# HIGHEST QUALITY COMPOST TO ASSURE HUMAN, ANIMAL AND ENVIRONMENTAL HEALTH

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## Introduction

When we speak of natural life-cycles we address recurring processes that will never take place exactly the same, yet do they always pass through particular chemical, biological or physical states. The water cycle - rainfall, use of water, evaporation, etc., - is just one of many examples for innumerable cycles on the surface of the planet, that are all connected and influencing each other.

For centuries, humankind has been used to relying on well functioning natural cycles. We didn't have to question the cycling of nutrients, carbon or water – they just took place. However this is not the case anymore. Anthropogenic influences have slowed down, altered or destroyed natural cycles, causing chaotic conditions on the surface of the planet. Pollution of water, contamination of foodstuffs and the warming of the atmosphere - are just a few of the consequences.

Technology can compensate some of those effects, but by far not all of them. For example, the contamination of soils with pathogens, like Salmonella, E. Coli, etc., (through (liquid)manure, sludge, organic waste application), which are then carried into the food chain. For the dimensions that are involved here, there are no technological solutions, and even if there were, no society would be able to raise the kinds of funds that would be needed. The only option is to learn to understand where natural cycles are out of balance and to reinstall the needed \`links\` that will provide the impulses towards the restarting of these mainly self-organizing processes.

At first sight it may seem far fetched to link human health to the quality of compost. However, once we pay attention to the reasons why fertile, biologically active soils, that are rich in living humus, assure the health of life on the planet, highest quality compost takes on a new role. Especially since compost is one of these links, that can provide the needed impulse towards the reconnection of healthy soil-cycles.

## Living humus protects all forms of life

The reason why fertile soils protect the health of all life forms are manifold and highly complex, and cannot be explained in a few sentences, yet a few key factors will be addressed here, as they are the same ones that will make highest quality compost so effective in re-establishing soil fertility.

A fertile soil contains *living humus*, meaning humus, which is alive with an abundance and great diversity of microlife. This microlife is mainly aerobic, since fertile soils have a crumb structure that allows for an active exchange of gasses and therefore a sufficient supply of oxygen. This aerobic life has a multitude of functions, of which the most important are: the transformation of **raw organic matter to humus** (digesting or rather hydrolysing polysaccharides of plant animal and fungal origin, proteins, nucleic acids, phenolic polymers, lipids), the **excretion of antibiotics** which counteract pathogens and strengthen the plant's immune system, the supply of **nutrients** and bioactive substances to plants, the **release and fixing of nutrients**, etc.

Fertile soils are the guarantee for clean water, as the aerobic life - covering the surface of humus particles - eliminates pathogens, while the clay-humus-complexes along with their colloidal forms, complex substances of decay and putrefaction (e.g. putrescin, cadaverin, hydrogen compounds like $NH_4$, etc.), keeping them from leaching into the ground water table or to be uptaken by plants. Furthermore is the flocculation of clay and humic colloids favourable for an aerated structure and adequate water storage.

Fertile soils protect the atmosphere in many aspects, some of the most important being: less release of greenhouse gasses, sequestration of $CO_2$ and the reduction of aerosols.

Modern agriculture has been the main cause for the destruction of soil fertility, because of the choice of technology, the handling of organic matter and the use of agrochemicals, which has caused the loss of humus, humifying microlife and consequentially soil structure and the ability to retain and cleanse water.

The most economically feasible and sustainable way of re-establishing soil fertility and microbial diversity is the use of highest quality compost, with a stable crumb structure, clay-humus-complexing, fixed nutrients, a diverse aerobic microbial population and excellent water retention.

Only compost with humifying abilities similar to that of highly fertile soils will refertilize soils within short periods of time.

## The Controlled Composting Process

Compost, as defined by the majority of composters and legislation, is an organic waste material, which has passed through a thermophilic phase, thus causing the decomposition of feedstocks to small particle size. EU-ordinances limit the metal, plastic, glass and/or heavy metal contamination. Beyond these restrictions, there is very little awareness for quality criteria for what a soil-like-compost with humifying abilities should be.

For the past 30 years, it has been our approach to composting, to study the path of organic matter within healthy soils, and derive from these observations, the optimal conditions for the turnover and stabilization of organic matter through composting.

These studies have led us to conduct a controlled composting process, where the material combination, addition of clay minerals and finished compost, water-management, inoculation and adequate technology are combined with a rigorous procedure to ensure an aerobically dominated composting process, allowing for the highest amount of humus synthesis within the shortest time-frame possible.

This means, regarding feedstock combination - structure and material-reaction-potential (release of nutrients, etc.) are considered, the turning frequency is determined by $CO_2$ concentrations, the moisture content is maintained high enough to be most conducive to humus formation and the compost is not allowed off the site before it has been analyzed according to the standards for finished-compost-parameters and complies with them.

## Material combination

Just like in soils, there is an optimal balance between the carbon and nitrogen content within a compost, that allows for efficient digestive processes of the organic matter and minimal loss of nutrients. This optimum C:N-ratio for compost is 30:1. However, just taking the C:N-ratio into account is not sufficient, the reaction potential of available feedstocks must be considered as well.

## Soil addition

The addition of clay minerals, in the form of a clay-loam soil at a rate of 10% by volume, while building the windrow, is necessary to allow for clay-humus-complexes to be formed. It provides a proper milieu for the microlife and it supplies an interim storage for substances released through 'breakdown', like fragmentation, enzymatic degradation, mineralization, etc. Analysis show, that composts which are made without soil addition, do not develop a stable crumb structure and nutrient fixation does not take place sufficiently.

## Windrow construction and size

Since the combination of moisture conditions, nutrient release, even blend of materials, etc. are crucial for an optimal start of the composting process and the minimization of potential losses, it is important to construct windrows carefully in layers.

The maximum dimensions of the compost windrows are defined by an optimized ratio between structure and airflow, in order to ensure aerobic conditions within the compost material. Our research regarding gas exchange in compost windrows, especially the continuous monitoring of gasses like $CO_2$, $CH_4$, $O_2$, $NH_3$, $N_2O$, etc. throughout the composting process has shown, that a triangular windrow shape will best support the gas dynamics within the windrow.

A maximum base width of 2.5 to 3m and a maximum height of 1.3 – 1.5 m, (length is optional), will allow for an aerobic process, in combination with an adequate turning frequency. Windrows of larger size run out of oxygen within a very short period of time, anything from just minutes to a few hours, causing the composting process to continually revert to anaerobic conditions.

Many companies have attempted to employ forced aeration, to make up for larger windrow size, yet there have not been satisfying solutions found, that are economical and lead to a high compost quality at the same time. This issue will be discussed later on.

## Microlife

From our research with fertile soils, we learned that only an aerobically dominated process forms stable, long-chain humic acids and humic substances, as most humifying microlife is an aerobic one and most conditions conducive to humus formation take place under the influence of oxygen. Therefore a composting process needs to take place under aerobic conditions, to insure the neosynthesis of various forms of long-chain humus compounds, that will later on be sustainable in soils.

Many of the feedstocks, used in composting, are populated with a microlife that enhances the digestion of organics but they do not provide the microlife which leads to the formation of high quality humus, as this microlife is soil borne and needs according conditions (e.g. clay minerals). Therefore an inoculum is used in a controlled composting process, which introduces humifying microlife to the feedstocks.

The most ideal situation for a composting facility is to have an on-site laboratory, where the microbial population of a (finished) compost can be assessed. Yet, even with the availability of suitable equipment and qualified staff, certain microbial analysies are only fit for scientific use, since they take too much time, for decisions regarding the composting process or sale of product.

As it is not possible for most compost practitioners, to take account of and gain detailed insight into the diversity of microbial species, present within a compost, we employ several qualitative and quantitative methods that can be carried out with little technological set-up, yet the information to be gained is of great value to science and practice alike.
Chromatography is one of these methods employed to determine the microbial diversity and maturity of compost. As an imaging-method, chromatograms provide a holistic insight into the life processes of soils and compost

Below two examples for filter-paper chromatograms showing a mature high quality compost on the left and a poor quality compost on the right.


good quality compost, image: Lübke-Hildebrandt


poor quality compost, image: Lübke-Hildebrandt

### Hygienization and Detoxification

Depending on origin and storage, organic waste materials, many times, carry a considerable amount of highly dangerous microlife, e.g. Rotavirus, Hepatitis, Polio, Salmonella, E. Coli, Listeria, Candida, Aspergillus, etc. along with worm eggs and larvae etc. Only an aerobic composting process ensures an adequate hygienization, via oxygen, temperature and microlife.

### Humus Test

Another assessment of compost quality is to determine the humus content of the mature compost. The Humus Test, according to Lübke, is an extraction of humus substances from compost, which is then compared to a color-scale to determine the result. The result is given as a relative number and is interpreted in reference to the content of the organic matter (OC).

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Humus/OM Ratio in Compost

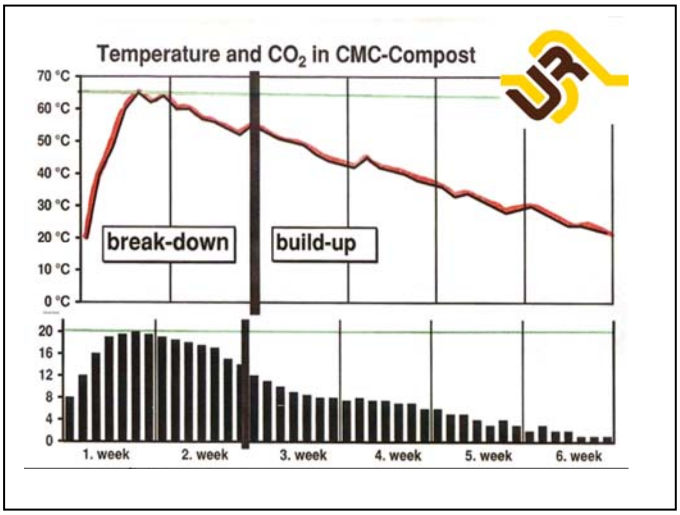
| OM % | Humusvalue (According to Lübke) | Interpretation |
|---|---|---|
| 30 | 180 | Raw Material |
| 18 | 70 - 80 | Excellent |
| 10 | 30 | Garden Soil |
| 25 | 40 | Raw Material & Losses |

## Gas Exchange, Daily Process Monitoring

The exchange of gasses within a compost windrow is crucial for the endproduct quality. As discussed before, aerobic conditions must be maintained during the composting process to avoid the formation of toxins and to allow for an efficient process, minimizing potential losses (carbon, nitrogen, sulphur, etc.) and for long-chain sustainable humus to be formed. Therefore the combination of material structure, windrow size and moisture are crucial and must be attended to closely, to ensure a continuous flow of gas formation and release. Since an aerobic process produces mainly $CO_2$, which collects at the windrow base, the center bottom of the windrow is the main measuring point for $CO_2$ and $O_2$ monitoring.

Similar to soils, sufficient oxygen must be available in the compost to ensure aerobic activity, which means a minimum of 5% oxygen needs to be available in the windrow air at all times. In case of less oxygen availability, the milieu reverts to anaerobic conditions which will enhance growth of pathogens, loss of gaseous carbon and nitrogen and formation of hydrogen compounds, which will eventually turn the process putrefied, if anoxic conditions persist for extended periods of time.
There are two major options to remove $CO_2$ from the compost windrow. One is by a good material structure, which allows a small amount of the total $CO_2$ to slowly 'flow' out of the windrow at the windrow-base. However, the amounts of $CO_2$ that will leave the windrow by flowing out at the base are small in comparison to the total amount of $CO_2$ produced.

Therefore the second option of enhancing gas exchange via turning with a compost turner, is the far more efficient release of $CO_2$, and at the same time the blending loosens and fluffs up the feedstock materials, to enhance the chimney effect, which also supports the release of gases.




As shown on the graph, the highest levels of $CO_2$ are released during the breakdown period, which are the first 2 weeks of a 6 - 8 week composting process. (An efficient, well controlled process, with a proper blend of feedstocks and moisture will finish within 6 – 8 weeks, including crumbstabilization and the formation of nutrient humus.) As soon as $O_2$ levels drop below 5% the compost must be aerated. The turning of the windrows takes place according to the $CO_2$ content of the windrow. Therefore daily $CO_2$ monitoring is needed for adequate compost care.

The second measurement, which is taken daily, is temperature. Since humifying microlife does not survive temperatures above 65° C, the temperature must be controlled accordingly by turning the windrow.

The turning frequency is influenced by the performance of the turner. The design of the drum with the tines is crucial towards the fluffing effect and the release of $CO_2$ from the windrow. The turner must be designed to adapt to the condition of the compost materials, operating at higher rpm's and low ground speed at the beginning of the process, whereas the rpm's need to be slower and ground speed can be faster towards the end of the composting process.


Image: courtesy of Gujer, Mesikon, Switzerland

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Proper Turning Speed

| process | ground speed | rpm's |
|---|---|---|
| First few turnings (1 -3) | 100 - 200 m/hr | 200 - 270 |
| beginning of process | 200 - 300 m/hr | 150 |
| during main process | 300 - 400 m/hr | 120 |
| end of process | up to 400 - 600 m/hr | approx. 100 |

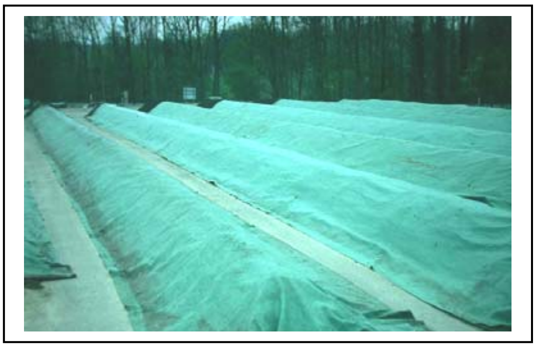
Forced aeration, as used in many indoor facilities, can support the release of $CO_2$ at the macrolevel, yet it does not remove the $CO_2$ at the microlevel.

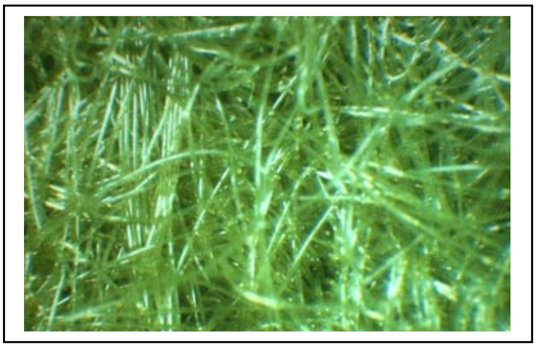
## Moisture Management

An efficient digestion of feedstocks and humus formation, which involves optimized carbon fixing, need a moisture content of 55 - 60%. Therefore it is crucial, to establish the necessary moisture as early in the process as possible. A lower moisture content (30 – 50%), will not inhibit the digestive processes completely, but it will slow down the turnover of organic matter and cause a much greater release of $CO_2$ than compost materials of proper moisture levels.

The humus-test (according to Lübke) along with other evaluation methods (nutrient fixation, chromatography, cress test, etc.) clearly show the difference in quality between composting processes at proper moisture or moisture deficiency.

An important aid in increasing and upkeeping the proper moisture levels in compost, is the use of Top-Tex compost covers. This fleece material (made from an endless polypropylene fibre) protects windrows from rainfall and at the same time it keeps the material from drying out. Experiments have shown, that in warm climates like Spain, California, South Africa, etc. water input can be reduced by 70% with the use of the Top-Tex covers.





## Finished compost testing parameters according to Lübke / Hildebrandt

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### FINISHED COMPOST PARAMETERS

| | |
|---|---|
| $CO_2$ | 0 - 1% |
| $O_2$ | 19 - 20% |
| Temperature | max. 5° C above soil temp |
| pH actual ($H_2O$) | 7 - 8 |
| pH potential (KCl) | 7 - 8 |
| Ammonium ( $NH_4$ ) | 0.5 ppm (max. 2 ppm) |
| Nitrate ( $NO_3$ ) | max. 300 ppm / summer, max. 100 ppm / winter |
| Nitrite ( $NO_2$ ) | 0 !!! |
| Sulfide ( $H_2S$ ) | 0 |
| Redox ( rH ) ORP | 27 - 29 |
| Humus value | ideally 70 - 80 |
| Organic matter | ~ 16 - 22 % |
| Chromatograms | determine maturity and microbial diversity |
| Crumb stability | high stability |
| Cress test | open and closed glass |
| Heavy metals | according to legislation |
| Conductivity | 800 - 1800 |
| Nutrient total-analysis NPK | e.g. **N** 0.8 – 1.2 % |

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## Conclusion

Many soil experts believe, that it is sufficient to take the composting process to a stage of breakdown, where humus precursors are formed, which are supposed to be integrated into the soil-whole by further transformation into stable forms of humus. This is true for soils with an abundant and diverse microlife, however that is not the case for most agriculturally used soils.

Various studies regarding the application of organic matter and the transformation into humus show, that most of the applied organic matter is decomposed and `disappears` within the first year of application. Accompanying ground water analysis provide an indicator of the whereabouts of part of the applied organic matter. The comparison of the numbers of total OC-application in Europe, with the actual SOM content shows that only a fraction of the applied organic matter is being transformed to sustainable humus or utilized by plants, the rest pollutes the environment.

Therefore the ONLY solution to re-establishing aerobic microbial diversity and permanent fertility in soils – is to stabilize all organic (waste) matter through an aerobic composting process, where carbon, nutrients, etc. are crumb-stabilized - before land application - to ensure their long-term-conservation within the topsoil. Consequentially highest quality compost also ensures improved food-quality and safer food production.