus determines its shape. Complex mathematical considerations result in a critical density of the universe. A structure can be assigned from the density parameter, omega, which is the quotient of the average density of the universe and the critical density. Three border cases emerge whose abstract values can be translated into two-dimensional images for a more vivid explanation (see picture):[1,2]

- The density is bigger than the critical density (omega > 1). The universe is big enough to stop the expansion sometime but after that point it will be shrinking again. This is called "closed universe".
- The density is smaller than the critical density (omega < 1). The universe expands forever and its shape is saddle-like. This is called "open universe".
- The density has the exact value of the critical density (omega = 1). The expansion rate decelerates over an infinite time-span and the shape is flat and endless.

Another discussed model is the "Picard topology" that defines the universe as a horn which is closed at the end. Here very surreal phenomena would occur depending on whether one is situated at the peak or the broad end.[3]

Measurements from the Wilkinson Microwave Anisotropy Probe (WMAP) give hints that the density of the universe equals the critical value. Accordingly, the shape would be flat. Still, with our limited technical possibilities we only can observe a very small area of the universe. No one can yet (or maybe never will?) know with absolute certainty how the universe looks like.[2]



Two dimensional illustrations of the universe's possible shapes: spherical or "closed" universe, saddle-like or "open" universe, and flat universe.[5]

Read more:

[1] http://www.space.com/24309-shape-of-the-universe.html (last access on 22.04.2016)
[2] http://map.gsfc.nasa.gov/universe/uni_shape.html (last access on 22.04.2016)
[3] http://www.heise.de/tp/artikel/17/17247/1.html (last access on 22.04.2016)

How Would Life Be without Satellites?

by Katharina Stockhofe

The first satellite in space was Sputnik 1, launched by the Soviet Union in 1957. Since that time more than 6000 satellites have been launched. From the (estimated) 3600 satellites that are still in the orbit, about 1000 are operational.[1–3] The rest of them are more or less useless and part of the space-debris, which is becoming a more and more important problem.

But what are they doing all the time?

Satellites can be distinguished by their usage into various categories. News, science, earth observation, navigation, and military satellites are only a few examples of the broad range of applications.

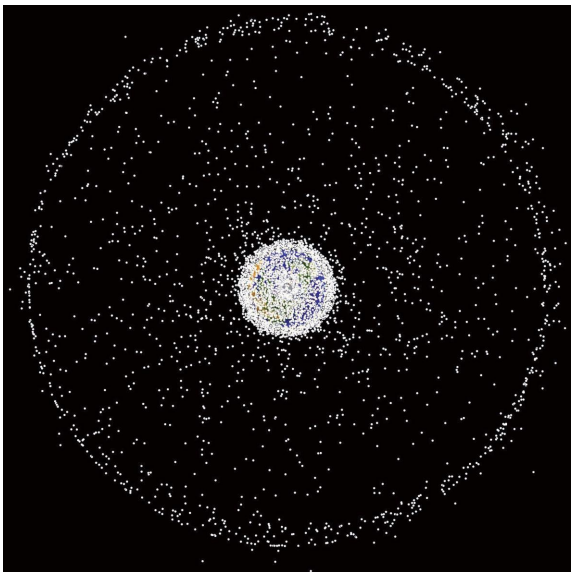
Just imagine. Your day starts with your alarm clock. It is an ordinary one, not a radio-controlled one, of course. After the first coffee you want to look up the weather forecast on your smartphone. No chance. Without weather satellites, a forecast is a possible but quite vague endeavor, but without adequate satellites, a smartphone is an absolutely useless device.

On your way to work you notice that your satnav neither is working. Of course not, how should it, without GPS?! GPS is the magic word for our modern world. ATMs are reliant upon GPS, as well as airports, telephone, stock exchange and so on.

Without satellites we'd be able to survive, at least, but our lives would change in so many ways. Scenarios where con-

[5] "End of universe". Licensed under public domain via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:End_of_universe.jpg.

fused people are walking around, fingers on a map, looking for an old-fashioned phone booth, are Hollywood-like and very improbable to happen.[4]



View of our planet. Can you spot it?[6]

Back to space-debris. What is happening to all the hundreds and thousands of tons of scrap? After 3–8 years, a satellite retires. Modern satellites have special engines that transport them into space-graveyard, where they travel forevermore. Elderly ones vaporize upon re-entry into the atmosphere.[5]

So, without satellites our lives would be totally different, and the view of our blue planet won't be blocked by thousands of tons of terrestrial garbage.

Read more:

[1] Rising, David (11 November 2013). "Satellite hits Atlantic — but what about next one?". Seattle Times

[2] http://www.esa.int/Our_Activities/Operations/Space_Debris/Global_experts_agree_action_needed_on_space_debris (last access 20.06.2016)

[3] http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.V2gwkjVmwnp (last access 20.06.2016)

[4] http://www.zeit.de/wissen/2012-07/esof-gps-sonnensturm (last access 20.06.2016)

[5] http://www.aktiv-online.de/nachrichten/detailseite/news/wie-satelliten-unseren-alltag-bestimmen-3938 (last access 20.06.2016)

What It Takes to Be Happy?

by Soham Roy

All of us are esurient creatures, when it comes to being happy. Everyone wants to be happy. There are myriad paths to happiness as well – religious, spiritual and even rational. The Dalai Lama, once remarked, "Happiness is not something ready made. It comes from your own actions." Yet it seems, year after year, that a group of people sharing a small genetic pool end up tops of the "The World Happiness Index".[1] The Danish, it seems, are genetically endowed when it comes to being happy.[2] A genetic mutation 5-HTTLPR seems to be behind it. This gene variant influences the metabolism of serotonin, the neurotransmitter which affects our moods. Does it then mean that you cannot be happy if you have not inherited Danish genes? No, there's more to this story. And that's where science opens a new door towards happiness.

Whether we are Danish or not, we produce a neurotransmitter called Anandamide.[3] The name of this molecule itself exudes joy, deriving from the Sanskrit word ananda or bliss. But then why aren't we all equally happy. That depends on the extent to which this "bliss molecule" is metabolized. People who produce less of the enzyme that aids in the metabolization are more prone to be calm and at peace.[4] Prof. Friedman, from the Weill Cornell Medical College, puts it elegantly when he says: "What we really need is a drug that can boost anandamide – our bliss molecule – for those who are genetically disadvantaged."[5]

Now it seems such a future is not that far off when we can engineer happiness. There are two things that one needs. To understand the genetic factors behind the different neurotransmitters. And how to manipulate them with nano-scale precision. Once we have that information, it will be possible to ingest a pill that carries predesigned nanobots to specific regions of the brain and turn on or off genes at will. This will then lead to a change in the perception of the immediate environment which would have otherwise strained our ability to be happy. Such a future was envisioned a decade back by author James Hughes in his book "Citizen Cyborg".

So yes, it seems highly likely that our next generation can buy over-the-counter pharmaceuticals that can generate the feeling of satisfaction, joy or bliss. But still to be truly happy and have a satisfying life, it would take more than a drug as after all, happiness "comes more from your own actions".

Read more:

[1] http://www.sciencealert.com/the-world-happiness-index-2016-just-ranked-the-happiest-countries-on-earth (last access 30.06.2016).

[2] http://www2.warwick.ac.uk/newsandevents/pressreleases/danish_dna_could/ (last access 30.06.2016).

[3] W. A. Devane, L. Hanus, A. Breuer, R. G. Pertwee, L. A. Stevenson, G. Griffin, D. Gibson, A. Mandelbaum, A. Etinger, R. Mechoulam, *Science* **1992**, *258*, 1946–1949.

[4] I. Dincheva, A. T. Drysdale, C. A. Hartley, D. C. Johnson, D. Jing, E. C. King, S. Ra, J. M. Gray, R. Yang, A. M. DeGruccio, C. Huang, B. F. Cravatt, C. E. Glatt, M. N. Hill, B. J. Casey, F. S. Lee, *Nat. Commun.* **2015**, *6*, 1–9.

[5] http://www.nytimes.com/2015/03/08/opinion/sunday/the-feel-good-gene.html?_r=0 (last access 30.06.2016)

[6] "Debris plot by NASA". Licensed under public domain via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:Debris-GEO1280_p.jpg.

Articles

Unusable Pretreatment of Steel and Zinc Surfaces Based on Phytic Acid

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The formation of a conversion layer for corrosion protection based on phytic acid (PA) solutions is described several times in the literature. The promising results induced us to verify the performance of PA based conversion layers as pre-treatment for organic coatings. The spectroscopic and optical analysis with infrared spectroscopy, atomic force microscopy, and scanning electron microscopy of the generated layer strengthened the hypothesis of a corrosion protective layer. Furthermore, the electrochemical analysis with cyclic voltammetry supported it but the results of the electrochemical impedance spectroscopy provided a first hint of an instable layer. Unfortunately, all kinds of tested conversion layers based on PA with and without a combination with molybdate increased the delamination of an applied coating and accelerated the corrosion process in the salt spray test. Therefore, all investigated PA based conversion layers are not suitable as pre-treatments for organic coatings.

1 Introduction

Corrosion is one of the greatest concerns for modern economies. The annual damage by corrosion causes a loss of 3–4% of the U.S. GDP.[1] To prevent corrosion, there are several methods in the market. In particular, conversion coatings are used with high success ever since the introduction of phosphate coatings.[2] Besides their good corrosion protection, many established conversion coatings are harmful to humans and environment.[3] Due to this fact, there is a high need for ecological and sustainable alternatives. Phytic acid (PA) is a "green" option for future conversion coatings and has been proposed as a raw material for conversion layers in several papers in the last decade.[4–7]

Phytic acid and its salts are used in many of our daily life products, e.g. cosmetics and water treatment.[8] Naturally occurring PA is contained in beans, brown rice, corn, sesame seeds, and wheat bran.[9] In the last years, novel production methods have been developed so that today PA can be easily extracted from rap filter cake.[10] Phytic acid consists of an inositol ring structure which is esterified with phosphoric acid. Up to twelve hydrogen atoms can be removed. Metals can build strong chelate complexes with the active acid groups (Figure 1).

To verify the performance of conversion layers based on PA, two strategies have been pursued:

1. Optimization of a conversion layer based only on PA and testing of the corrosion protective properties with an organic coating (clear coat) in a salt spray test.

2. Optimization of a conversion layer based on PA and molybdate[7]/ tungstate and testing the corrosion protective properties with an organic coating (epoxy based coating) in a salt spray test.

The structure and the corrosion resistance of PA conversion coatings on mild steel were observed at different pH values. The conversion coating was optimized with a leveling agent and molybdate as corrosion inhibitor. Reflection-absorption infrared spectroscopy (RAIRS), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDX) were used for characterization and verification. The film thickness was estimated twice via a gravimetric method and based on the interference color of the conversion layer. For the evaluation of the corrosion resistance, cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and the salt spray test (SST) were used.

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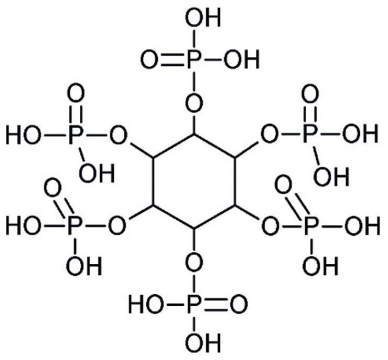

Figure 1: Chemical structure of PA, $C_6H_{18}O_{24}P_6$.

2 Experimental

2.1 Materials

The steel used in this study was mild steel with the classification DC04 (EN 10130) and the following chemical composition (wt%): C, 0.08%; P, 0.03%; S, 0.03%; Mn 0.4% (Krüppel, Germany). PA was used with a concentration of 50 wt% in water. Analytical purity grades of sodium hydroxide, potassium nitrate, ammonium heptamolybdate, and sodium tungstate were used for solution preparation. All chemicals were purchased from Sigma-Aldrich. Sokalan 64P as a leveling agent was purchased from BASF SE. All solutions were prepared with deionized water. For comparison, phosphate steel sheets (Chemetall) were used. Mild steel was cut into 110 x 65 x 2 mm samples. For the second series, steel, zinc coated steel and phosphate steel sheets were used in the size 100 x 200 mm. Before the metal sheets were immersed into the PA solution, they were cleaned as followed:
The samples were wiped with ethanol and then ultrasonically washed for three minutes in deionized water at room temperature. At the end they were wiped again with isopropanol.

2.2 PA Conversion Coatings

PA Layer
The PA solution (50 wt%) was diluted with deionized water to a 5 wt% solution. In the experiments, the different pH values (2, 4, and 6) were adjusted with sodium hydroxide. Potassium nitrate was added as a promoting agent (2 g/L). For the modification trials, Sokalan VA 64P was incorporated as a leveling agent (L) (1500 ppm). To achieve better corrosion properties, the inhibitor ammonium heptamolybdate (Mo) was used (1 wt% based on PA content). The test pieces were immersed for 30 minutes in the PA solutions (Table 1). The temperature of the solution was set to 35 °C.

Table 1: Experimental design, phytic acid.

	Pure PA solution	PA+L	PA+L+Mo
pH 2	#1.2	#2.2	#3.2
pH 4	#1.4	#2.4	#3.4
pH 6	#1.6	#2.6	#3.6

Phytic Acid Combined with Molybdate or Tungstate
The PA solution (50 wt%) was diluted with deionized water to a 5 wt% solution. The pH value of 2 was adjusted with sodium hydroxide. Potassium nitrate was added as a promoting agent (2 g/L). Sokalan VA 64P was incorporated as a leveling agent (1500 ppm). To achieve better corrosion properties, the inhibitor ammonium heptamolybdate (Mo) or sodium tungstate (W) were used, whereas 10 wt% heptamolybdate or 9 wt% tungstate based on PA content were added to the solution. The concentrations are near the solubility limit of the metal anions. The samples were immersed for six minutes (steel) or three minutes (zinc) in the PA solutions (Table 2). The temperature of the solution was set to 35 °C.

2.3 Characterization

SEM: The SEM pictures were obtained with a Zeiss DSM 982 Gemini device coupled with an EDX device "Oxford Instruments XMax^N".
RAIRS: The RAIRS spectra were measured with the Bruker Vector 22; IRRAS-module: Typ A 518 Refl. Unit 80°.
Electrochemical Methods: The EIS spectra and the CV were performed with a Zahner Zennium, Zahner-Elektrik GmbH.
CV: A solution of 3 wt% NaCl in deionized water was used as electrolyte. A scan rate of 100 mV s^{-1} for non-coated steel surfaces was used to assure that no iron dissolves into the solution. The PA layers were measured with a scan rate of 20 mV s^{-1}. The upper potential for all measurements was –0.3 V, the lower potential was –1 V and the starting potential was –0.6 V.
EIS: A 3 wt% solution of NaCl in deionized water was used as electrolyte. The amplitude was set to 10 mV. The frequency range was 100 mHz to 100 kHz. Stainless steel served as counter electrode.
SST: The SST were performed in the device from Liebisch Laborgeräte; Constatwin.

Table 2: Experimental design, PA combined with molybdate or tungstate.

Substrate	PA+Mo (10%)	PA+W (9%)	PA+Mo (10%)+L	PA+W (9%)+L
Steel	#4.1	#5.1	#6.1	#7.1
Zinc	#4.2	#5.2	#6.2	#7.2

Contact Angle: The contact angles from water of the conversion layers were evaluated with the Device from Dataphysics, Contact Angle System OCA 15plus.

3 Results and Discussion

3.1 Estimation of Conversion Layer Thickness

For estimation of conversion layer thickness, the density of iron phytinate was determined to be about 2.34 g/cm^3. After 30 minutes of immersion time at pH 2, an average thickness of 200 nm ($\pm$ 50 nm) was deposited. When leveling agent was added the conversion layer thickness was higher, caused by better substrate wetting. Based on the interference colors (blue and red) of the conversion layer (Figure 2), the thickness was between 118 nm and 188 nm, i.e. the same range as the evaluation based on the density of iron phytinate. The rough estimation was based on the wavelengths 450 nm for blue and 750 nm for red and the thickness was calculated with the Bragg equation:

$$2dn = (2m+1)\frac{\lambda}{2} \wedge m = 0, 1, 2, 3, \ldots \qquad (1)$$

In the equation d is the thickness of the layer, n the refractive index (estimation n = 1), λ the wavelength, and m (estimation m = 0) the order of the interference.

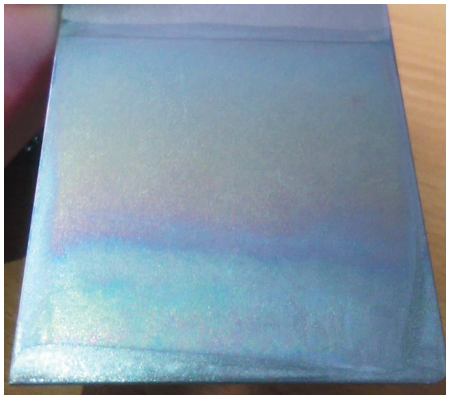

Figure 2: Picture of PA conversion layer on steel.

3.2 Scanning Electron Microscopy / Energy Dispersive X-Ray Spectroscopy

SEM / EDX pictures (Figure 3) illustrate the surface morphology of the conversion layer at different pH values and magnifications. In all SEM pictures, PA could be verified. The element analysis confirmed the following elements: P, O, Fe, C, Na, and K. Phytic acid contains P, O, and C, hence these elements of the analysis can be traced back to the PA. Iron is related to the substrate, while sodium and potassium are related to the additives. Figure 4 illustrates the element distribution in weight percent. Approximately 6 wt% of phosphorus and about 20 wt% oxygen were detected on all metal surfaces. The element ratio phosphorus:oxygen nearly correlates to the structure of PA (6:24).

At different pH values, the covered surface varies. It could be found that the best coverage is at pH 2 and decreases from pH 4 to pH 6. The same behavior is described in literature.[11] In Figure 3 d, an epitaxial growth could be seen on the PA conversion coating. In general, the morphology of PA showed some cracks. The reason for these cracks is the hydrogen evolution during the treatment process. (Figure 3 e & f).[3]

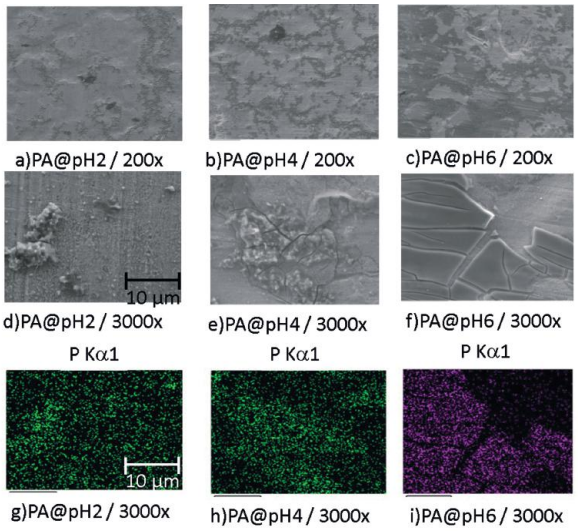

Figure 3: SEM / EDX spectra of PA layers on steel.

To reduce the amount of cracks, a leveling agent was added to the PA solution. The leveling agent improved the wetting and showed a homogenous leveling on the metal surface. Polymer spheres of incompatible leveling agent could be found on the PA surface (Figure 5 d). This effect only exists at pH 2. Especially at the pH level of 6, the surface coverage could be improved compared to the sample without leveling agent (Figure 5 b). With regard to the amount of cracks, no advantage could be achieved. In Figure 5 c, the bright areas represent chipped conversion coating (see EDX picture Figure 5 i). The incorporation of leveling agent boosted the adhesion (Figure 5 b).

In further experiments, molybdate anions were additionally added to the leveling agent (Table 1). With this inhibitor, an extra benefit for corrosion performance should be achieved. The EDX picture (Figure 5 i) shows that molybdate was homogenously distributed in the PA conversion coating. The amount of cracks was lowered with the combination of corrosion inhibitor and leveling agent (Figure 5 f). One explanation of this observation is the high coordination to other elements and therefore higher network density of molybdenum compounds.

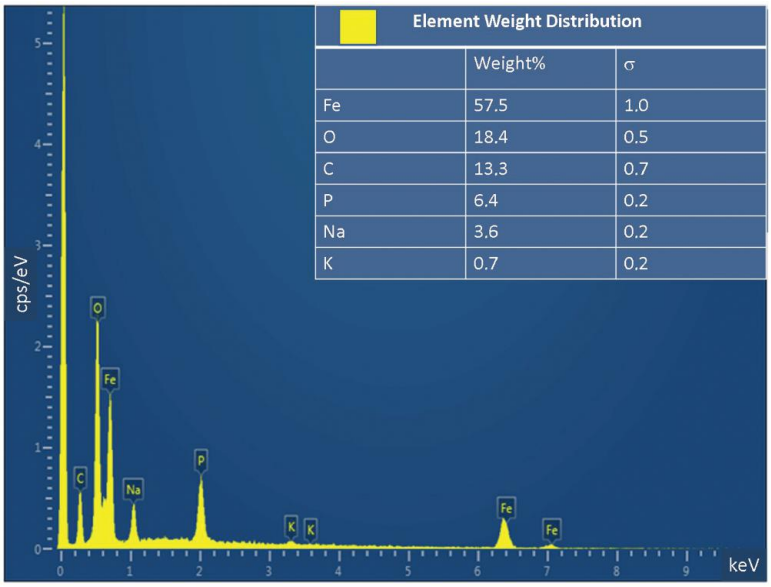

Figure 4: Element weight distribution #1.2 (Table 1).

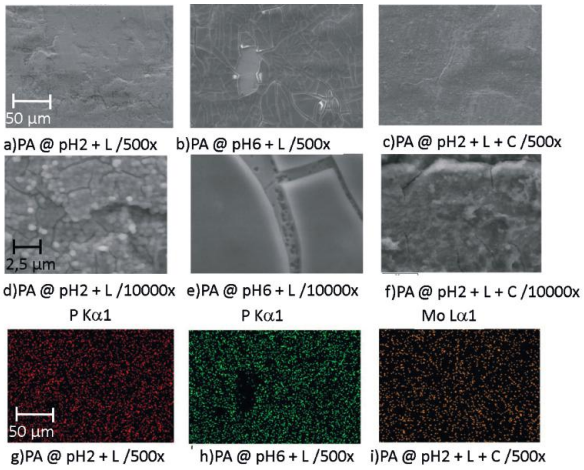

Figure 5: SEM / EDX spectra of PA conversion. Coating with modifications (L: leveling agent, C: corrosion inhibitor.)

3.3 Infrared Spectroscopy

The RAIRS spectra of PA and their conversion coatings at different pH values are displayed in Figure 6. The spectrum of PA and conversion coatings showed three bands at 972, 1011, and 1047 cm^{-1}, assigned to the P–O–H bond. Only for the PA spectrum, three bands at 951, 827, 737 cm^{-1} ($–PO_4^{3–}$) could be seen.[3] The bands at 1375 (PA) and 1371 cm^{-1} (PA conversion coating) were assigned to the –P=O bond.[12] The bands around 1600 cm^{-1} were related to $HPO_4^{2–}$ groups.[3] For the conversion coating, it is obvious that the phosphate hydrogen group was present while the phosphate group was absent. This indicates that the phosphate group of PA can form complexes with metal ions such as Fe^{2+} and Fe^{3+} resulting in the conversion coating on mild steel. The bands in the spectra of the conversion coating below 700 cm^{-1} also support the theory of the formation of metal-oxygen bonds.[12] It proved that PA was deposited on the metal surface. The samples of different pH values were similar to each other. Only in the range of 3500 cm^{-1}, the bands show differences. At pH 6, the band for –OH is more intensive than at pH 2 and 4. The reason for this is a lower deprotonation at pH 6.

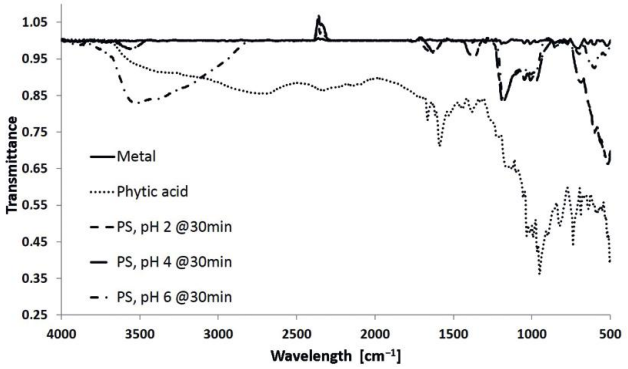

Figure 6: RAIRS spectra of PA conversion.

3.4 Cyclic Voltammetry

The cyclic voltammetry was used to determine the surface coverage of the PA layers on steel in contrast to non-coated mild steel (Table 3).[13] With respect to the different scan rates, it was assumed that the charge transferred with the faster scan rates of the uncoated iron equals one fifth of the charge transferred of the steel covered with PA.

$$5 \cdot t_{Fe} = t_{Phyt} \text{ and } Q = I \cdot t \rightarrow 5 \cdot Q_{Fe} = Q_{Phyt} \quad (2)$$

$$\Theta = 1 - \frac{Q_{Phyt}/A_{Phyt}}{5 \cdot Q_{Fe}/A_{Fe}} \quad (3)$$

Table 3: Cyclic voltammetry results.

Sample	Area / cm^2	Charge / mC	Charge/Area / mC/cm^2
mild steel #1	1.68	4.88	2.90
mild steel #2	2.38	2.83	1.19
mild steel #3	2.24	3.35	1.50
mild steel #4	2.08	2.33	1.12
		mean x 5	8.39

Table 4: Surface coverage.

Sample	Area / cm^2	Charge / mC	Charge/Area / mC/cm^2	Coverage / %
#1.2	1.3	4.5	3.5	58.5
#2.2 – 1	2.1	6.2	2.9	65.0
#2.2 – 2	2.2	6.5	2.9	65.6
#3.2 – 1	2.3	5.0	2.1	75.1
#3.2 – 2	2.2	5.0	2.2	73.3

The coverage increased after incorporation of the leveling agent. The highest coverage of 74% could be reached using the leveling agent and corrosion inhibitor (Table 4). This is explained by the better surface wetting resulting in smoother surface coverage using the leveling agent as discovered in the SEM measurements (Figure 5 f).

3.5 Electrochemical Impedance Spectroscopy

The electrochemical impedance spectroscopy was used to determine the corrosion behavior of PA coated steel. Figure 7 shows the impedance spectrum of a steel surface coated with PA at pH 2 at different times. The measurements showed a rapid dissolution of the PA layer (Figure 7) because the conversion layer was represented by a semicircle in the spectra that was only visible at t = 0 min.

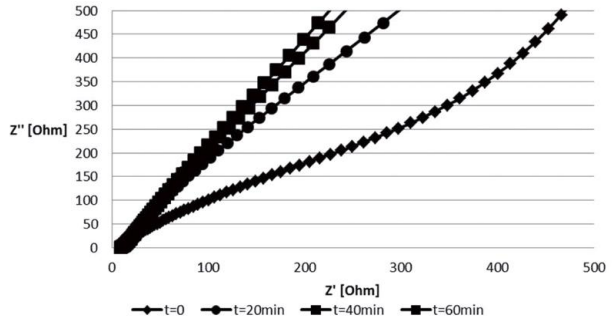

Figure 7: Nyquist plot of the conversion layer deposited at pH = 2 on steel at different times.

The half circle demonstrates a PA coating on the substrate.[14] With corrosion inhibitor (L+C), two half circles indicated the existence of a layer and an electrochemical double layer at the interface. Only the phosphated steel showed an active dissipation (Warburg impedance) visible by a linear behavior at low frequencies.[14] After 25 minutes, phosphate steel has the same behavior but the PA coatings vanished (Figure 8).

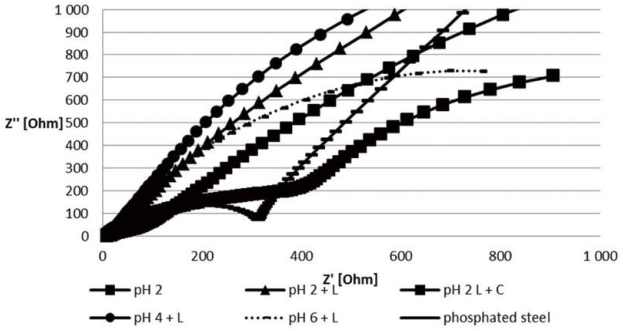

Figure 8: Nyquist plot at the beginning (t = 0 min) of the measurement.

3.6 Salt Spray Test

PA Layer

To determine the corrosion of the samples, a neutral SST was done. The samples were sprayed with a 2 pac acrylate clear coat (cross linking agent: isocyanate). All samples had a dry film thickness of 35±5 μm. The test duration was 68 hours. The degree of delamination was observed according to DIN EN ISO 4628-8 (Table 5).

Overall, PA conversion coatings did not show the same performance as phosphate steel. At least, modification with molybdate (Table 1, #3.2) showed a better resistance against delamination as the pure PA conversion layer.

Table 5: Delamination after 68 h SST.

Sample	d / mm
Phosphated steel	0.5
#1.2	11
#2.2	15
#3.2	8
#1.4	18
#1.6	20

Phytic Acid Combined with Molybdate or Tungstate
To determine the corrosion of the samples, a neutral SST was done. The samples were sprayed with a 2 pac epoxy based marine coating (cross linking agent: amine). All samples had a dry film thickness of 100±10 μm. Two samples of every layer system have been tested in the SST. The test duration was 215 hours. The degree of blister formation was observed according to DIN EN ISO 4628-8 (Table 6).

Table 6: Blister formation after 215 h SST. The values are the average of two samples.

Sample	Blister Size / Amount
Blind sample zinc	2/3
Blind samples steel	2/4
Blind samples phosphated zinc coated steel	1/3
#4.1	2/5
#4.2	1/3.5
#5.2	2/2
#6.2	1.5/3.5
#7.1	2/5

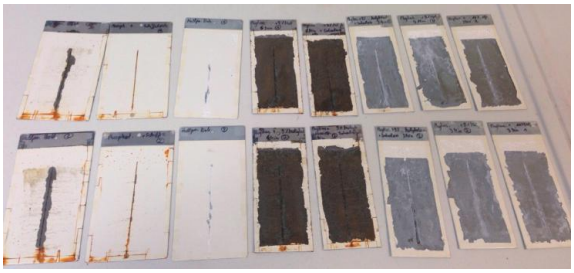

Figure 9: Pictures of the treated samples after 215 h SST. Left to right: steel, phosphate steel, zinc, PA/molybdate/leveling agent on steel, PA/molybdate on zinc, and PA/tungstate on zinc.

The missing samples in Table 6 have not been tested because no film formation of phytic acid with tungstate was possible under the conditions. Regarding the blister formation, the conversion layer #4.2 based on PA and molybdate achieved the performance level of the phosphate surface. The evaluation of the delamination rate after 215 hours gives a clear picture (Figure 9) about the performance of PA based conversion layers. All samples based on PA conversion layers completely delaminated and corrosion was visible on the complete sample surface.
There might be a protective effect of the conversion layer but there is no wet adhesion to the epoxy based coating. The same effect is visible on the 2 pac acrylate clear coat.

4 Conclusion

The results show that it is possible to deposit PA as a conversion coating. The formation and morphology of the coating depends on the pH value and the concentration of metal ions in the solution. It could be proved by IR and SEM / EDX that PA is precipitated. Furthermore, the leveling agent leads to the advantages of better wetting, higher coverage, and film thickness. Nevertheless, the conversion layer cannot improve the corrosion protective properties of an organic coating as shown with a 2 pac acrylate based clear coat and with a 2 pac epoxy based marine coating. The reason for this behavior probably originated from the low contact angle of the PA based conversion layer to water (Figure 10) and therefore a good wettability of the interface between conversion layer and coating. The wet interface reduces the adhesion between the coating systems, whereas the corrosion protective properties were completely destroyed.

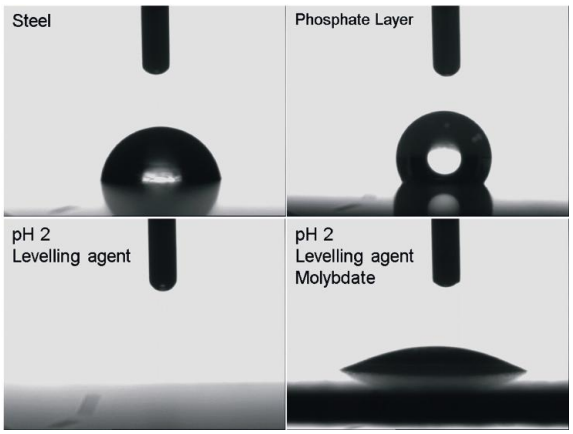

Figure 10: Pictures of the contact angle measurement of the surfaces with water.

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Chemical Free Household Products

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Household products from the food and cosmetics industry are advertized as "chemical free" in a nearly inflationary way. This declaration is mostly incorrect and it suggests that the products are produced from natural products, are extremely healthy, or completely free of artificial ingredients.[1–∞] We have investigated these labels for a broad variety of such products, including herbal supplements, processed food and beverages, next to cosmetic products and cleaning agents. As a result we were able to compile a complete list of all "chemical free" domestic products.

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Summary

We have examined and subjected to analysis an exhaustive number of consumer products, including but not limited to lotions and cosmetics, herbal supplements, household cleaners, food items, and beverages. As a result we describe all those consumer products herein, to our knowledge, that are appropriately labeled as “chemical free”.

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Alexander F. G. Goldberg was born in Toronto, Canada and received his PhD from the California Institute of Technology under the supervision of Prof. Brian Stolz. After a postdoc stay at the Weizmann Institute at the group of Prof. David Milstein, he returned to Canada to work as process chemist at Gilead Sciences in Edmonton.

Klaus Roth of the Freie Universität Berlin publishes regularly in “Chemie in unserer Zeit” about the significance of chemistry in everyday life.

CJ Chemjobber grew up in the United States and holds a PhD in organic chemistry. Today he works as process chemist in the chemical industry.

Notes and References

A small selection of relevant references:

[1] “Chemiefreie” Sonnenschutzmittel (chemical free sunscreens): http://campl.us/bmnl

[2] “Chemiefreier” Chemiebaukasten (chemical free chemistry kit): http://sciencegeist.net/my-chemically-fueled-life/

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[9] “Chemiefreies” Badezimmer (chemical free bathroom): http://kidzchaos.com/nachhaltig-leben/chemiefreies-badezimmer/

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[11] “Chemiefreie” Desinfektion (chemical free disinfection): http://www.berkefeld.com/de/downloads/pressemitteilungen/2012-11-16,Hohe_Raumluftqualitaet_durchchemiefreie_Desinfektion.htm

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[13] “Chemiefreie” Kleidung (chemical free clothing): www.alnatura.de/de-de/panorama/kultur-und-gesellschaft/gesellschaft/chemiefreie-kleidung

[14] “Chemiefreie” Unkrautvernichtung (chemical free herbicide): www.chemiefrei-thoma.de

[15] “Chemiefreie” Kartoffeln (chemical free potatoes): http://www.mz-web.de/zeitz/huehnerhof-zimmermann-bei-zeitz-chemiefreie-kartoffeln-und-glueckliche-huehner,20641144,32205770.htm

[16] “Chemiefrei” gegen Zecken (chemical free Tick-Spray): http://www.veterinaer-rundschau.de/chemiefrei-gegen-zecken-flohe-und-milben/

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[∞] “Chemiefreie” Haarfarbe (chemical free hair tining lotion): http://theos-hairdesign.de/die-chemiefreie-haarfarbe-elumen/

Views on Life, the Universe, and Everything

Sustainable Processing in Brazilian Industrial Infrastructures: An Utopia or Feasible Challenge?

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The continuous growth in human population implicates an increasing need for water. This demand encloses especially industrial structures. The federal state Pernambuco is one of the leading textile producers in Brazil. Although, the dry sub-humid state represents less than 5% of its national population, it covers approximately 20% of nationally manufactured jeans. Its high water consumption exacerbates the environmental situation during the actual strong drought which continues to impact the entire northern part of the South American continent. One main factor is the emission of chemically contaminated effluents from industrial laundries to Ipojuca river, being the third most contaminated river in Brazil. In this study, we analyse impact factors contributing to anthropogenic environmental damage in one of Pernambuco's main jeans producing region, Caruaru, and provide a sustainable solution towards waste water treatment. The methodology encloses a comparison of the exemplary sewage water management in the city Hof, Germany. Our results enclose parameters responsible for the damage to the fragile environment in Pernambuco and the Ipojuca River as well as a model for a sustainable infrastructure of the intended expansion of the industrial park in Caruaru.

1 Environmental Situation in Caruaru

The city of Caruaru is located in the state of Pernambuco, approximately 130 km from Recife (capital of Pernambuco). It is part of the semi-arid region, a transition area between the area of the Atlantic jungle and the arid region, approximately $540\,\mathrm{m}$ in altitude and divided by the river Ipojuca. The city expanded mainly due to factories producing textiles. The condition of the river Ipojuca as shown in Fig. 1 is considered to be critical since it is the third most polluted river of Brazil. Ipojuca river is contaminated by color pigments due to chemicals used to color denim. The rich wildlife is replaced by a small number of species like turtles that feed on waste water. The basin of the Ipojuca river is located between latitudes 8º09' and 8º40' south and longitudes 34º58' and 37º03' west of Greenwich, constituting the UP3 water planning unit, the State Water Resources Plan of Pernambuco - PERH/PE. Confined to the north by the river basin of the river Capibaribe, to the south, by the river basins of the rivers Una and Sirinhaém; east, by the second and third groups of basins of small coastal rivers and the Atlantic Ocean and to the west by the river basin Ipanema and the state of Paraiba. Thus, in general, the industrial laundries in Caruaru are responsible for the environmental degradation of the Ipojuca river, which bisects the city and receives chemical waste from jeans beneficiation processes. Studies of the State Agency for the Environment and Water Resources (CPRH) in 2005 show that in the Textile Local Productive Arrangement (APL), about 70% of industrial and sanitary waste generated by laundries are discarded without any treatment in the rainwater drainage system; 85% of them have no smog control system.[1] It was also observed that 40% of laundries discard their industrial effluents into the public sewage and 38% into canals.

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The percentage of sewage spilled into the river Ipojuca is 18%. In 2014, the Pernambuco Sanitation Company (COMPESA) which acts as the local water supplier had been ordered by the Federal Court to restore 37 sewage treatment plants in the state. Although domestic sewage contains approximately 99.9% water, it is due to the fraction of the remaining 0.1% high power contaminant, which required a treatment system.[2]

Figure 1: Contamination of the river Ipojuca with industrial sewage in 2015 in Caruaru, Pernambuco, Brazil.

Figure 2: Solid waste after sewage treatment of the water used throughout the processes (2014).

After the treatment of effluents, there usually remains solid waste (sludge) from drying, which is packed in bags for disposal by contractors in controlled landfill sites in the city of Recife (Fig. 2). The processing of jeans is one of the main economic pillars in the region. According to the Association of Textile Industries Brazilian (ABIT), in 2011, the Textile Local Productive Arrangement of Pernambuco (APLCAPE) accounted for 15% of jeans production in Brazil and for 3% of Pernambuco state GDP. Water is the main natural resource used throughout the process.

1.1 Water Usage in the Process of Jeans Manufacturing

During the laundry process, water is used for steam generation, boiler gas washing, cleaning of different instruments and in jeans beneficiation operations. The water used in various processing processes is stored in the primary water tank. To supply the primary tank, laundries in Caruaru use as the main water resource local water reservoirs like river water (Fig. 3). The water originates from ponds and pits in the area (up to 25 km away). This water is transported to the laundries by tanker trucks (owned or chartered). Most reservoirs are fueled solely by these sources, but some laundries use different sources of water, such as the local utility and water from artesian wells. In the research conducted by Silva in 2013 with the cooperation of local laundries in city of Caruaru, 105 laundries were addressed of which 62 completed the provided questionnaire.[10] It could be obtained that about 3% use solely water suppliers like COMPESA, and 97% utilize regional water of rivers and reservoirs. The water is transported by tanker trucks. Effluents can be directed to Effluent Treatment Plants (ETE) or discarded (some laundries do not use the ETE permanently due to higher process costs) in the rainwater drainage system.

2 Sewage Treatment in Caruaru and Hof

Nowadays, the pollution of natural water is one of the major problems in our contemporary society.

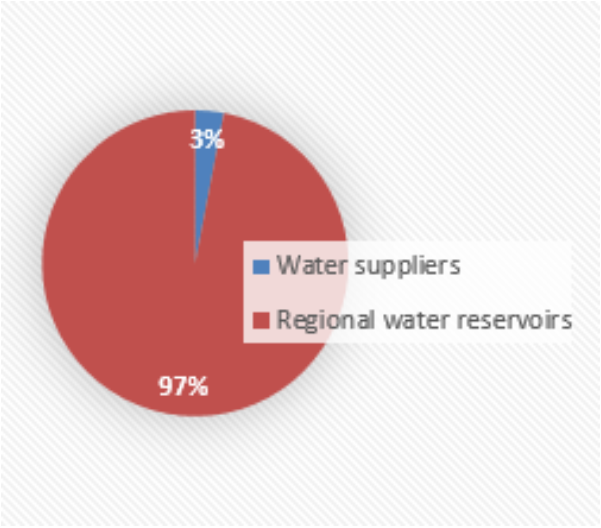

Figure 3: Water resources for jeans manufacturing in Caruaru (2014).

In 2010, through Resolution 64/292, the United Nations General Assembly recognized the human right to clean drinking water.[3] Recent studies address the issue of industrial jeans laundries' waste water disposal into rivers. Vieira *et al.* used a smectite clay to eliminate contaminants.[4] Santos *et al.* demonstrated that the use of solar Fenton process is an efficient alternative towards treating laundry

effluents.[5] Tutillo analyzes sustainability indicators of the 'Global Reporting Initiative' for companies of the jeans laundry industry. Results of this study show that some practices related to sustainable development have been adopted by various organizations. These practices are (1) the control of materials used in the production process of atmospheric emissions produced by operations and (2) water disposal control of laundry and dry cleaning processes, besides (3) control of expenditures and investments for environmental protection.[6] The work of Silva *et al.*[7] concludes that more attention is required in the waste water treatment with regard to parameters such as Biochemical Oxygen Demand (BOD), color and turbidity. Lima *et al.* made a mapping of the textile laundries of the Pernambuco clothing industry in relation to environmental aspects and the operational management of these laundries.[8] In their results, a major part indicated to have all environmental regulatory documentation, also claimed to have knowledge about environmental laws and never had to pay fines related to environmental damage. It was also noted that most of the respective laundries emit residues. Nascimento's work showed that industrial effluents can be made innocuous by advanced oxidation process with TiO_2 / H_2, O_2 and sunlight.[9] The minority of laundries use physicochemical treatment systems, where the effluent is subjected to solids separation processes (fluff and stones) as the first phase. In the second phase of the process, effluents are segregated in the equalization tank, which receives all waste water operations. The effluent is pumped to a physicochemical treatment tank, the treatment can be on batches or continuous, without addition of aluminum sulfate solution ($Al_2(SO_4)_3$) and calcium hydroxide ($Ca(OH)_2$) through metering pumps. After the addition of chemicals, the effluent flows into the coagulation / flocculation tank where there are two outlets for treated effluent and sludge discharge. The entire process as described can be compared to the treatment processes as applied in Hof. Caruaru has only one ETE located in the neighborhood of Rendeiras, but there is the possibility of building a second one, which is practically negligible in perception of the magnitude of population and quantitative population size. The textile industries are the main villains for the city of Caruaru, because there is no effective environmental enforcement to combat these irregularities. Currently COMPESA does not have a treatment plant incorporating the entire city. A way out of this problem is the waste disposal from the laundries and residences in channels which will pollute the river Ipojuca without any treatment, affecting water resources and their partly unique flora and fauna that make up this complex river. With its well in the Serra do Pau d'Arco, in the city of Arco Verde, it has a distance of 323.9 km and supplies several municipalities, among them Sanharó, Belo Jardim, Tacaimbó, São Caetano, Caruaru, Bezerros, Gravatá, Primavera, Escada and Ipojuca. In addition to direct pollution by waste disposal in the water, the site still receives all the city sewage.[10] The streams of Salgado, Mocó and Santa Rosa are channels that receive sewage *in natura*, released into the river without any treatment. There are two interconnected visions: the environmental one, in its preservation, and the other one in public health. This second vision does not efficiently exist in Caruaru and therefore causes the proliferation of rats and cockroaches, spread of diseases, verminosis, hepatitis, cholera and leptospirosis among others. That being said, it is of extreme importance to take care of this good outlook which is essential to life cycle. There was an impasse in 2011 with the First Civil Court of Caruaru suspending the sewage tax charges by COMPESA. This case received wide scale repercussion and was handled by Justice Court of Pernambuco (TJPE), which recommended to restart charging taxes as it could worsen the treatment situation in the city. Nowadays, the industrial residues are dumped in canals which consequently get access to the river that bisects the city. Its solid waste, in general, is collected and deposited on a landfill which is partner of Caruaru City Council. In the city of Hof, the sewage treatment system follows three stages consisting of mechanical, biological and chemical processes. The flow from ETE passes through large and fine grids. The system of large grid retains substances such as textiles or paper. The filtered materials are pressed in residue elimination facilities. In sand and grease tanks, air flows to waste water streams. Diverse greasy substances lift up to the surface. Sand is deposited on the bottom of the tank. These parts are finally stored in appropriate landfills. In primary sedimentation, gravity separates other salable materials, since they do not float on liquid surfaces. The final form of the material for the floating sludge is called primary mud and is removed from primary clarifiers.[11] Seven hundred kilometers of sewage channels are annually disposed in Hof and 60 other cities around its district. Services include the inventory collection and representation on a digital county mapping, axis measurement, gullies and boundaries, water valves, fire hydrants and street illumination. It is observed that both cities use similar processes for sewage treatment. That being said, the deficiency in the river in Caruaru has other factors which are elaborated as follows.

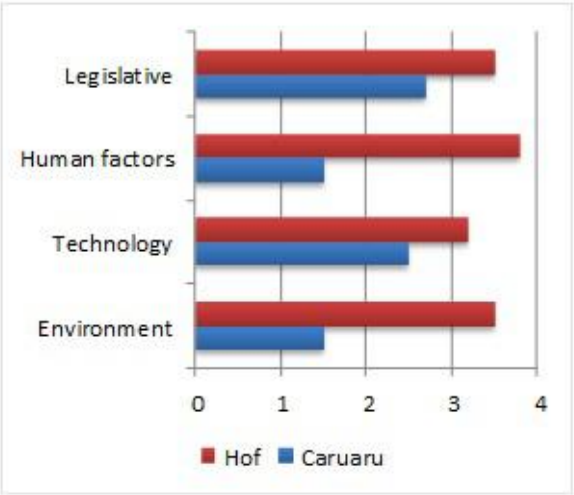

Figure 4: Distribution of potential impacts in the environmental variables in Caruaru and Hof.

3 Environmental Factor Analysis in the Cities of Caruaru and Hof

In order to measure and characterize the pollutant potential of an industrial effluent, the Chemical Oxygen Demand (COD) is utilized.

Table 1: Environmental factors in 2014.

No	ENVIRONMENTAL FACTORS IN BOTH CITIES		
	Factor	***Caruaru***	***Hof***
	Population	289.086	44,522
	Rainfall average in mm/month	45.91	61.8
1	Management plan	x	x
2	Environmental education plan	x	x
3	Selective waste collection	x	x
4	Recycling plant	x	x
5	Composting	-	x
6	Incineration	x	x
7	Effluent treatment	x	x
7.1	Treatment system	four stages	five stages
7.2	Support units	four lakes	four sources
7.3	Installed capacity	$180\,\mathrm{m}^3$ /day	$12\,000\,\mathrm{m}^3$ /day
7.4	Efficiency in organic load remotion	> 90%	> 90%
7.5	Finaltreated effluent destination	Aspersion on ground	Aspersion on river Saale
8	**Quality parameters of urban rivers**		
8.1	pH [6 to 9]	8.1	6.8
8.2	DO (mg/l) [$\geq$ 5]	2.7	6.1
8.3	BOD (5 days in 20 °C) [$\leq$ 5]	5.1	2.7
8.4	Ammonia (mg/l) [$\leq$ 1.0 - to 8.0 $\leq$ pH $\leq$ 8.5; $\leq$ 3.7 - to pH $\leq$ 7.5]	1.4	1.9
8.5	Phosphorous [$\leq$ 0.05]	1.155	0.023
8.6	Fecal coliforms [1000]	35.616	512
9	**City council professional qualification (%)**		
9.1	Primary school	79.6	18.7
9.2	Secondary school	19.4	59.2
9.3	Tertiary school	0.90	22.1

It is responsible to measure the quantity of required oxygen for organic matter oxidation of samples through the usage of chemical agents such as potassium dichromate, for example.[12] Beyond COD, the BOD is stated as the quantity of necessary oxygen for biochemical oxidation of organic matter, through aerobic bacteria, under specific conditions. According to CPRH N 2.001 Standard, the higher the relation COD / BOD is, the more biodegradable will be the effluent. According to CONAMA 357/2005 resolution, the river Ipojuca is classified as Class 2.[13] Generated effluent must be treated before it is released into rivers. The exigencies for pollutant sources with loads equal or superior to 100 kg/day must remove at least 90% of the BOD. Textile industries should establish a reduction of at least 80% in the values of COD, according to their types. According to Santos (2006), effluents from semi-arid textile regions present an average value of 1.135 mgO_2 / L.[14] After surveying both counties based on samples, the acts and industrial processes of waste management activities as well as effluent treatment have been analyzed. Based on samples and technical visits performed in the cities of Caruaru and Hof, acts and industrial processes of waste management and effluent treatment have been observed, analyzed and compared. Data in Table I has been analysed using Eq. 1.

$$\sum_{s=0}^{n+1} F_s = D_x \tag{1}$$

with F_S = +1 or F_S = -1

where F_s represents the specific group factor and D_x represents the distribution value. Thus, each positive factor received a positive score and each negative value, a negative score. Results of this evaluation can be observed in Fig. 4.

3.1 Environmental Laws

The first national law protecting the environment was issued in 1981 (n 6.938/81) and it is the milestone in terms of environmental protection standards. It is the most important environmental law and resolves the polluting group who are obliged to give restitution against environmental damages. Ministry of Public Affairs might propose civil responsibility for damages caused to environments. Imposing on the polluting group, there is obligation of recovering and / or the act to give restitution for caused damages. This Act created the necessity of studies and respective Environmental Impact Reports (EIA-RIMA).

4 Results

From Fig. 5, it can be observed that Caruaru has a strong political factor in terms of protective laws and sufficient technology to observe the sustainable environmental protection patterns.[15] However, human factors considering the profession and maintenance, as well as measurement of parameters in both rivers demonstrate the opposite. Water

quality parameters measured in river Ipojuca are 83.3% below the requirements of an intact river. Based on our interviews and technical visits, it can be said that although there exists the perception of the actual environmental issues a simultaneous paralysis in solving the problem with proposed methods is dominating. This result is alarming and requires immediate attention. In order to provide a solution to that, we propose a model encompassing quantity (horizontal axes) and quality in vertical extensions. From Fig. 5, it can be seen that public policies (first point from left) in diverse approaches for the sustainable waste water demand less horizontal than vertical approaches (x = 0.7; y = 2.7). Human factors (second point from left) represent another parameter, which requires improvement. Vertical development is needed to execute the laws and regulations including technology (third point from left) in order to guarantee the quality in the process (x = 1.8; y = 3.2).

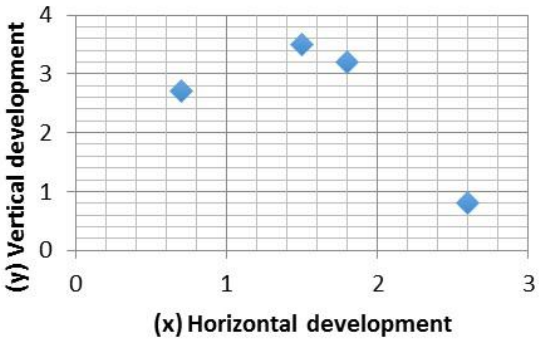

Figure 5: Vertical and horizontal development suggested from the factors in order to perform a sustainable sewage treatment facility.

Technically, the technology is sufficient to guarantee a process of requirements in standards of waste water treatment. However, the facilities need to be improved in order to realize this approach. Therefore, it is suggested in the model to focus in the horizontal instead of vertical (x = 2.6; y = 0.8). When it comes to the environment (fourth point from left), it is important to know that there are educational approaches installed. Education is not sufficient though, strict regulations must be applied so as to guarantee information and awareness. Therefore, both directions must be taken into consideration, vertical and horizontal (x = 1.5; y = 3.5). From the analysis of the results, a model was created that proposes the directions of a sustainable solution towards river depollution. In this model, an industrial waste water plant is considered, which is linked to the river Ipojuca, 12% of green area within an ecological park and sufficient area covering the needs for the industrial textile fabrication. Our model is based on the regulations given by the Economic Development Secretary of Caruaru (SDE). The basic principles were in conformation to municipal and state laws and recommendations for sustainable, efficient industrial facilities. In public areas, this model has (1) preservation areas of the river Ipojuca (30 m lateral), (2) forest park next to BR-232, (3) green belt around the entire textile district, (4) Technical School of Environmental Practice, (5) usage of high pressure sodium light bulbs (HPS). In industries, this model considers (1) reservoirs of rainfall water collection system, (2) turbid tiles usage for natural illumination, (3) garden irrigation with treated effluent, (4) green belt in 70% of the industry perimeter, (5) green area between front wall and industry sidewalk, (6) preview of water heating with solar energy, (7) preview of natural gas usage in energy matrix, (8) atmospheric emissions control system, (9) wastewater management system, (10) effluent treatment and reuse of 70% of water and (11) sanitary effluent treatment.

5 Conclusion

In this study, it was possible to show important factors that require consideration in order to perform consequently a sustainable sewage treatment. These factors include public policies, human factors, technology and environment. However, a main issue for the current situation is the lack of profit for governmental and industrial organs. It requires financial incentives in order to achieve consequent and sustainable sewage treatment. Rudimentary process quality control will then self-regulate itself. In contrast to other research articles, which do not investigate the origin of the problem, this article provides a state of the art solution.

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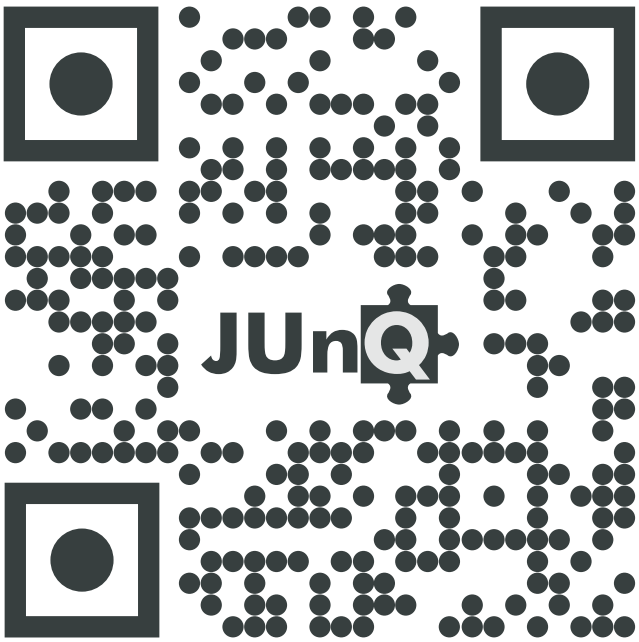

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