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# Research Methodology & Scientific Writing MOOC – Unite!Energy



Funded by  
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**Prof. Izabela Michalak**

# Personal data

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# Personal data

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<https://www.webofscience.com/wos/author/record/P-3770-2015>

**Scopus Author ID:** 23009441800

<https://www.scopus.com/authid/detail.uri?authorId=23009441800>

**Google Scholar:**

<https://scholar.google.com/citations?hl=pl&user=UEecLkwAAAAJ>

**LinkedIn:**

<https://www.linkedin.com/in/izabela-michalak-ba91aa4b/>

**ResearchGate:**

<https://www.researchgate.net/profile/Izabela-Michalak>



**Wrocław Tech**

# Lecturer / Academic teacher

LECTURER



## Lectures (L) / projects (P) in English:

- Agrochemicals and plant health products (L)
- Environment protection (L)
- Environment impact (L)
- Research methodology (P)
- The latest research directions in chemical engineering (L)

## Courses in Polish:

- Ecotoxicology (LAB)
- Development trends in chemical technology (L)
- Statistical methods for the results evaluation (P)

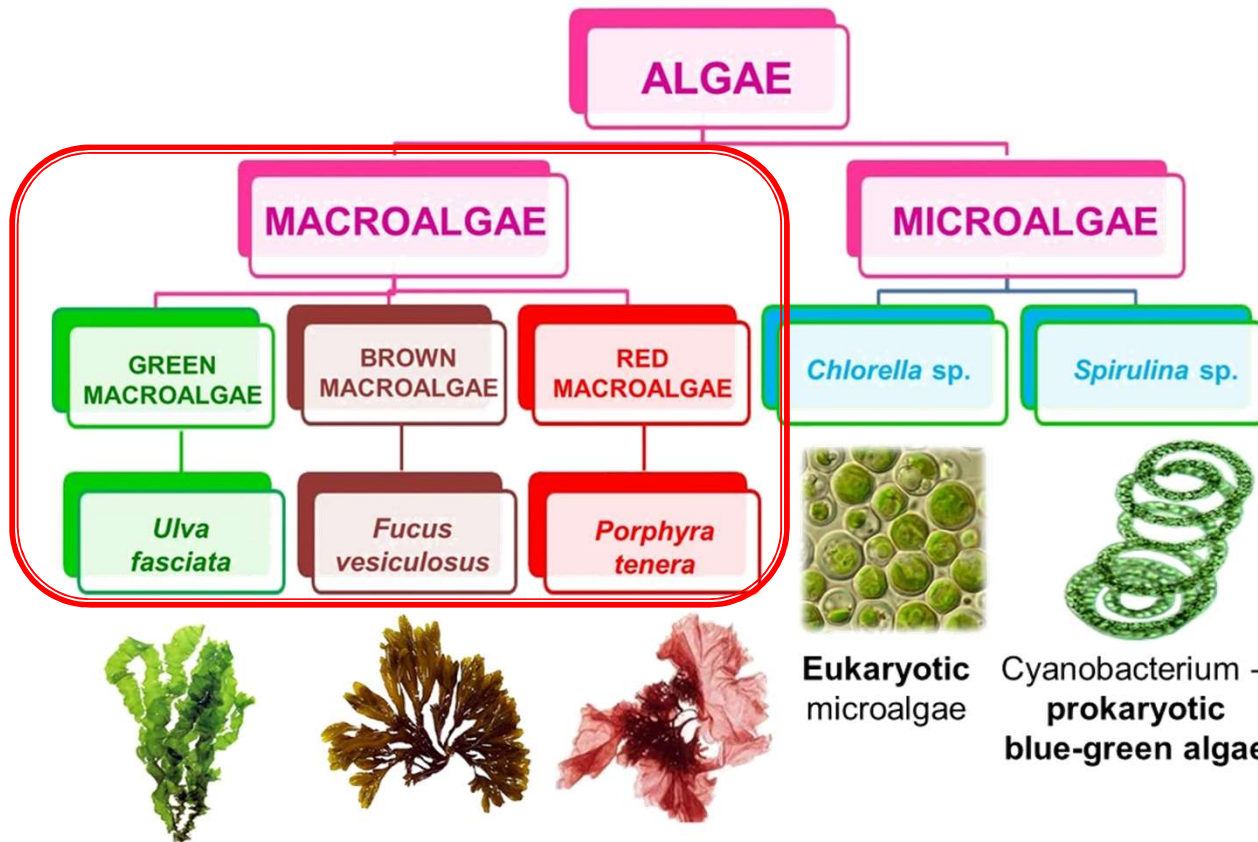
## Supervisor of:

- Engineering students
- Master's students
- Erasmus students
- PhD students
- Interns



# Scientist – my approach to research

SCIENTIST



**Valorization of waste biomass**  
(especially **seaweed biomass**)  
into valuable products for  
**modern agriculture**  
and **environmental protection.**

It is estimated that about **1800** different **brown macroalgae** (*Phaeophyceae*), **1800 green macroalgae** (*Chlorophyceae*) and **6200 red macroalgae** (*Rhodophyceae*) are found in the marine environment.

# Sources of the algal biomass in Poland



- Nowadays, macroalge (**seaweeds** / **freshwater macroalgae**) used for **agriculture purposes** are mainly based on the collected **wild biomass**
- In some cases, this is a „**win-win solution**”

- Large quantities mainly of green seaweeds, resulting from the **eutrophication**, are cast ashore on the beaches of Baltic Sea
- There is a necessity to collect this biomass and **dispose** in a **cost-effective** and **environmental-friendly method**



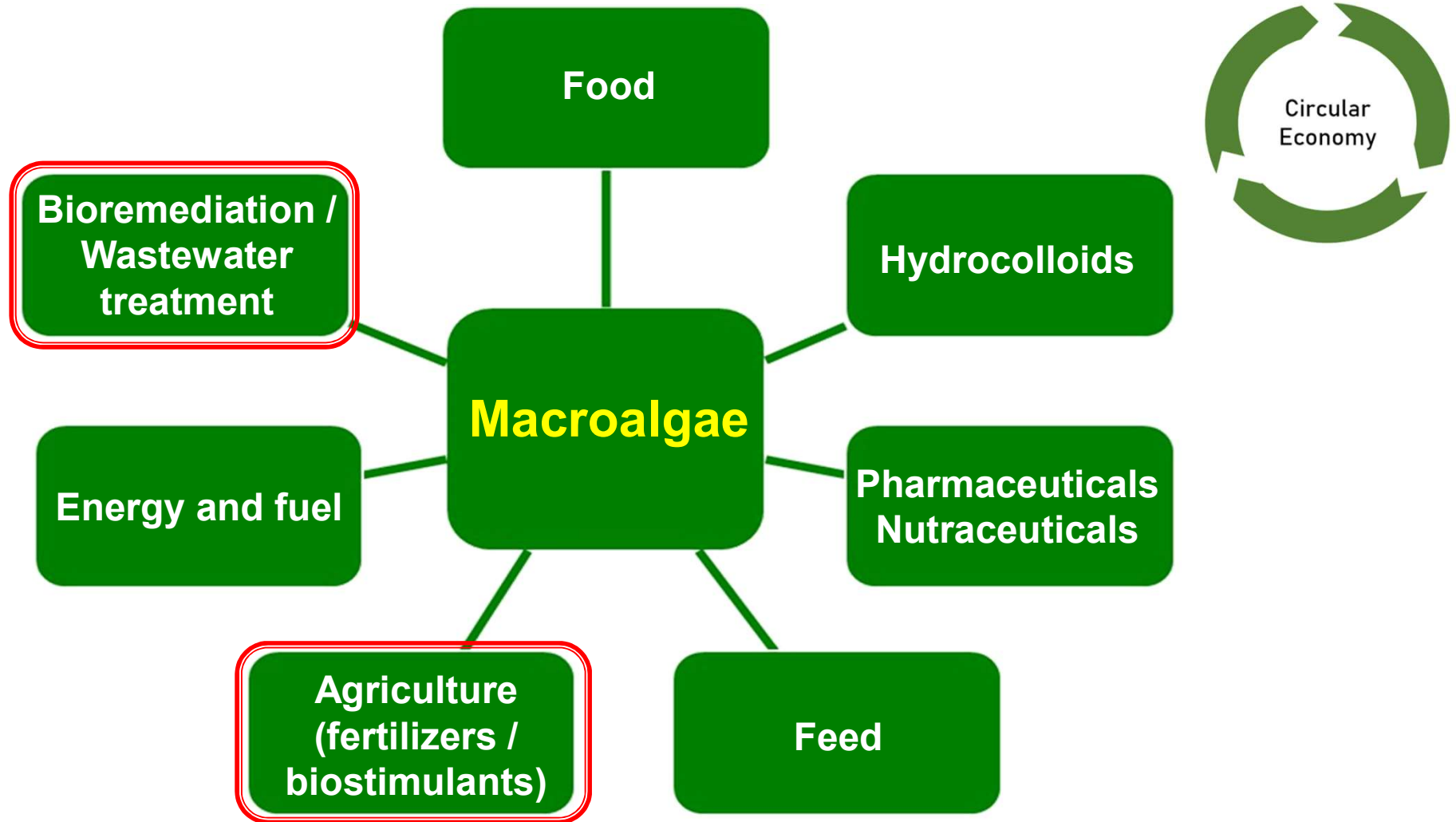
# Waste macroalgal biomass – a global problem



Pedro Portal / Miami Herald

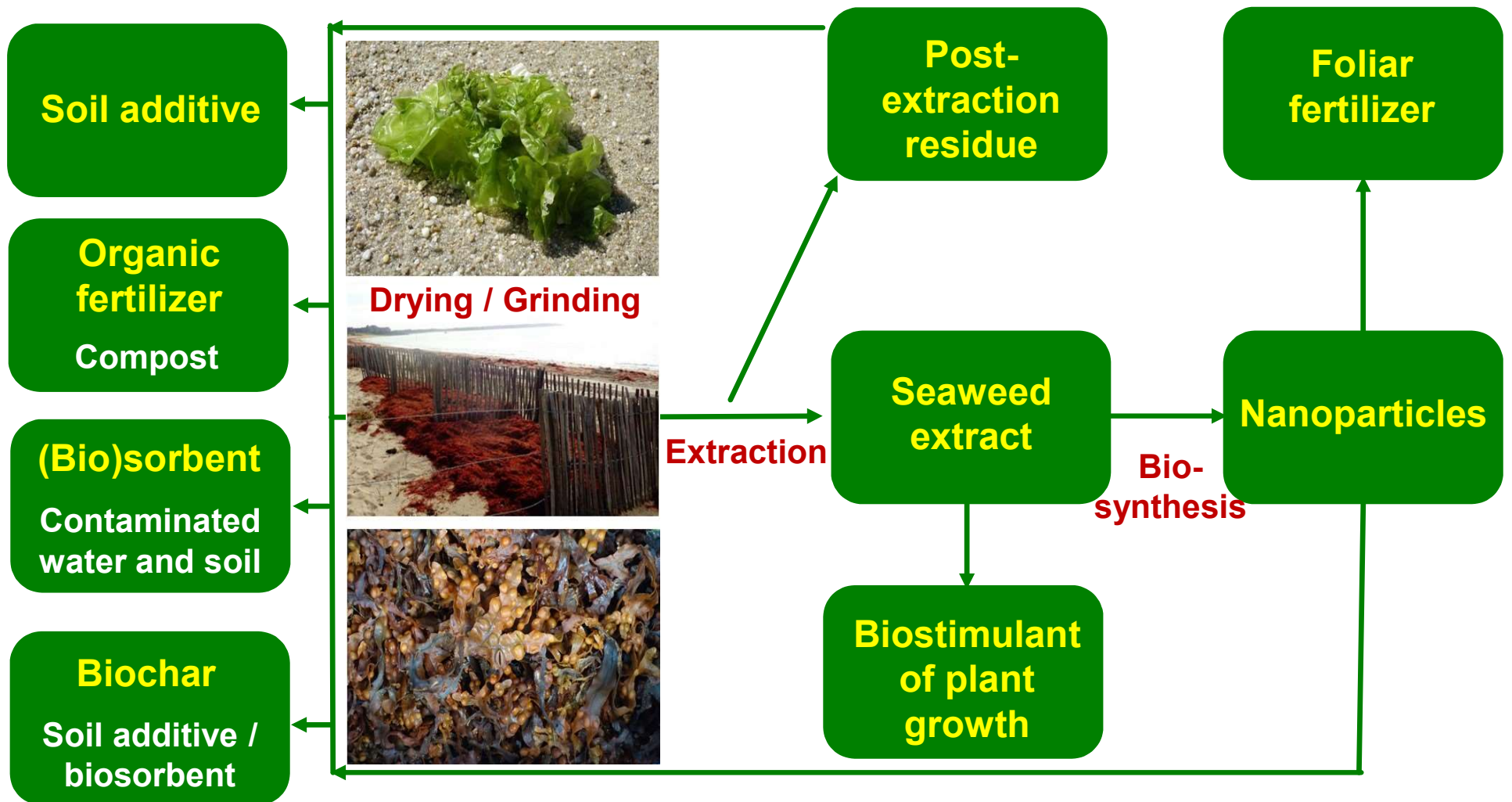
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# Potential applications of macroalgae



# My approach to research – methods of seaweed processing

You should like your research topic, then it becomes a passion !!!



# Projects concerning algae / seaweed

Research topics are very important because they enable obtaining funding for research !!!

MNiSW  
N N209 146136

Technology of feed additives from seaweeds enriched with microelements via biosorption and bioaccumulation method

(20.04.2009-26.02.2010)

NCN  
2012/05/D/ST5/03379

Biologically active compounds in extracts from Baltic seaweeds

(04.02.2013-03.02.2016)

NCBiR  
PBS/1/A1/2/2012

Innovative technology of seaweed extracts – components of fertilizers, feed and cosmetics

(11.11.2012-31.05.2016)

NCN  
2015/18/E/NZ9/00607

The effect of bioactive algae enriched by biosorption on the certain minerals such as Cr(III), Mg(II) and Mn(II) on the status of glucose in the course of metabolic syndrome horses. Evaluation *in vitro* and *in vivo*

(01.04.2016-14.06.2021)

NCN  
2019/33/B/NZ9/01844

Eco-friendly technologies for the management of seaweed biomass for products useful for sustainable agriculture and biosorbents used for the removal of heavy metal ions from the environment

(18.02.2020-17.02.2024)

# Research Methodology & Scientific Writing MOOC – aim

Aim of the course:

unite!



1

How to plan research

2

How to present research methodology

3

How to prepare a thesis proposal /  
How to effectively write a scientific paper

# Research Methodology & Scientific Writing MOOC – conditions

## **Duration of classes:**

- One hour = 45 min
- A break of 15 minutes should be taken after every 45 minutes

## **3-hours classes (90 min + 45 min):**

9:00-9:45-10:30 → 15 minutes break → 10:45-11:30

## **2-hours classes (90 min):**

9:00-9:45-10:30

# Research Methodology & Scientific Writing MOOC – content

## Research process – Step 1

1. Formulating the research problem / Identifying a research topic
2. Finding background information / Extensive literature survey (systematic tracking of scientific literature; creating search queries; current databases – Web of Knowledge, Scopus, Google Scholar, etc.)
3. Developing the research hypothesis
4. Preparing the research design (approach / methodology)
5. Collecting the research data / Variables and their types (basic elements of statistical analysis)
6. Analysis of data
7. Hypothesis testing
8. Interpretation of data / Findings and drawing conclusions



BRIDGE CENTER

RESEARCH METHODOLOGY: TOOLS AND TECHNIQUES

Dr. Prabhat Pandey

Dr. Meenu Mishra Pandey

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# Research Methodology & Scientific Writing MOOC – content

## Research process – Step 2

1. Methods of presenting results (figures, tables, drawings, photos, etc.)
2. Preparing of the report / thesis
3. Writing of scientific publication:
  - Discussion of the structure of a research publication (Instructions for authors) / Different publication templates depending on the publisher
  - Abstract writing strategies / Preparing a graphic abstract
  - Preparing a Cover Letter
  - Discussing the publication submission system / Selecting the most appropriate journal
  - Corresponding with editors and responding to questions from reviewers and the editor

# Assessment – Final report

## Report – Research Methodology & Scientific Writing MOOC – Unite!Energy

1. Name and surname
2. E-mail address
3. University name
4. Scientific profiles – if applicable
5. PhD title / Proposed PhD title
6. Summary of planned research (500 words)
7. Graphical abstract presenting the topic of the PhD thesis
8. Keywords (5-7)
9. What is the research hypothesis put forward in the doctoral dissertation?
10. What is (or could be) the „bottleneck” in your research and why?
11. List of 3-5 best journals in the research area of the doctoral dissertation (e.g., with the highest Impact Factor and Category quartile, briefly justify)
12. List of the 5-10 best scientific papers in the research area of the doctoral dissertation (number of citations)
13. The best scientific publication you have read so far and motivate shortly your choice
14. The worst scientific publication you have read so far and motivate shortly your choice
15. List 3 patents (patent number) that are similar to the topic of the doctoral dissertation
16. Data on the researchers (2-3) and their affiliations where would you like to do an internship (briefly justify)

**Deadline: 31 October 2025** ➡ **E-mail:** [izabela.michalak@pwr.edu.pl](mailto:izabela.michalak@pwr.edu.pl)



# Research methods vs. Research methodology

## Research Methods

Behaviors and instruments used in the selection and construction of the research technique



VS

## Research Methodology

Science of understanding how research is performed methodically



Source: Surbhi, 2016

Guide2Research

**Research methods** may be understood as all methods / techniques that are used for conduction of research.

**Research methodology** is a way to systematically solve the **research problem**

# Formulating the research problem / Identifying a research topic

- ❑ The researcher must decide the **general area of interest** or **aspect of a subject matter** that he would like to inquire into and then research problem should be formulated.
  - The **innovativeness of research** should be pointed out
  - A **gap in scientific research** should be pointed out
  - If you are solving an existing problem, you should show the advantages of your solution /method / approach in comparison to previous works of other researchers
- ❑ Once the problem is formulated the researcher should undertake **extensive literature survey** connected with the problem and **patent database review** – „patent purity”
- ❑ **The literature search in databases should result in the collection of valuable publications (pdf files) of high scientific quality.**



Then, the source of publications related to the research topic we are dealing with may be **citations / references** in these publications.

# „References” section in publications

## scientific reports

OPEN **Brown seaweed: *Fucus vesiculosus* as a feedstock for agriculture and environment protection**

Karolina Krautforst<sup>1</sup>, Anna Szymczycha-Madeja<sup>2</sup>, Maja Welna<sup>2</sup> & Izabela Michalak<sup>1,3</sup>

Check for updates

### References

1. Chojnacka, K. *et al.* Algal extracts as plant growth biostimulants. In *Marine algae extracts: Processes, products, and applications* Vol. 11 (eds Kim, S. K. & Chojnacka, K.) 189–212 (Wiley-VCH Verlag GmbH & Co. KGaA, 2015).
2. Żurek, G. Alternative plants for phytoextraction of heavy metals from contaminated areas. *Prob Inz. Rol.* 3, 83–89 (2009).
3. Savci, S. Investigation of effect of chemical fertilizers on environment. *APCBEE Proc.* 1, 287–292 (2012).
4. Bikovens, O. *et al.* Development of the approaches for complex utilization of brown algae (*Fucus vesiculosus*) biomass for the obtaining of value-added products. 8th International Scientific Conference Rural Development 222–225 (2017).
5. Peng, Y. *et al.* Chemical composition of seaweeds. *Seaweed Sustain.* 5, 79–124 (2015).
6. Balina, K., Romagnoli, F. & Blumberga, D. Chemical composition and potential use of *Fucus vesiculosus* from Gulf of Riga. *Energy Procedia* 95, 43–49 (2015).
7. Catarino, M. D., Silva, A. & Cardoso, S. M. Phycochemical constituents and biological activities of *Fucus* spp. *Mar. Drugs* 16(8), 249 (2018).
8. Łęska, B., Messyasz, B. & Schroeder, G. Application of algae biomass and algae extracts in cosmetic formulations. In *Algae Biomass: Characteristics and Applications* (eds Chojnacka, K. *et al.*) 89–101 (Springer, 2018).
9. Jimenez-Lopez, C. *et al.* Main bioactive phenolic compounds in marine algae and their mechanisms of action supporting potential health benefits. *Food Chem.* 341, 128262 (2020).
10. Mzibra, A. *et al.* Biostimulants derived from Moroccan seaweeds: Seed germination metabolomics and growth promotion of tomato plant. *J. Plant Growth Regul.* 40, 353–370 (2021).
11. Abd-Elhady, E. S. E. Evaluation of algae dry biomass as a biochemical soil remediation for polluted soil. *Int. J. Environ.* 4(4), 309–314 (2015).
12. Abd-Elhady, E. S. E. & El-Zabalawy, K. M. Remediation of a soil contaminated with heavy metals using some seaweeds. *J. Soil Sci. Agricult. Eng.* 5(12), 1623–1633 (2014).
13. Ahmed, D. A. E. A., Gheda, S. F. & Ismail, G. A. Efficacy of two seaweeds dry mass in bioremediation of heavy metal polluted soil and growth of radish (*Raphanus sativus* L.) plant. *Environ. Sci. Pollut. Res.* 28, 12831–12846 (2021).
14. Michalak, I. The application of seaweeds in environmental biotechnology. *Adv. Bot. Res.* 95, 85–111 (2020).

### General note:









When citing publications / book chapters, regardless of the type of work (publication, doctoral thesis, report, etc.), the **citation style should be unified.**


# Patent database – Polish Patent Office

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WYSZUKIWARKA PROSTA ?

Wyszukiwanie:   Uwzględnij polskie znaki

Kryteria wyszukiwania

▼ Rodzaje PWP  WYSZUKIWARKA ZAAWANSOWANA



## PAT: Biostymulator wzrostu roślin (Plant growth biostimulant – Polish patent)



Numer zgłoszenia	Application number	P.412074	Numer prawa wyłącznego	Pat.230687		
Data zgłoszenia	Application date	2015-04-20	Status ⓘ	Current status	Prawo w mocy	Valid
Nazwa/Tytuł	Application title	Biostymulator wzrostu roślin	Zgłaszający/Uprawniony	Applicant	UNIwersytet Opolski, Opole, PL, POLITECHNIKA WROCŁAWSKA, Wrocław, PL, UNIwersytet im. Adama...	

### Skrót opisu - tekst (Short description)

Wynalazek dotyczy biostymulatora wzrostu roślin przeznaczonego do zwiększania wydajności plonowania, zawierającego od 0,1 do 60% masowych nadkrytycznego ekstraktu z biomasy alg, wybranych z grupy obejmującej mikroalgi, korzystnie Spirulina species i makroalgi, korzystnie Fucus species oraz makroalgi bałtyckie z rodzaju Cladophora i Enteromorpha, uzyskanego przy użyciu ekstrahenta w postaci nadkrytycznego ditlenku węgla (CO<sub>2</sub>). Ponadto biostymulator wzrostu roślin zawiera od 0,1 do 60% masowych emulgatora, wybranego z grupy obejmującej jonowe, niejonowe i amfoteryczne środki powierzchniowo czynne oraz od 5 do 95% masowych wody. Ujawniono również sposób wytwarzania biostymulatora wzrostu roślin, który polega na tym, że rozdrobnioną biomasę alg, ekstrahuje się nadkrytycznym ditlenkiem węgla, w temperaturze od 35°C do 70°C, pod ciśnieniem od 300 do 1000 bar, z zachowaniem proporcji ekstrahenta do surowca, w granicach od 30 do 80 kg CO<sub>2</sub> na 1 kg biomasy. Ekstrakt miesza się z emulgatorem w proporcji od 1 : 99, wybranym z grupy obejmującej jonowe, niejonowe i amfoteryczne środki powierzchniowo czynne, a następnie miesza się z wodą, w takiej proporcji, aby udział ekstraktu algowego w całkowitej masie biostymulatora wynosił od 0,1 do 60%. Korzystnie przed procesem ekstrakcji, biomasę alg kondycjonuje się w roztworze kwasu nieorganicznego i/lub poddaje się działaniu ultradźwięków lub mikrofal.

















# Patent database – Polish Patent Office

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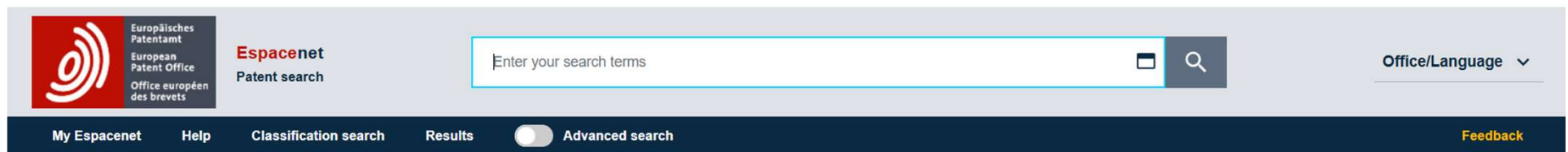
  
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# Patent database – International databases

- ❑ **Espacenet** – an international database of patent documents maintained by the EPO (European Patent Office): <https://worldwide.espacenet.com/>
- ❑ **PATENTSCOPE** – an international database of patent documents maintained by WIPO (World Intellectual Property Organization, an organization established under the Stockholm Convention in 1967 to promote industrial and intellectual property matters): <https://www.wipo.int/en/web/patentscope>
- ❑ **Google Patents** – an international database of patent documents maintained by Google: <https://patents.google.com/advanced>
- ❑ **USPTO** – an international database of patent documents maintained by **United States Patent and Trademark Office**: <https://www.uspto.gov/patents/search/patent-public-search>



The screenshot shows the top navigation bar of the Espacenet website. On the left, there is a logo for the European Patent Office (EPO) with text in German, English, and French. Next to it is the 'Espacenet Patent search' logo. A search bar is centered, containing the placeholder text 'Enter your search terms' and a magnifying glass icon. To the right of the search bar is a dropdown menu labeled 'Office/Language'. Below the search bar is a dark blue navigation bar with links for 'My Espacenet', 'Help', 'Classification search', 'Results', and 'Advanced search' (which has a toggle switch). A 'Feedback' link is located on the far right of this bar.

Espacenet: free access to over 160 million patent documents

# Searching for articles in databases

- **Library account** – <https://biblioteka.pwr.edu.pl/en/>
- **Web of Science**
- **Scopus**
- **PubMed**
- **Google Scholar**
- **ResearchGate**
- **Loop** (Frontiers)
- **SciProfiles** (MDPI)
- ...



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## e-Resources

Library has signed licence contracts for electronic files. Access to these files is restricted to staff members and students of Wrocław University of Science and Technology (WUST) and is controlled by means of local campus-wide access, i.e. restricted to work stations registered in the IP-domain of the University, and by means of authentication as staff member or student of the WUST. The electronic databases can also be accessed from pc's off campus after logging in to **HAN**.

- Databases
- e-Books
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APS/AIP	▼
Architectus (Wroclaw University of Science and Technology)	▼
Archives of Civil and Mechanical Engineering (Wroclaw University of Science and Technology)	▼
ASTM	▼
BioMed Central	▼
Cambridge University Press (CUP)	▼
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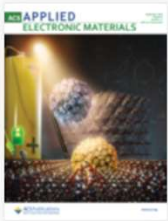
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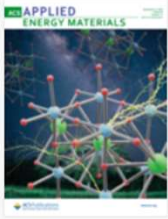
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 Journal  
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# Web of Science database

The screenshot displays the Web of Science database search interface. At the top, the browser address bar shows the URL `webofscience.com/wos/alldb/basic-search`. The page header includes the Clarivate logo, language settings (English), and product information. The main navigation bar features 'Web of Science™', 'Smart Search', 'Advanced Search' (which is the active tab), and 'Research Assistant'. A toggle for 'Try the new search' and links for 'Sign In' and 'Register' are also present.

The search interface is divided into two main sections: 'DOCUMENTS' and 'RESEARCHERS'. The 'DOCUMENTS' section contains a search bar with the text 'Search in: All Databases' and 'Collections: All'. Below this, there are three tabs: 'FIELD SEARCH' (active), 'QUERY BUILDER', and 'CITED REFERENCES'. The 'FIELD SEARCH' section includes a dropdown menu for selecting the search field, currently set to 'Topic', and a text input field with the example query 'oil spill\* mediterranean'. A second search field is also visible, with the same example query. A '+ Add row' button is located below the search fields.

A dropdown menu is open, showing the following options: 'Search', 'Topic', 'Title', 'Author', 'Publication/Source Titles', and 'Year Published'. The 'Topic' option is highlighted. To the right of the dropdown, a tooltip provides information about the 'Topic' search field: 'Topic Searches title, abstract and indexing. Examples: robot\* control\* "input shaping"'. The 'Clear' and 'Search' buttons are visible at the bottom right of the search area.

At the bottom right of the page, there is a 'Sign in to access' button and a help icon with the number '26'.

**Highly Cited Papers** are papers that perform in the top **1%** based on the number of citations received when compared to other papers published in the same field in the same year.

**Hot Papers** are papers published in the last two years that are receiving citations quickly after publication. These papers have been cited enough times in the most recent bimonthly period to place them in the top 0.1% when compared to papers in the same field and added to the database in the same period.

**DOCUMENTS** **RESEARCHERS**

Search in: All Databases ▾ Collections: All ▾

FIELD SEARCH QUERY BUILDER CITED REFERENCES

Topic ▾ biochar in agriculture ×

+ Add row + Add date range

× Clear 🔍 Search

If we want to narrow down the topics of the publications we are searching for ↓

Search > Refine results for biochar in agriculture (Topic) and Preprint Citation Index (...)

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biochar in agriculture (Topic) → Copy query link

+ Add Keywords Quick add keywords: < + biochar + soil amendment + biochar amendment + rice husk biochar + biochar application + biochar-based fertiliz >

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1 Production of biochar aggregate particles used for industrial applications e.g. agriculture and composting, involves collecting biochar fines, adding binding agent to fines and forming fines and agent into solid aggregate particles

US2017197192-A1; US10322389-B2  
Inventors : MALYALA R; TRAXLER V; (...); BELCHER R W  
Assignee : COOL PLANET ENERGY SYSTEMS INC  
Derwent Primary Accession Number : 2017-478564

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1 Web of Science Core Collection

### A comprehensive review of engineered biochar: Production, characteristics, and environmental applications

381

Citations

286

References

Panahi, HKS; Dehghaghi, M; (...); Lam, SS

Oct 10 2020 | JOURNAL OF CLEANER PRODUCTION 270

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# A comprehensive review of engineered biochar: Production, characteristics, and environmental applications

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By



Michalak I. / Izabela M.

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JCR Category	Category Rank	Category Quartile
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ENVIRONMENTAL SCIENCES <i>in SCIE edition</i>	23/374	Q1
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Cites in 2009 to articles published in:

- 2008 = 9000
- 2007 = 8000

Total recent citations in 2009 = 17000

Number of items published in:

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- 2007 = 1200

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Impact Factor:

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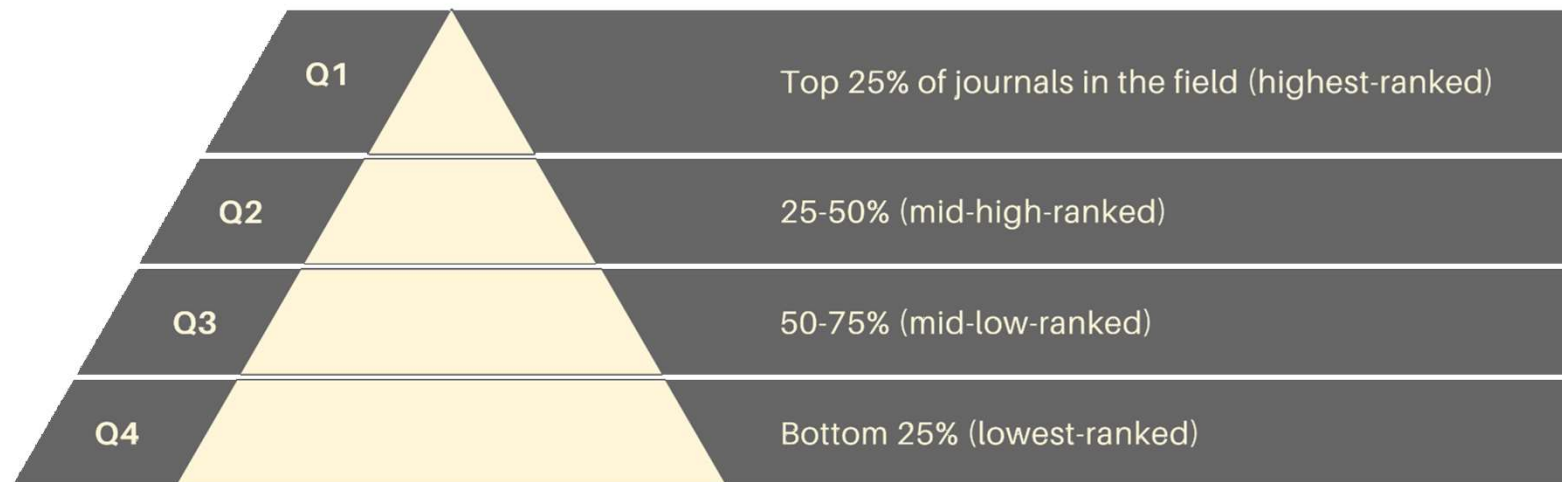
Q1	$0.0 < Z \leq 0.25$	Highest ranked journals in a category
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**Z is defined as  $Z = X / Y$**

where:

X – is the journal rank in category

Y – is the number of journals in the category



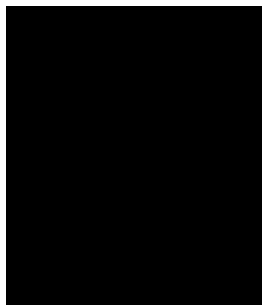
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The development and recycling of biomass production can partly solve issues of energy, climate change, population growth, food and feed shortages, and environmental pollution. For instance, the use of seaweeds as feedstocks can reduce our reliance on fossil fuel resources, ensure the synthesis of cost-effective and eco-friendly products and biofuel ... Show more  
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Seaweed-based biochars stemmed from the solid wastes of seaweed-based biomass pyrolysis were used to reduce the emission of elemental mercury. An environmentally-friendly ultraviolet/hydrogen peroxide advanced oxidation process modification method was used to increase the active species over seaweed-based biochars for elemental mercury ... Show more  
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Kumar, P; Patel, AK; (...); Dong, CD  
Nov 2023 | BIORESOURCE TECHNOLOGY 388  
Despite the remarkable Cu(II) sorption biochar potential, it is challenging to desorb them for repeated biochar usage. The present study aims to develop engineered biochar by polarizing *Ascophyllum nodosum* (seaweed) biomass and magnetizing it with Fe<sub>3</sub>O<sub>4</sub> nanoparticles coating. SEM, EDX, XRD, BET, and FT-IR helped to characterize engineered biochar ... Show more  
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**Feasibility of Biochar from Seaweed for Ferroalloy Production** 21 References  
Senanu, S; Sandquist, J; (...); Windfeldt, M  
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Biochar from seaweed, specifically sugar kelp, cultivated on the Norwegian coastline has been investigated as a possible biocarbon source for the metal industry to reduce the dependency on terrestrial biomass. Pre-processing of the biomass prior to pyrolysis is needed to reduce the water and ash content and was performed by water and acid wash ... Show more  
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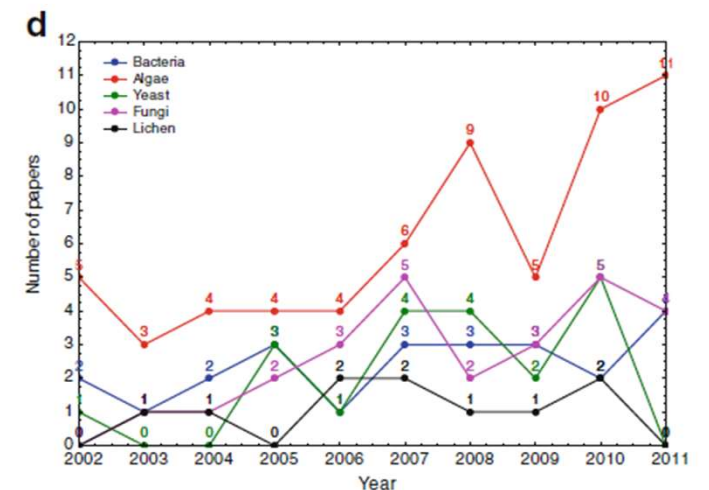
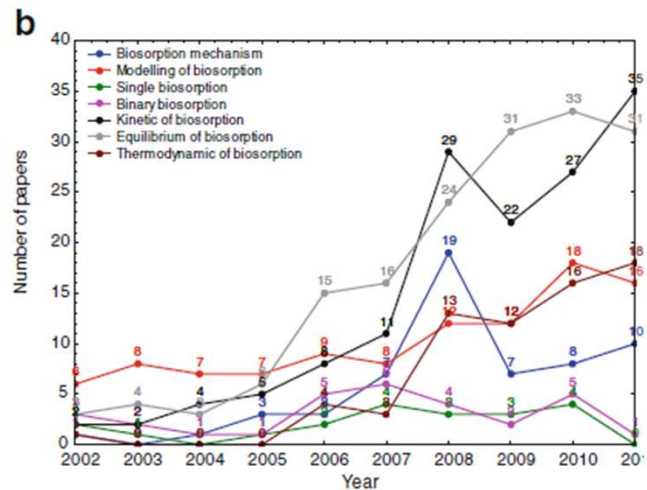
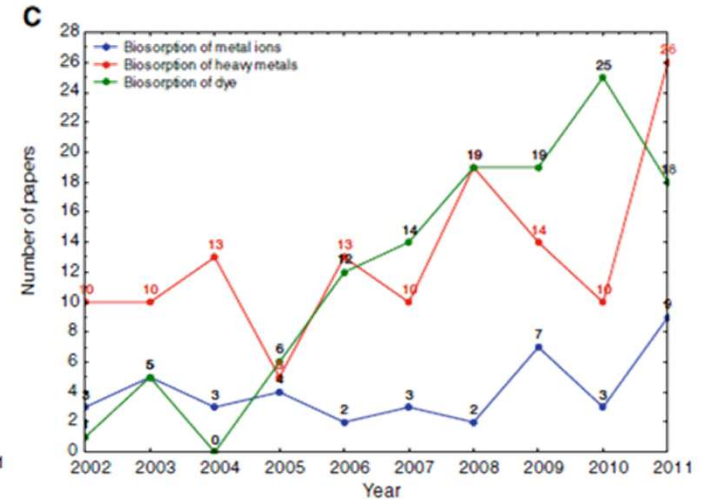
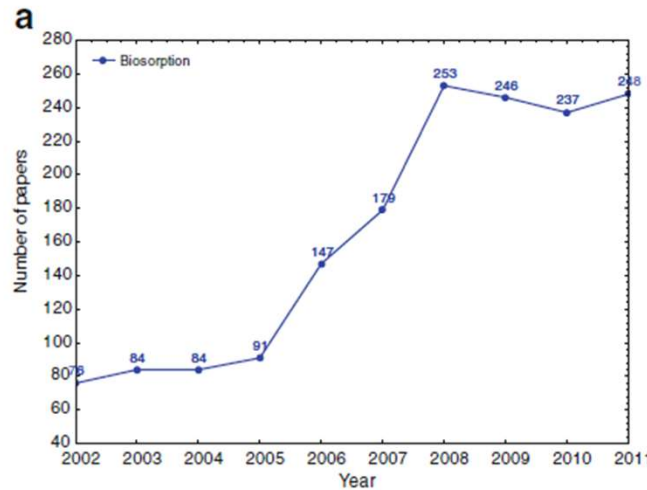
Number of papers on biosorption with:

**a** “biosorption” word in the topic of publication

**b** different “key words” in the topic

**c** different “key words” in the topic: type of sorbate

**d** different “key words” in the topic: type of biosorbent



# Web of Science – example

Figure 1 presents several articles that concern the potential application of seaweed biochar in different areas.

For this purpose, the following keywords regarding **the topic of the publication** were searched in the **Web of Science database**:

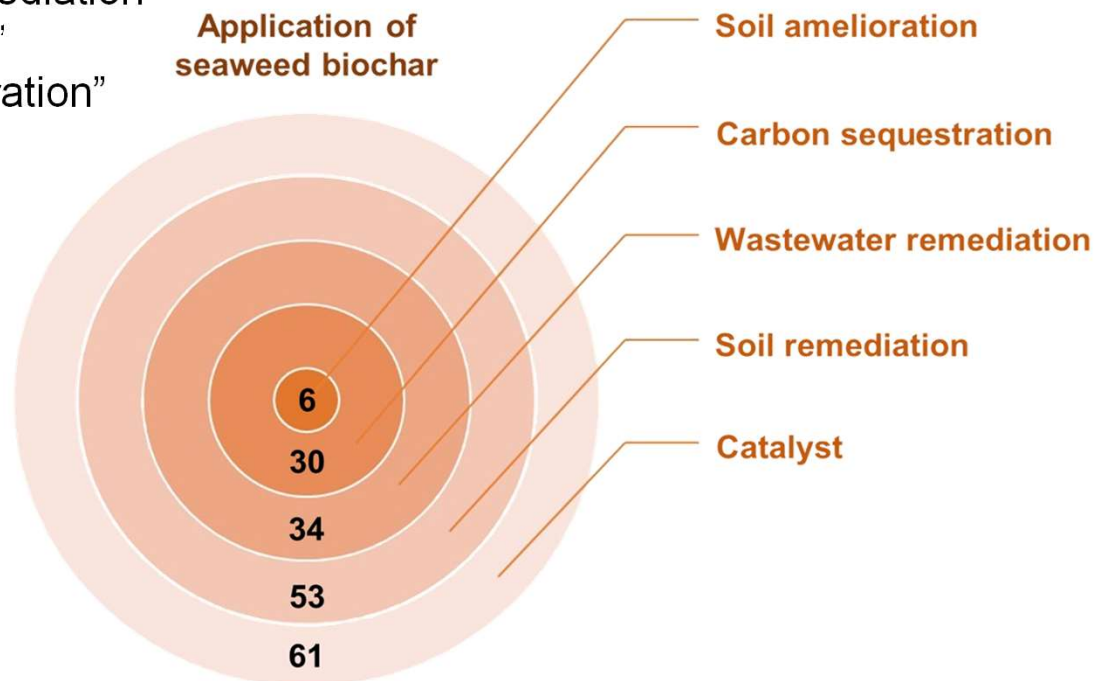
“seaweed biochar” and – “soil amelioration”

“seaweed biochar” and – “wastewater remediation”

“seaweed biochar” and – “soil remediation”

“seaweed biochar” and – “carbon sequestration”

“seaweed biochar” and – “catalyst”



**Figure 1.** The number of publications that concerned potential applications of seaweed biochar (own source; according to the Web of Science database, 7 March 2025)

# Web of Science – example

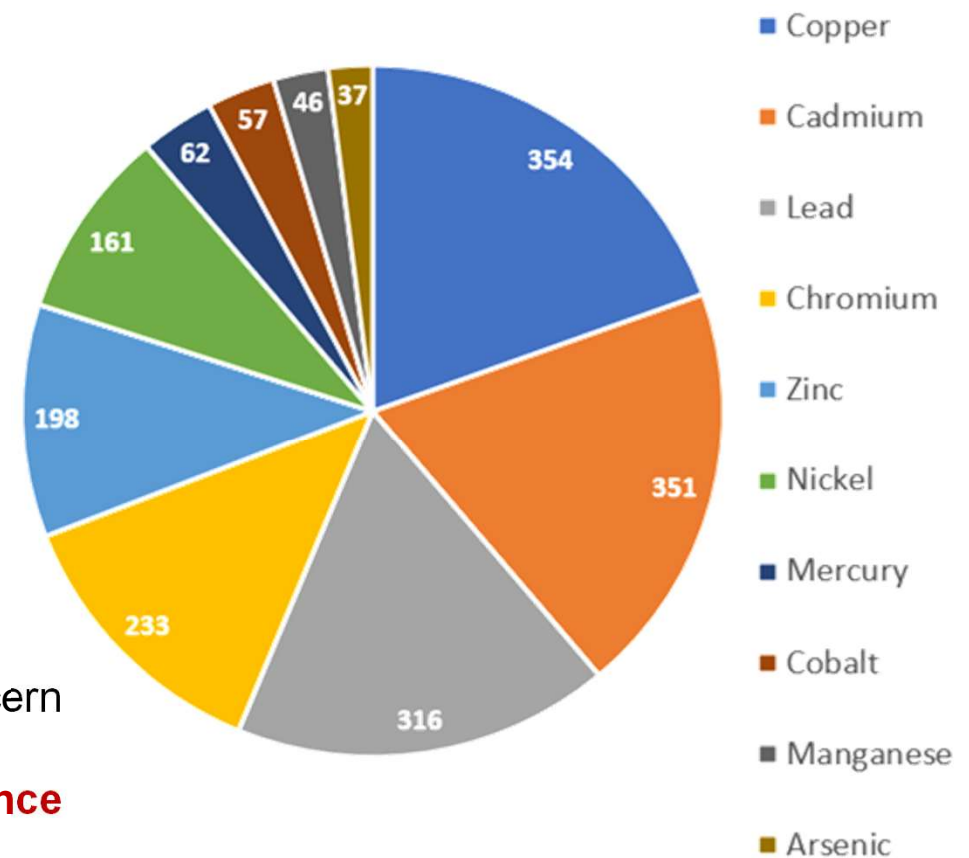
Seaweed biomass is very popular for removing heavy metal ions from wastewater.

Figure 2 presents the number of publications, concerning the biosorption of heavy metal ions by seaweed.

For this purpose, the following keywords were searched in the Web of Science database on **the topic of the publication**:

“biosorption by seaweed” and “coper”;

“biosorption by seaweed” and “cadmium”, etc.



**Figure 2.** The number of publications that concern potential applications of seaweed biochar (own source; according to the Web of Science database, 11 March 2025)

# Scopus database

A very important database – when assessing the **scientific achievements of scientists**, data from this database is often taken into account – it is worth being registered here. Author indicators are higher in the Scopus database than in the Web of Science database because it also includes **book chapters**.

The ***h-index*** is a quantitative metric based on analysis of publication data using **publications** and **citations** to provide “an estimate of the importance, significance, and broad impact of a scientist’s cumulative research contributions.”



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ACS Agricultural Science and Technology, 2025, 5(4), pp. 424–453

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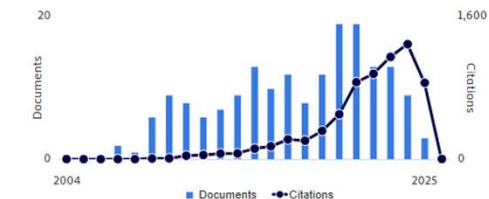
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Citations

Choulot, M., Jabbour, C., Burlot, A.-S., ... Michalak, I., Bourgoignon, N.

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Waste and Biomass Valorization  
<https://doi.org/10.1007/s12649-025-02970-5>

## ORIGINAL PAPER



## Sustainable Applications of *Cladophora glomerata* Hydrolysates: *Nostoc commune* Cultivation and Utilizing Biowaste for Agricultural and Environmental Purposes

Ella Lio<sup>1</sup> · Katarzyna Łukowiak<sup>2</sup> · Martina Dramis<sup>1</sup> · Natalia Niedzbała<sup>2</sup> · Gianluca Ottolina<sup>1</sup> · Francesco Secundo<sup>1</sup> · Izabela Michalak<sup>2</sup>  → **ORCID number – once you click, you will be redirected to the ORCID database**

Received: 14 September 2024 / Accepted: 8 February 2025  
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### Abstract

The green macroalga *Cladophora glomerata*, a species commonly infesting surface waters, was hydrolyzed by Liquid Hot Water treatment under acidic, neutral, and alkaline conditions. The liquid fraction obtained after hydrolysis was added to BG11 medium to cultivate the valuable cyanobacterium *Nostoc commune* under mixotrophic conditions, while the insoluble fraction was tested as a biosorbent of metal ions. In addition, cyanobacteria were grown under autotrophic conditions also in the presence of ZnO nanoparticles, biosynthesized using aqueous *C. glomerata* extract. Mixotrophic conditions with the use of acidic and alkaline algal hydrolysates produced the largest amount of *N. commune*. The post-culture media after *N. commune* separation were tested as potential biostimulants of plant growth, while the alga itself and the solid residue after hydrolysis were tested for the biosorption capacity of Cr(III) ions. The study presents an environmentally friendly method to transform the waste algal biomass into beneficial products for agriculture and the environment.

**Keywords** *Cladophora glomerata* · Thermal hydrolysis · *Nostoc commune* · Germination tests · Biosorption

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

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Narodowa Agencja Wymiany Akademickiej (Warsaw, PL)  
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CONTRIBUTORS: Pushp Sheel Shukla; Izabela Michalak; Anne-Sophie Burlot; Nathalie Bourgougnon; Bruno Daridon; Domenico Ronga; Anicia Hurtado; Alan T. Critchley

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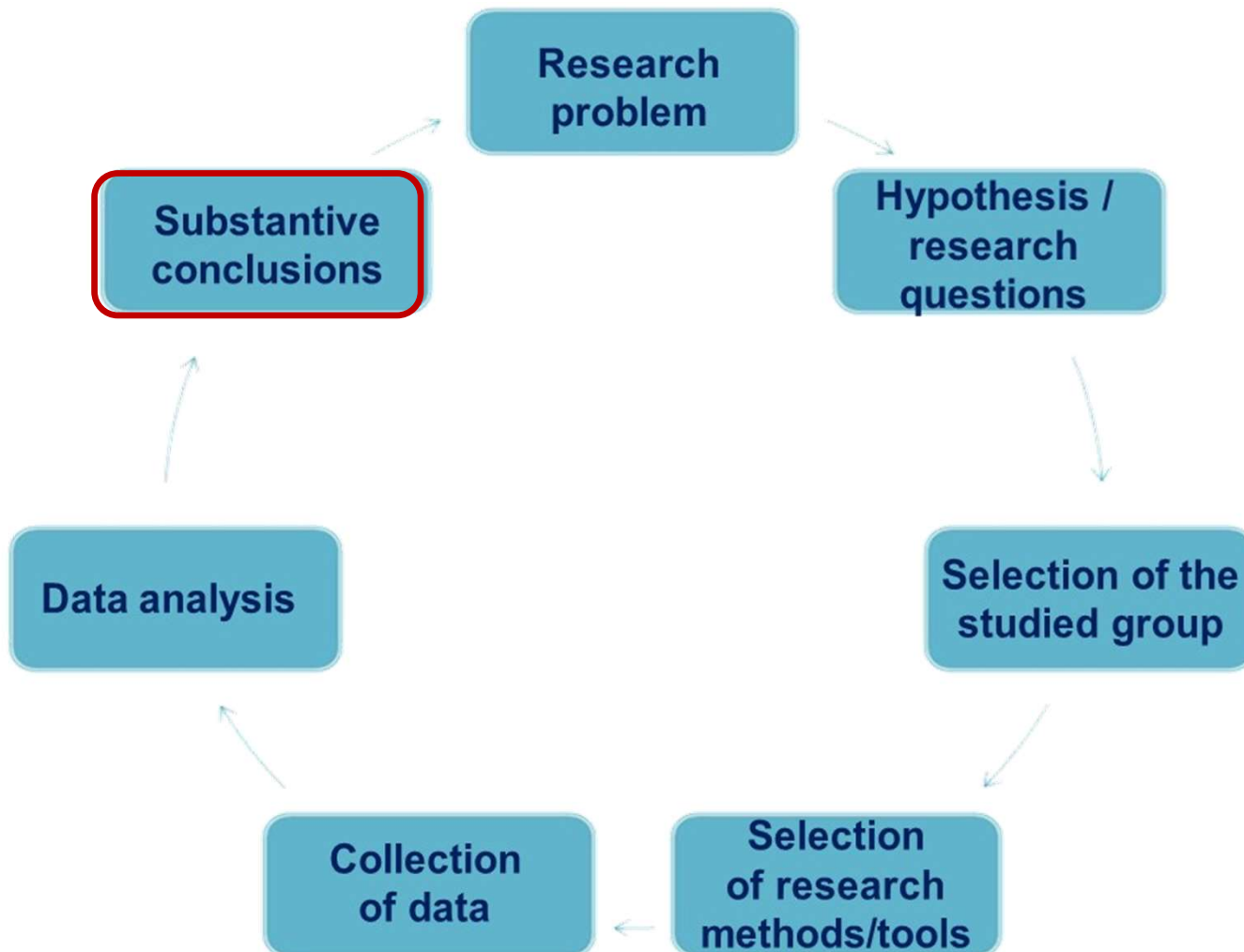
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# Benefits of a good literature review

- ❑ it is worth spending time reviewing publications related to a given research topic (**do it yourself**)
- ❑ you will become familiar with the **structure of a scientific publication** and **scientific language**
- ❑ you should be critical of the publications you read – unfortunately, due to the number of publications currently published, there may be publications of poor scientific quality (**quantity vs. quality**)
- ❑ publications (Materials and Methods section) may describe the use of **new research techniques** that you do not have in your laboratory, but may be useful in solving your research problem – this may be a **motivation to start new scientific cooperation**
- ❑ pay attention to the **authors of the publications** and their scientific achievements – they may be **potential reviewers of your publications** (when submitting a publication to a journal, you should usually suggest several reviewers, but this does not mean that they will be selected)
- ❑ pay attention to the **affiliation of the authors** of the publication – which research unit deals with a given topic – this may be a potential **place for a research internship** (after obtaining funding)

# General scheme of the research process



A **statistical hypothesis**

–  
is an assumption about a population parameter.

A **parameter** is a measurable characteristic of a population.

This assumption may or may not be true.

# Developing the research hypothesis

After extensive literature survey, researcher should state in clear terms **the hypothesis / hypotheses** or **research questions**.

❑ In some disciplines, the hypothesis is called a “**thesis statement**”



**Example:** The addition of biochar to the soil increases wheat yield compared to soil without biochar.



**Example:** Will the addition of biochar to the soil increase wheat yield compared to soil without biochar?

❑ If a hypothesis is put forward in the prepared study, at the end of this study there should be a **verification of this hypothesis** – whether it has been confirmed / accepted or rejected.

# Preparing the Research design

**Research design** is the framework of **research methods** and **techniques** chosen by a researcher.

- ❑ Good research design enables you to obtain appropriate evidence to address the research problem effectively.

**Research methods** are systematic processes / strategies and techniques (instruments – measurements) for **collecting** and **analyzing data** to answer research questions and test hypotheses.

They are categorized broadly into:

- ❑ **quantitative** (using numerical data and statistics),
- ❑ **qualitative** (focusing on descriptive, non-numerical data),
- ❑ and mixed methods (combining both).

Common **quantitative methods** often **involve experiments, surveys**, and **qualitative methods** include interviews, focus groups, case studies, and observation.

# Preparing the Research design

**Quantitative research approach** – gathers numerical data:

- Data collected is numerical
- Data is analysed and converted into statistics
- Sample sizes should be quite large (to ensure that the differences for the measured parameter between the study groups are statistically significant)

**Statistical data analysis** – deals with methods of description and analysis of numerical regularities occurring in **mass phenomena (processes)**.

- We deal with mass phenomena when a sufficiently large number of units is examined → only then can certain regularities be observed.
- They cannot be detected by observing a single unit or a small set of units.

**Examples of mass phenomena:**

- Demographic phenomena** (e.g., births, marriages, deaths)
- Cases of illness** in medicine
- Phenomena in industry and transport** (e.g., production of various articles, passenger transport)
- Phenomena on the financial markets** (e.g., loan volume, stock prices on the stock exchange)

# Quantitative research approach

POPULATION

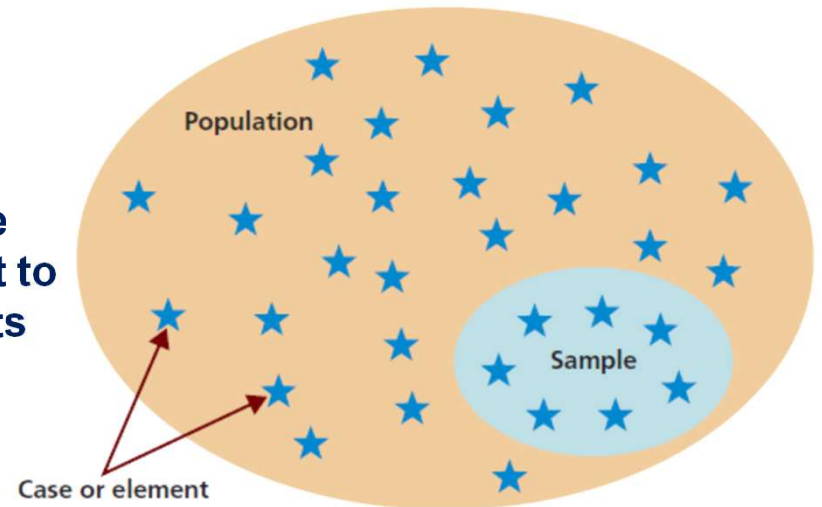
Random  
sampling



We take a sample from the population and then we want to transfer the obtained results to the entire population.

SAMPLE

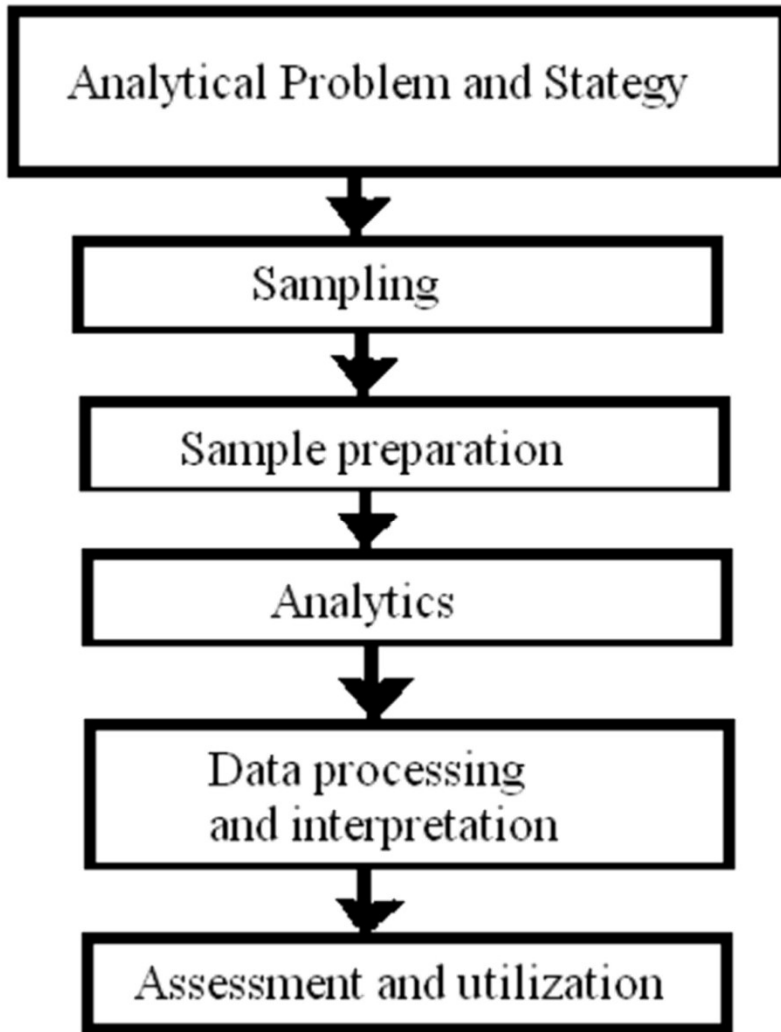
(group that we are able to test)



The sample is required to be **representative** – to describe the structure of the general population. The method of selecting the sample and the size of the sample affect the **representativeness of the sample**.

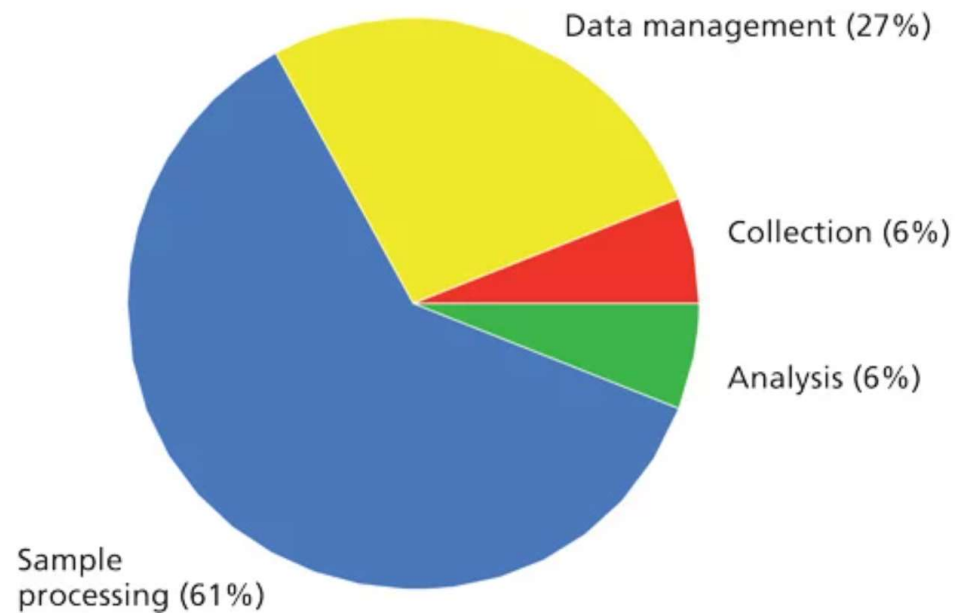
**If the sample is randomly selected and is large enough, the sample is said to be representative.**

# Procedure of analytical method



The "**bottleneck**" of an analytical method is often the sample preparation step, as it is frequently the most time-consuming, complex, and error-prone part of the overall analytical process.

While analytical chemists are developing faster and more efficient techniques, the thoroughness of sample preparation remains critical, acting as a crucial foundation that **can significantly impact the reliability of the final results**.



# Statistical analysis of data

## Objective of statistical analysis:

- ❑ the need to draw conclusions about a group of measurements being studied
- ❑ inferring characteristics of a group of data by analyzing the characteristics of a small sample of the group

Before statistical analysis of the results, we should ensure a **sufficient number of replications in the study groups** (at least  $N=6$ ) and select an appropriate statistical test.

The number of repetitions should be taken into account when planning experiments.

**Results obtained in a single replicate cannot be reported (the result may be unreliable)!!!**

Selected statistical test should answer the question of **whether there are statistically significant differences between the compared groups or not.**

# Criteria for selecting a statistical test

1

## The nature of comparative groups

- Independent
- Dependent

In **independent samples**, subjects in one group do not provide information about subjects in other groups.

Each group contains different subjects and there is no meaningful way to pair them.

**Example:** A medication trial has a control group and a treatment group that contain different subjects.

In **dependent samples**, subjects in one group do provide information about subjects in other groups.

The groups contain either the same set of subjects or different subjects that the analysts have paired meaningfully.

**Example:** A training program assessment takes pre-test and post-test scores from the same group of people.

# Criteria for selecting a statistical test

2

## Number of comparison groups

- 2 groups (test *t*; Student *t*-test)
- more than 2 groups (One-Way Analysis of Variance – ANOVA)

**Variance** – a measure of the variation among values. It is calculated by adding up squared differences of each value and the mean and then dividing the sum by the number of samples.

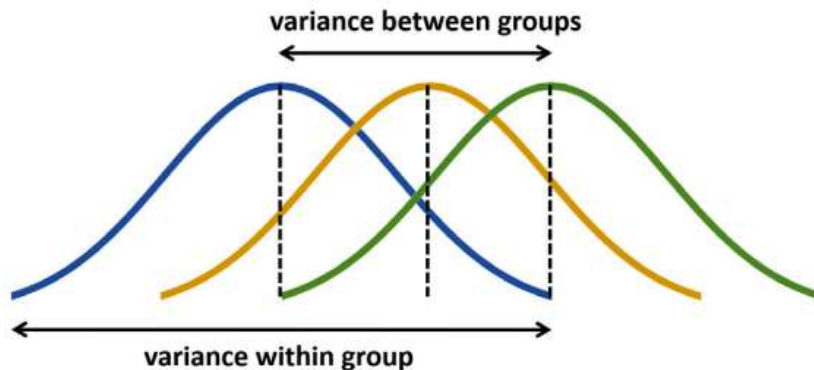
**Standard deviation** (SD) – the square root ( $\sqrt{\quad}$ ) of variance.

$$\text{Variance} = \frac{\sum(x_i - \text{mean})^2}{N}$$

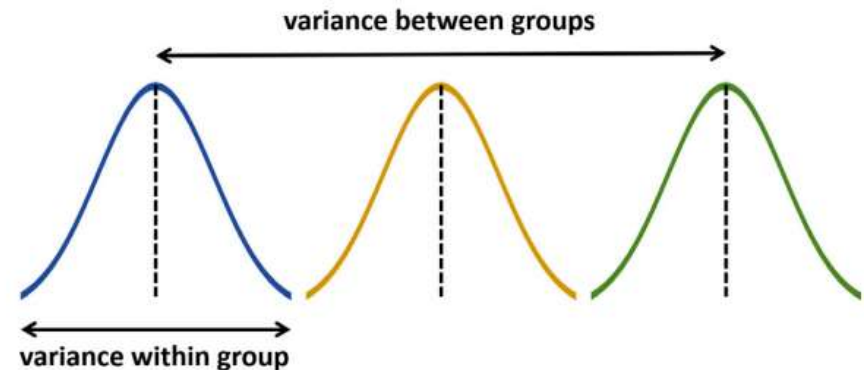
$x_i$  = value *i*

*N* = number of values

Mean = average of all values



**Groups not significantly different**

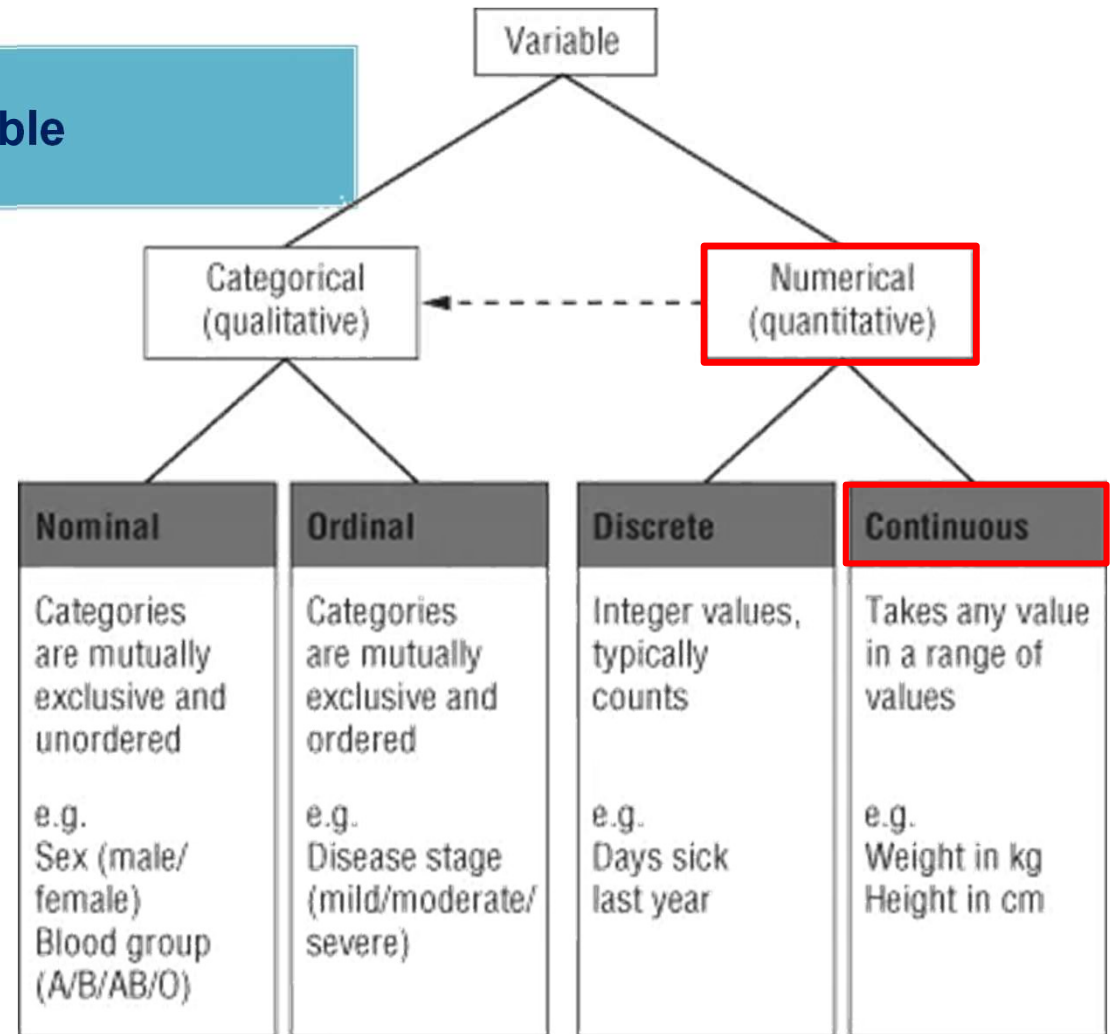


**Groups significantly different**

# Criteria for selecting a statistical test

3

## Types of variable

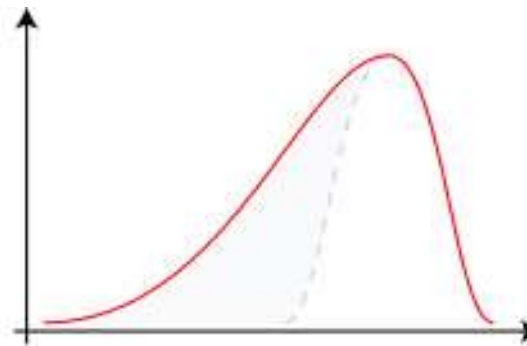
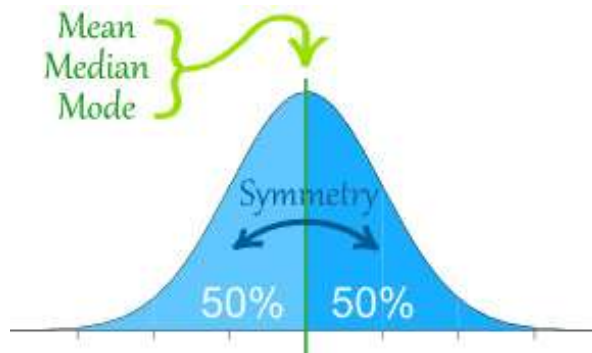


# Criteria for selecting a statistical test

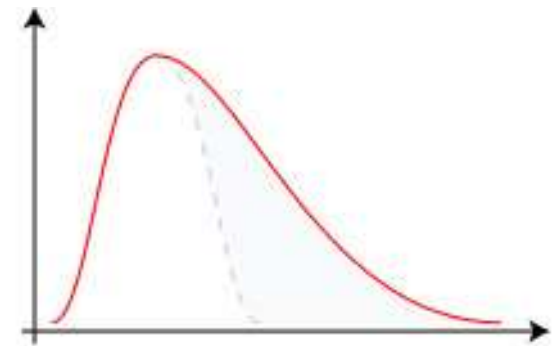
4

The nature of the variable distribution

- normal
- other than normal



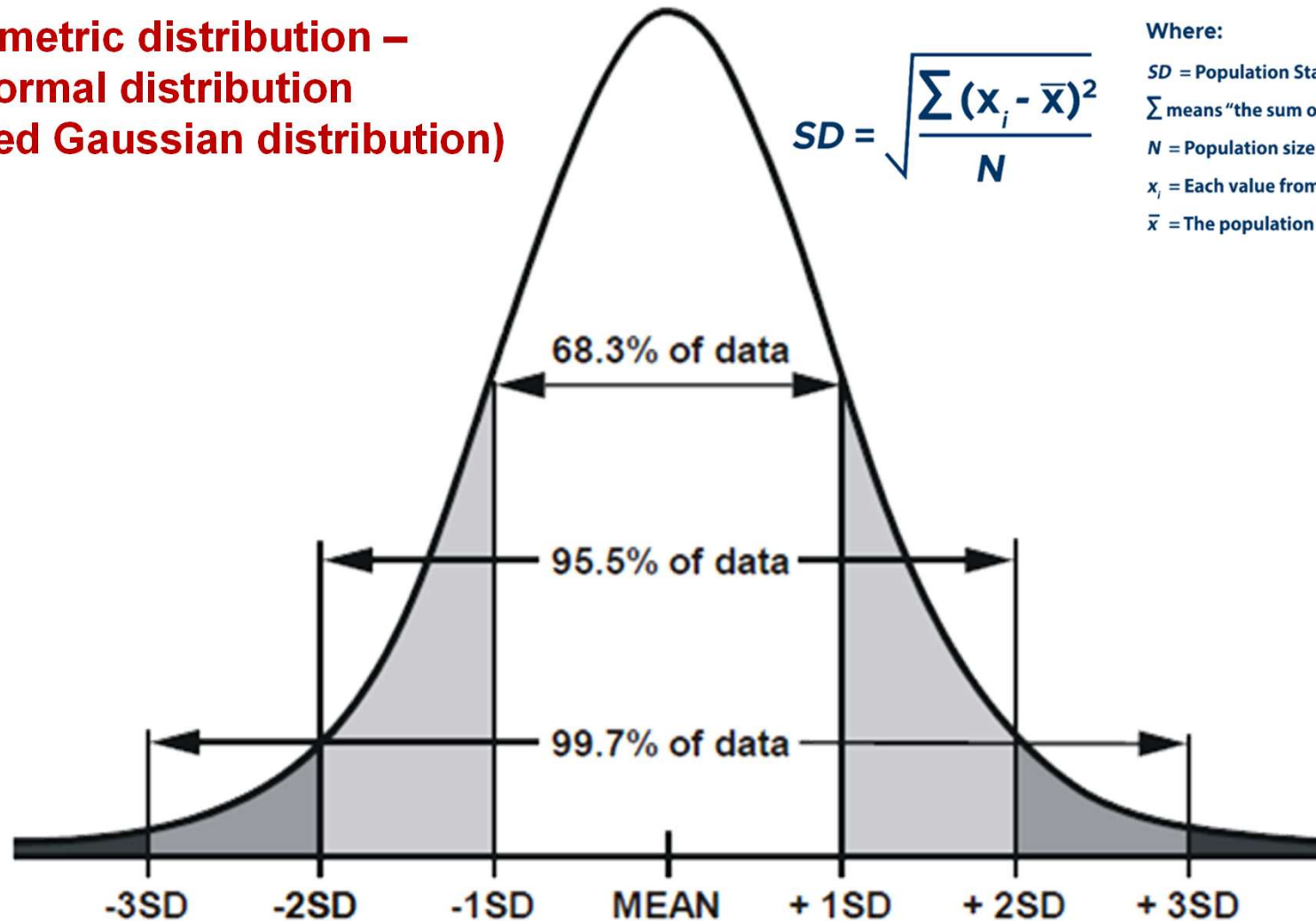
Negative Skew



Positive Skew

# Mean and standard deviation

**Symmetric distribution –  
Normal distribution  
(also called Gaussian distribution)**



$$SD = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N}}$$

Where:

SD = Population Standard Deviation

$\sum$  means "the sum of"

N = Population size

$x_i$  = Each value from the population

$\bar{x}$  = The population Mean

# Mean or Median?

[3, 4, 5, 6, 7]



**Median**

(Odd number of data)

[3, 4, 5, 6, 7, 8]



$$(5 + 6) / 2 = 5.5$$

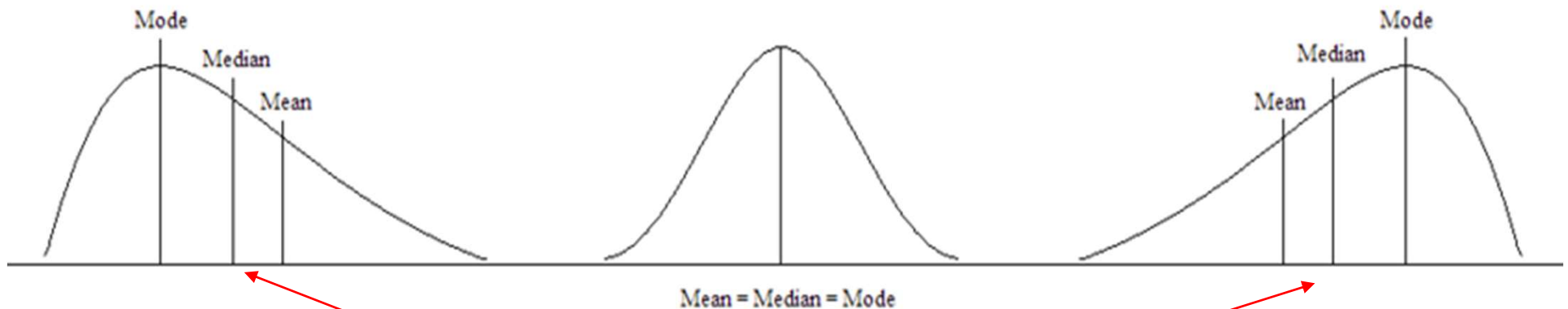
**Median**

(Even number of data)

Skewed Right

Symmetric Distribution

Skewed Left



The **median** is a better **measure** for an **asymmetric distribution**.

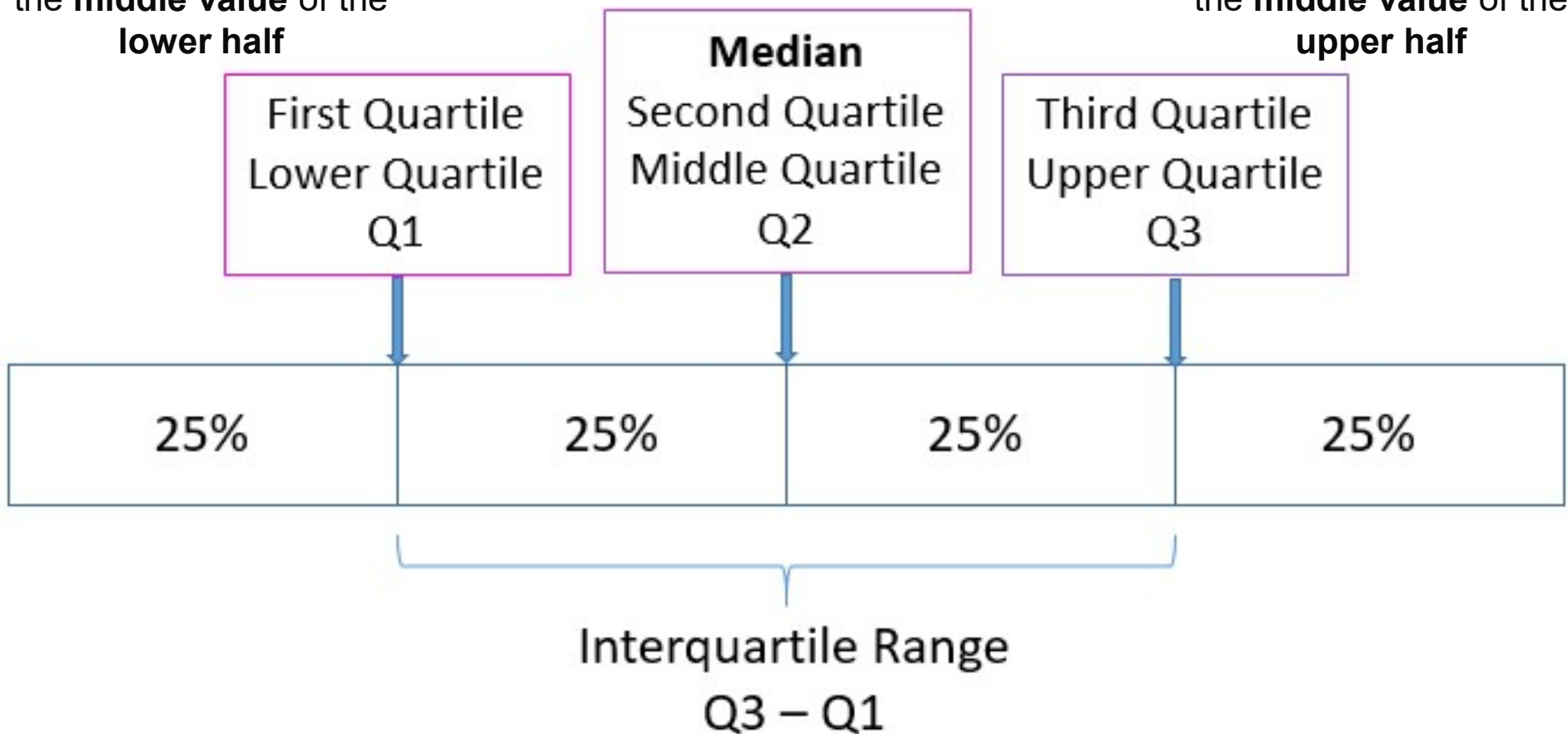
The **mode** is the most frequently occurring value.

# Median and quartiles

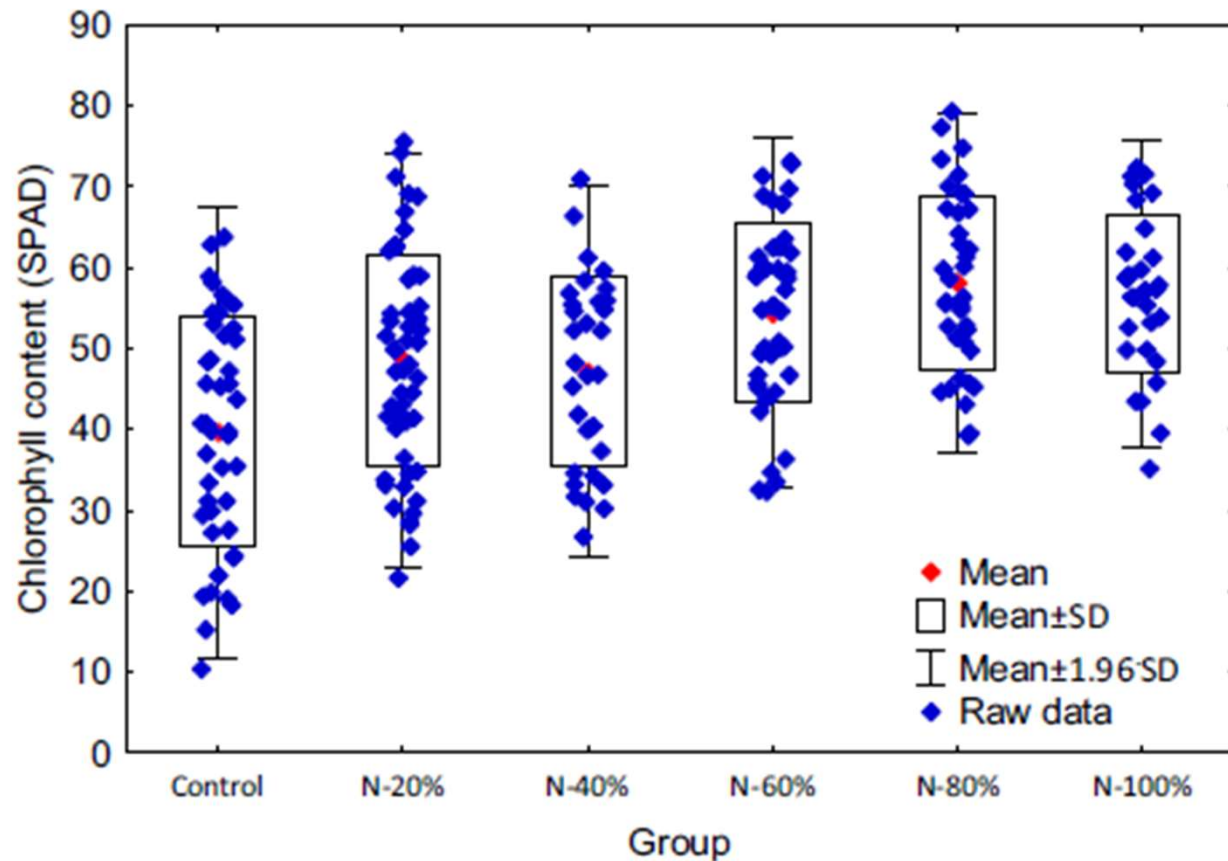
The **lower quartile** is the **middle value** of the **lower half**

The **median** divides the data into a **lower half** and an **upper half**

The **upper quartile** is the **middle value** of the **upper half**



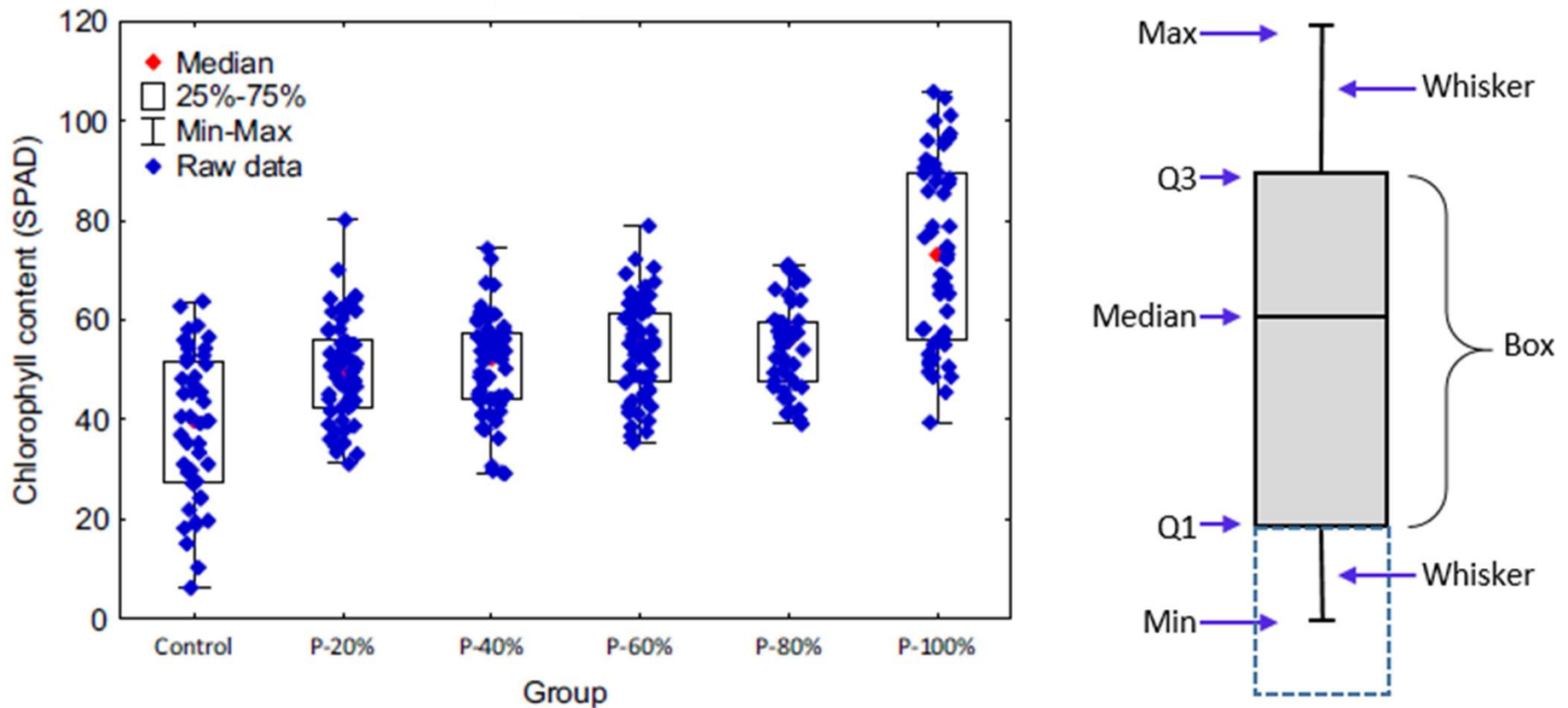
# Box & Whisker plot – A normal distribution



Germination tests on  
radish

**Figure.** Effect of different concentrations of algal extract obtained with Neutrased® on the chlorophyll content in radish seedlings

# Box & Whisker plot – A non-normal distribution



**Figure.** Effect of different concentrations of algal extract obtained with Protamex® on the chlorophyll content in radish seedlings

# Criteria for selecting a statistical test

5

Homogeneity (equality) of variances  
in groups

- yes
- no

**Homogeneity of variance** – is an assumption underlying both *t*-tests and ANOVA tests in which the population variances (i.e., the distribution or “spread” of scores around the mean) of two or more samples are considered equal.

# Test selection for independent 2 groups

Shapiro-Wilk Test  
 $p > 0.05$



Whether the distribution is normal?

YES

NO

A  $p$  value measures the probability of obtaining the observed results

Brown-Forsythe Test  
 $p > 0.05$



Whether the variances are homogeneous?

YES

NO

Statistically significant differences between tested groups

Parametric test

Non-parametric test

Statistical test  
 $p < 0.05$

Test  $t$       Welch Test      Mann-Whitney Test

# Test selection for independent more than 2 groups

Shapiro-Wilk Test  
 $p > 0.05$

A *p value* measures the probability of obtaining the observed results

Brown-Forsythe Test  
 $p > 0.05$

Statistically significant differences between tested groups

Statistical test  
 $p < 0.05$

Parametric Test

more than 2 groups

Numerical variables

Whether the distribution is normal?

YES

NO

Whether the variances are homogeneous?

YES

NO

Test F

Kruskal-Wallis Test

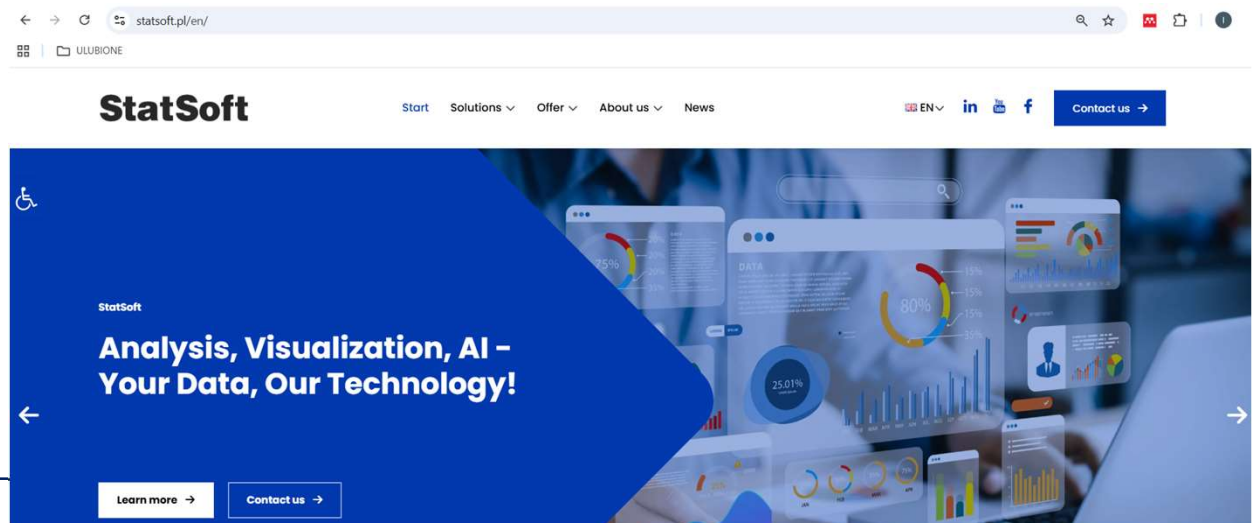
Tukey Test

Non-parametric Test

# Example: description of the „Statistical analysis” section in the publication

Most often, this description is in the „**Materials and Methods**” section as the last subsection.

**Statistical analysis.** Statistical analysis was performed using *Statistica* ver. 13.0 (TIBCO Software Inc., Tulsa, OK, USA). For all experimental groups, descriptive statistics (mean and standard deviations or median and quantiles) were performed. The Shapiro–Wilk test was used to assess the normality of the distribution of experimental results. The Brown-Forsythe’s test was used to check the homogeneity of variances. The statistical test (used to investigate the significance of differences between the tested groups) was selected based on the previously mentioned tests. The one-way analysis of variance (ANOVA) allowed the determination of the statistically significant differences between several groups. The Tukey multiple comparison test was used for normal distribution and homogeneous variances. For the lack of the normal distribution or lack of the homogeneity of variances, the Kruskal–Wallis test was used. The results were considered significantly different when  $p < 0.05$ .



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# Interpretation of data / Findings and drawing conclusions

An example of presenting research results from statistical analysis of results – **tests on plants** using different products from macroalgae – seaweed extract or biochar

**Germination tests**



**Pot tests**



# Interpretation of data / Findings and drawing conclusions

**Germination tests** on plants using different concentrations of algae extracts vs. control group with distilled water

<https://doi.org/10.1038/s41598-023-36881-z>

Parameter	Root length (cm)	Roots weight (g)	Aboveground part length (cm)	Aboveground part weight (g)	Chlorophyll content—SPAD Index (-)
Group	Median	Mean ± SD	Median	Mean ± SD	Mean ± SD
E (20%)	6.4 <sup>a,b</sup> (N=90)	0.231 ± 0.077 (N=4)	3.1 (N=90)	1.28 ± 0.20 (N=4)	55.7 ± 8.2 (N=81)
E (40%)	5.3 <sup>c,d</sup> (N=72)	0.180 ± 0.037 (N=4)	3.0 <sup>a</sup> (N=72)	1.03 ± 0.42 (N=4)	54.5 ± 9.6 (N=65)
E (60%)	5.6 <sup>e</sup> (N=86)	0.198 ± 0.035 (N=4)	3.3 (N=86)	1.39 ± 0.22 (N=4)	55.7 ± 9.4 (N=71)
E (80%)	7.1 <sup>c,f,g</sup> (N=78)	0.236 ± 0.041 (N=4)	3.6 <sup>a,b</sup> (N=78)	1.42 ± 0.28 (N=4)	52.9 ± 11.3 (N=63)
E (100%)	4.2 <sup>a,f</sup> (N=71)	0.176 ± 0.067	3.0 (N=71)	1.05 ± 0.34 (N=4)	52.5 ± 12.7 (N=55)
C (H <sub>2</sub> O)	3.5 <sup>b,d,e,g</sup> (N=62)	0.175 ± 0.039 (N=4)	3.1 <sup>b</sup> (N=62)	1.24 ± 0.23 (N=4)	54.4 ± 11.9 (N=57)

**Table 2.** The results of germination tests on radish seeds treated with various concentrations of seaweed extract. *N* number of measurements in each group, *E* experimental group (extract concentration in the bracket), *C* control group. <sup>a,b,c...</sup> Statistically significant differences for  $p < 0.05$  (Kruskal–Wallis test; results present as a median).

Example explanation of the table in the text of the publication

According to the statistical analysis, various concentrations of *Fucus vesiculosus* extracts influenced radish growth. The median root length in all experimental groups was greater than in the control group, which shows the stimulating effect of *Fucus vesiculosus* extract on the radish root growth. Statistically significant differences were found between E 20% and E 100%, between E 20% and the control group, successively between E 40% and E 80%, and between E 40% and the control group. In addition, statistically significant differences were also found between E 60% and the control group, between E 80% and E 100%, and between E 80% and the control group.

# Thank You for Your Attention

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